

A MATHEMATICAL MODEL FOR THE TRANSIENT ELECTROCHEMICAL RESPONSE  
OF A CONTINUOUS GLUCOSE SENSOR

By

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A DISSERTATION PRESENTED TO THE GRADUATE SCHOOL  
OF THE UNIVERSITY OF FLORIDA IN PARTIAL FULFILLMENT  
OF THE REQUIREMENTS FOR THE DEGREE OF  
DOCTOR OF PHILOSOPHY

UNIVERSITY OF FLORIDA

2022

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To Kristin and Ayden.

## ACKNOWLEDGEMENTS

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LIST OF OBJECTS

Objects

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## LIST OF ABBREVIATIONS

$\Sigma$	Denotes the summation of a series of terms
$\cap$	A really big bigcap
fractal	A geometric pattern that is repeated at ever smaller scales to produce irregular shapes and surfaces that cannot be represented by classical geometry. Fractals are used especially in computer modeling of irregular patterns and structures in nature.
polynomial	(in one variable) an expression consisting of the sum of two or more terms each of which is the product of a constant and a variable raised to an integral power: $ax^2 + bx + c$ is a polynomial, where $a, b,$ and $c$ are constants and $x$ is a variable.

Abstract of Dissertation Presented to the Graduate School  
of the University of Florida in Partial Fulfillment of the  
Requirements for the Degree of Doctor of Philosophy

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December 2022

Chair: Mark E. Orazem

Major: Chemical Engineering

Continuous glucose monitors provide an indirect measurement of blood-glucose via a series of enzymatic and electrochemical reactions on a sensor. A model for the dynamic response of the sensor was developed. Diffusion-reaction equations of the mobile species of the system were considered for glucose, hydrogen peroxide, oxygen, gluconic acid, hydrogen and hydroxide ions, and bicarbonate buffer species. Glucose oxidase, responsible for the conversion of glucose, was assumed to be immobilized. All species modeled were coupled to the response of the transient response of the sensor. The sensor consists of an electrode, an adjacent membrane containing immobilized glucose oxidase enzyme, and a glucose limiting membrane. Additional layers were considered including a diffusion blocking layer between the electrode and enzyme layers, and an external diffusion layer adjacent to the glucose limiting membrane. Governing equations were discretized with a central-differencing scheme and solved with Newman's BAND algorithm. The transient response is dependent upon the thickness of the sensor, diffusion coefficients, and enzymatic rate constants. Transient concentration and reaction profiles are presented to describe the various dynamic current phenomena observed under multiple initial conditions. The model was fit to experimental measurements involving steady and transient techniques, which provided the model with adjusted parameters.

## CHAPTER 1 INTRODUCTION

Continuous glucose monitors (CGMs) have gained popularity in recent years as they provide periodic estimates of the blood glucose concentration. Insulin dosing regimens are improved by type I diabetic individuals as their blood glucose concentration reading is updated more frequently than with self recorded finger pricks. The sensor on the CGM is a flexible circle which can quickly injected into the subcutaneous tissue where it detects the glucose of the surrounding interstitial fluid. Despite their consistent accuracy, there may be a lag between the true blood glucose concentration and the value detected by the sensor. This lag is attributed to the physiological response to implanted biosensors and the diffusion-reaction mechanisms occurring within the sensor.[12] The sensor's contribution to the time-dependent response may be understood by developing a highly detailed diffusion-reaction model. This model could assist in characterizing the physical properties of the sensor and surrounding tissue which may lead to signal bias and lag.

History on the development of CGMs and the present modeling approach is discussed in Chapter 2. Enzymatic glucose sensor development has been ongoing since Clark and Lyons[10] produced the first device in 1962. Over the last 50+ years vast improvements have been made to enzyme stability and lifetime, device accuracy, noise reduction, and miniaturization. Modern CGM sensors most often utilizes the enzyme, glucose oxidase (GOx), for conversion of glucose to hydrogen peroxide via enzyme ping-pong kinetics. The flux of hydrogen peroxide oxidized on an adjacent electrode surface is directly proportional to the reacting glucose concentration at mass-transfer limited applied potentials. Few mathematical models exist that describe the response of the sensor by accounting for the reacting species, buffer and acid dissolution, and electrode kinetics for multiple heterogeneous reactions. Gao[19, 20] has developed a highly detailed model for the steady and impedance response. The present work adapts this model to the time domain.

The development of a simplified model, which assumes constant pH throughout the sensor thickness, is described in Chapter 3. Deviating from the work of Galceran[18], the enzyme reactions, describing the ping-pong kinetics, are accounted for individually. The mathematical

and numerical model for the diffusion-reaction mechanisms are described. Solutions to the steady and transient model are provided. Calculations of the polarization behavior and individual species concentration profiles are presented for the steady model. The transient solution to potential and glucose perturbations are presented, and the time constants are characterized by the dimensions of the sensor, the diffusion coefficient of glucose, and the enzymatic rate constants.

The investigation on the influence of an external diffusion layer is presented in Chapter 4. The mathematical and numerical technique to account for concentration partitioning across the sensor/diffusion layer interface is described. The relationship between steady current, diffusion layer thickness, and oxygen concentration is described. The transient model describes the response of a glucose perturbation through the diffusion layer. Individual time constants of the transient current were identified. A simplified analytic expression for glucose diffusion through the external layer was in good agreement with the numerical model.

Acetaminophen in the body is readily oxidized by the sensor at operating potentials which yields a positive current bias. Chapter 5 describes the influence of a blocking layer inserted between the electrode and enzyme layers with the desired effect of eliminating this bias. Adverse impact to the sensor response was characterized as a function of the blocking and diffusion layer thickness, oxygen concentration, and diffusivity of individual species. The blocking layer may reduce the detectable range of glucose concentration and increase the response sensitivity to oxygen. Design of the layer should focus on high selectivity to hydrogen peroxide and oxygen diffusion to minimize the impact to the sensor response while still effectively screening the reactive acetaminophen.

A more detailed model involving the influence of pH on the electrode reactions is presented in Chapter 6. Polarization behavior of this model is similar to the model presented in Chapter 3, but evolution of hydrogen results in deviation at cathodic potentials. Individual failure modes and design parameters of the sensor are identified; steady and transient calculations characterizing these failure modes and design parameters are described. Failure modes studied include enzyme deactivation, oxygen deficiency, and membrane deterioration. The design parameters investigated

were thickness of the glucose limiting membrane, enzyme layer, and the selectivity of the individual layers.

Experimental measurements of glucose sensors provided by Medtronic are presented in Chapter 7. Experiments are categorized as steady-state, transient, or impedance measurements. For steady-state measurements, the polarization behavior and glucose calibration are presented. Transient measurements included the sensor response to glucose and oxygen perturbations. The model introduced in Chapter 6 was fit to the steady and transient experimental results. The sensor's impedance response was analyzed in detail. Two approaches to fitting of the impedance data, which are presented in Chapter 2, are compared. The electrolyte resistance, capacitance, and diffusion resistance were calculated and compared for both techniques. Extracted values for these parameters provide the charging characteristics of the transient model.

## CHAPTER 2 BACKGROUND

### 2.1 Continuous Glucose Sensor

The number of adults with diabetes increased from 108 million in 1980 to 422 million in 2014. This is an increase from 4.3% to 9% of the global population for men, and 5% to 7.9% for women. It is predicted that 700 million adults will have diabetes by 2025.[56] Diabetic individuals require frequent monitoring of their blood glucose concentration. Subcutaneous glucose sensors offer a low-cost and readily available method for the individual to monitor their glucose levels.

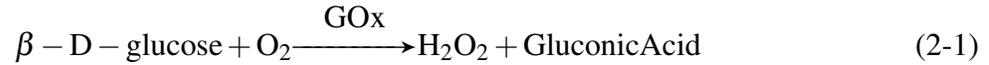
#### 2.1.1 Type 1 and Type 2 Diabetes

Individuals with diabetes are categorized as either Type 1 or Type 2. Type 1 diabetics have a genetic autoimmune disease whereby their immune system attacks pancreatic cells. An individual with Type 1 has greatly reduced insulin response to glucose variation. Type 2 diabetics often have insulin resistance and/or their body has a reduced insulin response. Type 2 diabetes is correlated to a family history of diabetes, long term diets with a high calorie surplus, and sedentary lifestyles. Blood glucose binds to hemoglobin (HbA1c in the blood. Many of the symptoms and complications of diabetes are related to blood circulation and metabolism. Complications include heart attacks, stroke, kidney damage, nerve damage, slow healing wounds, weight loss, and blurred vision. Type 1 individuals usually experience these symptoms more rapidly than Type 2 symptoms as their blood glucose goes completely unregulated without insulin.[47]

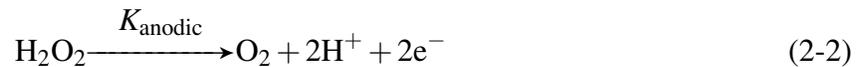
Type 2 diabetics can often manage their blood glucose and insulin response with a well-balanced diet, adequate sleep, and physical activity. Type 2 individuals may require synthetic insulin. The only treatment for Type 1 diabetes currently is careful monitoring of glucose and periodic dosing of insulin.[47] Self measurement of glucose is often carried out by frequent finger pricking and measurement of the blood on an external device. Since 1999, subcutaneous glucose sensors have been approved by the FDA. These devices consist of an implanted biosensor which periodically monitors interstitial glucose concentration. They greatly reduce the frequency of finger pricking required to monitor an individuals glucose concentration.[42]

### 2.1.2 History of the Continuous Glucose Sensor

The use of an enzyme based biosensor to detect glucose was first devised by Clark and Lyons in 1962. An electrode was coated with a thin layer of glucose oxidase (GOx). The overall reaction between glucose, oxygen and GOx,



allowed for the detection of unreacted oxygen at the electrode by oxygen reduction.[10] The cathodic current from oxygen reduction provides an indirect measurement of the glucose reacted in the enzyme layer. Updike and Hicks introduced a secondary, uncoated electrode, to determine dissolved interstitial oxygen. The technique allowed for correction of the variable oxygen concentration outside the enzyme sensor.[48] Due to the variation of interstitial oxygen, and the coupling of oxygen in the enzyme and electrode reaction, these devices were often inaccurate. A device which oxidized the hydrogen peroxide produced in Equation (2-1), following



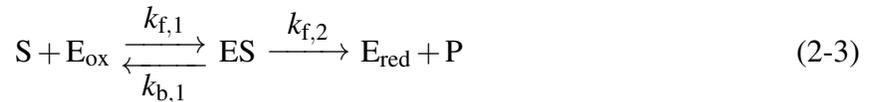
, was developed by Guilbault and Lubrano in 1973. The device demonstrated improved stability and accuracy.[23] During the 1980's, the glucose sensors incorporated ferrocene to assist electron transfer, and improve stability of the GOx enzyme. The ferrocene reduced sensitivity to oxygen and pH variation.[8, 16] Ferrocene in modern sensors was withheld due to concern the toxic compound would leach. Sensor development in the 1990's focused on improving mobility of the low molecular weight species. Development of polymer matrices bound to the GOx enzyme led to improved selectivity for transport to the electrode and stability of the bio sensors.[13, 40] Sensors miniaturization and stability was, and still is a priority, to make them wearable and low maintenance to the end user. Gough demonstrated intravenous sensors that operated for 108 days without requiring a calibration. Minimed Inc. released the first commercially available glucose sensor in 1999.[26]

Development of the sensors since 2000 has prioritized modification and optimization of the

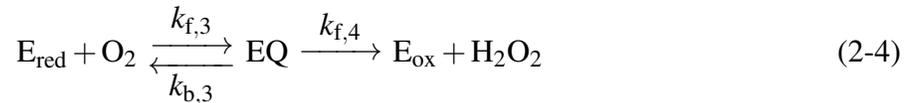
electrode/enzyme interface. Willner et al. built a device with a GOx bound to a pyrroloquinoline quinone/FAD monolayer deposited on a gold electrode. The device demonstrated maximum sensitivity due to the fast kinetics of the enzyme adjacent to the electrode.[51]. Chen et al. deposited a composite film on a glassy carbon electrode to improve oxygen reduction and hydrogen peroxide oxidation kinetics.[9] Glucose oxidase is the most commonly utilized enzyme in continuous glucose sensors due to its selectivity of  $\beta$  – D – glucose compared to other substrates. Protein engineering has led to improving the selectivity of enzyme based glucose sensors over the last two decades.[41, 28, 53, 24]

Recent work on sensors have improved sensitivity to glucose and amplified the current response. This has been accomplished by dispersing nanoparticles in the enzyme layer to enhance the electrode kinetics.[52] Operating potentials to oxidize hydrogen peroxide also allows for the oxidation of other species such as acetaminophen and ascorbic acid.[33] To avoid the undesired elevation in current due to other species, a barrier was added over the enzyme layer to allow selective diffusion of glucose while blocking other oxidizable species.[30, 55, 34]

Modern CGM devices operate by reaction of  $\beta$  – glucose with the enzyme glucose oxidase(GOx) and oxygen to form hydrogen peroxide. Bright and Gibson[21, 4, 3] proposed the 2 step mechanism:



and the regeneration reaction

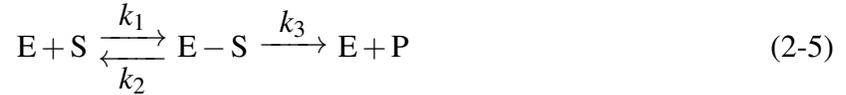


where  $E_i$  is the enzyme concentration of the oxidized (ox) or reduced (red) form. S is the substrate, most commonly  $\beta$  – glucose. P is the product of the first step, gluconic acid. All  $k_{f,i}$  and  $k_{b,i}$  correspond to the forward and backward rate constants for the individual reactions. All reaction equilibrium coefficients are defined as  $K_{eq,i} = k_{f,i}/k_{b,i}$ . E-S and E-Q are the complex-enzymes formed from reaction 1 and 3 respectively. Hydrogen peroxide formed in reaction (2-4) is oxidized on an electrode with an applied anodic potential. The current produced

from oxidation of the hydrogen peroxide is directly proportional to the concentration of glucose.

### 2.1.3 Mathematical Model of Glucose Sensor

Rapid equilibrium of the adsorption between an enzyme and substrate to form the enzyme-substrate complex is often assumed.[35] Briggs and Haldane proposed the reaction scheme between an enzyme and substrate,[2]



where  $k_1 - k_3$  are rate constants for substrate adsorption, complex desorption, and enzyme catalysis respectively, E is the free enzyme, S is the substrate, E-S is the enzyme-substrate complex, and P is the product which forms when the free enzyme is recovered. If  $k_2 \gg k_3$ , then the rate of product formation is obtained

$$\frac{dc_P}{dt} = \frac{V_{\max}c_S}{k_d + c_S} \quad (2-6)$$

where  $V_{\max} = k_3c_{E_0}$ ,  $c_{E_0} = c_E + c_{E-S}$ , and  $k_d = k_2/k_1$ . Galceran employed this result as an approximation for Equation (2-3) and assumed Equation (2-4) proceeds in a single, irreversible, step. The four individual reactions were represented by the single expression,

$$R_i = \frac{k_{f,4}k_{f,2}c_{E_0}c_{glu}c_{O_2}}{k_{f,2}K_Mc_{O_2} + k_{f,4}c_{glu}c_{O_2} + k_{f,2}c_{glu}} \quad (2-7)$$

where  $K_M = (k_{b,1} + k_{f,2})/k_{f,1}$ ,  $c_{glu}$  and  $c_{O_2}$  is the concentration of oxygen and glucose. The reaction-diffusion equations on a two dimensional disk were solved with finite elements. Steady-state species profiles and fluxes were modeled as a function of rate constants, electrode dimensions, and bulk glucose concentration.[18] Gough et al. modeled a cylindrical glucose sensor, based on oxygen detection of excess oxygen from the reaction in Equation (2-4). The device consisted of a platinum wire inside a concentric layer of immobilized enzyme, and an external hydrophobic layer. Glucose and oxygen diffused into the enzyme layer axially, but only oxygen could diffuse into the device radially due to the hydrophobic layer. Oxygen not consumed by the reaction in Equation (2-4) was reduced at the internal platinum wire. The oxygen flux at

the platinum wire was nonlinearly proportional to the glucose concentration.[22] Novak et al. developed a transport model, also with Michaelis-Menten Kinetics, to study the effects of biofouling on the sensor reading. They concluded the thickness of the biofouling does not significantly influence glucose transport, but accompanying inflammatory cells may consume diffusing glucose and reduce the sensor signal.[38] Gao et al. relaxed the assumptions of rapid-equilibrium and explicitly modeled the 4 individual enzyme reactions from Equations (2-3) and (2-4) in both steady and impedance models. The model demonstrated a difference in the impedance spectra for separate glucose and enzyme concentrations which produced similar steady-state current. [19] Gao further developed this model to include the influence of pH and the buffer system on the heterogeneous reactions and enzyme activity.[20]

There is always a delay between changes in the intravenous blood-glucose and the feedback from the CGM. For rapid blood-glucose elevation. This delay is usually 5 minutes, but may be as large as 30 minutes.[42] Lag between an intravenous glucose measurement and the CGM reading is rooted in both the CGM and the interstitial-intravenous transport.[12] A physics-based dynamic transport model could elucidate the contribution of the CGM to this lag.

The dynamic behavior of the sensor could be better understood with a time-dependent transport model. This model would provide time constants attributed to the transport of the contributing species and dimensions of the sensor. The sensor's contribution of the intravenous-interstitial lag could be studied in response to a change in glucose concentration. Objective of the present work is to develop a transient adaptation of the steady model produced by Gao[19]. This model would assist in understanding the time-dependent variation of the charging and faradaic current, and contributing species including oxygen, hydrogen peroxide, glucose, enzyme and the homogeneous reaction profiles. Sensor response to potential and glucose perturbations would be studied and analytic expressions for the current response time constants could be derived. The transient model was also able to provide pseudo-steady initial conditions for the impedance model presented by Gao to better understand how non-steady operation of the sensor could influence the impedance response.

#### **2.1.4 Influence of Enzyme Activity on Dynamic Response of Sensor**

#### **2.1.5 In Vitro Response of Glucose Sensor**

Continuous blood-glucose monitoring (CGM) devices have become a common tool among individuals with diabetes as a convenient method to track blood-glucose. Recent studies have linked the use of CGM with a 50% faster response to hypoglycemia, and less glycemic variability in diabetic individuals.[7] Evaluation of the CGM device variability and accuracy has been extensive. In vivo and in vitro quantification of the mean absolute relative difference has been evaluated for all modern commercially available devices.[39, 1, 31] Dynamic studies of the continuous glucose monitor have also been carried out to assess lag, which is due to transport of intravenous glucose to interstitial fluids and reaction-diffusion within the sensor.[54, 12]

While the long time behavior ( $>5$  minutes) of glucose sensors has been studied, there has been minimal effort to understand the early behavior of sensors ( $<5$  minute) after a perturbation has been made to surrounding glucose, oxygen, or applied potential. The steady, transient, and impedance response of a Medtronic Guardian 3 sensor are measured. Polarization of the sensor was used to extract kinetic parameters for the heterogeneous reactions. The dynamic response of the sensor to glucose and oxygen perturbations was used to estimate diffusion coefficient and partition coefficients of the individual layers of the sensor, and homogeneous rate constants involved with the conversion of glucose to hydrogen peroxide. Electrochemical impedance spectroscopy was used to calculate the electrolyte resistance, double layer capacitance, and diffusion resistance of the sensor.

### **2.2 Electrochemical Impedance Spectroscopy**

Electrochemical impedance spectroscopy (EIS) is a transient electrochemical experimental technique with broad applications. It has been used to detect adsorbed intermediates which form films too thin for direct observation, measure corrosion rates too small for mass change measurements, estimating thickness of oxide films, and many other complex electrochemical systems.[14, 15, 44, 45]

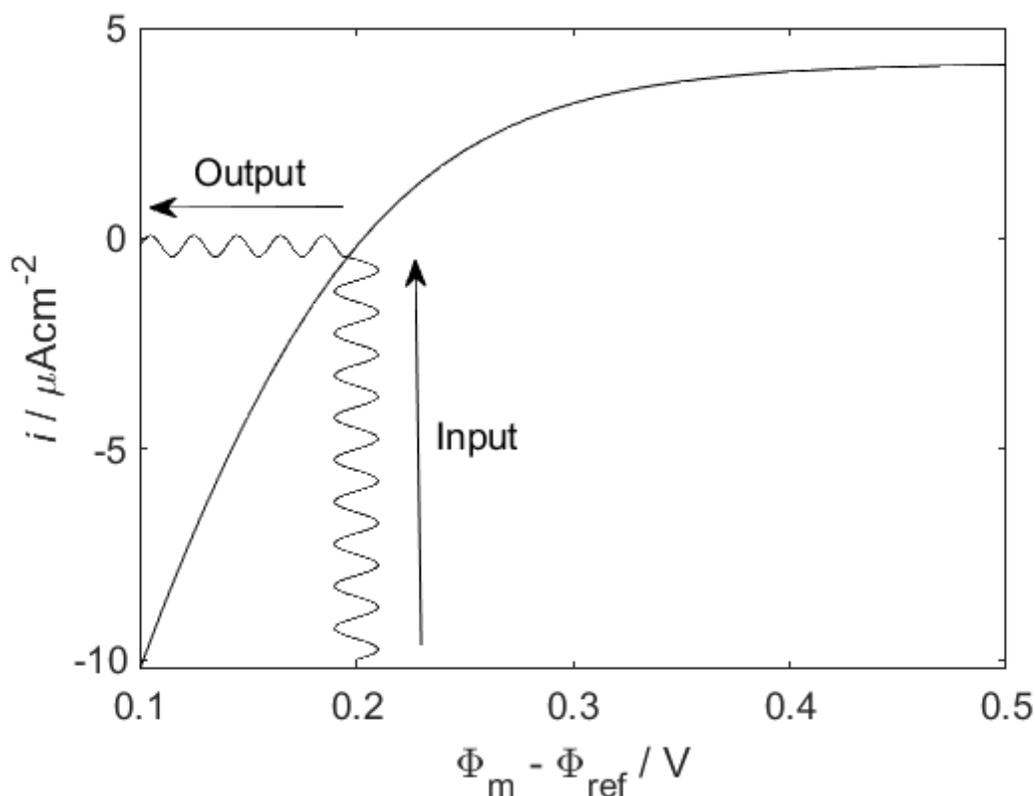


Figure 2-1. Representation of EIS potential input and current output on a polarization curve. The polarization curve is often produced in conjunction with EIS measurements to develop an understanding of the system being analyzed.

### 2.2.1 Transfer Function

Electrochemical impedance spectroscopy is a transfer function technique where a sinusoidal input is applied and a sinusoidal output is measured. For potentiostatic modulation, a potential waveform is applied,

$$V = \bar{V} + |\Delta V| \cos(\omega t) \quad (2-8)$$

where  $V$  is the applied potential drop between a working electrode and the reference,  $\bar{V}$  is the steady applied potential,  $\Delta V$  is the amplitude of the perturbation relative to  $\bar{V}$ ,  $\omega$  is the angular frequency of the input potential, and  $t$  is the time. The current output wave form is measured,

$$I = \bar{I} + |\Delta I| \cos(\omega t + \varphi) \quad (2-9)$$

where  $\varphi$  is the phase shift between current and potential. From Euler's relations, the potential input and current output may be presented as,

$$V = \bar{V} + \text{Re}\{\tilde{V} \exp(j\omega t)\} \quad (2-10)$$

and

$$I = \bar{I} + \text{Re}\{\tilde{I} \exp(j\omega t)\} \quad (2-11)$$

where  $\tilde{V}$  and  $\tilde{I}$  are the complex potential and current. An example of a potential input and current output during EIS measurements are presented on a polarization curve in Figure 2-1. The output current is dictated by the frequency of potential modulation, charging of the electrode, reacting species on the electrode, mass transfer of reacting species to the electrode, and the presence of films covering the electrode. The overall impedance at a specified frequency,  $\omega$ , is calculated in a similar relationship to Ohm's Law

$$Z = \frac{\tilde{V}}{\tilde{I}} \quad (2-12)$$

where  $Z$  is the impedance. The impedance may be presented in real and imaginary components

$$Z = Z_{\text{real}} + jZ_j \quad (2-13)$$

and is often presented in this manner on a Nyquist Plot.[45]

### 2.2.2 Fitting Impedance Response of Electrochemical Systems

Experimental impedance measurements are regressed with two different fitting techniques: the measurement model and process model. One characteristic of impedance acquired from EIS is the models that fit the data are not unique. A model which fits the impedance response does not imply it is representative of the system. Examples of the measurement model and process model fitting are presented on EIS measurements of a continuous glucose sensor. Both fitting techniques utilize a Levenberg-Marquardt algorithm for the nonlinear regression of parameters. The examples demonstrate how an electrolyte resistance, diffusion resistance, and capacitance are extracted for both techniques.

Table 2-1. Comparison of the Measurement Model and Process Model regression techniques

Measurement Model	Process Model
<ul style="list-style-type: none"> <li>• Series of Voigt elements</li> <li>• Number of Voigt elements arbitrary, but constrained to satisfy the Kramers-Kronig Relations</li> <li>• Provides statistically significant fit to a variety of impedance spectra</li> <li>• Extract electrolyte resistance, capacitance, and polarization resistance</li> <li>• Useful with minimal knowledge of the system</li> </ul>	<ul style="list-style-type: none"> <li>• User-defined model representative of system</li> <li>• Typically fewer parameters, not constrained to circuit analogs</li> <li>• Provides stastically significant fit to data, but not robust like measurement model</li> <li>• Extract parameters specific to electrochemical systems</li> <li>• Useful when the system is well understood</li> </ul>

### 2.2.2.1 Measurement Model

For the measurement model technique, a series of statistically significant Voigt elements are fit to the experimental data,

$$Z = R_0 + \sum_{k=1}^K \frac{R_k}{1 + j\omega\tau_k} \quad (2-14)$$

where  $R_0$  and  $R_k$  are resistors and  $\tau_k$  is a time constant equivalent to  $R_k C_k$ . Voigt elements and frequencies are eliminated based on statistically significant parameters, and satisfaction of the Kramers-Krognig relations. 5 time constants were fit to sample data in Figure 2-2. Resistance and time constant values for the individual Voigt element are presented Table 2-2. Capacitance of the

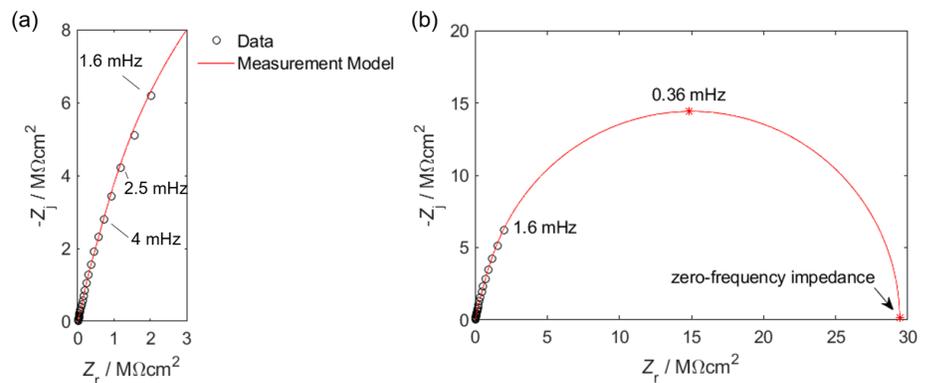


Figure 2-2. Nyquist plots for the measurement model fit with 5 Voigt elements to sample data. Fitting results are presented for (a) Nyquist plot in the high frequency limit and available data and (b) Nyquist plot of the full extrapolated measurement model fit. The measurement model provides estimates of the capacitance, characteristic frequency, and zero-frequency resistance, or polarization resistance ( $R_p$ ).

Table 2-2. Parameters obtained from the measurement model

k	$R_k / \text{k}\Omega\text{cm}^2$	$\tau_k / \text{s}$
0	20.2	n/a
1	3.33	0.140
2	16.9	0.945
3	28780	444
4	516	27.8
5	102	4.69

measurement model is calculated from the individual fitted time constants,

$$C = \frac{1}{\sum_{k=1}^K \frac{1}{C_k}} = \frac{1}{\sum_{k=1}^K \frac{R_k}{\tau_k}} \quad (2-15)$$

thus the estimated capacitance is influenced by the number of time constants fit. The measurement model also provides an estimate of the characteristic frequency in situations where it would not be feasible to make measurements at such small frequencies. The overall characteristic frequency of the fit is

$$f_c = \frac{1}{2\pi C R_p} \quad (2-16)$$

where  $f_c$  is the characteristic frequency, and  $R_p$  is the polarization resistance. This frequency is labeled in Figure 2-2b.

The measurement model is appropriate when little is known about the system, but it is often compared with a process model fit to provide better estimates of the systems capacitance, characteristic frequencies, and polarization resistance.

### 2.2.2.2 Process Model

Impedance models are not unique as proven by the fitting provided by the measurement model. When the mechanistic properties of the electrochemical system of interest are understood, a process model fit of the data can provide additional insight. The sample impedance data presented are impedance data from a continuous glucose sensor acquired from 1 Hz to 1.6 mHz. Gao and Orazem[19, 20] derived a process model fit with the equivalent circuit presented in Figure 2-3. The circuit is representative of a rough electrode with heterogeneous reaction(s) rates

controlled by mass-transfer. The lack of a dimensionless diffusion impedance requires the diffusion resistance to be much larger than the charge transfer resistance. The rough electrode yields a CPE at high frequency, with a phase angle less than  $\| -90^\circ \|$ . The diffusion resistance  $R_d$ , is an evaluation of the mass transfer of reactive species to the electrode and the involved species including glucose, oxygen, and hydrogen peroxide. The rough electrode yields a distribution of

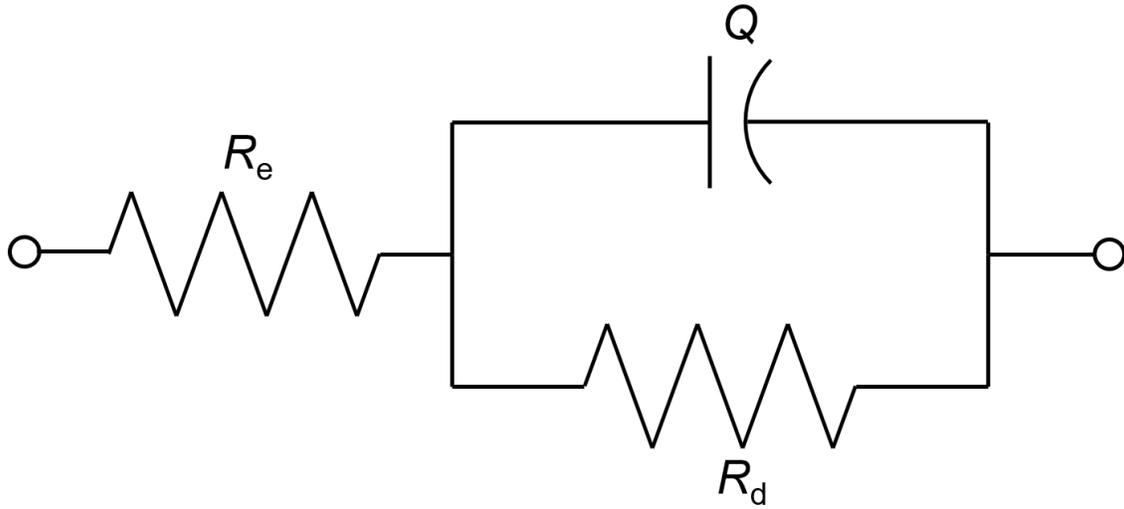


Figure 2-3. Equivalent circuit representation of the sensor impedance model. The electrolyte resistance in series with a parallel constant-phase-element (CPE) and diffusion resistance ( $R_d$ ) yields a single semicircle with a phase angle less than  $\| -90^\circ \|$  at high frequency. This model was derived from a physical understanding of the impedance response of the sensor.

time constants along the surface. Brug et al.[5] provides an estimate of effective capacitance from a CPE when  $R_d$  is much larger than  $R_e$  for a surface distribution of time constants

$$C_{\text{eff,surf}} = Q^{1/\alpha} R_e^{(1-\alpha)/\alpha} \quad (2-17)$$

where  $\alpha$ , which is less than 1 but greater than 0.5, and  $Q$  are CPE parameters related to capacitance and the phase angle. The impedance of the equivalent circuit is

$$Z = R_e + \frac{R_d}{1 + (j\omega)^\alpha R_d Q} \quad (2-18)$$

For cases where  $\alpha = 1$ ,  $C = Q$  and the CPE becomes an ideal capacitor. The process model fit with equation 2-18 to sample data is presented in the Nyquist plots in Figure 2-4. The fit provides estimates of the CPE parameters and diffusion resistance. With equation 2-17, the effective capacitance is estimated. The characteristic frequency of the process model follows

$$f_{c,ProcessModel} = \frac{1}{2\pi R_d C_{eff,surf}} \quad (2-19)$$

, thus a discrepancy in diffusion resistance between the measurement model and process model will yield a discrepancy in the characteristic frequency. Comparison of parameters extracted from the process and measurement models are presented in Table 2-3. There is less than 10% difference in the fitted values for  $R_e$  and capacitance. There was more uncertainty in fitting the low frequency portion of the data, which is reflected by the discrepancy in the fitted values of  $R_d$  and  $f_c$ . Additional measurements at low frequency would improve agreement in these parameters.

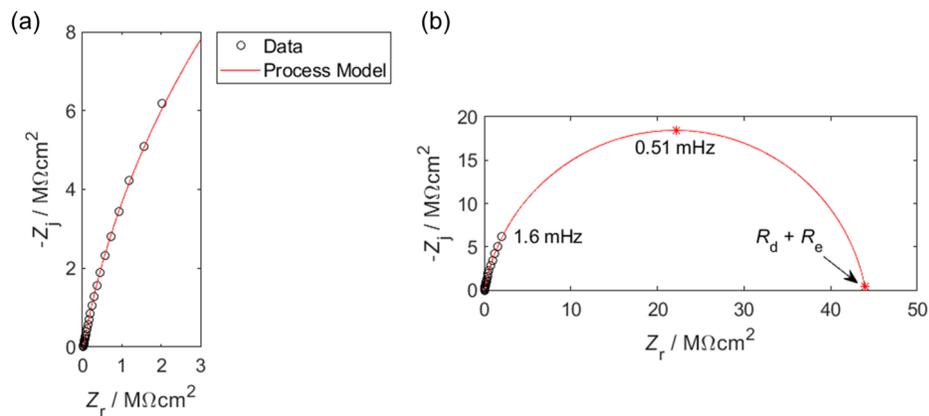


Figure 2-4. Nyquist plots for the process model fit with equation 2-18 to sample data. Fitting results are presented for (a) Nyquist plot in the high frequency limit and available data and (b) Nyquist plot of the full extrapolated process model fit. The process model provides estimates of the CPE parameters, diffusion resistance, effective capacitance, and characteristic frequency ( $R_d C_{eff,surf}$ ).

### 2.2.2.3 Error Structure

Parameter estimation of the fitting techniques presented are improved by modeling the stochastic error structure of the data. This error model provides a weighting strategy of the

Table 2-3. Comparison of fitted parameters from measurement model and process model

Parameter / Units	Measurement Model	Process Model
$R_e / k\Omega$	20.2	18.4
$C / \mu F$	6.81	7.02
$R_d / M\Omega$	29.4	44.1
$f_c / mHz$	0.36	0.51

impedance data.[43] An error structure model of the form,

$$\sigma = \alpha \|Z_j\| + \beta \|Z_r - R_e\| + \lambda \|Z\|^2 + \delta \quad (2-20)$$

provides a strategy to estimate the stochastic variation as a function of frequency.  $\sigma$  is the frequency-dependent variation of the data,  $\alpha$  is the weighting coefficient for the imaginary part of the impedance,  $\beta$  is the weighting coefficient for the real part of the impedance,  $\gamma$  is the weight coefficient for the modulus of the impedance, and  $\delta$  is a variation bias independent of frequency. Not all parameters in equation 2-20 are found to significantly contribute to the error structure; only the parameters which provide the minimal absolute error fit of the data are selected. A sample fit to the stochastic error is presented in Figure 2-5. The error structure model presented only utilized the  $\alpha$  and  $\gamma$  parameters, corresponding to the frequency-dependent weighting of the imaginary and modulus of the impedance, respectively. One characteristic of stochastic error is the real and imaginary variation of the impedance should have an even distribution from frequency to frequency. From Figure 2-5, the variation trend of the imaginary and real overlap. This is a characteristic of the stochastic error.

### 2.3 Numerical Methods

Steady and transient model equations are both resolved numerically with the Newton-Raphson method. The coupled nonlinear equations are discretized with central-difference-second-order-accurate finite-difference formulas. The equations are solved in FORTRAN using the BAND algorithm developed by Newman,[37] which utilizes a Newton-Raphson technique and variation of the Thomas algorithm to quadratically converge to solutions.

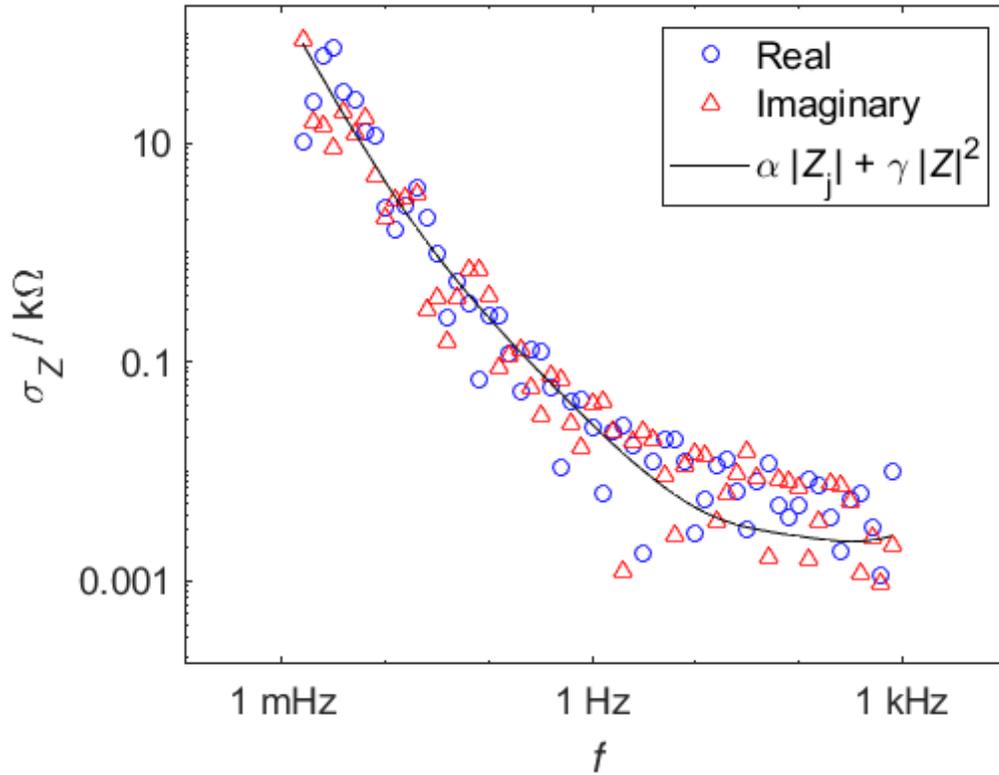


Figure 2-5. Stochastic variation as a function of frequency for the real and imaginary parts of the impedance. An error model of the form presented by equation 2-20 was fit to the data with only  $\alpha$  and  $\gamma$  weighting parameters selected. Stochastic error of the data is characterized by a distribution of the imaginary and real variation of the impedance.

### 2.3.1 Finite-Difference Technique

Steady model equations are discretized with central-difference-second-order-accurate finite-difference formulas. These are expressed as

$$\left. \frac{dc}{dy} \right|_J = \frac{c(J+h) - c(J-h)}{2h} + \mathcal{O}(h^2) \quad (2-21)$$

for a first-order derivative and

$$\left. \frac{d^2c}{dy^2} \right|_J = \frac{c(J+h) - 2c(J) + c(J-h)}{h^2} + \mathcal{O}(h^2) \quad (2-22)$$

for second-order derivative approximations of  $c$  evaluated at  $y = J$ , where  $J$  is the central node and  $h$  is spatial step size.

Partial differential equations, as presented by the transient model, are resolved with the Crank-Nicolson[11] discretization expressed as

$$\left. \frac{dc}{dy} \right|_{J,n} = \frac{c^{n+1}(J+h) - c^{n+1}(J-h) + c^n(J+h) - c^n(J-h)}{2h} + \mathcal{O}(h^2) + \mathcal{O}(t^2) \quad (2-23)$$

for a first-order spatial derivative,

$$\left. \frac{d^2c}{dy^2} \right|_{J,n} = \frac{c^{n+1}(J+h) - 2c^{n+1}(J) + c^{n+1}(J-h) + c^n(J+h) - 2c^n(J) + c^n(J-h)}{2h^2} + \mathcal{O}(h^2) + \mathcal{O}(t^2) \quad (2-24)$$

for a second-order spatial derivative and

$$\left. \frac{dc}{dt} \right|_{J,n} = \frac{c^{n+1}(J) - c^n(J)}{\Delta t} + \mathcal{O}(h^2) + \mathcal{O}(t^2) \quad (2-25)$$

for a first-order time derivative evaluated at spatial node J, and temporal node n+1/2 with a temporal step size of  $\Delta t$ . Only  $c$  at temporal step n+1 is the value which must be found with this system as time is stepped iteratively after the previous step converges.

### 2.3.2 BAND Algorithm

Newman[37] presented the BAND algorithm for solving coupled, non-linear differential equations. A coupled set of non-linear equations are linearized by either equations 2-21 and 2-22 or equations 2-23 and 2-24 and presented in the form

$$\sum_{k=1}^n A_{i,k}(J)C_k(J-1) + B_{i,k}(J)C_k(J) + D_{i,k}(J)C_k(J+1) = G_i(J) \quad (2-26)$$

where the system must be resolved at all nodes J for all variables i,  $A_{i,k}(J)$ ,  $B_{i,k}(J)$ , and  $D_{i,k}(J)$  are the partial derivatives for variable i and position J evaluated at J-1, J, and J+1 respectively.

Equation 2-26 is presented in Figure 2-6, which illustrates the tri-diagonal matrix formation.

$$\begin{bmatrix} B_i(1) & D_i(1) & 0 & & \\ A_i(2) & B_i(2) & D_i(2) & 0 & \\ & & \cdot & & \\ & 0 & A_i(NJ-1) & B_i(NJ-1) & D_i(NJ-1) \\ & & 0 & A_i(NJ) & B_i(NJ) \end{bmatrix} \Delta C = G$$

Figure 2-6. The BAND algorithm forms a tri-diagonal Jacobian matrix with variables  $A_{i,k}(J)$ ,  $B_{i,k}(J)$ , and  $D_{i,k}(J)$ .  $\Delta C$  is the change variable vector which adjusts the variable guesses for all  $c_{i,k}$  until the solution vector,  $G=0$ , converges.

## CHAPTER 3 SIMPLIFIED MODEL FOR CONTINUOUS GLUCOSE SENSOR

This chapter describes the steady and transient model for the simplified continuous glucose sensor. The model does not contain the influence of hydrogen ion or buffer species on the sensor response. The model includes 4 individual immobilized enzymatic species, the oxidized and reduced form of glucose oxidase and the 2 reaction intermediates all coupled through 4 individual homogeneous enzyme reactions. There are 4 mobile species in  $\beta - D -$  glucose, gluconic acid, oxygen, and hydrogen peroxide. The hydrogen peroxide may be oxidized or reduced at the electrode and oxygen may be reduced. The transient model includes the influence of charging on the double layer potential as applied potential and concentration of the electroactive species adjusts. The chemistry and transport for the system of the coupled diffusion-reaction equations are presented in detail. The model provides the steady and transient solutions to the system of equations. An understanding of the steady and transient concentration profiles is established by presenting sample calculations of the model. The steady model provides the polarization behavior of the sensor and the initial conditions for the transient model. The transient model provides the current response to either a potential or glucose perturbation.

### 3.1 Mathematical Model

The sensor consists of an enzyme loaded GOx layer over the electrode. Over the enzyme layer, an additional diffusion layer, the glucose limiting membrane (GLM), is between the GOx layer and bulk concentration. The GLM acts to limit the amount of glucose entering the GOx layer to prevent from overwhelming the enzyme. A cross section diagram of this sensor is illustrated in Figure 3-1.

The present model is the transient adaptation of the steady model presented by Gao.[19] This CGM model contains a suspended glucose oxidase (GOx) layer as well as a glucose limiting membrane (GLM). The GLM prevents glucose from overwhelming the glucose oxidase to prevent the limiting behavior of the sensor depending on available enzyme concentration. A diagram of the CGM domains are presented in Figure 3-1. Measurable hydrogen peroxide is produced through a set of two coupled reversible-irreversible homogeneous reactions.  $\beta - D -$  Glucose reacts with oxidized glucose oxidase enzyme, to form an intermediate complex. The complex

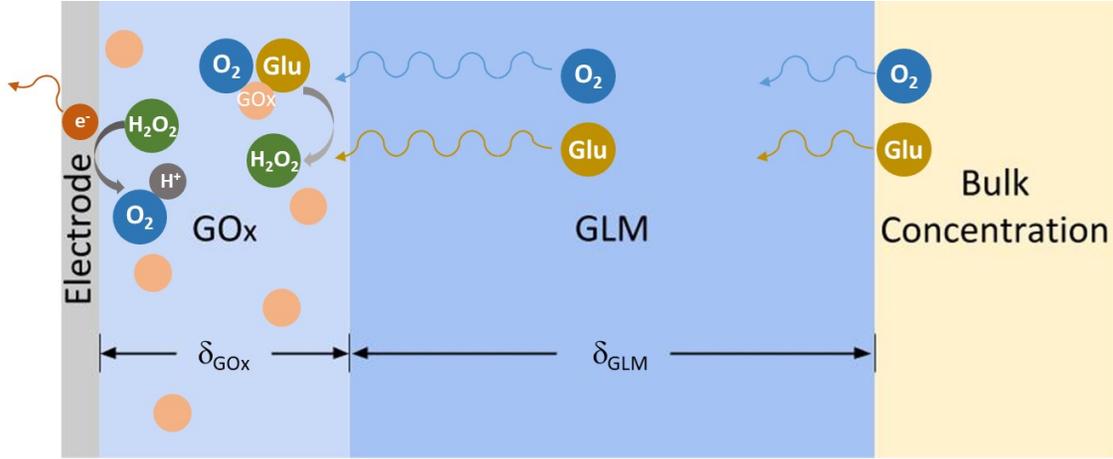
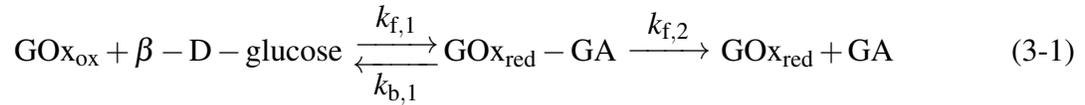
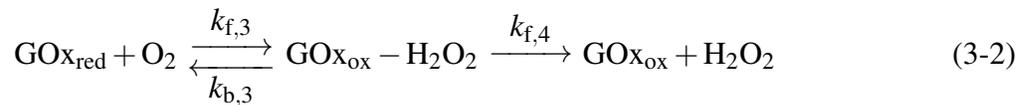


Figure 3-1. A one-dimensional diagram of the continuous glucose monitor showing the diffusion and reaction of the individual species. Glucose and oxygen diffuse through the GLM and into the GOX layer. Glucose reacts with the oxidized enzyme to form the reduced enzyme. Oxygen reacts with the reduced enzyme to form hydrogen peroxide and recover the oxidized enzyme. Hydrogen peroxide reacts at the electrode which forms oxygen and an anodic current.

dissociates into gluconic acid and the reduced glucose oxidase. This first coupled system is



where GOx is glucose oxidase (oxidised or reduced), and GA is gluconic acid.  $\text{GOX}_{\text{red}}$  reacts with dissolved oxygen to form a second intermediate complex. This complex dissociates into hydrogen peroxide and recovered  $\text{GOX}_{\text{ox}}$ . This second coupled system is



following the work of Harding and Gao [19, 25] the system is posed as reactions 1-4,

$$R_1 = k_{f,1}c_{\text{GOX}_{\text{ox}}}c_{\text{glu}} - k_{b,1}c_{\text{GOX}_{\text{red}}-\text{GA}} \quad (3-3)$$

$$R_2 = k_{f,2}c_{\text{GOX}_{\text{red}}-\text{GA}} \quad (3-4)$$

$$R_3 = k_{f,3}c_{\text{GOX}_{\text{red}}}c_{\text{O}_2} - k_{b,3}c_{\text{GOX}_{\text{ox}}-\text{H}_2\text{O}_2} \quad (3-5)$$

$$R_4 = k_{f,4}c_{\text{GOX}_{\text{ox}}-\text{H}_2\text{O}_2} \quad (3-6)$$

where  $R$  is reaction and  $c$  is concentration of the individual species. By assumption that no enzyme species diffuses, the individual enzyme concentrations are calculated by balance of the reactions outlined in equations (3-3)-(3-6). The balances are

$$\frac{\partial c_{GO_{ox}}}{\partial t} = R_4 - R_1 \quad (3-7)$$

for oxidized glucose oxidase,

$$\frac{\partial c_{GO_{red-GA}}}{\partial t} = R_1 - R_2 \quad (3-8)$$

for the first enzyme complex formed, and

$$\frac{\partial c_{GO_{red}}}{\partial t} = R_2 - R_3 \quad (3-9)$$

for reduced glucose oxidase and  $t$  is time. To enforce the total conservation of enzyme not inherent in finite difference calculations, a total enzyme balance

$$c_{GO_{ox-H_2O_2}} = E_0 - c_{GO_{ox}} - c_{GO_{red-GA}} - c_{GO_{red}} \quad (3-10)$$

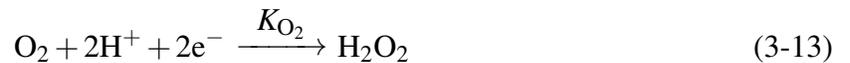
is used to calculate the concentration of the second enzyme complex. Tissue fluid is assumed to contain supporting electrolyte and migration is neglected. For diffusing species, the balances are

$$\frac{\partial c_i}{\partial t} = D_{eff,i} \frac{\partial^2 c_i}{\partial y^2} + \sum_i R_i \quad (3-11)$$

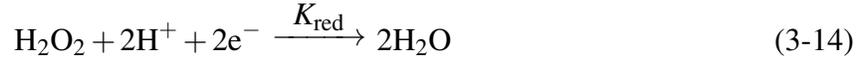
where  $i$  is the individual species,  $y$  is position, and  $D_{eff,i}$  is the effective diffusion coefficient based on porosity of the film as calculated by Bruggeman.[6] At the electrode, hydrogen peroxide is oxidized into oxygen and hydrogen ions,



where  $K_i$  denotes the heterogeneous rate constant. There are two cathodic reactions,



the reverse direction for equation (3-13), and



the reduction of hydrogen peroxide. Individual current densities are calculated from equations (3-12)-(3-14) with the Tafel expression,[37]

$$j_{\text{H}_2\text{O}_2} = K_{\text{H}_2\text{O}_2} c_{\text{H}_2\text{O}_2}(0) \exp(b_{\text{H}_2\text{O}_2} V) \quad (3-15)$$

where  $j_i$  is the current density for heterogeneous reaction  $i$ ,  $c_{\text{H}_2\text{O}_2}(0)$  is concentration of hydrogen peroxide at the electrode,  $b_i$  is a constant related to the Tafel slope of the reaction, and  $V$  is double layer potential. Equilibrium potential of the heterogeneous reaction is absorbed into  $K_{\text{H}_2\text{O}_2}$ . For this simplified model, hydrogen ion concentration is assumed to be constant and also absorbed into the heterogeneous rate constants. For the reduction reactions the current is

$$j_{\text{O}_2} = -K_{\text{O}_2} c_{\text{O}_2}(0) \exp(-b_{\text{O}_2} V) \quad (3-16)$$

for the reverse reaction, and

$$j_{\text{red}} = -K_{\text{red}} c_{\text{H}_2\text{O}_2}(0) \exp(-b_{\text{red}} V) \quad (3-17)$$

for hydrogen reduction. A species balance at the electrode yields a flux controlled by the individual currents,

$$\left. \frac{dc_i}{dy} \right|_{y=0} = \sum_i \frac{s_i}{nF D_{\text{eff},i}} j_i \quad (3-18)$$

where  $s_i$  is the stoichiometric coefficient,  $n$  are the number of electrons exchanged in the heterogeneous reaction, and  $F$  is the Faraday constant. For  $\beta - D -$  glucose and gluconic acid, that do not participate in the heterogeneous reactions, their flux is

$$\left. \frac{dc_i}{dy} \right|_{y=0} = 0 \quad (3-19)$$

Concentration of enzyme is conserved at each position and does not require a boundary condition. A diagram of the sensor is presented in Figure 3-1. Concentration where the GLM interfaces with

the bulk tissue is determined by the concentration in the bulk and the film partition coefficient,

$$c_i(\delta_{GOx} + \delta_{GLM}) = K_{i,partition}c_{i,bulk} \quad (3-20)$$

where  $K_{i,partition}$  is the partition coefficient, and  $c_{i,bulk}$  is the concentration of species  $i$  in the bulk.

Fluxes match at the GOx-GLM interface,

$$D_{GOx,i} \left. \frac{dc_i}{dy} \right|_{y=\delta_{GOx}} = D_{GLM,i} \left. \frac{dc_i}{dy} \right|_{y=\delta_{GOx}} \quad (3-21)$$

where  $D_{GOx,i}$  and  $D_{GLM,i}$  are the effective diffusion coefficients for the GOx and GLM films respectively.

To account for charging current, double layer potential  $V$  is controlled indirectly by modulating applied potential. A current balance of the circuit yields the expression

$$V_{applied} = R_e \left( i_F + C \frac{dV}{dt} \right) + V \quad (3-22)$$

where  $V_{applied}$  is applied potential,  $R_e$  is electrolyte resistance,  $i_F$  is the faradaic current from the heterogeneous reactions, and  $C$  is the double layer capacitance. The equivalent circuit representation of the system is shown in Figure 3-2 where  $R_t$  is the charge-transfer resistance which creates an offset between  $V_{applied}$  and  $V$ .

### 3.2 Numerical Methods

The numerical domain consists of 3 individual mesh spaces: fine mesh GOx layer adjacent to the electrode, a rough mesh GOx between the fine mesh and the GLM, and a GLM mesh between the rough GOx mesh and outer bulk concentration. The finer mesh close to the electrode yields greater accuracy in areas with steeper species flux without the computation expense of using a finer mesh throughout the entirety of the GOx layer. A single node lies on the electrode, and 200 nodes are located in each mesh area for a total of spatial 601 nodes. Temporal meshing began at 0.1 ms and stepped logarithmically to 200 ms for a total of 2600 temporal nodes and 60 s simulated. Solutions to the nonlinear coupled partial differential equations are found numerically with Newman's BAND algorithm in FORTRAN.[36] Transient calculations are initialized with

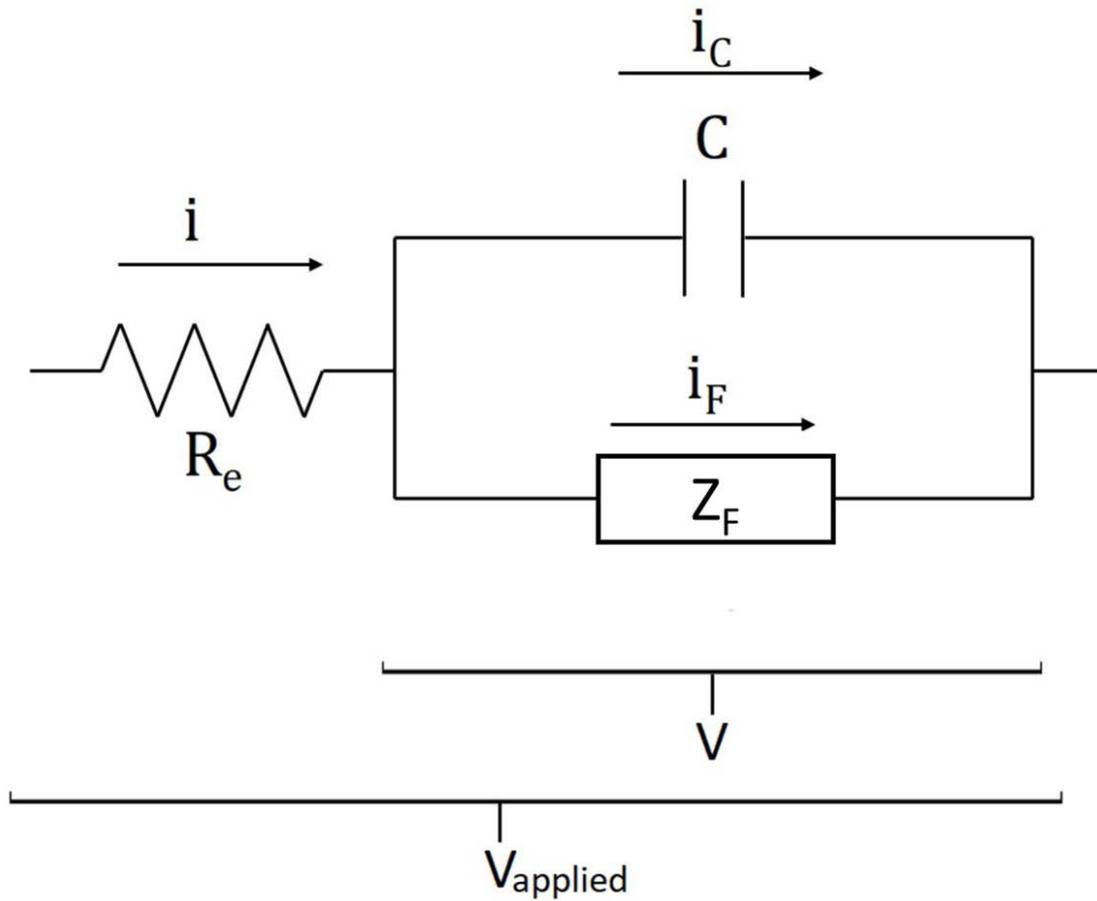


Figure 3-2. Equivalent circuit representation of double-layer. Charging current is modeled as current flow through a capacitor, while the faradaic current is considered a faradaic impedance,  $Z_F$ .

concentration profiles and potential calculated at steady state prior to system perturbation. At long times, transient calculations are in agreement with steady calculations at post-perturbation parameters. Each simulation is carried out on a single core of an Intel i7-3770 processor at 3.4 GHz in approximately 150 seconds.

### 3.2.1 Steady State

Transport equations were discretized with second-order accurate finite difference formulas,

$$0 = D_i \frac{d^2 c_i}{dy^2} \rightarrow 0 = D_i \frac{c_{i,J+1} - 2c_{i,J} + c_{i,J-1}}{\Delta y^2} + O\Delta y^2 \quad (3-23)$$

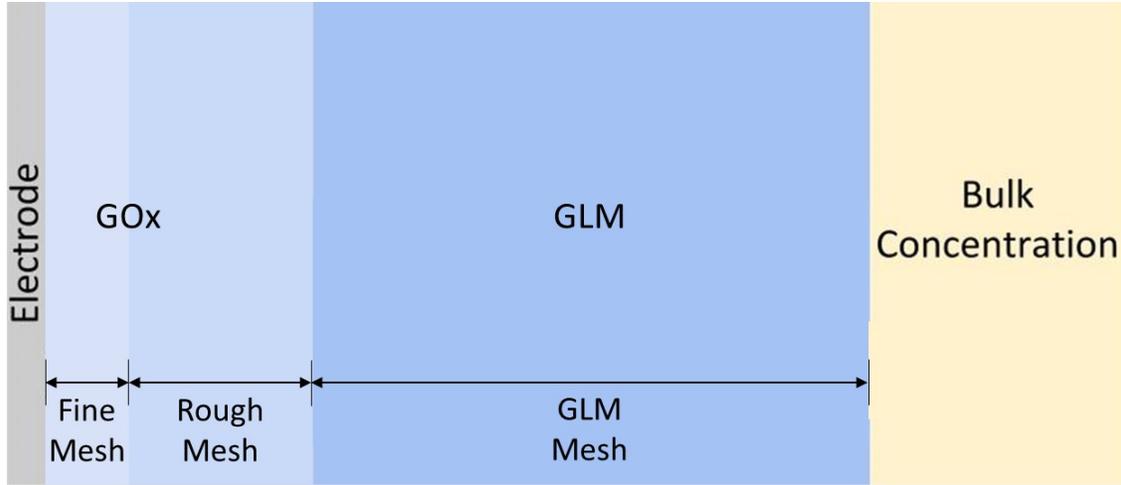


Figure 3-3. Spatial discretization of the entire glucose sensor numerical domain. Each mesh spacing consists of 200 nodes, plus an additional node for the electrode for a total of 601 nodes.

where  $J$  is the node of the discretization, and  $\Delta y$  is the spacing between nodes. For nodes with unequal spacing, such as the interface between the fine mesh and rough mesh, or where the GOx and GLM interface, a mass balance is carried out at the quarter-mesh nodes adjacent to the interface. An illustration of the quarter mesh points are illustrated in Figure 3-4. A mass balance at  $J-1/4$  yields

$$(\nabla \cdot N_i + R_i) \Big|_{J-1/4} = \frac{N_{i,J} - N_{i,J-1/2}}{\Delta y_{\text{left}}} + \frac{3R_{i,J} + R_{i,J-1}}{4} \quad (3-24)$$

and at  $J+1/4$  yields

$$(\nabla \cdot N_i + R_i) \Big|_{J+1/4} = \frac{N_{i,J+1/2} - N_{i,J}}{\Delta y_{\text{right}}} + \frac{3R_{i,J} + R_{i,J+1}}{4} \quad (3-25)$$

where  $\Delta y_{\text{left}}$  and  $\Delta y_{\text{right}}$  is the spacing between  $J$  to  $J-1$  and  $J$  to  $J+1$ , respectively. Expanding the flux with diffusion through a film in equations (3-24) and (3-25) and adding them together leads to cancellation of  $N_{i,J}$  terms.

### 3.2.2 Transient

Governing equations are discretized with Crank-Nicolson scheme across the domain to maintain second-order accuracy in spatial and temporal step size.[11] A central difference spacing

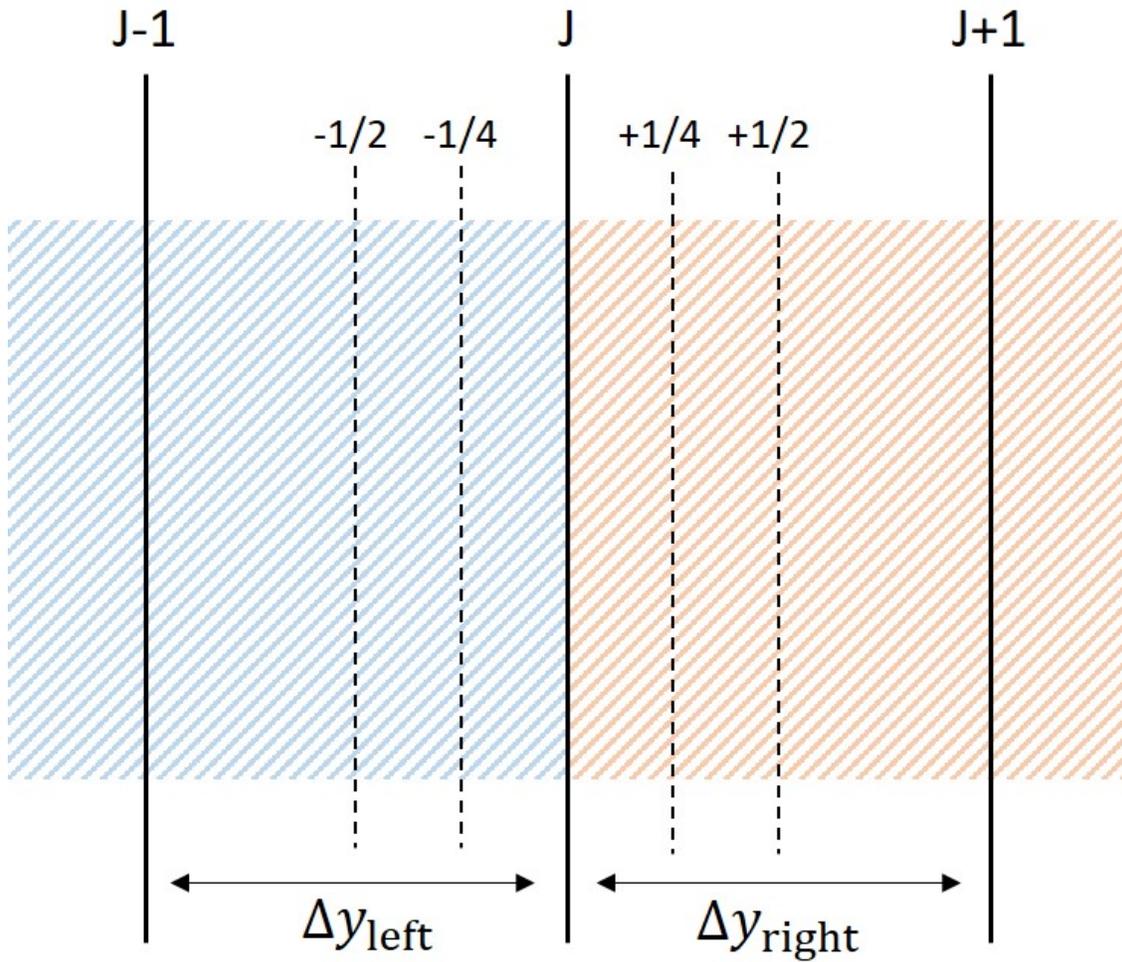


Figure 3-4. Visualization of the quarter-mesh points around node J, where two individually spaced regions interface. A mass balance around J-1/4 and J+1/4 allows for a central difference scheme.

across time and space for transient diffusion yields

$$\frac{c_{i,J}^{n+1} - c_{i,J}^n}{\Delta t} = D_i \frac{c_{i,J+1}^{n+1} - 2c_{i,J}^{n+1} + c_{i,J-1}^{n+1} + c_{i,J+1}^n - 2c_{i,J}^n + c_{i,J-1}^n}{2\Delta y^2} \quad (3-26)$$

where  $\Delta t$  is the temporal step size, and  $n$  is the present time step. The steady model provides initial conditions for the transient model.

### 3.3 Results

Simulations were performed with parameters presented in Table 3-1. Polarization behavior of the steady model was investigated for varied glucose concentrations. The steady model served as the initial conditions for the transient model. Current response to potential and glucose steps were simulated with the transient model. The influence of transient concentration profiles as initial conditions for the impedance model were investigated. This serves as a prediction of nonstationary conditions on the impedance response of the sensor.

#### 3.3.1 Steady State

The steady model allows for calculation of the Polarization behavior. Gao et al.[19] presented steady state concentration profiles for both the enzyme and diffusing species. Polarization curves from -0.1 to 0.5 V from and glucose concentrations of 100, 200 and 300 mgdL<sup>-1</sup> are shown in Figure 3-5. Mass transfer limited current occurs at approximately 0.4 V for all 3 glucose concentrations. Magnitude of the faradaic current from hydrogen peroxide oxidation and reduction is much larger than oxygen reduction. Electrode concentration of glucose and hydrogen peroxide as a function of potential is presented in Figure 3-6. Hydrogen peroxide concentration at the electrode reaches a peak at intermediate potentials and becomes mass transfer limited at large cathodic and anodic potentials.

#### 3.3.2 Transient

A transient calculation was carried out for a potential step increase from 0.3 to 0.4 V. Transient concentration profiles in response to the potential step for hydrogen peroxide and oxygen are presented in Figure 3-7. As the electrode charges, additional hydrogen peroxide is consumed at the surface and additional oxygen is produced. The initial rise and drop in faradaic current after the potential step is due to an excess concentration of hydrogen peroxide at the electrode at short times. At long times, diffusion-reaction effects are seen as the concentrations of hydrogen peroxide and oxygen are uniformly reduced and increased respectively. Double layer potential, charging, and faradaic currents are presented in Figure 3-8. Double layer potential transitions to the stepped value with a time constant of  $R_eC$ , or 0.3 s. After the applied potential is

Table 3-1. Parameter values used for numerical simulations.

Parameter	Value	Units
Bulk Oxygen Concentration, $c_{O_2,o}$	52.8	nmol/cm <sup>3</sup>
Total Enzyme Loading, $c_{E,o}$	0.356	μmol/cm <sup>3</sup>
Diffusion coefficient of Glucose, $D_{GLU}$	$2.98 \times 10^{-6}$	cm <sup>2</sup> /s
Diffusion coefficient of Gluconic Acid, $D_{GLA}$	$2.98 \times 10^{-6}$	cm <sup>2</sup> /s
Diffusion coefficient of Oxygen, $D_{O_2}$	$2.46 \times 10^{-5}$	cm <sup>2</sup> /s
Diffusion coefficient of Hydrogen Peroxide, $D_{H_2O_2}$	$1.83 \times 10^{-5}$	cm <sup>2</sup> /s
Porosity of GOX Layer	0.8	
Porosity of GLM Layer for O <sub>2</sub> and H <sub>2</sub> O <sub>2</sub>	0.42	
Porosity of GLM Layer for GLU and GLA	0.169	
Partition Coefficient for Hydrogen Peroxide	0.32	
Partition Coefficient for Oxygen	0.11	
Partition Coefficient for Glucose and Gluconic Acid	0.025	
GOX Layer Thickness	10	μm
Glucose Limiting Membrane Layer Thickness	20	μm
Electrolyte Resistance, $R_e$	10	Ωcm <sup>2</sup>
Double Layer Capacitance, $C$	$20 \times 10^{-6}$	F/cm <sup>2</sup>
Forward rate and equilibrium constants for Reaction 1, $k_{f,1}$ and $k_{b,1}$	$1 \times 10^9$ and $1 \times 10^7$	cm <sup>3</sup> mol <sup>-1</sup> s <sup>-1</sup>
Forward constant for Reaction 2, $k_{f,2}$	$1 \times 10^9$	s <sup>-1</sup>
Forward rate and equilibrium constants for Reaction 3, $k_{f,3}$ and $k_{b,3}$	$1 \times 10^9$ and $1 \times 10^7$	cm <sup>3</sup> mol <sup>-1</sup> s <sup>-1</sup>
Forward constant for Reaction 4, $k_{f,4}$	$1 \times 10^3$	s <sup>-1</sup>
Heterogeneous rate constant, H <sub>2</sub> O <sub>2</sub> oxidation, $K_a$	0.2	A/mol · cm <sup>2</sup>
Electrode Constant, H <sub>2</sub> O <sub>2</sub> oxidation, $b_a$	37.42	V <sup>-1</sup>
Heterogeneous rate constant, O <sub>2</sub> reduction, $K_a$	$5 \times 10^{-6}$	A/mol · cm <sup>2</sup>
Electrode Constant, O <sub>2</sub> reduction, $b_a$	38.4	V <sup>-1</sup>
Heterogeneous rate constant, H <sub>2</sub> O <sub>2</sub> reduction, $K_a$	$5 \times 10^4$	A/mol · cm <sup>2</sup>
Electrode Constant, H <sub>2</sub> O <sub>2</sub> reduction, $b_a$	32	V <sup>-1</sup>

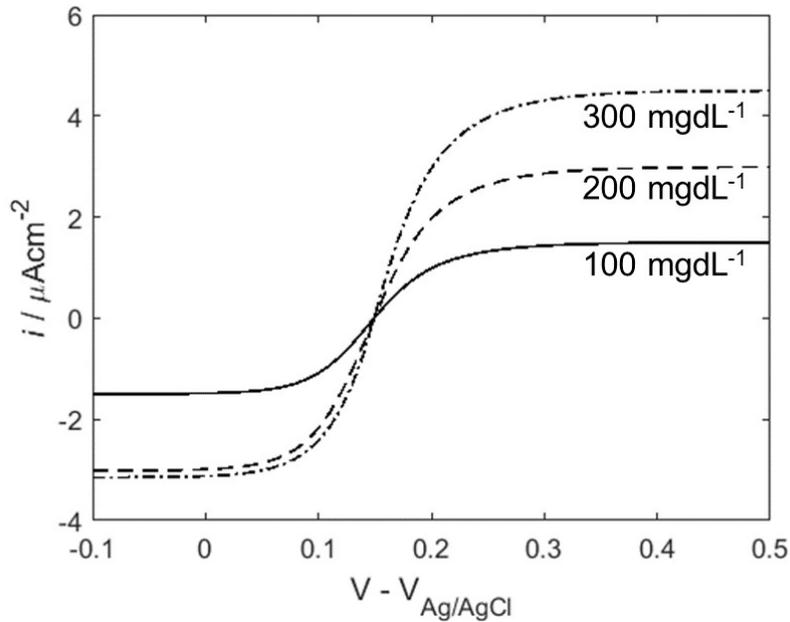


Figure 3-5. Polarization curves from -0.1 to 0.5 V for glucose concentrations of 100, 200 and 300  $\text{mgdL}^{-1}$ . Peak anodic current increases with increasing glucose. Mass transfer limited potential is the same for all 3 glucose concentrations.

stepped, charging current jumps to a peak value of  $R_c^{-1}\Delta V$  ( $575 \mu\text{Acm}^{-2}$ ). Faradaic current reaches a peak value while the electrode is charging and excess hydrogen peroxide is reacted at the electrode. The current responses are presented on a semi-log time scale in Figure 3-9; individual time constants of the current response are more pronounced on the log time scale.

Distinct from the steady model, homogeneous reaction rate profiles are not equal during intermediate response times. With present model parameters,  $R_1$  occurs at the same rate as  $R_2$  and  $R_3$  occurs at the same rate as the  $R_4$ . The difference between  $R_3$  and  $R_1$  is also the rate of

Table 3-2. Parameter values for transient simulations by perturbation type

Potential	Glucose Concentration	Perturbation Type	Figures
0.30 $\rightarrow$ 0.40 V(Ag/AgCl)	300 mg/dL	Potential Step	3-7,3-8,3-9,3-10
0.40 V(Ag/AgCl)	100 $\rightarrow$ 300 mg/dL	Glucose Step	3-11
0.35 V(Ag/AgCl)	300 mg/dL	Impedance Response	3-12,3-13
0.30 $\rightarrow$ 0.40 and 0.40 $\rightarrow$ 0.30 V(Ag/AgCl)	300 mg/dL	Potential Step	3-14

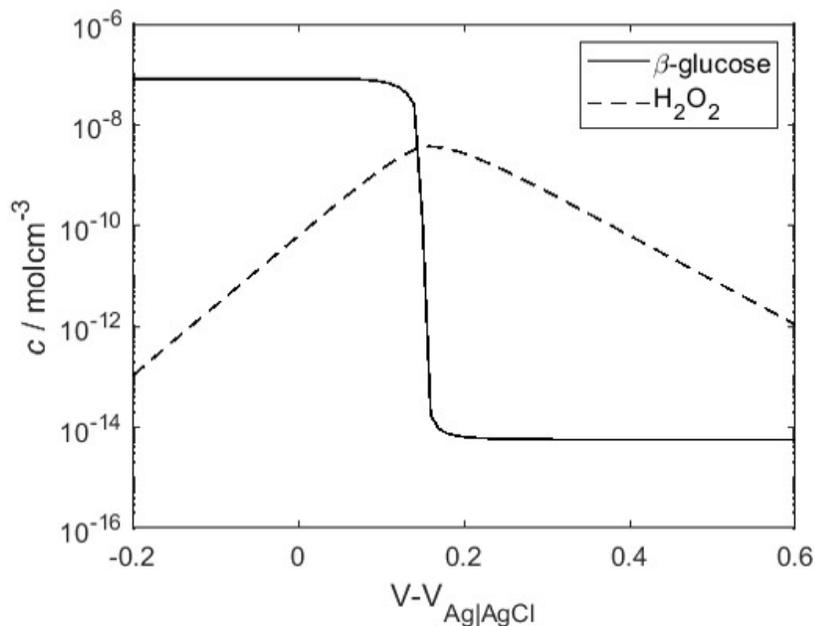


Figure 3-6. Steady concentration of glucose and hydrogen peroxide at the electrode surface as a function of potential for a bulk glucose concentration of  $300 \text{ mgdL}^{-1}$ . Hydrogen peroxide is mass transfer limited at cathodic and anodic potentials.

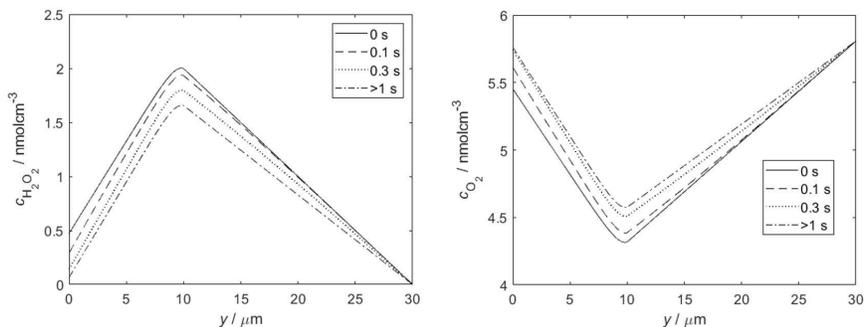


Figure 3-7. Transient concentration profiles for a) Hydrogen Peroxide and b) Oxygen at 0 s, 0.1 s, 0.3 s, and times past 1 s in response to a potential step from 0.3 to 0.4 V at 0 s. In response to the potential step, the anodic reaction rate of hydrogen peroxide is increased. Rate of consumption and production of hydrogen peroxide and oxygen, respectively, at the electrode are increased.

accumulation of  $\text{GOx}_{\text{red}}$ ; these results are presented in Figure 3-10. Enzyme concentrations are coupled to the nonlinear reaction rates, thus the rate of accumulation of the different forms of the enzyme influence the transient current response.

Distinguishing itself from the impedance model of Gao[19], the transient model allows for

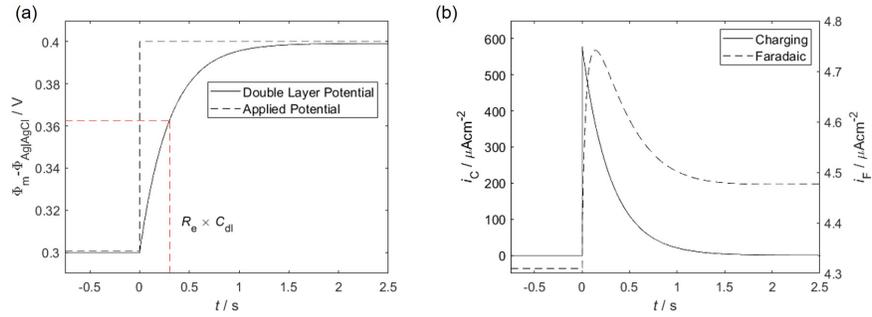


Figure 3-8. Transient response of a) double layer potential and b) charging and faradaic current. Double layer potential charges with a time constant of  $R_e C$  from 0.3 to 0.4 V. Charging current begins at peak value as double layer charging rate is maximal, and decays to 0 when fully charged. Faradaic current reaches peak value during charging as excess hydrogen peroxide is reacted.

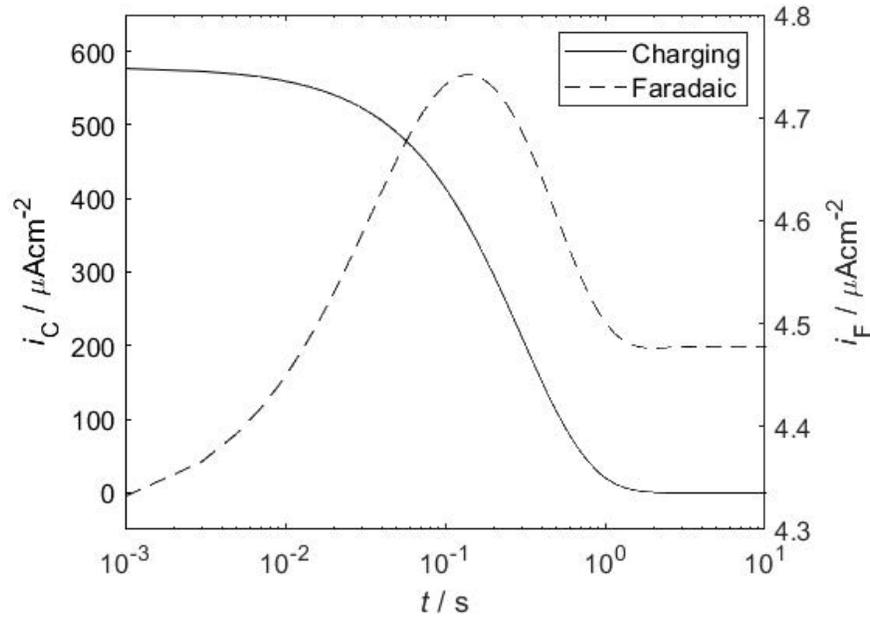


Figure 3-9. Results of Figure 3-8 b) presented on a semi-log time scale. Faradaic current reaches a peak value during the charging process, as excess hydrogen peroxide is consumed at the electrode.

perturbations to glucose concentration. Charging and faradaic current responses to a step change in bulk glucose from  $100$  to  $300 \text{ mgdL}^{-1}$  are presented in Figure 3-11. The duration of the initial delay in the faradaic response is the time required for the elevated glucose concentration at the edge of the GLM to reach the enzyme layer. The characteristic time constant for one-dimensional

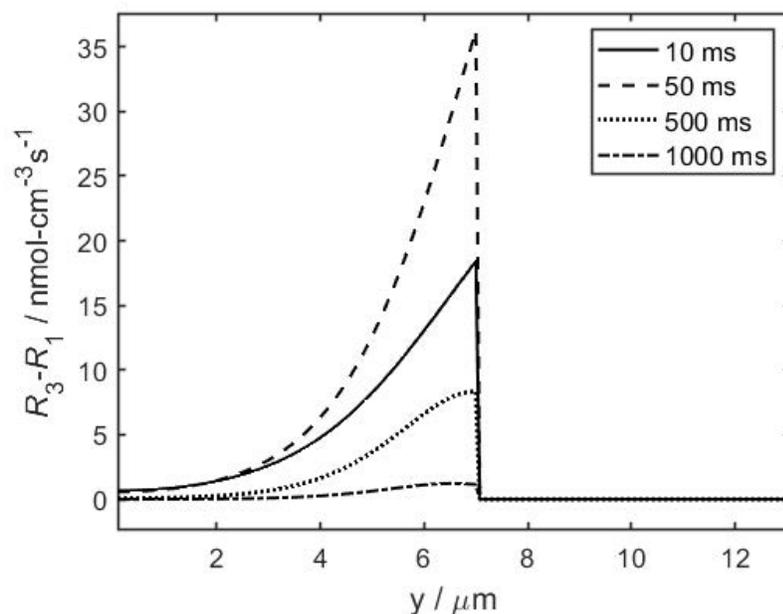


Figure 3-10. Reaction difference between  $R_3$  and  $R_1$  presented from 10 to 1000 ms in response to a potential step from 0.3 to 0.4 V. Complex dissociation for this group of simulations is assumed to occur rapidly.  $R_2$  and  $R_4$  occur at the same rate as  $R_3$  and  $R_1$ ; thus the difference is also the rate of accumulation of  $\text{GO}_{\text{ox}}$ . At intermediate times this rate of accumulation reaches a maximum. As steady state is approached at long times, the difference goes to zero and the individual enzyme concentrations stop changing.

diffusion in a finite domain with a concentration defined at both boundaries is  $\delta^2(\pi^2 D)^{-1}$  where  $\delta$  is the domain thickness and  $D$  is the diffusion coefficient. For  $\delta$  equal to the GLM thickness and the diffusion coefficient of the glucose in the GLM, this time constant is in close agreement with the initial delay in the response (1.97 s). Once the introduced glucose reaches the enzyme layer, hydrogen peroxide elevates rapidly through the enzyme reactions and diffuses to the electrode. Charging current is also nonzero during the faradaic transient due to the coupling of double layer potential and faradaic current in equation (3-22). During glucose step experiments, applied potential is held constant. Faradaic current increases with increased glucose and double layer potential decreases.

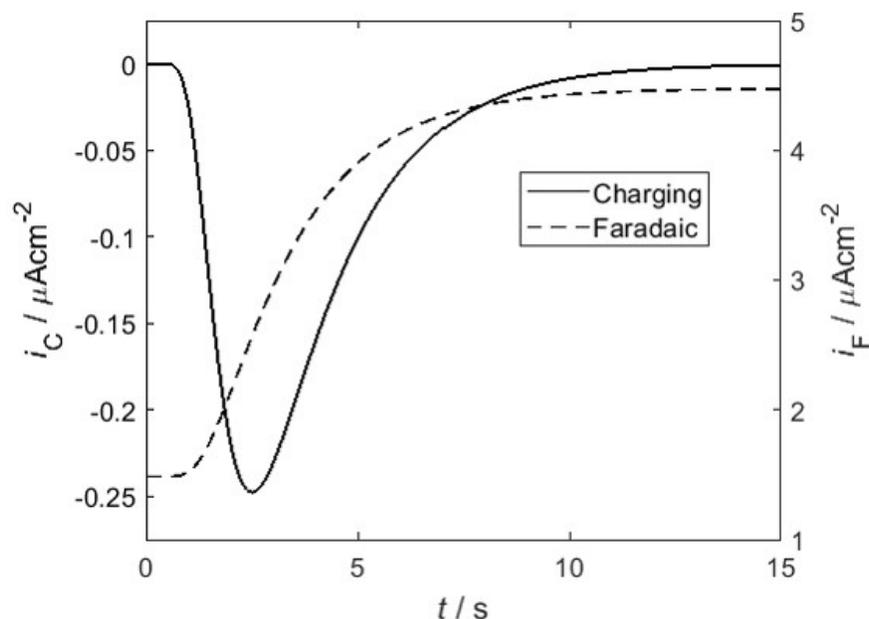


Figure 3-11. Charging and faradaic current response to a step in bulk glucose concentration from  $100 \text{ mgdL}^{-1}$  to  $300 \text{ mgdL}^{-1}$  at time = 0 s. The initial delay in the faradaic response is the time for the elevated glucose to transport through the GLM. Charging current is nonzero during the faradaic current transient.

### 3.3.3 Impedance Response vs. Transient Response

The transient model provides pseudo steady initial conditions for the impedance model by Gao [19]. Impedance results are presented in Figure 3-12 for 3 different initializing conditions: steady state at 0.35 V, an intermediate time between a potential step from 0.3 V to 0.4 V, and also for a potential step from 0.4 V to 0.3 V. Concentration profiles for hydrogen peroxide and oxygen are presented in Figure 3-13(a) for the 3 cases when double layer potential is 0.35 V. At intermediate times after a potential perturbation, the transient model yields reaction profiles which are unequal as presented in Figure 3-13(b). Faradaic and charging current response to the potential step increase, or decrease, between 0.3 and 0.4 V are presented in Figure 3-14.

## 3.4 Discussion

The present steady-state model was compared to the Michaelis-Menten kinetic model by Galceran.[18] Equation (2-7) was used in lieu of equations (3-3)-(3-6). Only  $\beta$  – glucose, oxygen, and hydrogen peroxide concentration profiles are calculated with the Michaelis-Menten model.

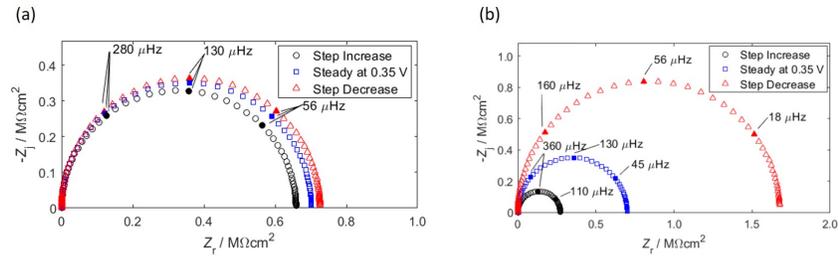


Figure 3-12. Overall impedance response for 3 different initializing conditions: steady state at 0.35 V, and intermediate times for either a potential step increase from 0.3 V to 0.4 V or step decrease from 0.4 V to 0.3 V. For the transient initializing case, the conditions were either chose when (a) the double layer potential reached 0.35 V, or (b) the faradaic current matched that of the steady case at 0.35 V, or  $4.43 \mu\text{Acm}^{-2}$

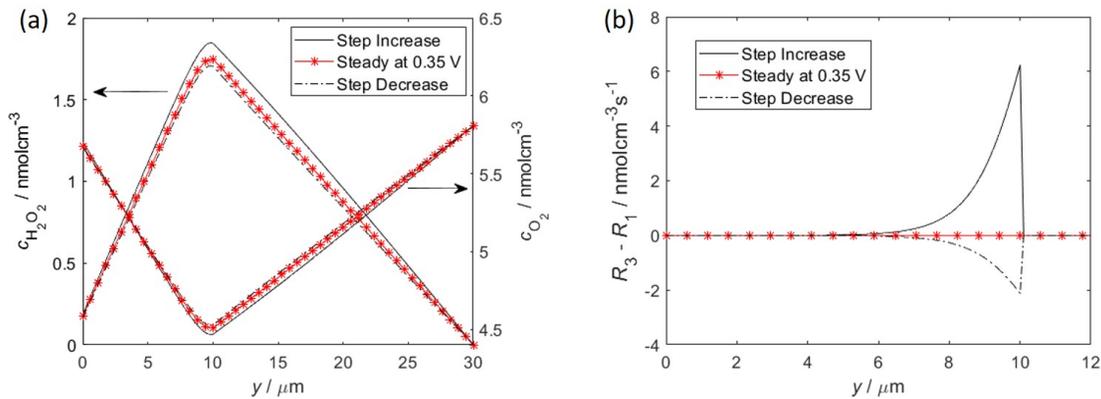


Figure 3-13. Profiles presented at intermediate times for the 3 cases when double layer potential is 0.35 V for (a) concentration of hydrogen peroxide and oxygen, and (b) difference between reactions 3 and 1. At intermediate times for the transient response, reaction profiles are unequal which leads to accumulation, or depletion, of the various forms of the enzyme. These differences in initial parameters lead to differences in the impedance response.

For cases where equation (3-6) is not rate limiting, the models are in perfect agreement. Potential and bulk oxygen varied steady state currents are presented in Figure 3-15. The Michaelis-Menten model is in good agreement for values of the rate constant,  $k_{f,4}$ , greater than  $1000 \text{ s}^{-1}$ . For smaller values of the rate constant, the dissociation of the enzyme complex is slow and the assumption of the Michaelis-Menten model is not correct. For small values of the equilibrium constant in equation (3-5), the reaction also becomes more sensitive to oxygen concentration; the Michaelis-Menten Model deviates in a similar fashion as reducing the value of  $k_{f,4}$ . Polarization

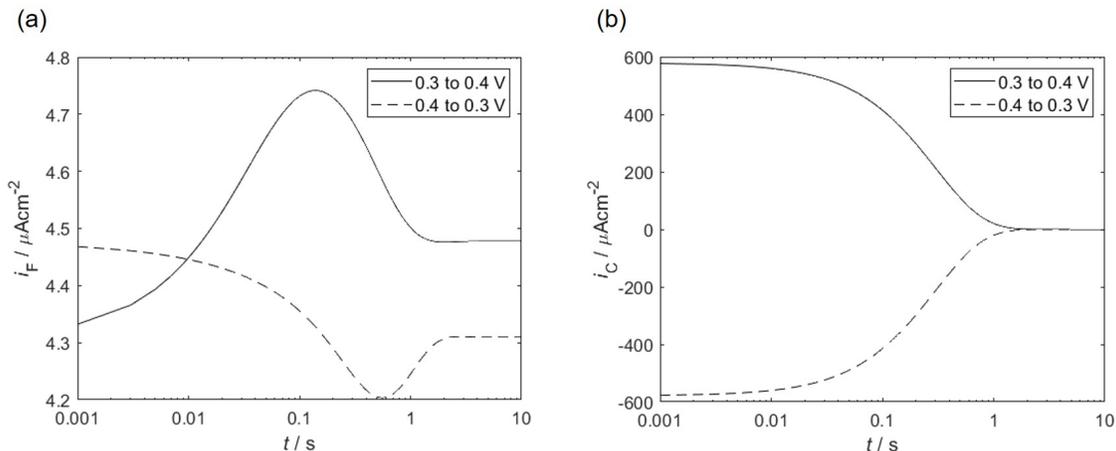


Figure 3-14. A potential step increase from 0.3 to 0.4 V, or decrease from 0.4 to 0.3 V was simulated; during the charging process, the transient results served as initial conditions for the impedance model. For a potential step change there is a corresponding (a) faradaic current response and (b) charging current response. Results are presented on a log-time scale.

and oxygen dependent current as a result of reducing  $K_{eq,3}$  are presented in Figure 3-16.

Only the total enzyme concentration is considered with the Michaelis-Menten kinetics, individual enzyme species are not explicitly considered. The transient model presented demonstrates unequal enzyme reactions and thus  $GOx_{ox}$  and  $GOx_{red}$  accumulation and depletion. The Michaelis-Menten model is not sufficiently detailed to provide the same observation. Consideration of the explicit reactions is necessary to study the transient system when varying enzyme reaction rate constants.

A comparison of charging and faradaic current response for potential and glucose steps are presented in Figure 3-17. Initial time constants associated with the potential step are related to double layer charging according to  $R_e \times C$ . Subsequent time constants are related to hydrogen peroxide and oxygen diffusion in the GOx layer; both processes are faster than diffusion of glucose through the GLM. The response time of the system to a potential step at a mass-transfer-limited potential is more rapid than the response to a glucose concentration step at the same applied potential. At mass-transfer-limited potential, charging current is greater than the faradaic current and dominates the total current response to a potential step. For a step in glucose

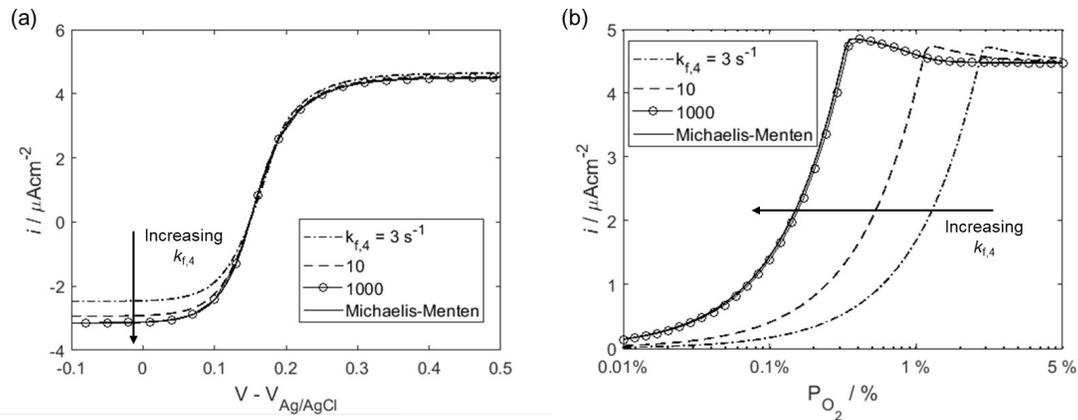


Figure 3-15. Comparison of steady model with Michaelis-Menten model as a function of (a) potential at 5%  $P_{O_2}$  and (b) oxygen concentration at 0.4 V. The Michaelis-Menten model assumes equation (2-4) proceeds irreversibly with rapid dissociation of the enzyme complex. Reducing the rate constant,  $k_{f,4}$ , relaxes the assumption of rapid complex dissociation in this reaction. For  $k_{f,4} = 1000 \text{ s}^{-1}$ , polarization and oxygen curve behavior is in good agreement with the Michaelis-Menten model.

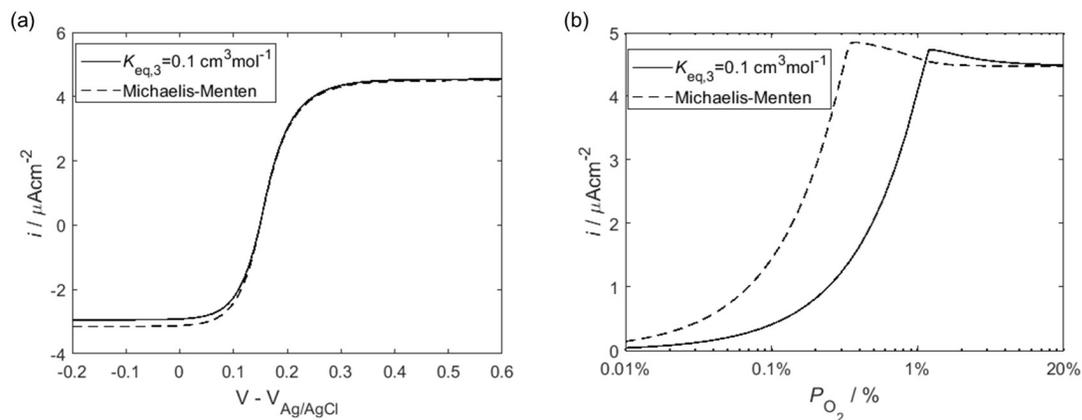


Figure 3-16. Comparison of steady model with Michaelis-Menten model as a function of (a) potential at 5%  $P_{O_2}$  and 300  $\text{mgdL}^{-1}$  and (b) oxygen concentration at 0.4 V. The Michaelis-Menten model assumes equation (2-4) proceeds irreversibly with rapid dissociation of the enzyme complex. Reducing the equilibrium constant,  $K_{eq,3}$ , relaxes the assumption of irreversibility.

concentration, double layer potential is weakly affected and the faradaic current response is much greater than the charging current response; for a glucose concentration step, the total current response is close in magnitude to the faradaic current response. The use of potential, or concentration steps, allows for the study of individual time constants present in the system tied to

heterogeneous reactions, homogeneous reactions, and diffusion for both small and large species.

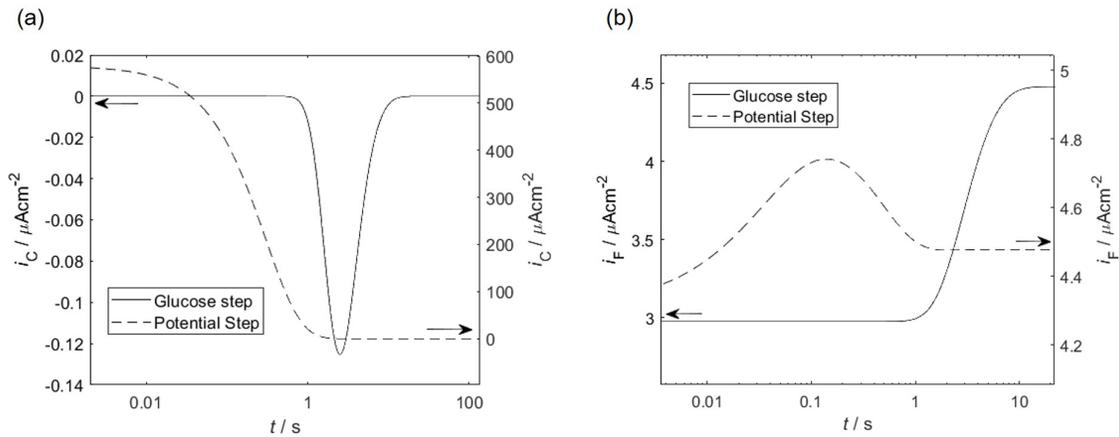


Figure 3-17. Semilog current response to a potential step from 0.3 to 0.4 V and 300 mgdL<sup>-1</sup> glucose, or a glucose step from 200 to 300 mgdL<sup>-1</sup> and 0.4 V for the (a)charging current and (b)faradaic current. These results suggest the response to a step change in potential are more rapid than the response to a step change in glucose on the mass-transfer limited plateau.

Individual contribution of the homogeneous reactions (equations 3-3-3-6) to the long-time behavior were studied by maintaining 1 forward rate constant much smaller than the other 3. The reaction associated with the smallest rate constant controls the current response in the long time for the case of a glucose step. The glucose step was chosen for this series of simulations as it is analogous to the variation of glucose concentration during sensor operation and the time constants are related to a portion of the sensor lag to manual measurement of intravenous blood glucose. The analytic expression for the largest time constant is dependent on the limiting reaction. When reaction 2 or 4 equations 3-4 and 3-6 are rate limiting, the enzyme complex accumulates. The complex does not diffuse, and the time constant of the current response is independent of the mass-transfer or spatial dimensions of the system. The long time constant in this case is expressed as

$$\tau_{k_{f,2or4}} = (k_{f,2or4})^{-1} \quad (3-27)$$

where  $\tau$  is the exponential rate constant fit at long times of the current response according to

$$i \propto \exp(-t/\tau) \quad (3-28)$$

, the current response proportional to the exponential time constant decay. As the rate constant is made large, a lower limit for the time constant is reached related to glucose diffusion through the GLM

$$\tau_{\text{GlucoseDiffusion}} = \frac{\delta_{\text{GLM}}^2}{\pi^2 D_{\text{glu, GLM}}} \quad (3-29)$$

where  $\delta_{\text{GLM}}$  is the thickness of the GLM layer. This expression characterizes the lower limit for the current response rate of a concentration change in glucose outside the sensor. A less rapid change in glucose concentration outside the sensor (ie. a gradual glucose ramp), would yield a larger time constant. Current response for varied  $k_{f,2}$  and the accompanying time constants are presented in Figure 3-18. The rate constants for reactions 2 and 4 have units of  $\text{s}^{-1}$ , and they yield the same time constants for the same set of limiting rate constants. The enzyme is overwhelmed for a sufficiently small rate constant which may provide infinitely large time constants, but is not representative of actual CGM operation. Time constants presented would be inconsequential to

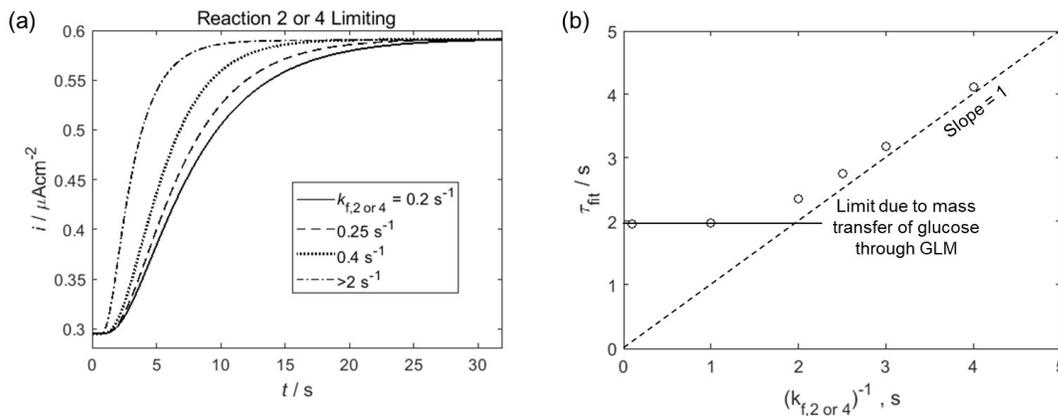


Figure 3-18. (a) Current response to glucose step from  $20$  to  $40 \text{ mgdL}^{-1}$  at  $0.4\text{V}$  for varied values of the limiting rate constant when the limiting constant is  $k_{f,2}$  or  $k_{f,4}$ . (b) Exponential time constant fits of the current response follow a slope of  $1$  vs.  $(k_{f,2})^{-1}$  for small rate constants. A lower limit time constant of approximately  $2 \text{ s}$  is reached due to the time required for glucose diffusion through the GLM.

the intrinsic lag of the sensor relative to the rate of exchange between the intravenous-interstitial fluid. Additional physics, not considered in this model, that would influence the long time constant are diffusion through an interstitial layer adjacent to the GLM, enzyme deactivation, and

adsorption controlled reactions on the electrode, such as an oxide growth. These mechanisms have the capability of yielding significantly larger time constants and the sensor would become a significant contribution to the sensor lag.

Behavior of the current response is similar when reactions in equations 3-3 or 3-5 are limiting. For Reaction 1 limiting, the time constant is proportional to

$$\tau_{k_{f,1}} = (c_{E_0} k_{f,1})^{-1} \quad (3-30)$$

where  $c_{E_0}$  is the total enzyme loading in the system. The small time constant limit is the same as presented in equation (3-29). This study reveals the long time behavior of the model is dependent on the reaction rate in the GOx layer, until the rate constants exceed the time constant associated with glucose diffusion through the GLM.

Use of the transient model to initialize the impedance model provides insight for cases where impedance measurements are made at nonstationary conditions. As outlined by Gao's model, diffusion resistance dominates the impedance response when

$$\frac{R_t}{R_d} \ll 1 \quad (3-31)$$

where  $R_t$  is the charge transfer resistance, and  $R_d$  is the diffusion resistance. For an impedance response dominated by diffusion resistance, the characteristic frequency is  $R_d C_{dl}$ . For the impedance response when the intermediate conditions initialize the impedance once double layer potential reaches 0.35 V, as presented in Figure 3-12(a), an excess concentration of hydrogen peroxide is present at the electrode for the case of the potential step increase. For a potential step increase from 0.3 V to 0.4 V, the observed diffusion resistance at 0.35 V is less than the diffusion resistance of steady state, or for a potential step decrease from 0.3 V to 0.4 V, at 0.35 V. A diffusion resistance between 0.66 and 0.72  $M\Omega cm^2$  for a potential step increase and decrease, at 0.35 V, respectively. Charging of the electrode occurs with a time constant of  $R_e C_{dl}$ . A double layer potential of 0.35 V is reached in 0.2 S when stepping between 0.3 V and 0.4 V for a time constant of 0.3 s. The difference in hydrogen peroxide and oxygen concentration presented in

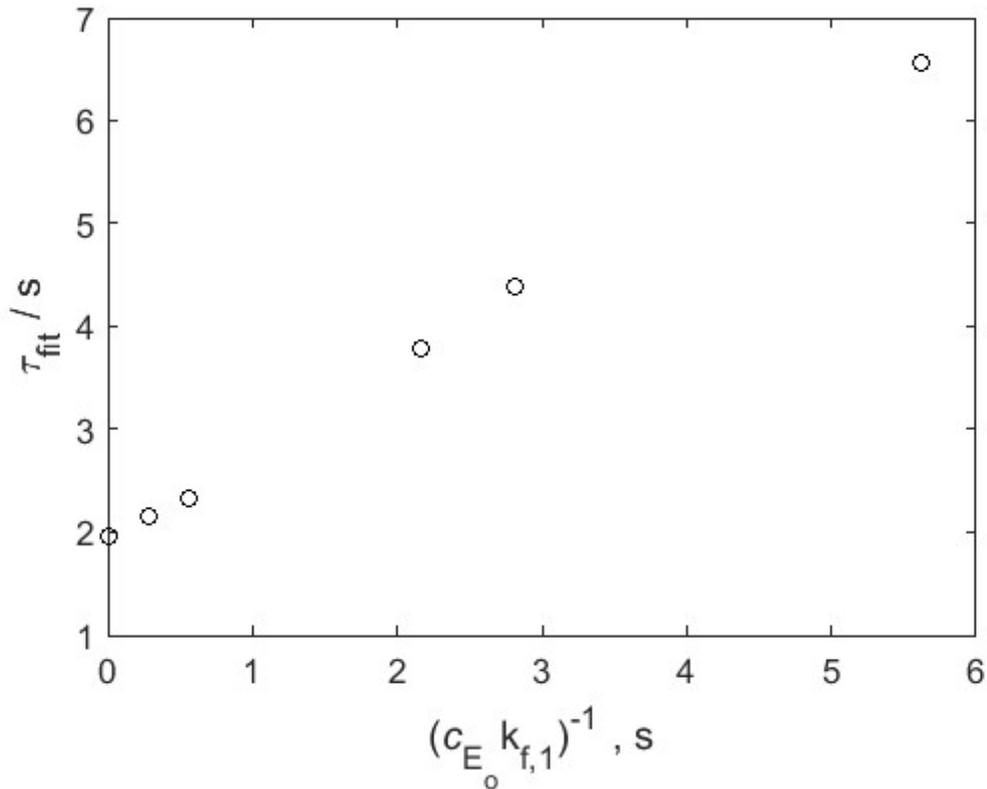


Figure 3-19. Exponential time constant fits of the current response when equation (3-3) is the limiting reaction. A lower limit time constant of approximately 2 s is reached due to the time required for glucose diffusion through the GLM.

Figure 3-13(a) between the 3 cases is consistent with the differences observed in the overall impedance response. At steady state, all concentrations for the various enzyme forms are also steady. During transient operation, the enzyme forms are either accumulating or depleting. For a potential step increase from 0.3 V to 0.4 V, the concentration of oxygen is increasing. This further drives enzyme Reaction 3; a positive difference between Reaction 3 and 1 means  $GO_{ox}$  is accumulating and  $GO_{red}$  is depleting. Excess  $GO_{ox}$  is conducive of sufficient oxygen and reduced diffusion resistance. The converse is true for the case of a potential step decrease from 0.4 V to 0.3 V, as observed by the negative difference between Reaction 3 and 1 in Figure 3-13(b).

CHAPTER 4  
INFLUENCE OF EXTERNAL DIFFUSION LAYER ON SENSOR RESPONSE

This chapter describes the steady and transient model for a glucose sensor with an adjacent diffusion layer. The model relaxes the assumption made in Chapter 3, and concentration of mobile species at the GOx-Tissue interface are no longer constant. The model accounts for an external diffusion layer adjacent to the GLM. The steady model provides the steady concentration profiles and polarization behavior as a function of the diffusion layer thickness. The transient model provides the influence of the diffusion layer on an external change in glucose concentration and the current response.

### 4.1 Mathematical Model

The governing equations are those presented for the simple model in Chapter 3, except for the boundary condition at the GLM-tissue interface. The present model adds an additional layer between the GLM and bulk concentration, the tissue diffusion layer. A one-dimensional cross section of the sensor and adjacent diffusion layer are presented in Figure 4-1. At the GLM-tissue interface the flux are

$$D_{\text{GLM},i} \left. \frac{dc_{\text{GLM},i}}{dy} \right|_{y=\delta_{\text{GOx}}+\delta_{\text{GLM}}} = D_{\text{tissue},i} \left. \frac{dc_{\text{tissue},i}}{dy} \right|_{y=\delta_{\text{GOx}}+\delta_{\text{GLM}}} \quad (4-1)$$

where the distance  $\delta_{\text{GOx}} + \delta_{\text{GLM}}$  is the location of the GLM-Tissue interface, and the subscripts GLM and tissue refer to the variables in the GLM and tissue layers respectively. The other boundary condition enforced at the interface is matching concentration

$$c_{\text{GLM},i}(\delta_{\text{GLM}} + \delta_{\text{tissue}}) = K_{\text{partition},i} c_{\text{tissue},i}(\delta_{\text{GLM}} + \delta_{\text{tissue}}) \quad (4-2)$$

where  $K_{\text{partition},i}$  is the partition coefficient at the GLM-tissue interface for species  $i$ . These boundary conditions are resolved with central difference formulas in 4.2 Effective diffusion coefficients for the GOx and GLM layers are modified by a porosity according to Bruggeman[6], as presented in equation 3-11.

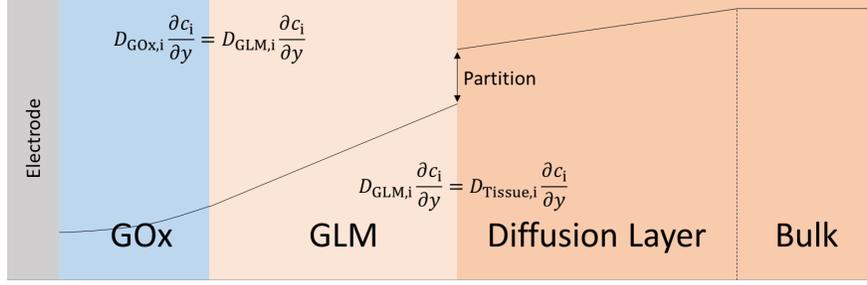


Figure 4-1. One-dimensional cross section of the glucose sensor with an adjacent diffusion layer. Species flux at the GLM-tissue interface match. The outer boundary of the diffusion layer matches a bulk concentration of an adjacent well mixed region.

## 4.2 Numerical Methods

The quarter-mesh-point technique outlined in 3.2 is employed to enforce the boundary conditions in equations 4-1 and 4-2

$$\left( D_{\text{GLM},i} \frac{d^2 c_i}{dy^2} \right) \Big|_{J-1/4} + \left( D_{\text{tissue},i} \frac{d^2 c_i}{dy^2} \right) \Big|_{J+1/4} = D_{\text{GLM},i} \frac{K_i c_i(J) - c_i(J-1)}{\Delta y_{\text{GLM}}} + D_{\text{tissue},i} \frac{c_i(J+1) - c_i(J)}{\Delta y_{\text{tissue}}} \quad (4-3)$$

where the partition coefficient  $K_i$  is only multiplied by the concentration at node J for the mass balance in the GLM. For a value of  $K_i$  between 0 and 1, this will yield a smaller concentration in the GLM than the tissue region at node J.

The transient model is still discretized by the technique demonstrated in equation 3-26, except the time derivative in the GLM layer is expressed as

$$\frac{dc_i}{dt} \Big|_{J-1/4} = \frac{3K_i (c_i^{n+1}(J) - c_i^n(J)) + (c_i^{n+1}(J-1) - c_i^n(J-1))}{4\Delta t} \quad (4-4)$$

where n and n+1 represents the present and next time step. This technique allows second-order accuracy to be maintained in both temporal and spatial variable step size. One consequence of enforcing the partition coefficient at node J, is the mass balance at node J-1 must also enforce the partition coefficient such that

$$D_{\text{GLM},i} \frac{d^2 c_i}{dy^2} \Big|_{J-1} = \frac{K_i c_i(J) - 2c_i(J-1) + c_i(J-2)}{\Delta y^2} \quad (4-5)$$

where the concentration at node J is scaled by the partition coefficient for the species. This

modification is employed in both the steady and transient discretization.

### 4.3 Results

Steady concentration and reaction profiles are presented for 3 individual external diffusion layer thickness. The steady current is also calculated for multiple diffusion layer thickness and oxygen concentrations. The transient concentration and current response to a step change in glucose is calculated for multiple diffusion layer thickness. Parameters for steady and transient calculations are presented in Table 4-1. Steady sensor operation as a function of the diffusion layer thickness is dependent on accurate diffusion coefficient values for hydrogen peroxide and glucose in tissue, which were found by works cited. [17, 32, 46]

Table 4-1. Parameter values used for numerical simulations of model with tissue diffusion layer.

Parameter	Value	Units
Applied Potential, $\Phi - \Phi_{\text{Ag}\backslash\text{AgCl}}$	0.4	V
Total Enzyme Loading, $c_{\text{E},0}$	0.356	$\mu\text{mol}/\text{cm}^3$
Diffusion coefficient of Glucose, $D_{\text{GLU}}$	$2.98 \times 10^{-6}$	$\text{cm}^2/\text{s}$
Diffusion coefficient of Gluconic Acid, $D_{\text{GLA}}$	$2.98 \times 10^{-6}$	$\text{cm}^2/\text{s}$
Diffusion coefficient of Oxygen, $D_{\text{O}_2}$	$2.46 \times 10^{-5}$	$\text{cm}^2/\text{s}$
Diffusion coefficient of Hydrogen Peroxide, $D_{\text{H}_2\text{O}_2}$	$1.83 \times 10^{-5}$	$\text{cm}^2/\text{s}$
Porosity of GOX Layer	0.8	
Porosity of GLM Layer for $\text{O}_2$ and $\text{H}_2\text{O}_2$	0.42	
Porosity of GLM Layer for GLU and GLA	0.169	
Partition Coefficient for Hydrogen Peroxide	0.32	
Partition Coefficient for Oxygen	0.11	
Partition Coefficient for Glucose and Gluconic Acid	0.025	
GOX Layer Thickness	10	$\mu\text{m}$
Glucose Limiting Membrane Layer Thickness	20	$\mu\text{m}$
Electrolyte Resistance, $R_e$	10	$\Omega\text{cm}^2$
Double Layer Capacitance, $C$	$20 \times 10^{-6}$	$\text{F}/\text{cm}^2$
Forward rate and equilibrium constants for Reaction 1, $k_{\text{f},1}$ and $k_{\text{b},1}$	$1 \times 10^9$ and $1 \times 10^7$	$\text{cm}^3\text{mol}^{-1}\text{s}^{-1}$
Forward constant for Reaction 2, $k_{\text{f},2}$	$1 \times 10^9$	$\text{s}^{-1}$
Forward rate and equilibrium constants for Reaction 3, $k_{\text{f},3}$ and $k_{\text{b},3}$	$1 \times 10^9$ and $1 \times 10^7$	$\text{cm}^3\text{mol}^{-1}\text{s}^{-1}$
Forward constant for Reaction 4, $k_{\text{f},4}$	$1 \times 10^3$	$\text{s}^{-1}$
Heterogeneous rate constant, $\text{H}_2\text{O}_2$ oxidation, $K_a$	0.2	$\text{A}/\text{mol} \cdot \text{cm}^2$
Electrode Constant, $\text{H}_2\text{O}_2$ oxidation, $b_a$	37.42	$\text{V}^{-1}$
Heterogeneous rate constant, $\text{O}_2$ reduction, $K_a$	$5 \times 10^{-6}$	$\text{A}/\text{mol} \cdot \text{cm}^2$
Electrode Constant, $\text{O}_2$ reduction, $b_a$	38.4	$\text{V}^{-1}$
Heterogeneous rate constant, $\text{H}_2\text{O}_2$ reduction, $K_a$	$5 \times 10^4$	$\text{A}/\text{mol} \cdot \text{cm}^2$
Electrode Constant, $\text{H}_2\text{O}_2$ reduction, $b_a$	32	$\text{V}^{-1}$

### 4.3.1 Steady Model

Steady-state calculations were made at 20, 50, and 80  $\mu\text{m}$  tissue diffusion layer thickness, applied potential of 0.4 V vs. Ag\AgCl, and 300  $\text{mgdL}^{-1}$  total glucose concentration. Steady concentration profiles for  $\beta - D -$  glucose, oxygen, hydrogen peroxide, and enzyme reaction rate profiles are presented for the 3 tissue diffusion layer thickness in Figure 4-2. Glucose and oxygen concentrations change immediately at the GLM-tissue interface due to the partition coefficient in equation 4-2. This drop is presented in Figure 4-2(a) for glucose. Glucose concentration slightly decreases from the bulk region to the GLM-tissue interface, as presented in Figure 4-2(b). The diffusion layer was omitted from Figure 4-2(c) to better illustrate the oxygen concentration within the sensor. The flux of glucose through the diffusion layer are approximately equal for the 3 individual diffusion layer thickness. From Figure 4-2(d), peak hydrogen peroxide concentration slightly increases for an increase in diffusion layer thickness from 20 to 80  $\mu\text{m}$ . This is apparent by the reduced flux of hydrogen peroxide in the diffusion layer as the thickness is increased. The reaction position, presented in Figure 4-2(e), does not vary with the thickness of diffusion layer.

Steady current was calculated for 100, 200, and 300  $\text{mgdL}^{-1}$  total glucose and diffusion layer thickness was varied from 5  $\mu\text{m}$  to 1 cm. The steady current calculations are presented in Figure 4-3 on a log scale for the diffusion layer thickness. As the diffusion layer thickness is increased, steady current reaches a peak at 400  $\mu\text{m}$ . This peak is more pronounced for additional glucose in the system. As the diffusion layer thickness is increased past 400  $\mu\text{m}$ , the current decreases. This drop in current is more pronounced as the thickness of the diffusion layer is made larger.

Influence of oxygen on the steady current was calculated for 10  $\mu\text{m}$ , 100  $\mu\text{m}$ , and 1 mm diffusion layer thickness as presented in Figure 4-4. For the 10 and 100  $\mu\text{m}$  diffusion layer thickness, current reaches a maximum for an intermediate value of oxygen. This peak is absent from the current for 1 mm diffusion layer thickness and current continually decreases with decreasing oxygen concentration. For all 3 diffusion layer thickness, a steep drop in current is observed when oxygen partial pressure becomes small. Insufficient oxygen leads to halting of

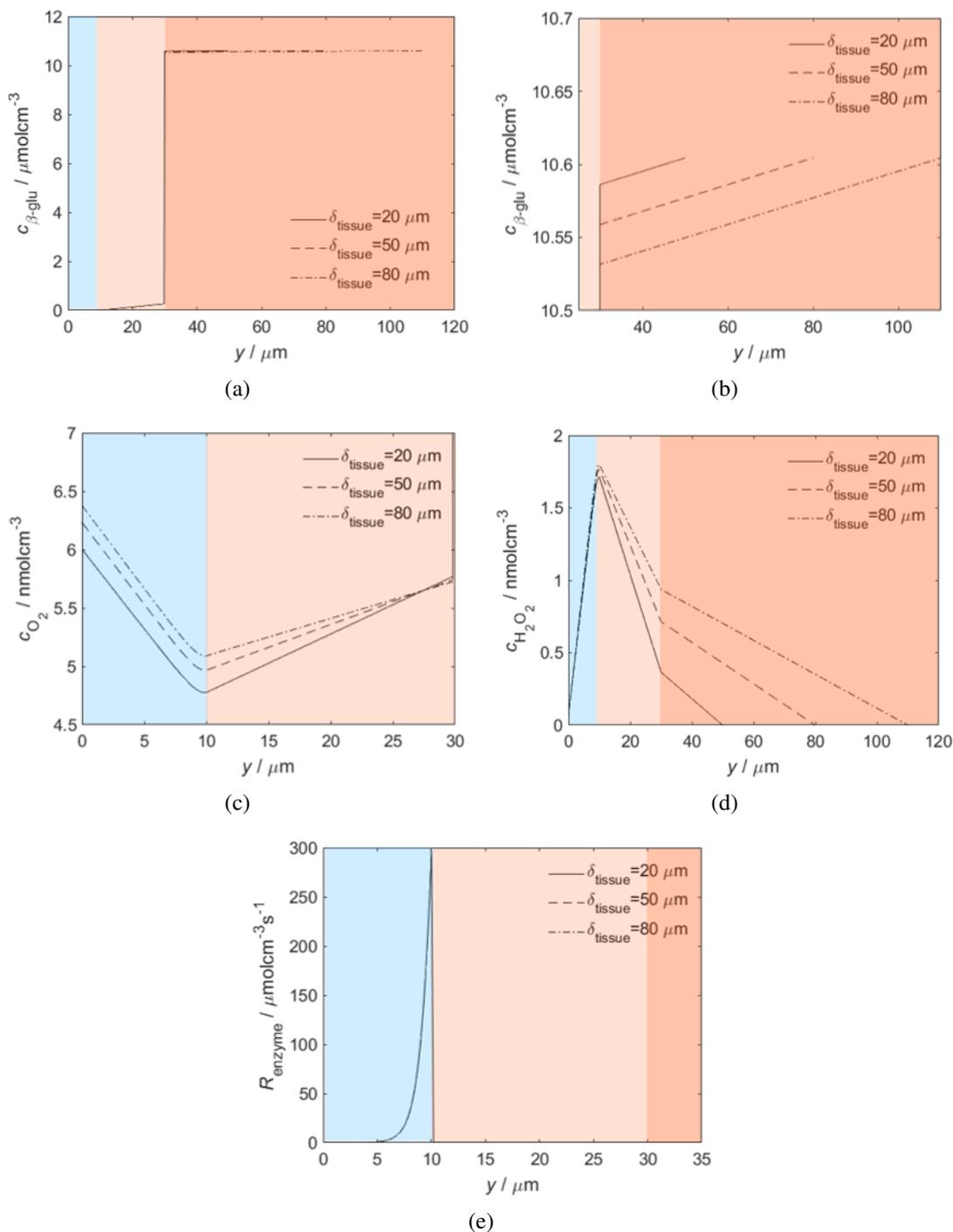


Figure 4-2. Steady profiles for tissue diffusion layer thicknesses of 20, 50, and 80  $\mu\text{m}$ , total glucose concentration of 300  $\text{mgdL}^{-1}$ , and applied potential of 0.4 V vs. Ag\AgCl. Steady profiles presented with distance from the electrode on the horizontal axis: (a)  $\beta - D -$  glucose concentration through the entire sensor; (b)  $\beta - D -$  glucose concentration from the bulk region to the GLM-tissue interface; (c) oxygen concentration for the GOx and GLM layers; (d) hydrogen peroxide concentration through the entire sensor; and (e) enzyme reaction profile in the GOx layer.

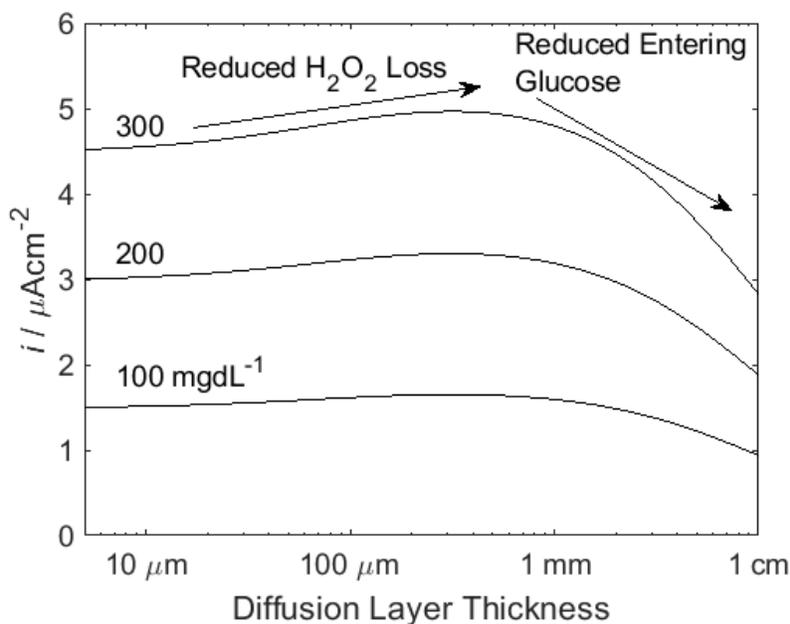


Figure 4-3. Steady current for a diffusion layer thickness from  $5 \mu\text{m}$  to  $1 \text{cm}$  calculated for 100, 200, and  $300 \text{mgdL}^{-1}$  glucose. A peak in current is reached at  $400 \mu\text{m}$  due to the reduced diffusion of hydrogen peroxide out of the sensor, additional diffusion layer thickness leads to a decline in current as the glucose flux decreases. This peak is more pronounced as glucose concentration increases.

enzyme reaction 3, equation 3-2.

### 4.3.2 Transient Model

Parameters of various transient calculations are presented in Table 4-2. The initial steady calculation was made for  $100 \text{mgdL}^{-1}$  which served as the initial condition for transient calculations. An immediate step in glucose concentration was made from  $100$  to  $300 \text{mgdL}^{-1}$  directly adjacent to the outer boundary of a  $100 \mu\text{m}$  tissue diffusion layer. The resulting current response and glucose concentration profile are presented in Figure 4-5. Glucose is stepped at 0 seconds in the bulk region outside of the tissue diffusion layer. An initial lag in the current is observed as the increased flux of glucose must first reach the sensor. Current elevates proportional to the change in glucose as the increased flux reacts and steady state current is approached after 60 seconds. The partition coefficient at the GLM-tissue interface reduces the flux of glucose through the tissue. An analytic expression for the concentration of glucose after a concentration

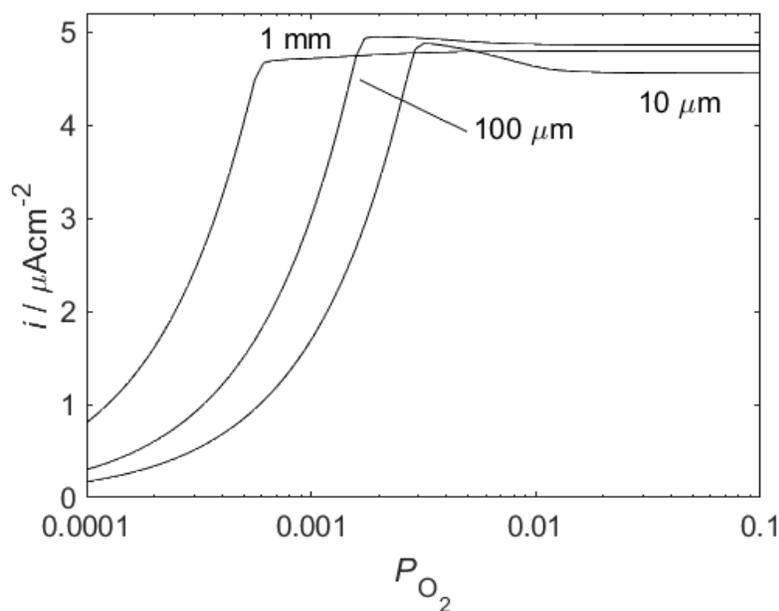


Figure 4-4. Steady current for 0.01 % to 10% partial pressure oxygen and 10  $\mu\text{m}$ , 100  $\mu\text{m}$ , and 1 mm diffusion layer thickness. For the two smaller diffusion layer thickness values, a peak in current is observed at an intermediate value for the oxygen concentration. This peak is absent, and current continues to drop with decreasing oxygen for the diffusion layer thickness of 1 mm.

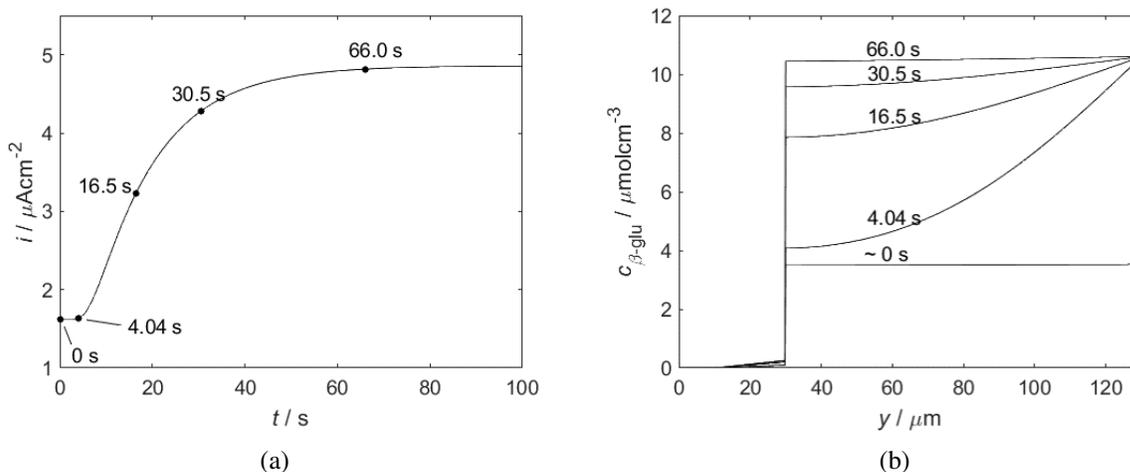


Figure 4-5. Glucose is stepped from 100 to 300  $\text{mgdL}^{-1}$  at the outer boundary of a 100  $\mu\text{m}$  tissue diffusion layer. (a) The current increases with time as the (b) glucose concentration through the diffusion layer and sensor elevate to the final steady state. Steady current is reached after approximately 60 s.

step is made is presented in Section 4.4. This expression provides insight into the time-dependent response of the sensor. A glucose step from 100 to 300 mgdL<sup>-1</sup> was applied to a sensor with

Table 4-2. Parameter values for transient simulations by perturbation type

Glucose Concentration	$P_{O_2}$	Diffusion Layer Thickness	Figures
100 → 300 mg/dL	0.05	100 μm	4-5
100 → 300 mg/dL	0.05	10, 50, 100, 1000 μm	4-6

diffusion layer thickness of 10 μm, 50 μm, 100 μm, and 1 mm. The resulting current response to the different diffusion layer thickness are presented in Figure 4-6 on linear and log time scales. A

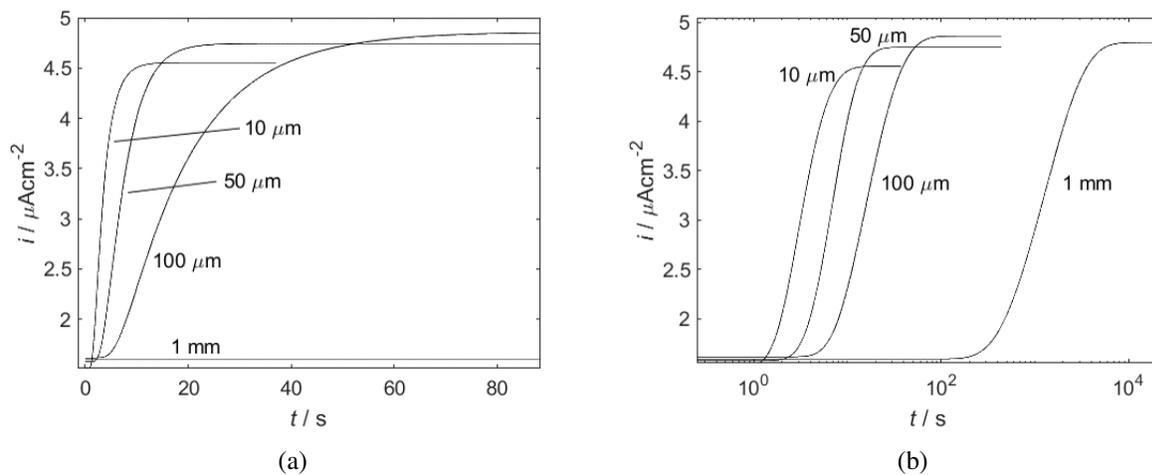


Figure 4-6. Glucose is stepped from 100 to 300 mgdL<sup>-1</sup> at the outer boundary of diffusion layer thicknesses of 10 μm, 50 μm, 100 μm, and 1 mm. Results are presented: (a) linear time scale; (b) log time scale. The 1 mm diffusion layer demonstrates a response lag of 200 s.

wide range of diffusion layer thickness demonstrates the impact of the thickness on the response time of the sensor. For a 1 mm diffusion layer thickness, the current only begins to change after 200 seconds and the final steady state is reached after 5000 seconds.

#### 4.4 Discussion

The steady model demonstrates concentration profiles which immediately change at the GLM-tissue interface, as expected from the presence of the partition coefficient in equation 4-2.

The role of the partition coefficient in glucose transport into the GLM prevents from

overwhelming the enzyme with excess glucose. Prevention of overwhelming the enzyme is important to maintain a linear response between bulk glucose concentration and the steady current value.

Steady current rises as the diffusion layer thickness is increased to 400  $\mu\text{m}$ . Current then decreases for additional thickness as presented in Figure 4-3. The initial rise in current when going from a 5 to 400  $\mu\text{m}$  diffusion layer thickness is not explained by a change in the rate of enzyme reaction. The enzyme reaction rate, presented in Figure 4-2(e), only negligibly varies as a function of diffusion layer thickness. As diffusion layer thickness is increased, the flux of exiting hydrogen peroxide and entering glucose is reduced. These flux are presented in Figure 4-7 for a diffusion layer thickness from 5  $\mu\text{m}$  to 1 cm and 100, 200, and 300  $\text{mgdL}^{-1}$  glucose. Improved retention of the hydrogen peroxide produced in the GOx enzyme layer yields larger currents. However, reduced incoming glucose reduces current. The flux of the exiting hydrogen peroxide and incoming glucose are two competing factors which yield a peak current at some intermediate diffusion layer thickness. These competing factors are labeled in Figure 4-3. The current increase due to improved retention of hydrogen peroxide is greater than the current decrease due to reduced glucose flux as the diffusion layer thickness is increased up to 400  $\mu\text{m}$ . Further increase in diffusion layer thickness yields a negligible improvement in hydrogen peroxide retention, and the glucose flux begins to decrease rapidly for thicknesses greater than 1 mm leading to a steep drop in current.

The competing dynamic of hydrogen peroxide retention and entering glucose is also observed for varied oxygen partial pressure. The enzyme reaction rate profile and exiting hydrogen peroxide flux are presented in Figure 4-8 with partial pressure of oxygen as a parameter. When the diffusion layer thickness is thin, the location of the peak in enzyme reaction rate has a larger impact on the exiting hydrogen peroxide flux. When oxygen is low, the majority of hydrogen peroxide is produced at the electrode and it must diffuse further through the GOx layer to exit the sensor. More hydrogen peroxide is reacted on the electrode, and an increase in current is observed for an intermediate value of oxygen. For a large diffusion layer thickness, the

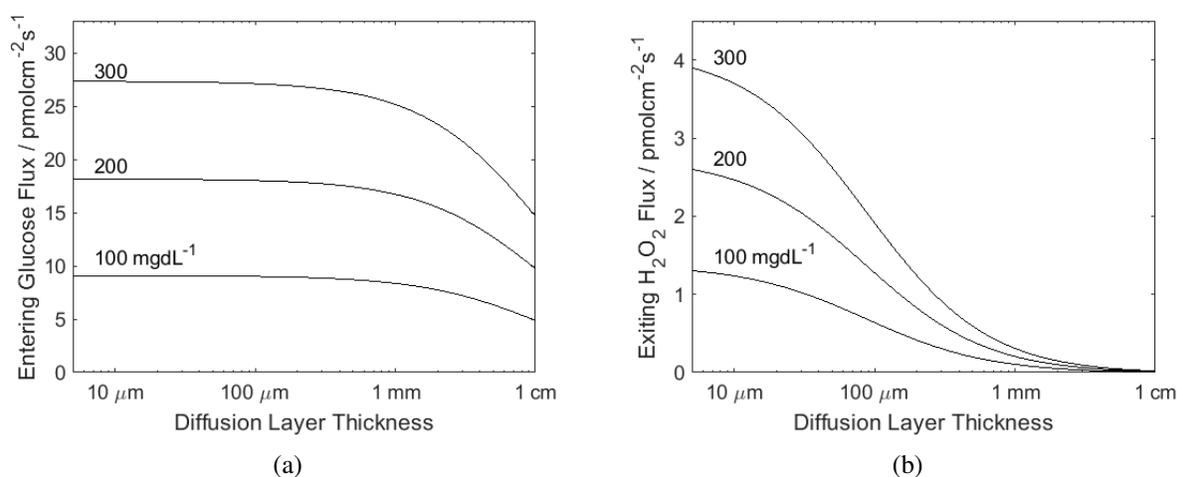


Figure 4-7. Steady flux of individual species for diffusion layer thickness varied from  $5\ \mu\text{m}$  to  $1\ \text{cm}$  and  $100, 200,$  and  $300\ \text{mgdL}^{-1}$  glucose: (a) entering glucose; (b) exiting hydrogen peroxide. As diffusion layer thickness is increased, the flux of exiting hydrogen peroxide is reduced while the flux of entering glucose is reduced. The latter and former increase and decrease the steady current response, resulting in a peak in current as observed in Figure 4-3.

hydrogen peroxide is maximally retained, and the location of the peak enzyme reaction rate has no impact on the hydrogen peroxide flux as long as sufficient oxygen is supplied to react all of the entering glucose. The loss of hydrogen peroxide to the tissue is an important design consideration of the glucose sensor. The influence of oxygen on the steady current can be mitigated with a sufficiently thick diffusion layer, but the glucose flux must be minimally impacted. A similar effect could be produced if the hydrogen peroxide permeability through the GLM could be reduced without influencing the permeability of oxygen and glucose.

The observed peak in current for an intermediate value of the diffusion layer thickness is dependent on the value of the diffusion coefficient and partition coefficient of glucose. The current peak is still observed for glucose diffusion and partition coefficient within an order of magnitude for the cases when  $K_{\text{glu}} \times D_{\text{glu}}$  is a constant. Steady current as a function of diffusion layer thickness is presented in Figure 4-9 for a diffusion coefficient of glucose that is either 0.1, 1, or 10 times the value presented in Table 4-1. The peak current is reduced as the diffusion coefficient of glucose is reduced; in the presence of a diffusion layer, the increased retention of

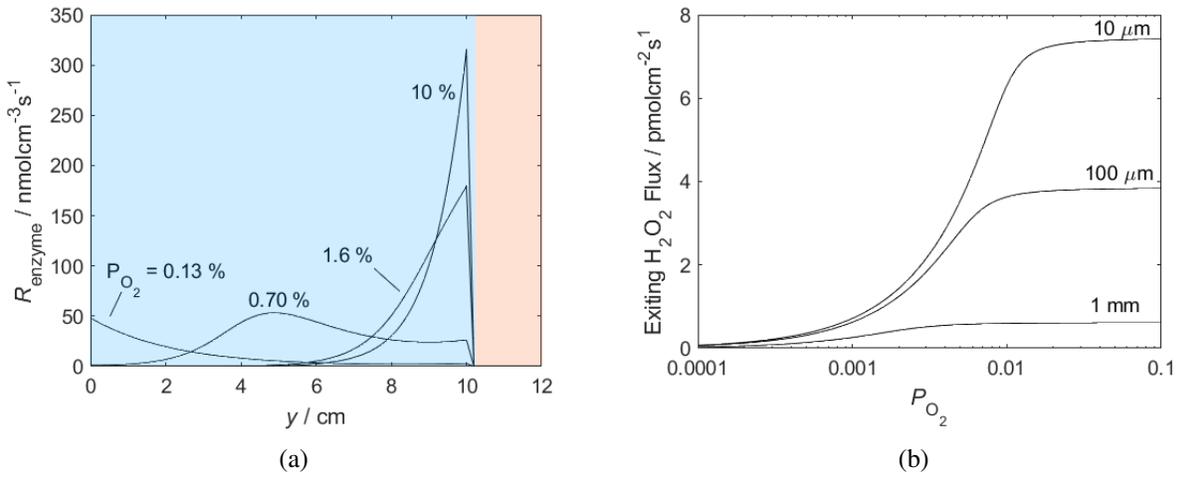


Figure 4-8. Presented are: (a) enzyme reaction rate profile with partial pressure of oxygen as a parameter; (b) exiting hydrogen peroxide flux with oxygen and diffusion layer thickness as parameters. As oxygen is reduced, the peak enzyme reaction shifts towards the electrode which shifts where the majority of hydrogen peroxide is produced. For a thin (10  $\mu\text{m}$ ) diffusion layer thickness, the location of the reaction peak has a larger influence on the hydrogen peroxide flux than for a thick (1 mm) diffusion layer thickness. For varied oxygen, the current yields a peak, as seen in Figure 4-4, which is more pronounced for thinner diffusion layer thickness. For a sufficiently thick diffusion layer this peak is absent as the hydrogen peroxide is maximally retained by the diffusion layer, and the reaction peak has no influence on the flux of hydrogen peroxide.

hydrogen peroxide is further countered by the reduced flux of incoming glucose. The presence of a diffusion layer will adversely impact the lag and response time to reach a new steady state when glucose outside of the sensor is varied. From Figure 4-5(b), glucose was stepped outside a 100  $\mu\text{m}$ , an initial lag of 4 seconds is observed. The initial lag is

$$t_{\text{lag}} = \frac{\delta^2}{\pi^2 D_1} \quad (4-6)$$

where  $t_{\text{lag}}$  is the lag time before the initial change in current and  $\delta$  is the thickness of the diffusion layer. When diffusion through the GLM is a slower process than diffusion through the diffusion layer, the lag time depends on the thickness of the GLM and diffusion coefficient in the GLM rather than the diffusion layer.

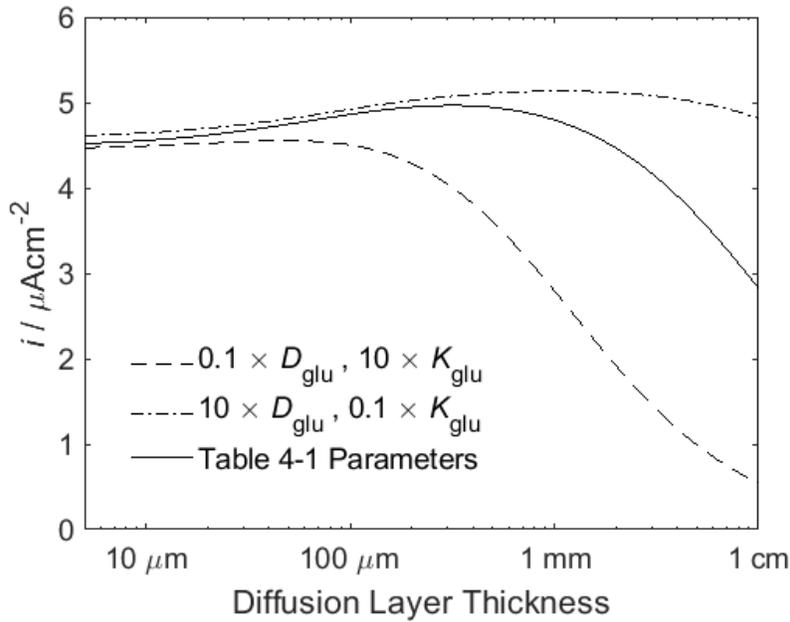


Figure 4-9. Steady state current for 300 mgdL<sup>-1</sup> glucose and diffusion layer thickness varied from 5 μm to 1 cm. Diffusion coefficient was either 0.1×, 1×, or 10× the stated value in Table 4-1. The partition coefficient was maintained such that  $K_{glu} \times D_{glu}$  is a constant between all 3 cases. This provides a similar steady current for all 3 cases.

The approach to a new steady state current is proportional to an exponential decay

$$i(t) \propto \exp(-t/\tau) \quad (4-7)$$

where  $\tau$  is the exponential time constant.  $\tau$  was obtained by nonlinear regression of the current response. Current response to a step in glucose concentration from 100 to 300 mgdL<sup>-1</sup> for a 10 to 100 μm diffusion layer thickness are presented in Figure 4-10. An increase in diffusion layer thickness yields larger lag and total response time to a final steady state. Time constants were fit to a glucose step response for diffusion layer thickness from 10 μm to 10 cm, as presented in Figure 4-11. When the diffusion layer thickness is thin, the time constant for glucose diffusion through the GLM is consistent with Equation 4-6. This applies because the glucose concentration at the GOx-GLM interface is small due to the rapid reaction rate of glucose with the GOx enzyme. As the diffusion layer thickness is increased to become the slower layer to penetrate by

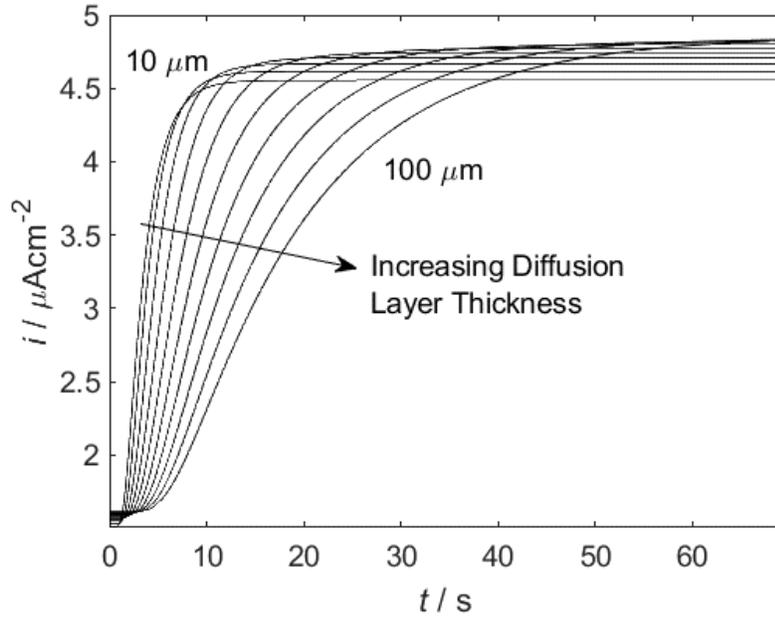


Figure 4-10. The current response to a glucose step from 100 to 300 mgdL<sup>-1</sup> for diffusion layer thicknesses from 10 to 100 μm. As diffusion layer thickness is increased, the lag time and time to reach the final steady state is increased. Each response may be fit to a characteristic time constant from equation 4-7.

glucose the time constant is observed,

$$\tau \propto \frac{4\delta^2}{\pi^2 D_i} \quad (4-8)$$

, which is the characteristic time constant for a concentration step with the flux fixed at the other boundary. Partition of the glucose concentration across the GLM-tissue interface greatly reduces the reaction rate of the glucose available in the bulk and the flux of glucose at this interface is small. For a very large (> 10 cm) diffusion layer thickness the time constant approaches equation 4-6; this is due to a non-negligible concentration of glucose significantly drops across the diffusion layer. When the time constant for a concentration step through the diffusion layer is accurately described by equation 4-8, the concentration profile from the bulk region to the GLM-tissue interface is found through the infinite series

$$\frac{c(y,t)}{c_\infty} = \frac{2}{\pi} \sum_{n=0}^{\infty} \frac{(-1)^n}{n + \frac{1}{2}} \left( 1 + \exp\left(-\frac{(n + \frac{1}{2})^2 \pi^2 D t}{\delta^2}\right) \right) \cos\left[\frac{(n + \frac{1}{2}) \pi y}{\delta}\right] \quad (4-9)$$

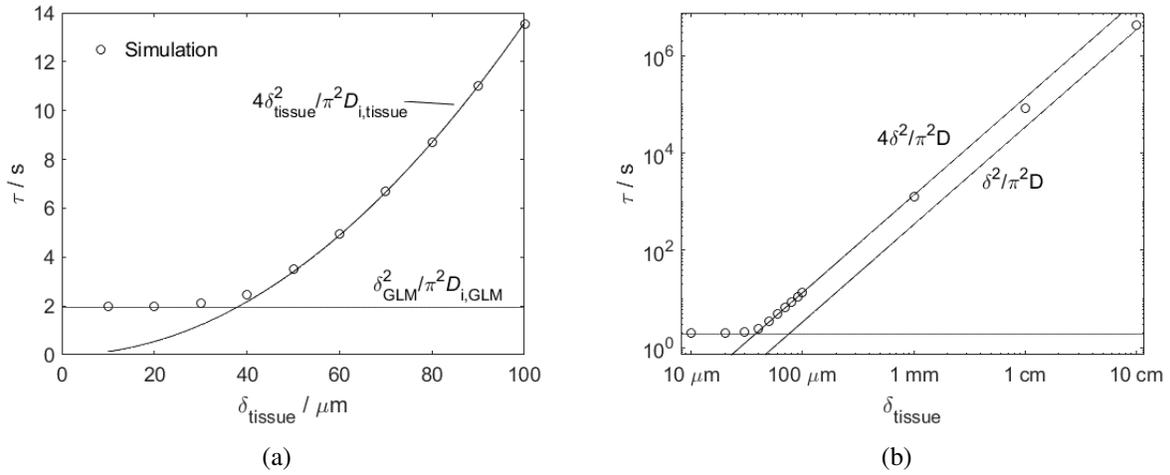


Figure 4-11. Fit exponential time constants with diffusion layer thickness as a parameter: (a) Fit time constants for diffusion layer thickness from 10 to 100  $\mu\text{m}$  (b) Fit time constants for diffusion layer thickness from 10  $\mu\text{m}$  to 10 cm. The time constant observed is dependent on the slowest layer to penetrate. For a thin diffusion layer, the time constant of diffusion through the GLM is observed. As diffusion layer thickness is increased from 10  $\mu\text{m}$  to 50  $\mu\text{m}$  the time constant for the diffusion layer is observed, characteristic of a zero-flux boundary condition at the GLM-tissue interface. For a very large diffusion layer thickness, the time constant of the diffusion layer shifts from a zero-flux to a fixed concentration time constant at the GLM-tissue interface. For a 10 cm diffusion layer, the fixed concentration time constant is still not observed.

where  $c_\infty$  is the concentration in the bulk,  $n$  is an integer from 0 to  $\infty$ , not to be confused with its use in equation 4-4.  $y = 0$  is defined at the GLM-tissue interface and  $y = \delta$  is defined at the tissue-Bulk concentration interface. The slowest decaying time constant is observed for  $n = 0$  when time is large, which is in agreement with equation 4-8. A comparison of equation 4-9 with a glucose step across a 100  $\mu\text{m}$  diffusion layer are found to be in good agreement, as presented in Figure 4-12.

The presence of a diffusion layer adjacent to the glucose sensor may have a detrimental impact on the lag and response time of the sensor. The implantation of a sensor will also illicit a foreign body response which will yield a macrophage layer that would also act as an additional diffusion layer, perhaps with slower glucose diffusion than the surrounding interstitial fluid. Reducing the glucose diffusion coefficient due to a foreign body response could further adversely

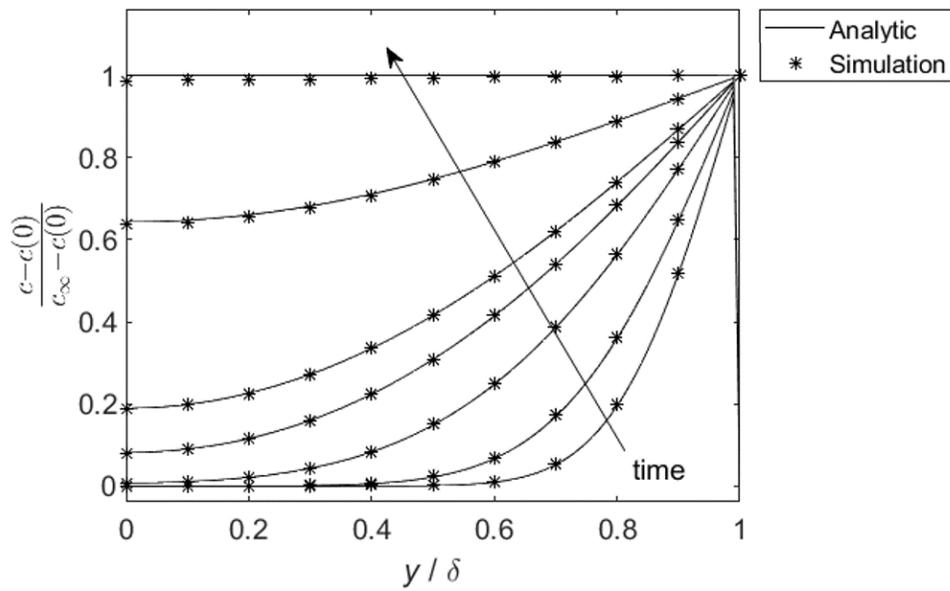


Figure 4-12. Comparison of equation 4-9 for  $n = 0$  to  $10^4$  and simulation of a glucose step from  $100$  to  $300 \text{ mgdL}^{-1}$  across a  $100 \text{ }\mu\text{m}$  diffusion layer.  $c(0)$  is the initial concentration in the domain. The simulation and analytic expression are in good agreement. Maximum error is 1% for all positions except close to  $y = \delta$  where an infinite number of terms are required.

impact the response time of the sensor.

CHAPTER 5  
INFLUENCE OF INTERNAL BLOCKING LAYER ON SENSOR RESPONSE

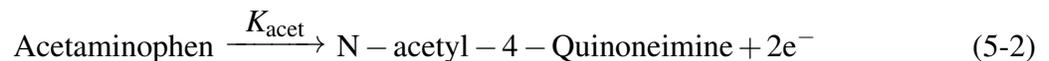
This chapter describes the steady for a glucose sensor with a blocking layer covering the electrode. The model consists of the physics and domain outlined in both Chapter 3 and 4, and an additional layer between the electrode and GOx enzyme layer. This blocking layer acts to reduce the direct oxidation of species, such as acetaminophen, while still providing adequate transport for hydrogen peroxide to react. The steady model provides the steady concentration profiles and polarization behavior as a function of the blocking layer thickness and interfering species concentration.

### 5.1 Mathematical Model

A blocking layer was added to the model outlined in Chapter 3. The governing equations are also those presented in Chapter 3, in addition to diffusion through a blocking layer which is encapsulated between the electrode and GOx enzyme layer. This addition to the sensor is presented in the cross section outlined by Figure 5-1. Transport through the blocking layer follows

$$\frac{\partial c_i}{\partial t} = D_{\text{Blocking},i} \frac{\partial^2 c_i}{\partial y^2} \quad (5-1)$$

and reactions at electrode still follow equations 3-12-3-14. The transport of acetaminophen is added to the model with the boundary condition at the GLM-bulk concentration interface presented in equation 3-20. Acetaminophen is oxidized at the electrode following



which yields an anodic current density

$$j_{\text{acet.}} = K_{\text{Acet.}} c_{\text{Acet.}}(0) \exp(b_{\text{Acet.}} V) \quad (5-3)$$

and the flux at the electrode follows equation 3-18. In the presence of both acetaminophen and glucose, this yields a total current greater than if just glucose was present.

### 5.2 Numerical Methods

Introducing the blocking layer into the existing model from Chapter 3 is adapted to the central difference schemed outlined in equation 3-23 for the steady model and equation 3-26 for

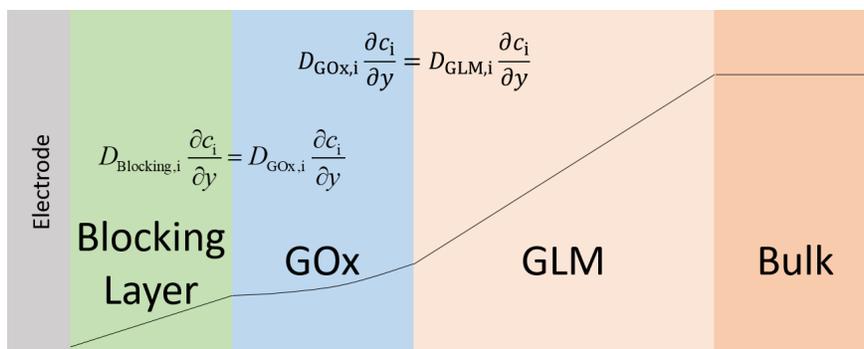


Figure 5-1. One-dimensional cross section of the glucose sensor with a blocking layer between the electrode and GOx enzyme layer. Species flux and concentration at the blocking layer-GOx interface match.

the transient model. The boundary conditions at the blocking-GOx layer interface are defined the same as those presented in equations 3-24 and 3-25.

### 5.3 Results

Polarization curves and concentration profiles are presented for the steady model with varying acetaminophen concentration and blocking layer thickness. Influence of the diffusion coefficient of acetaminophen and hydrogen peroxide in the blocking layer are also investigated. The model assists in sensor design criteria to minimize sensitivity to oxygen while mitigating the influence of the acetaminophen on the sensor response. Coupling of the influence of the blocking layer and diffusion region discussed in Chapter 4 was also considered. The influence of the blocking layer on the dynamic response of the sensor was investigated with the transient model. Parameters are presented in Table 5-1 and 5-2.

#### 5.3.1 Steady Model

An increase in the current is observed when acetaminophen is oxidized at anodic potentials. This could incorrectly be interpreted as a heightened glucose concentration. Polarization curves for  $200 \text{ mgdL}^{-1}$  of glucose, and 0, 10, and  $20 \mu\text{gcm}^{-3}$  of acetaminophen are presented in Figure 5-2. The acetaminophen is assumed to not interact with any other species, and yields a linear concentration gradient. The acetaminophen flux is constant through the sensor. Concentration profiles for acetaminophen for an applied potential of 0.4 V are presented in Figure 5-3 for 3

Table 5-1. Parameter values used for numerical simulations of model with blocking layer.

Parameter	Value
Total Enzyme Loading, $c_{E,o}$	$0.356 \mu\text{mol}/\text{cm}^3$
Partition Coefficient for Hydrogen Peroxide	0.32
Partition Coefficient for Oxygen	0.11
Partition Coefficient for Glucose and Gluconic Acid	0.025
Partition Coefficient for Acetaminophen	0.15
GOx Layer Thickness	$10 \mu\text{m}$
Glucose Limiting Membrane Layer Thickness	$20 \mu\text{m}$
Electrolyte Resistance, $R_e$	$170 \Omega\text{cm}^2$
Double Layer Capacitance, $C$	$1.7 \times 10^{-3} \text{F}/\text{cm}^2$
Forward rate constant for Reaction 1, $k_{f,1}$	$1 \times 10^9 \text{cm}^3\text{mol}^{-1}\text{s}^{-1}$
Equilibrium constant for Reaction 1, $k_{EQ,1}$	$1 \times 10^7 \text{cm}^3\text{mol}^{-1}$
Forward constant for Reaction 2, $k_{f,2}$	$1 \times 10^9 \text{s}^{-1}$
Forward rate constant for Reaction 3, $k_{f,3}$	$1 \times 10^9 \text{cm}^3\text{mol}^{-1}\text{s}^{-1}$
Equilibrium constant for Reaction 3, $k_{EQ,3}$	$1 \times 10^7 \text{cm}^3\text{mol}^{-1}$
Forward constant for Reaction 4, $k_{f,4}$	$1 \times 10^3 \text{s}^{-1}$
Heterogeneous rate constant, $\text{H}_2\text{O}_2$ oxidation, $K_a$	$20 \text{Acm}/\text{mol}$
Electrode Constant, $\text{H}_2\text{O}_2$ oxidation, $b_a$	$22.4 \text{V}^{-1}$
Heterogeneous rate constant, $\text{O}_2$ reduction, $K_a$	$5 \times 10^{15} \text{Acm}^7/\text{mol}^3$
Electrode Constant, $\text{O}_2$ reduction, $b_a$	$38.4 \text{V}^{-1}$
Heterogeneous rate constant, $\text{H}_2\text{O}_2$ reduction, $K_a$	$7.5 \times 10^{23} \text{Acm}^7/\text{mol}^3$
Electrode Constant, $\text{H}_2\text{O}_2$ reduction, $b_a$	$30 \text{V}^{-1}$
Heterogeneous rate constant, $\text{H}_2$ evolution, $K_{\text{H}_2}$	$2.8 \times 10^{16} \text{Acm}^4/\text{mol}^2$
Electrode Constant, $\text{H}_2$ Evolution, $b_{\text{H}_2}$	$15 \text{V}^{-1}$
Heterogeneous rate constant, Acetaminophen oxidation, $K_a$	$20 \text{Acm}/\text{mol}$
Electrode Constant, Acetaminophen oxidation, $b_a$	$22.4 \text{V}^{-1}$

Table 5-2. Diffusion coefficients for individual species and layers. All diffusion coefficient units are presented as  $10^{-6} \text{cm}^2\text{s}^{-1}$ .

Species	Blocking Layer	GOx	GLM
$\beta$ - D-glucose	0.207	2.13	0.207
gluconic acid	0.207	2.13	0.207
oxygen	6.70	17.6	6.70
hydrogen peroxide	4.98	13.1	4.98
gluconate ion	0.207	2.13	0.207
hydrogen ion	24.5	64.4	24.5
hydroxide ion	10.9	28.6	10.9
carbon dioxide	6.78	17.8	6.78
carbonic acid	3.54	9.3	3.54
bicarbonate ion	5.01	13.2	5.01
acetaminophen	0.207	2.13	0.207

different bulk concentrations. As concentration of the acetaminophen increases, the flux into the sensor increases for increasingly anodic potentials until oxidation is mass transfer limited. The role of adding a blocking layer between the electrode and GOx layer is to reduce the diffusion of acetaminophen to the electrode without hindering transport of the smaller reacting species such as hydrogen peroxide and oxygen.

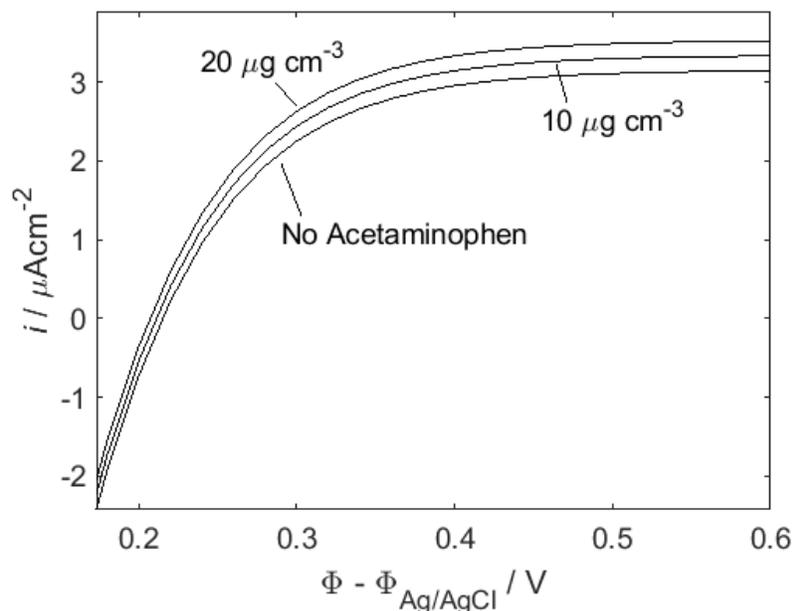


Figure 5-2. Calculated current density as a function of applied potential for a glucose concentration of 200 mg/dL with acetaminophen concentration as a parameter. The increased current density associated with the acetaminophen could be incorrectly interpreted as being due to a higher concentration of glucose

While the goal of the blocking layer is to reduce the acetaminophen's contribution to the current response, it will also impact the performance of the sensor. Diffusion coefficients of the GLM were used as an approximation of the diffusion coefficients in the blocking layer. As the blocking layer thickness increases, the flux of hydrogen peroxide to the electrode is reduced. Total current is reduced as the blocking layer thickness is increased. Polarization curves for a blocking layer thickness of 0, 2, 4, and 6  $\mu\text{m}$  are presented in Figure 5-4. The blocking layer will reduce the current contribution of all faradaic reactions, and not just the reaction associated with acetaminophen. A 20% reduction in current is observed when going from no blocking layer to a 6

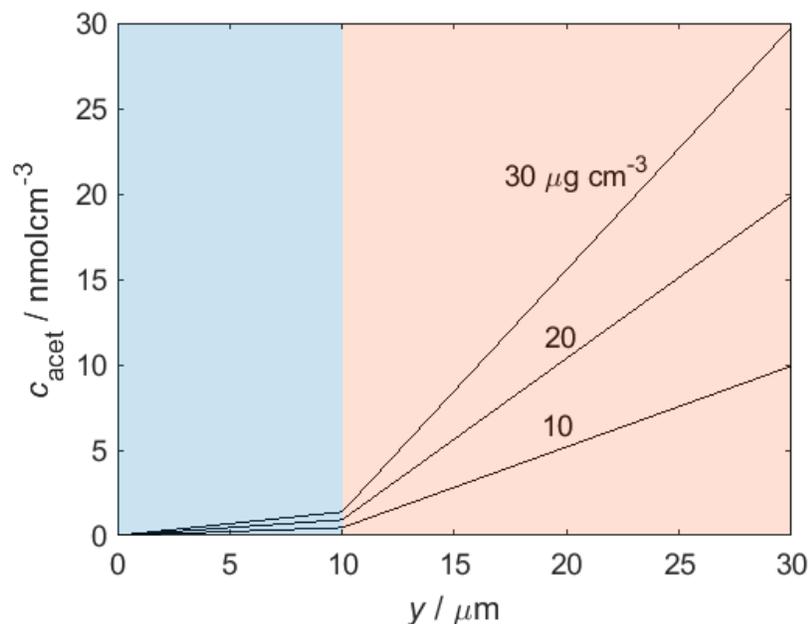


Figure 5-3. Steady acetaminophen concentration profiles at 0.4 V applied potential with acetaminophen concentration as a parameter. The acetaminophen is assumed to not interact with the other species of the model; the concentration profile is characteristic of purely diffusive behavior with no reaction generating or consuming it. Flux remains constant across the entire sensor.

$\mu\text{m}$  blocking layer at  $200 \text{ mgdL}^{-1}$  total glucose and 5% partial pressure of oxygen.

The blocking layer adds an additional diffusion barrier for hydrogen peroxide and oxygen between the electrode and the GOx enzyme layer. As blocking layer thickness increases, the hydrogen peroxide flux to the electrode is reduced and the concentration in the GOx layer increases. Peak hydrogen peroxide concentration in the GOx layer was increased over 100% with the addition of a  $6 \mu\text{m}$  blocking layer. For the same blocking layer, minimum oxygen concentration in the GOx layer was reduced by 20%. The residence time of hydrogen peroxide is increased due to the blocking layer, and the loss of hydrogen peroxide to the bulk tissue is increased, as discussed in Chapter 4.4. The oxygen flux from the electrode is reduced with the hydrogen peroxide, and concentration of oxygen decreases in the GOx layer.

Addition of the blocking layer reduces oxygen concentration, and thus the maximum glucose flux which may be reacted by the enzyme. As glucose is increased, current eventually

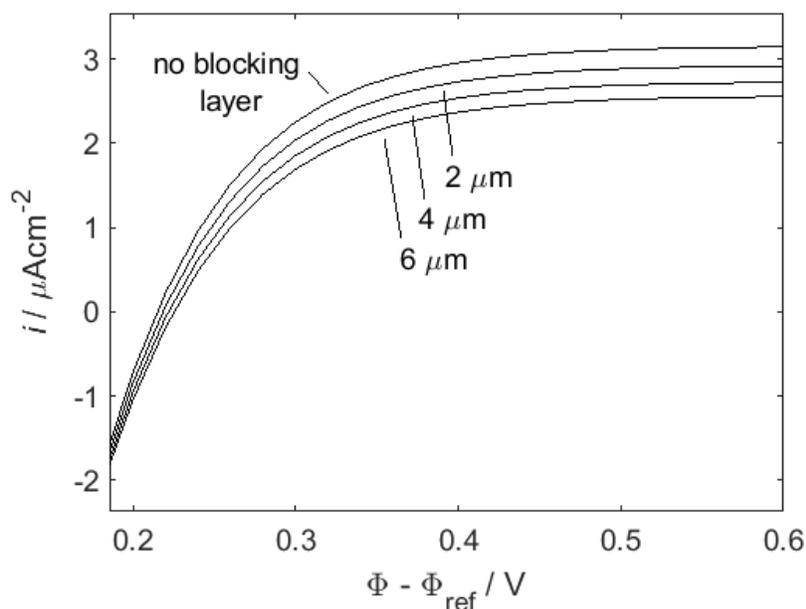


Figure 5-4. Current density as a function of applied potential at 5% partial pressure of oxygen and 200 mg/dL total glucose with the blocking layer thickness as a parameter. The flux of hydrogen peroxide to the electrode decreases as the blocking layer thickness is increased, and the current decreases. The blocking layer reduces all contributing currents, and not just the current due to oxidation of the acetaminophen.

plateaus as the oxidized glucose oxidase is depleted. The maximum glucose a sensor may detect is presented in Figure 5-6(a) as a function of the blocking layer thickness and partial pressure of oxygen. The capacity of the sensor is most greatly affected by the introduction of any blocking layer thickness, as maximum glucose reacted decreases by 40% when adding a 1  $\mu\text{m}$  blocking layer. The addition of a blocking layer has a similar effect on the reaction profile as reducing the bulk partial pressure of oxygen. As blocking layer thickness increases, the concentration of oxygen available for reaction in the enzyme layer is reduced. This depletes the oxidized glucose oxidase starting at the GOx - GLM interface, and shifts the reaction profile towards the blocking layer - GOx interface, as presented in Figure 5-6(b). As partial pressure of oxygen decreases the blocking layer thickness which yields a shift in the reaction profile from the GLM to the blocking layer becomes thinner.

The blocking layer should minimize the current contribution of the acetaminophen while

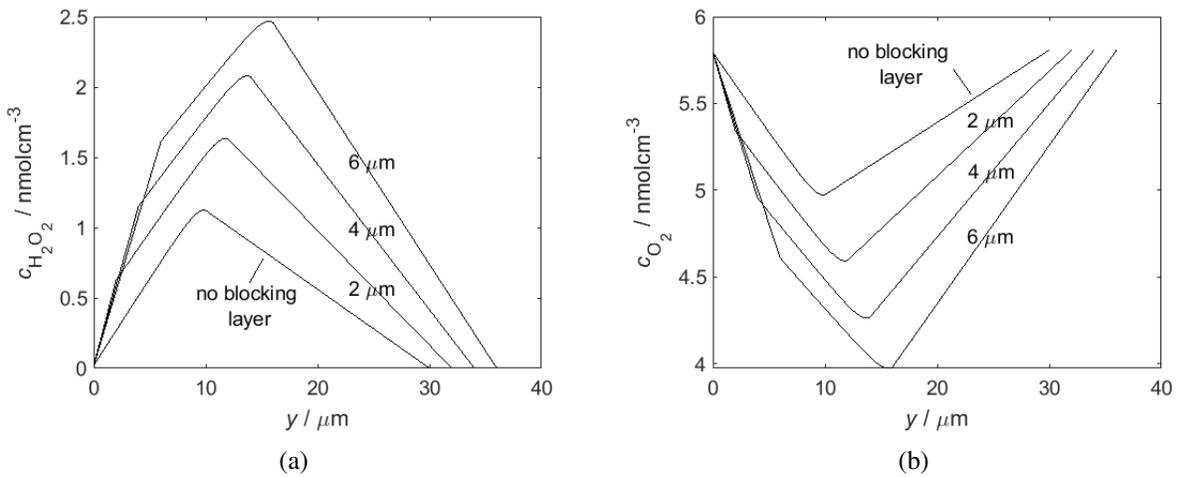


Figure 5-5. Steady concentration profiles for: (a) hydrogen peroxide and (b) oxygen with blocking layer thickness as a parameter. As the blocking layer thickness is increased, the hydrogen peroxide flux to the electrode is reduced and it accumulates to higher concentrations in the GOx layer. The returning flux of recovered oxygen produced at the electrode is also reduced, and the concentration of oxygen is reduced in the GOx layer.

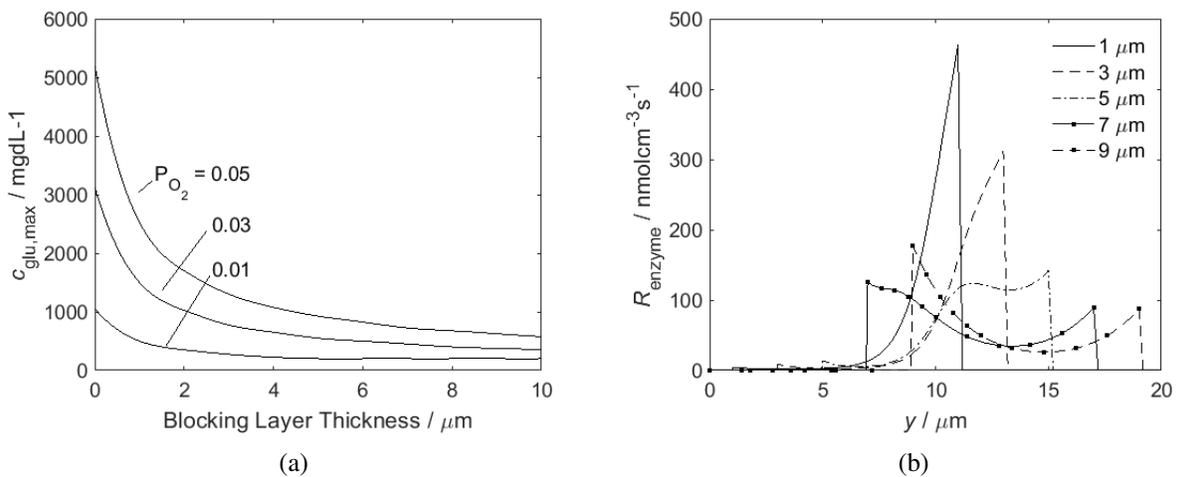


Figure 5-6. Calculations corresponding to sensor parameters presented in Tables 5-1 and 5-2: (a) Maximum glucose concentration which will still yield a signal change as a function of blocking layer thickness with partial pressure of oxygen as a parameter and (b) Steady enzyme reaction profiles for  $700 \text{ mgdL}^{-1}$  glucose, 0.4 V, and 5% Partial pressure oxygen with blocking layer thickness as a parameter. As the blocking layer thickness is increased, the oxygen available in the enzyme layer is reduced and reaction profiles shift towards the blocking layer - GOx layer interface.

minimally impacting the current signal of the reacted glucose. Thus the selection of the blocking layer thickness is dependent on the diffusion coefficient of acetaminophen. A smaller acetaminophen diffusion coefficient in the blocking layer will require a thinner blocking layer to screen its transport to the electrode. Presented in Figure 5-7 are glucose and acetaminophen current signals as a function of blocking layer thickness. Currents are scaled by dividing the corresponding current at a specified blocking layer thickness by its current value in the absence of a blocking layer. The current signal for glucose is divided by the glucose current signal with no blocking layer, and the acetaminophen signal is divided by the acetaminophen current with no blocking layer. The acetaminophen current was modeled for 3 individual acetaminophen diffusion coefficients in the blocking layer: 100%, 50%, and 10% of the diffusion coefficient for acetaminophen in the GLM. From Table 5-2, the diffusion coefficient in the GLM for acetaminophen is  $2.07 \times 10^{-7} \text{ cm}^2\text{s}^{-1}$ . Thus the smallest value of the diffusion coefficient in the blocking layer modeled is  $2.07 \times 10^{-8} \text{ cm}^2\text{s}^{-1}$ . At this diffusion coefficient, the acetaminophen signal was decreased to 17% while maintaining 70% of the glucose signal for a  $10 \mu\text{m}$  blocking layer.

Influence of blocking layer diffusion selectivity on the steady current was modeled by varying the diffusion coefficient of hydrogen peroxide. Polarization behavior is presented in Figure 5-8(a) for a  $0.5 \mu\text{m}$  blocking layer while varying the blocking layer diffusion coefficient between 1% to 100% of the GLM diffusion coefficient for hydrogen peroxide only. At mass transfer control, the current is only marginally reduced for a diffusion coefficient of 30% of the value of the diffusion coefficient for hydrogen peroxide in the GLM. Current as a function of the diffusion coefficient is presented in Figure 5-8(b) for blocking layer thickness of 0.1, 0.5, 1 and  $5 \mu\text{m}$ . Blocking layer thickness greatly reduces the current when the diffusion coefficient is also being varied; for a diffusion coefficient value 10% of the GLM diffusion coefficient, current is only slightly reduced for a  $0.1 \mu\text{m}$  block layer, but reduced by over 70% for a  $5 \mu\text{m}$  blocking layer.

The influence of the combination of a blocking layer and diffusion layer outlined in Chapter

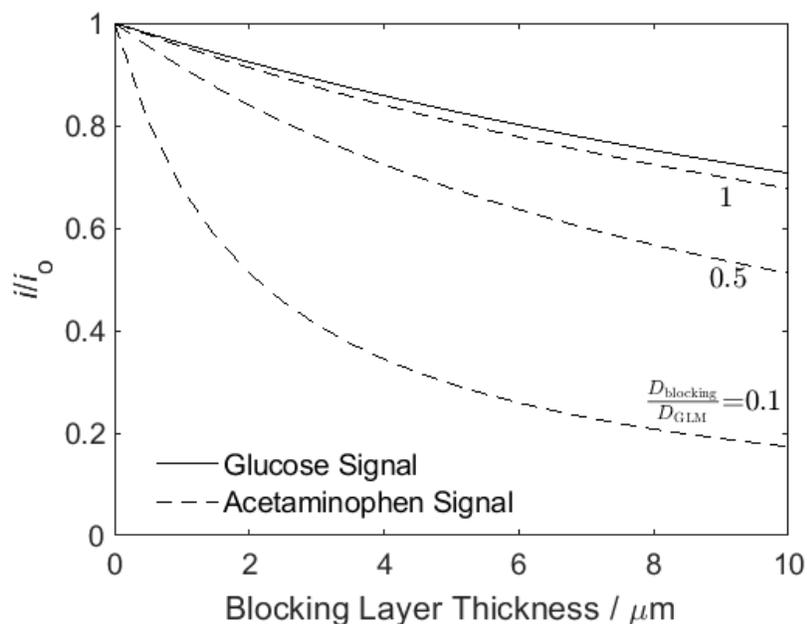


Figure 5-7. Glucose signal(solid line) and acetaminophen signal (dashed line) as a function of blocking layer thickness with the acetaminophen diffusion coefficient in the blocking layer as a parameter. The acetaminophen diffusion coefficient in the blocking layer is presented as 10%, 50%, and 100% of the diffusion coefficient in the GLM. The diffusion coefficient of all other species are the values presented in Table 5-2. Currents are scaled by their respective values in the absence of a blocking layer. ie. a value of 0.5 for the acetaminophen current is the calculated current at the corresponding blocking layer thickness divided by the current due to acetaminophen in the absence of a blocking layer.

4 were investigated simultaneously. The blocking layer acts to reduce current by increasing the hydrogen peroxide flux exiting the sensor, as shown in Figure 5-5(a). A diffusion region between the GLM and bulk concentration acts as a barrier for the hydrogen peroxide, and provides additional time for the hydrogen peroxide formed in the sensor to diffuse to the electrode. The current and exiting hydrogen peroxide flux are presented in Figure 5-9 as a function of blocking and diffusion layer thickness for 1% and 5% partial pressure of oxygen. Current output of the sensor was greater for a 4  $\mu\text{m}$  blocking layer when a diffusion region of 250  $\mu\text{m}$  was introduced compared to a sensor with no blocking layer or diffusion layer thickness. Flux of exiting hydrogen peroxide may be greatly reduced in the presence of a diffusion region in the tissue.

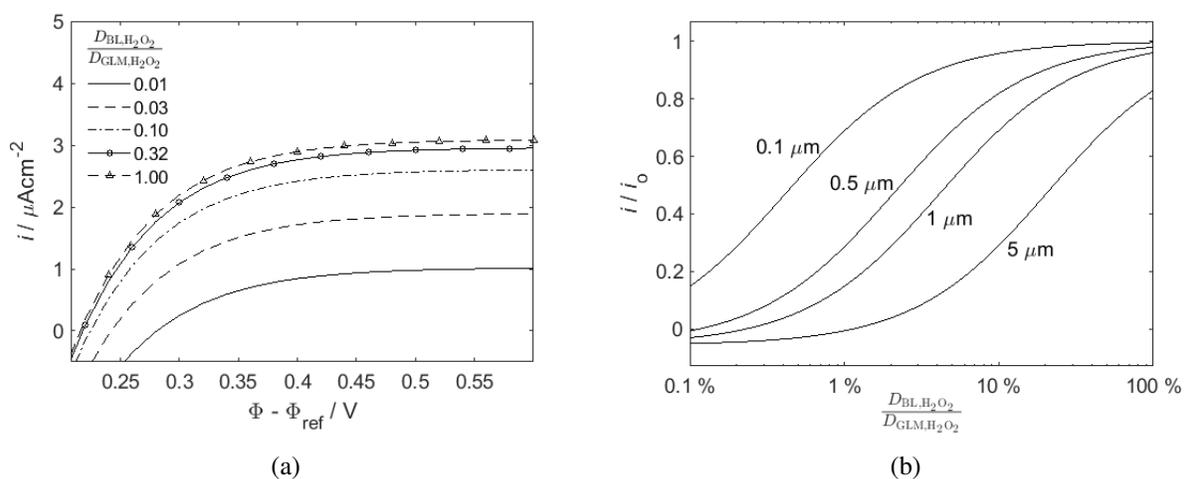


Figure 5-8. Current at 200 mg/dL glucose and 5% partial pressure oxygen calculated as a function of: (a) potential with the ratio of the diffusion coefficient for hydrogen peroxide in the blocking layer to the GLM as a parameter for a 0.5  $\mu\text{m}$  blocking layer and (b) the ratio of the diffusion coefficient for hydrogen peroxide in the blocking layer to the GLM with blocking layer thickness as a parameter. The current is scaled by the current in the absence of a blocking layer.

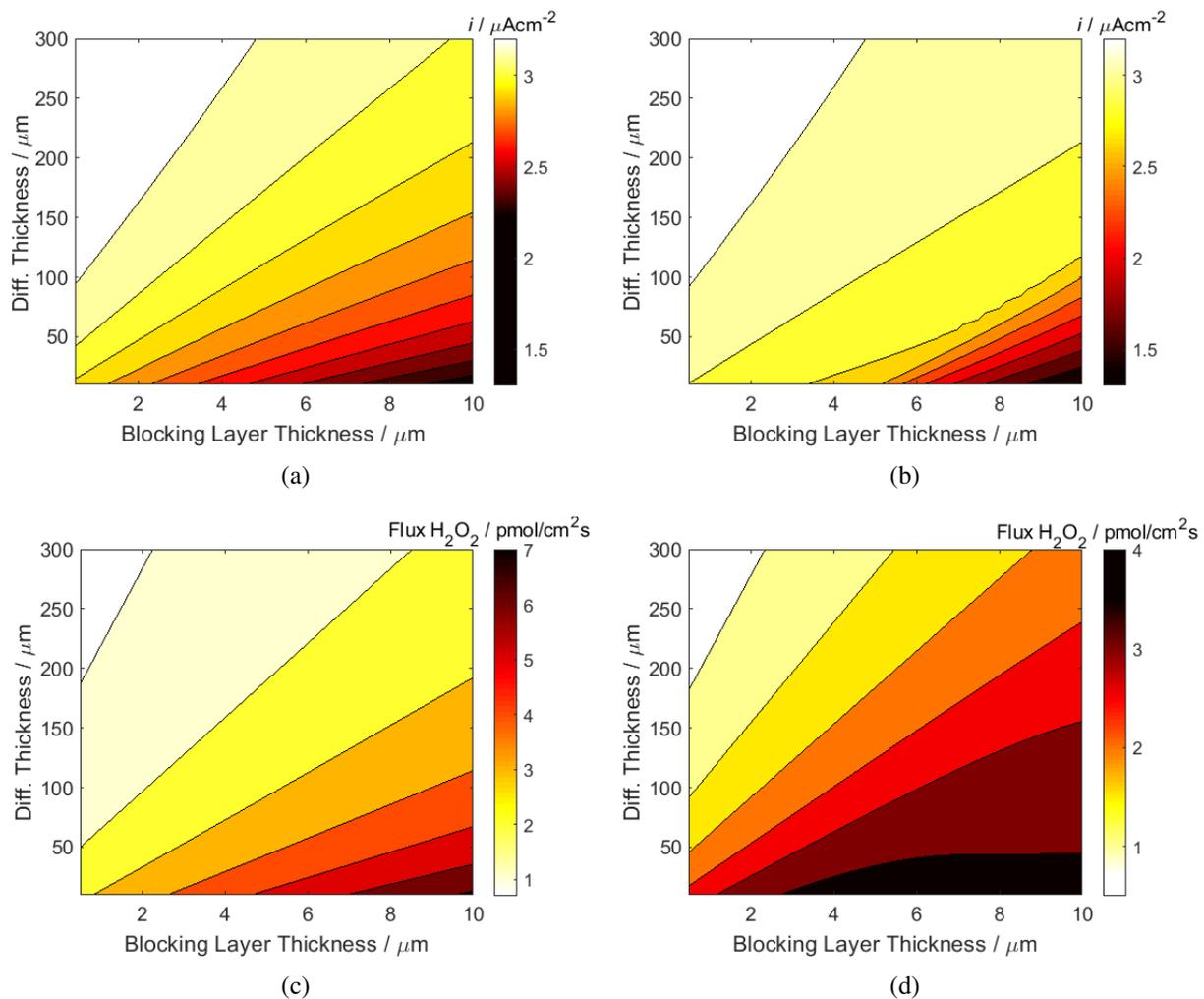


Figure 5-9. Calculated values as a function of blocking layer and diffusion layer thickness: (a) current with 5% and (b) 1% oxygen, (c) exiting flux of hydrogen peroxide with 5% and (d) 1% oxygen. Current reduction as a result of adding a blocking layer may be countered by the introduction of a diffusion layer. The diffusion layer reduces the exiting hydrogen peroxide flux to the bulk tissue.

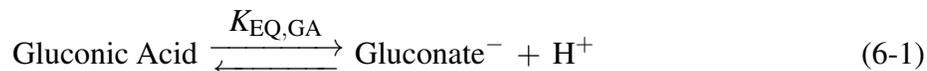
## CHAPTER 6 ADVANCED MODEL AND PARAMETRIC STUDY

This Chapter introduces a model which includes the influence of hydrogen ion on the heterogeneous reactions, dissociation of gluconic acid, and the bicarbonate buffer system. The model primarily differs from the simplified model presented in Chapter 3, where the assumption of constant pH was made. Hydrogen ions are produced at the electrode via the oxidation of hydrogen peroxide, and consumed at the electrode via the reduction of oxygen, reduction of hydrogen peroxide, and formation of hydrogen. Thus hydrogen ions influence the model at cathodic and anodic potentials. Furthermore, the gluconic acid formed in the enzyme reaction dissociates and is coupled to the bicarbonate buffer system.

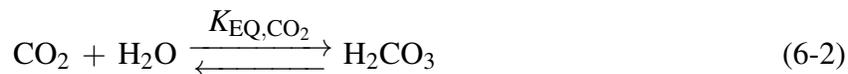
Steady and transient behavior of this model was investigated by classifying parameter groups into failure modes and design of the sensor. Failure modes include enzyme deactivation, oxygen deficiency, and membrane decomposition. Design of the sensor was evaluated by varying the thickness of the enzyme and glucose limiting membrane layers, and the diffusive selectivity of these layers.

### 6.1 Mathematical Model

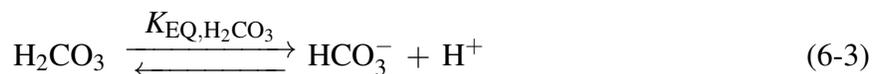
Gluconic acid and the bicarbonate buffer species are assumed to dissociate rapidly and reversibly. Gluconic acid dissociates to gluconate ions and hydrogen ions



where  $K_{\text{EQ,GA}}$  is the equilibrium constant of the forward and backward rates of dissociation and association of gluconic acid, respectively. The bicarbonate buffer system occurs in 2 individual steps which occur rapidly. First, the hydration of carbon dioxide to carbonic acid,



where  $K_{\text{EQ,CO}_2}$  is the equilibrium constant of  $\text{CO}_2$  hydration. Next, the dissociation of carbonic acid to bicarbonate and a hydrogen ion,



where  $K_{\text{EQ,H}_2\text{CO}_3}$  is the equilibrium constant of carbonic acid dissociation. The dissociation of water to hydrogen and hydroxide ions is also considered



where  $K_{\text{EQ,w}}$  is the equilibrium constant of water dissociation. Equations (6-1) through (6-4) are presented as

$$R_6 = k_{\text{f,GA}} \left( c_{\text{GA}} - \frac{1}{K_{\text{EQ,GA}}} c_{\text{GI}^-} c_{\text{H}^+} \right) \quad (6-5)$$

for gluconic acid dissociation,

$$R_7 = k_{\text{f,CO}_2} \left( c_{\text{CO}_2} - \frac{1}{K_{\text{EQ,CO}_2}} c_{\text{H}_2\text{CO}_3} \right) \quad (6-6)$$

for carbon dioxide hydration,

$$R_8 = k_{\text{f,H}_2\text{CO}_3} \left( c_{\text{H}_2\text{CO}_3} - \frac{1}{K_{\text{EQ,H}_2\text{CO}_3}} c_{\text{HCO}_3^-} c_{\text{H}^+} \right) \quad (6-7)$$

for carbonic acid dissociation, and

$$R_9 = k_{\text{f,H}_2\text{O}} \left( 1 - \frac{1}{K_{\text{EQ,H}_2\text{O}}} c_{\text{OH}^-} c_{\text{H}^+} \right) \quad (6-8)$$

for water dissociation. These rates are incorporated into the mass balance expressions

$$\frac{\partial c_{\text{GI}^-}}{\partial t} = D_{\text{GI}^-} \frac{\partial^2 c_{\text{GI}^-}}{\partial y^2} + R_6 \quad (6-9)$$

for the concentration of gluconate ion,

$$\frac{\partial c_{\text{CO}_2}}{\partial t} = D_{\text{CO}_2} \frac{\partial^2 c_{\text{CO}_2}}{\partial y^2} - R_7 \quad (6-10)$$

for the concentration of carbon dioxide,

$$\frac{\partial c_{\text{H}_2\text{CO}_3}}{\partial t} = D_{\text{H}_2\text{CO}_3} \frac{\partial^2 c_{\text{H}_2\text{CO}_3}}{\partial y^2} + R_7 - R_8 \quad (6-11)$$

for the concentration of carbonic acid,

$$\frac{\partial c_{\text{HCO}_3^-}}{\partial t} = D_{\text{HCO}_3^-} \frac{\partial^2 c_{\text{HCO}_3^-}}{\partial y^2} + R_8 \quad (6-12)$$

for the concentration of bicarbonate ion,

$$\frac{\partial c_{\text{H}^+}}{\partial t} = D_{\text{H}^+} \frac{\partial^2 c_{\text{H}^+}}{\partial y^2} + R_6 + R_8 + R_9 \quad (6-13)$$

for the concentration of hydrogen ion, and

$$\frac{\partial c_{\text{OH}^-}}{\partial t} = D_{\text{OH}^-} \frac{\partial^2 c_{\text{OH}^-}}{\partial y^2} + R_9 \quad (6-14)$$

for the concentration of hydroxide ion. To enforce rapid dissociation, the mass balance expressions for the gluconate ion, bicarbonate ion, and hydroxide ion are subtracted from the mass balance for the hydrogen ion which yields cancellation of the rates in equations (6-5), (6-7), and (6-8) from the expression. Similarly, summation of mass balance equations (6-10), (6-11), and (6-12) leads to cancellation of the rates associated with carbon dioxide hydration and carbonic acid dissociation from the expressions. This technique to eliminate the rates from the mass balance expressions of the buffer species provides only two governing equations associated with mass balance. The remaining required equations are provided by the expression

$$0 = k_{\text{EQ,acid}} c_{\text{HI}} - c_{\text{H}^+} c_{\text{I}^-} \quad (6-15)$$

which is true for rapid dissociation of all acids and buffer species.

In addition to the 3 electrode reactions in equations (3-15) - (3-17), an additional cathodic reaction

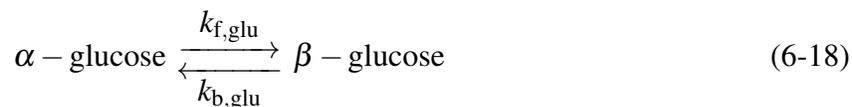


is accounted for in hydrogen evolution. The current for hydrogen evolution is

$$j_{\text{H}_2} = K_{\text{H}_2} c_{\text{H}^+}(0)^2 \exp(-b_{\text{H}_2} V) \quad (6-17)$$

and the buffer species act to counter the drop in pH at the electrode.

Finally, the influence of the anomerization between  $\alpha$ -glucose and  $\beta$ -glucose was introduced. These two anomers exist in equilibrium following



where  $k_{f,\text{glu}}$  and  $k_{b,\text{glu}}$  are the forward and backward anomerization rates between the two forms. The significance of this reaction on the performance of the glucose sensor is the GOx enzyme's selectivity to react primarily with  $\beta$ -glucose. The  $\beta$ -glucose concentration is greatly reduced in the GOx layer and the anomerization of  $\alpha$ -glucose to balance the equilibrium supports the current response further.

## 6.2 Steady Model

Steady calculations were made with the sensor dimension and kinetic parameters presented in Table 6-1, diffusion coefficients presented in Table 6-3, and the dissociation constants presented in Table 6-2. Many of the parameter values were influenced by the work of Gao[19, 20] and experimental work in Chapter 7.

At anodic potentials the oxidation of hydrogen peroxide is the dominant faradaic reaction and the current is nearly identical to the model in Chapter 3. Polarization of the sensor is presented in Figure 6-1. Hydrogen evolution dominates at cathodic potentials and leads to a rapid decrease in current as potential is reduced. Hydrogen peroxide oxidation dominates at anodic potentials and the current increases linearly with total glucose concentration. In contrast to the simplified model in Chapter 3, oxygen reduction does not play a large role in the cathodic current.

At positive current values, the rate of formation of hydrogen at the electrode due to hydrogen peroxide oxidation is greater than the rate of consumption by hydrogen evolution. The pH decreases inversely with the concentration of glucose. The pH, at 0.4 V, as a function of position is presented in Figure 6-2 with glucose concentration as a parameter at. At 0.4 V and 400 mgdL<sup>-1</sup> glucose the rate of hydrogen ion formation is four times greater than at 100 mgdL<sup>-1</sup>. The difference in pH between these two glucose concentrations is only a 15 % difference in

Table 6-1. Parameter values used for numerical simulations of advanced model

Parameter	Value
Total Enzyme Loading, $c_{E,o}$	$0.356 \mu\text{mol}/\text{cm}^3$
Partition Coefficient for Hydrogen Peroxide	0.32
Partition Coefficient for Oxygen	0.11
Partition Coefficient for Glucose and Gluconic Acid	0.025
GOx Layer Thickness	$10 \mu\text{m}$
Glucose Limiting Membrane Layer Thickness	$20 \mu\text{m}$
Electrolyte Resistance, $R_e$	$170 \Omega\text{cm}^2$
Double Layer Capacitance, $C$	$1.7 \times 10^{-3} \text{F}/\text{cm}^2$
Forward rate constant for Reaction 1, $k_{f,1}$	$1 \times 10^9 \text{cm}^3\text{mol}^{-1}\text{s}^{-1}$
Equilibrium constant for Reaction 1, $k_{EQ,1}$	$1 \times 10^7 \text{cm}^3\text{mol}^{-1}$
Forward constant for Reaction 2, $k_{f,2}$	$1 \times 10^9 \text{s}^{-1}$
Forward rate constant for Reaction 3, $k_{f,3}$	$1 \times 10^9 \text{cm}^3\text{mol}^{-1}\text{s}^{-1}$
Equilibrium constant for Reaction 3, $k_{EQ,3}$	$1 \times 10^7 \text{cm}^3\text{mol}^{-1}$
Forward constant for Reaction 4, $k_{f,4}$	$1 \times 10^3 \text{s}^{-1}$
Heterogeneous rate constant, $\text{H}_2\text{O}_2$ oxidation, $K_a$	$20 \text{Acm}/\text{mol}$
Electrode Constant, $\text{H}_2\text{O}_2$ oxidation, $b_a$	$22.4 \text{V}^{-1}$
Heterogeneous rate constant, $\text{O}_2$ reduction, $K_a$	$5 \times 10^{15} \text{Acm}^7/\text{mol}^3$
Electrode Constant, $\text{O}_2$ reduction, $b_a$	$38.4 \text{V}^{-1}$
Heterogeneous rate constant, $\text{H}_2\text{O}_2$ reduction, $K_a$	$7.5 \times 10^{23} \text{Acm}^7/\text{mol}^3$
Electrode Constant, $\text{H}_2\text{O}_2$ reduction, $b_a$	$30 \text{V}^{-1}$
Heterogeneous rate constant, $\text{H}_2$ evolution, $K_{\text{H}_2}$	$2.8 \times 10^{16} \text{Acm}^4/\text{mol}^2$
Electrode Constant, $\text{H}_2$ Evolution, $b_{\text{H}_2}$	$15 \text{V}^{-1}$

Table 6-2. Acid and buffer dissociation equilibrium constants

Parameter	Value
Gluconic Acid Equilibrium Constant, $K_{EQ,GA}$	$2 \times 10^{-4} \text{mol}/\text{cm}^3$
$\text{CO}_2$ Hydration Equilibrium Constant, $K_{EQ,\text{CO}_2}$	$1.7 \times 10^{-3}$
Carbonic Acid Equilibrium Constant, $K_{EQ,\text{H}_2\text{CO}_3}$	$5.26 \times 10^{-7} \text{mol}/\text{cm}^3$
Water Dissociation, $K_{EQ,\text{H}_2\text{O}}$	$10^{-20} \text{mol}^2/\text{cm}^6$

Table 6-3. Diffusion coefficients for individual species and layers. All diffusion coefficient units are presented as  $10^{-6} \text{ cm}^2\text{s}^{-1}$ .

Species	GOx	GLM
$\beta$ - D-glucose	2.13	0.207
gluconic acid	2.13	0.207
oxygen	17.6	6.70
hydrogen peroxide	13.1	4.98
gluconate ion	2.13	0.207
hydrogen ion	64.4	24.5
hydroxide ion	28.6	10.9
carbon dioxide	17.8	6.78
carbonic acid	9.3	3.54
bicarbonate ion	13.2	5.01
acetaminophen	2.13	0.207

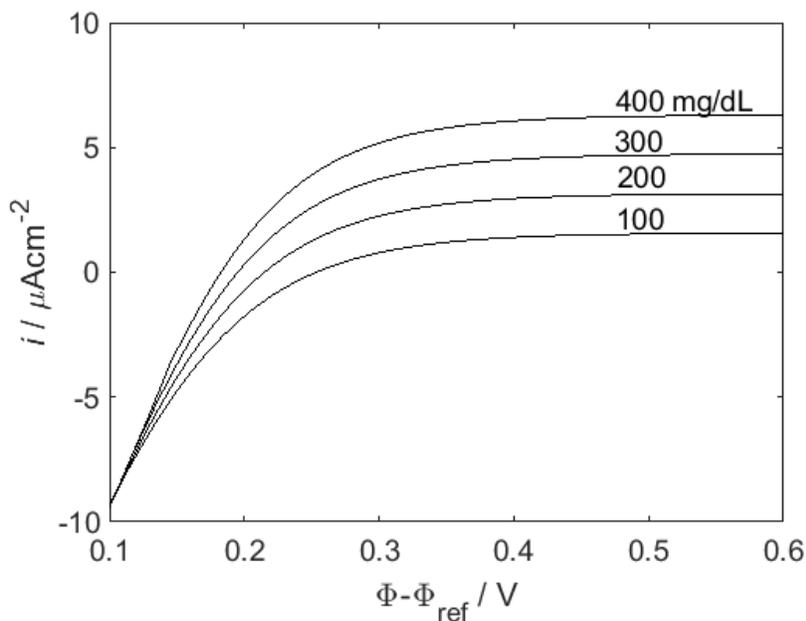


Figure 6-1. Current density as a function of potential with glucose concentration as a parameter. At anodic potentials, the oxidation of hydrogen peroxide dominates and the dependence on glucose concentration is similar to the polarization curve presented in Figure 3-5. At cathodic potentials the buffer species replenishes the drop in pH and the current drops dramatically.

hydrogen ion concentration at the electrode, thus the buffer species act rapidly.

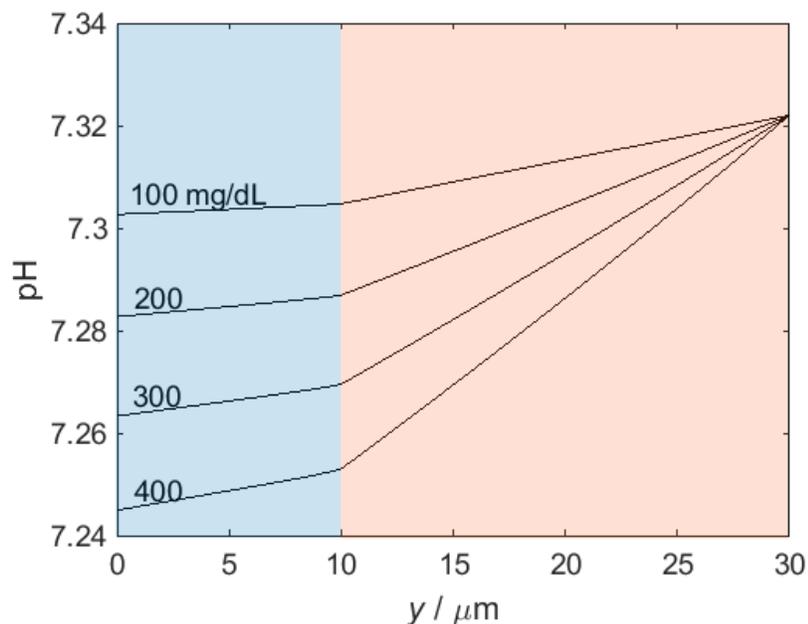


Figure 6-2. Steady pH profiles as a function of position with glucose concentration as a parameter. Applied potential is 0.4 V and oxygen partial pressure is 5 %. At anodic potentials, the decrease in pH is proportional to the increase in glucose concentration.

### 6.3 Sensor Design and Operation

Steady and transient operation of the sensor was investigated as a function of design and failure parameters. Groups of parameters were studied for each failure mode and design parameter. Design parameters studied include membrane thickness, and diffusion selectivity. Failure modes studied include enzyme activity, oxygen deficiency, and membrane deterioration. Modeling these mechanisms provides insight into the expected sensor behavior.

#### 6.3.1 Failure Modes

Potential failure modes for the glucose sensor and the parameters studied are presented in Table 6-4. For each mode, the influence of the parameters on the steady current, and transient current response to a glucose perturbation at an applied potential of 0.4 V are evaluated. To compliment the analysis of the current response, concentration and reaction profiles are examined to illustrate root cause of observed phenomena. These phenomena include unexpectedly slow response times, and current increase, or decrease, where the opposite behavior might be expected.

Table 6-4. Glucose sensor failure modes and parameters of interest varied.

Failure Mode	Parameter	Value Range
Enzyme deactivation	Total enzyme concentration	0.1 to 100 % of $0.356 \mu\text{mol}/\text{cm}^3$
Oxygen deficiency	Oxygen partial pressure	0.01 to 10 %
Membrane deterioration	Global multiplier for diffusion coefficients	0.1 to $10 \times$ default diffusion coefficient

### 6.3.1.1 Enzyme activity

As the enzyme ages, the overall activity is reduced. In order to prolong the useful duration of the sensor, excess enzyme is initially present which yields glucose capacity an order of magnitude greater than a glucose concentration of  $250 \text{ mgdL}^{-1}$ , which is common for hyperglycemic episodes. Deactivation of the enzyme may be accelerated by exposure to elevated glucose concentrations, particularly at open circuit.[49]

Current as a function of enzyme activity is presented in Figure 6-3(a). Reduced enzyme activity is initially marked by a small increase in current, followed by a rapid decrease as the active enzyme is reduced below the concentration required to react all the glucose. A decrease in enzyme activity yields a shift in the enzyme reaction profile towards the electrode, as presented in Figure 6-3(b). This shift leads to more hydrogen peroxide generation near the electrode and a slight increase in current.

A step change in glucose from  $200$  to  $300 \text{ mgdL}^{-1}$  was modeled for individual enzyme activity and an applied potential of  $0.4 \text{ V}$ . Steady calculations at  $200 \text{ mgdL}^{-1}$  were first carried out to initialize the transient model. Transient current calculations are presented in Figure 6-4 as a function of time with enzyme activity as a parameter. As the enzyme activity is reduced, the rate of the response also decreases. The relative rate of response for individual enzyme activity is easier to observe for normalized current responses as presented in Figure 6-4(b). The time constant of the response are related to the homogeneous rates of reaction, as investigated in Chapter 3.3.2. The final steady state is reached within 10 to 15 seconds for enzyme activities greater than 2 %.

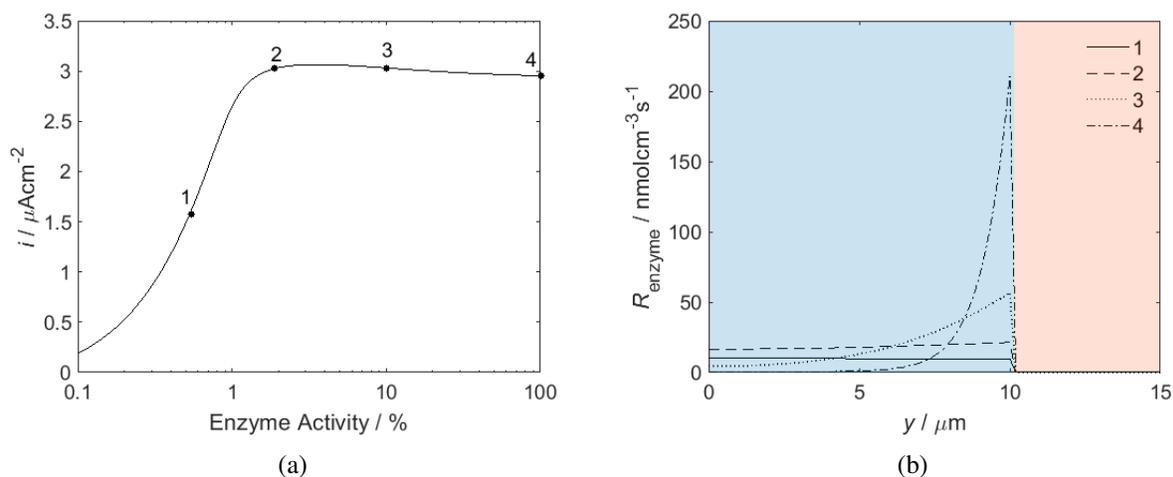


Figure 6-3. Calculated values for (a) steady current as a function of enzyme activity at 200 mg/dL and 0.4 V and (b) enzyme reaction profile as a function of position with enzyme activity as a parameter. As the enzyme is decreased from 100 % the current gradually increases, until the active enzyme remaining is insufficient to react all glucose present. The current increase is due to the reaction profile shifting the location where the majority of hydrogen peroxide is generated in the enzyme layer.

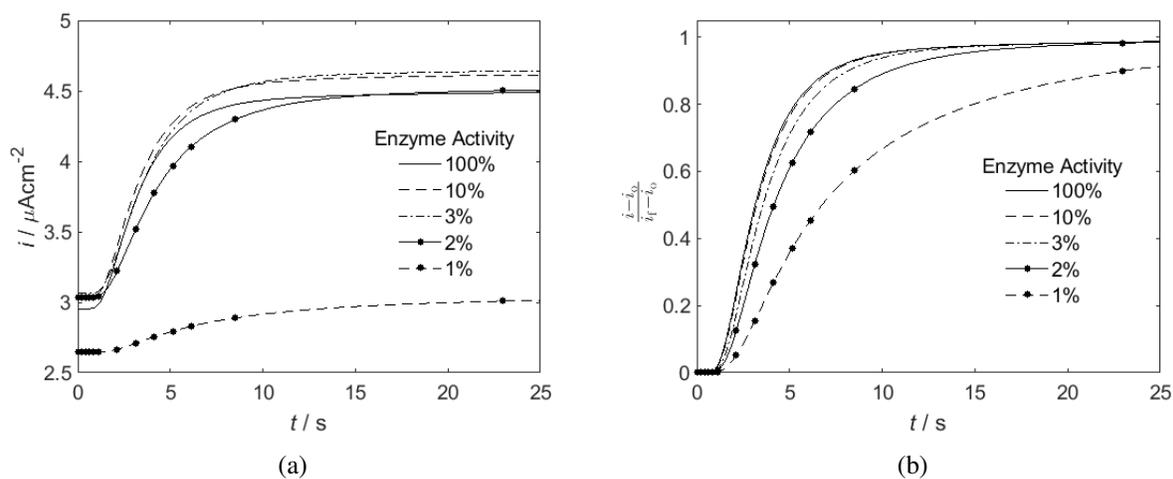


Figure 6-4. Calculated current response as a function of time with enzyme activity as a parameter. At initial times, the system is perturbed with a glucose step from 200 to 300 mg/dL. Current response rate decreases with reduced enzyme activity. Rates slow most noticeably when the enzyme reaction is limited by the available enzyme and instead of glucose concentration. For the normalized current in the right plot, subscripts o and f represent the initial and final current respectively.

### 6.3.1.2 Oxygen deficiency

A sensor may experience oxygen deficiency depending on injection site location, injection into scar tissue or repeat injection sites, applying pressure to the sensor which commonly occurs when sitting or laying, or more serious underlying issues in a patient leading to hypoxia. Oxygen has a direct role in carrying out the enzyme reactions. Varying the partial pressure of oxygen yields similar results as varying enzyme activity.

Current as a function of partial pressure of oxygen is presented in Figure 6-5(a). A current peak is observed at 0.2 % partial pressure of oxygen. This peak in current develops as the reaction profile shifts from the GLM interface to the electrode interface in the enzyme layer. The shift occurs as oxidized glucose oxidase is depleted, beginning at the GLM interface and progressing towards the electrode. The enzyme reaction rate as a function of position is presented in Figure 6-5(b) with oxygen partial pressure as a parameter. When oxygen is less than 0.2 % partial pressure, current and reaction rate decreases. Glucose begins to accumulate at this oxygen concentration, and oxygen becomes the limiting reactant.

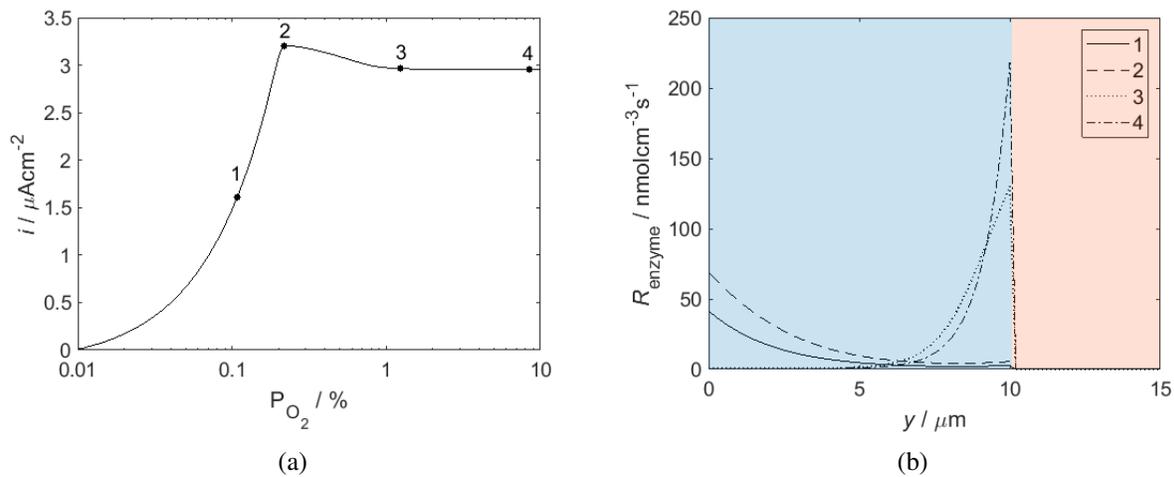


Figure 6-5. Calculated values for the (a) steady current as a function of oxygen partial pressure on a semi-log scale and (b) steady reaction profiles as a function of position with oxygen partial pressure as a parameter. Glucose concentration was 200 mg/dL and applied potential was 0.4 V. A peak in current occurs at 0.2 % oxygen partial pressure, which is a result of the reaction profile shifting from the GOx-GLM interface to the electrode-GOx interface.

Transient calculations were made for a glucose step from 200 to 300 mgdL<sup>-1</sup> with the partial pressure of oxygen varied as a parameter. Current is presented as a function of time in Figure 6-6 with oxygen partial pressure as a parameter. At 10 % oxygen, the current reaches a new steady state by 10 seconds. There is a reduction in the rate of response between 1 % and 2 % with steady states obtained around 40 and 15 seconds respectively. A similar rate is observed for 0.5 % and the rate increases again when oxygen is decreased to 0.2 %. At 0.2 % partial pressure oxygen, the current only changes slightly as the enzyme is overwhelmed by glucose at the initial conditions.

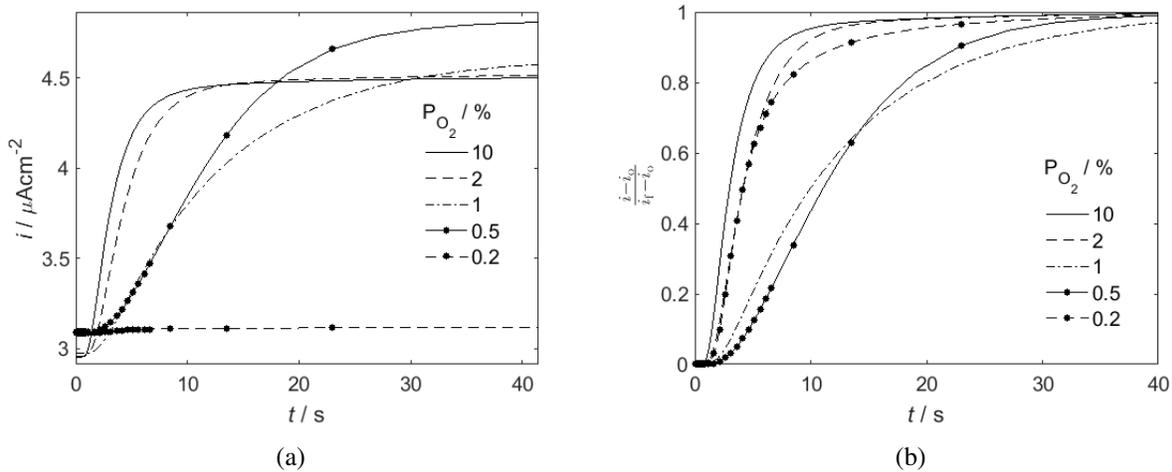


Figure 6-6. Calculated current response as a function of time with partial pressure of oxygen as a parameter. Current is presented as (a) total current and (b) normalized current such that all currents begin at 0 and end at 1. At the initial time, the system is perturbed with a glucose step from 200 to 300 mg/dL. Current response slows dramatically from 2% to 1% partial pressure oxygen. At 0.2 % partial pressure oxygen, little response is observed as the enzyme is already overwhelmed by the initial concentration of glucose. For the normalized current, subscripts o and f represent the initial and final current respectively.

A difference in response time correlates to a shifting in the location of the enzyme reaction peak within the GOx layer; as glucose is elevated in the sensor, the reaction peak first increases, then shifts towards the electrode as the available  $\text{GOx}_{\text{ox}}$ . When excess  $\text{GOx}_{\text{ox}}$  is present at the GOx/GLM interface, a perturbation of glucose will not yield a large shift in the reaction peak and the rate of current response will be relatively fast. When  $\text{GOx}_{\text{ox}}$  is limited at the interface, a

glucose perturbation results in further shift of the reaction profile and the current response slows. Presented in Figure 6-7 are initial and final enzyme concentrations for  $\text{GOx}_{\text{ox}}$  and  $\text{GOx}_{\text{red}}$  as a function of position. A large shift in the enzyme concentration, away from the edge of the  $\text{GOx}/\text{GLM}$  interface, was observed for 1 % and 0.05 % partial pressure of oxygen when glucose was perturbed from 200 to 300  $\text{mgdL}^{-1}$ . The two slowest current responses were observed for these oxygen concentrations in Figure 6-6. A difference between enzyme reactions in equations (3-3) and (3-5) are observed during the transient response. Transient reaction differentials in response to a glucose perturbation are presented in Figure 6-8 for partial pressure of oxygen at 2, 1, 0.05, and 0.02 %. The largest magnitude and shifts in the reaction differential along the length of the  $\text{GOx}$  layer are associated with the slowest current response, such as the case for 1 % (Figure 6-8(b)) and 0.5 % (Figure 6-8(c)). These large shifts occur in regions of the  $\text{GOx}$  layer where oxygen concentration is smallest. Thus shifting the location of the reaction profiles is a slower process than mass transfer of the glucose, as demonstrated in Chapter 3. Reducing the enzymatic reaction rate constants would further slow the current response.

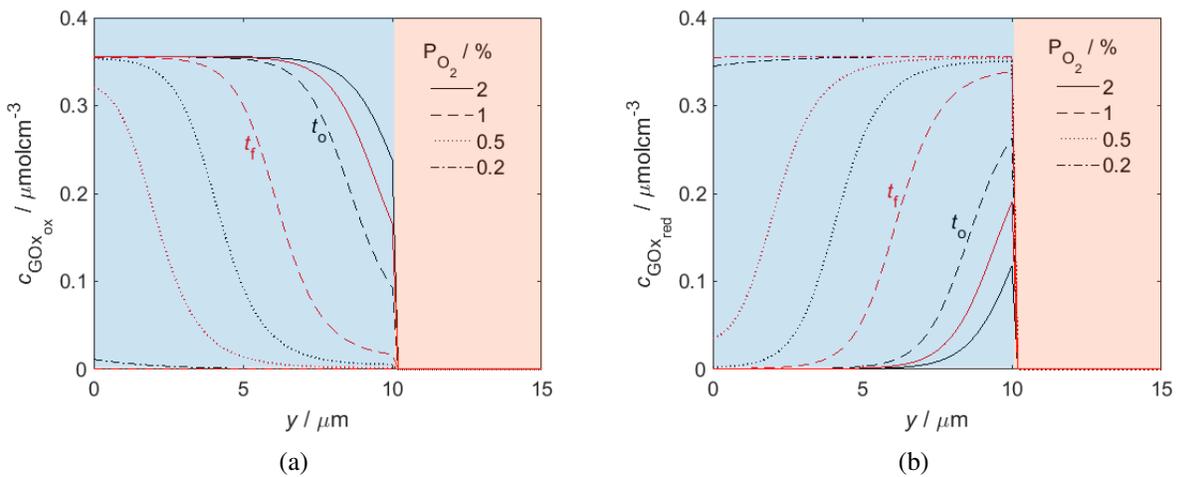


Figure 6-7. Calculated concentration profiles before and after a step change in glucose from 200 to 300  $\text{mgdL}^{-1}$  for (a)  $\text{GOx}_{\text{ox}}$ , oxidized glucose oxidase, and (b)  $\text{GOx}_{\text{red}}$ , reduced glucose oxidase. Initial and final concentrations are black and red respectively. The largest shifts in the enzyme concentrations are observed for 1 % and 0.05 % partial pressure of oxygen, which were the conditions associated with the slowest current response.

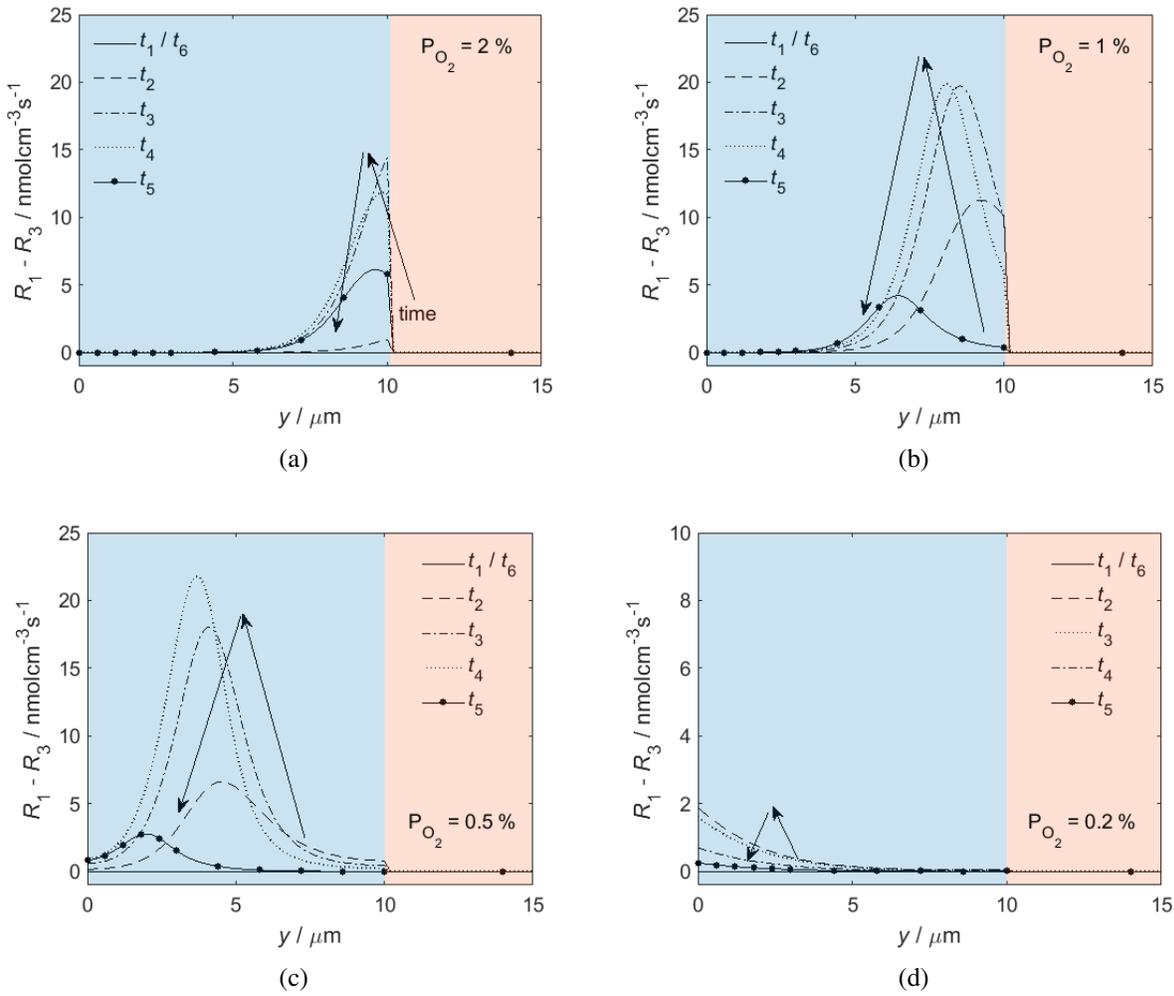


Figure 6-8. Calculated difference between enzyme reaction profiles in equations (3-3) and (3-5) during transient operation of sensor due to a glucose perturbation for partial pressure oxygen of (a) 2 %, (b) 1 %, (c) 0.5 %, and (d) 0.2 %. Conditions which demonstrated the slowest current response in Figure 6-6 are associated with the largest magnitude in the difference of the enzyme reaction rates. Times are in order:  $t_1 < t_2 < t_3 < t_4 < t_5 < t_6$ .

### 6.3.1.3 Membrane deterioration

The glucose oxidase enzyme layer and glucose limiting membrane may both degrade. These porous membranes reduce the diffusivity of glucose, oxygen, hydrogen peroxide, acids, and buffer species throughout the sensor. The diffusion coefficient in either region may vary due to manufacturing variability, aging, pH variability, constriction/expansion as a function of solution ionic strength, or deformation of the flexible sensor. For membrane deterioration, diffusion coefficients of the specified layer for all species are assumed to either increase or decrease proportionally.

Steady current was measured with diffusion coefficients in Table 6-3 multiplied by a factor between 0.1 and 10. This was done independently for the GOx and GLM layers. The steady current as a function of the diffusion coefficient are presented in Figure 6-9. As permeability of the GLM is increased (Figure 6-9(a)), the current continues to rise as additional glucose enters the sensor and reacts in the GOx region. This leads to additional hydrogen peroxide loss to the bulk concentration boundary and the current increase is not linear with the proportional increase to diffusion coefficients. A current plateau is observed as the permeability of the GOx layer is increased (Figure 6-9(b)); diffusion through the GLM becomes the limiting factor and further increases to the diffusion coefficients in the GOx layer have a negligible effect. For reduced permeability of the GOx region, a sharp current drop occurs.

The influence of GLM permeability on the current response to glucose perturbations was investigated. Diffusion coefficients for the GLM in Table 6-3 were modified by a factor of 0.5, 1, 2, and 5. Current response to a glucose step from 200 to 300 mgdL<sup>-1</sup> are presented in Figure 6-10 with diffusion coefficients in the GLM as a parameter. As permeability of the GLM increases, the magnitude and rate of response is increased. For diffusion coefficients presented in Table 6-3, the diffusion of glucose through the GLM controls the initial lag and rate of the response at long times. For parameters where the GLM is limiting the current response rate, the time constant observed is  $\delta^2/\pi^2 D_{\text{GLM,glu}}$ . Deviation from this time constant occurs when the permeability of the GLM exceeds the GOx layer. The normalized current response are presented in Figure 6-11 as

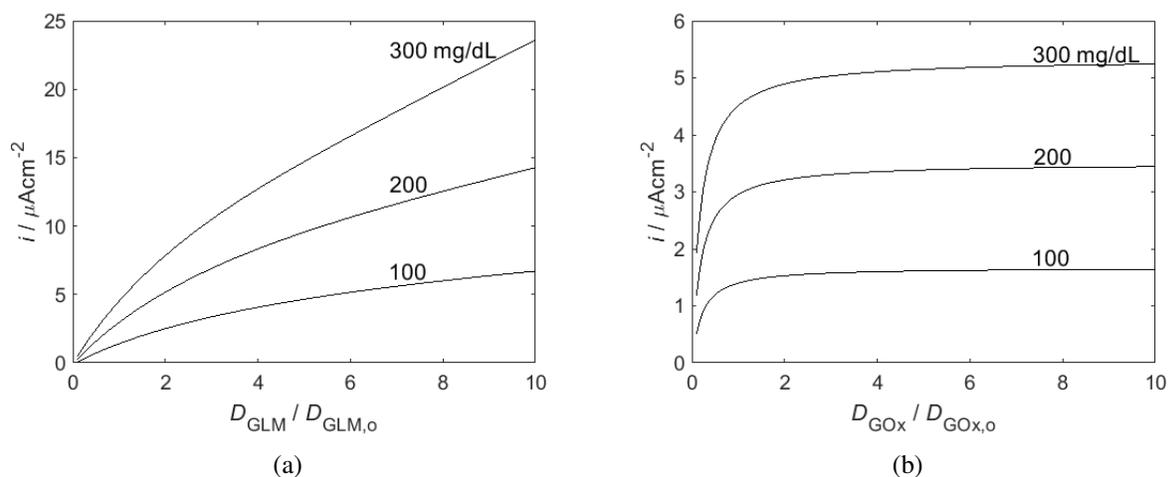


Figure 6-9. Calculated steady currents as a function of the diffusion coefficients for either (a) GLM or (b) GOx layer with glucose concentration as a parameter. Diffusion coefficients on the horizontal axis are scaled by the values in Table 6-3 for the GLM ( $D_{\text{GLM},o}$ ) and GOx ( $D_{\text{GOx},o}$ ) layers respectively. The GLM acts as the primary diffusion barrier between the GOx region and bulk concentration boundary; as permeability of the GLM is increased, current continues to rise. For sufficient permeability in the GOx layer, the current is not greatly influenced as the GLM remains the primary diffusion barrier. A sharp decrease in current is observed when permeability of the GOx layer is reduced.

a function of time nondimensionlized by the diffusion of glucose through the GLM. When diffusion of glucose through the GLM controls the response rate, the current response overlap. When the GOx controls the rate of the response, the characteristic time constant depends on the flux of glucose at the GOx/GLM interface and the rate of consumption of glucose.

Transient current responses were calculated while varying the GOx permeability. Current response are presented as a function of time in Figure 6-12 with all diffusion coefficients in the GOx layer as a parameter. The magnitude of the response was influenced; as GOx permeability increased, hydrogen peroxide is generated closer to the electrode, thus increasing current. The rate of the response was not greatly impacted for the range of diffusion coefficients tested. For all conditions, the GLM remained the largest diffusion barrier, and the time constant observed was characteristic of glucose diffusion through the GLM in response to a step at the bulk boundary interface.

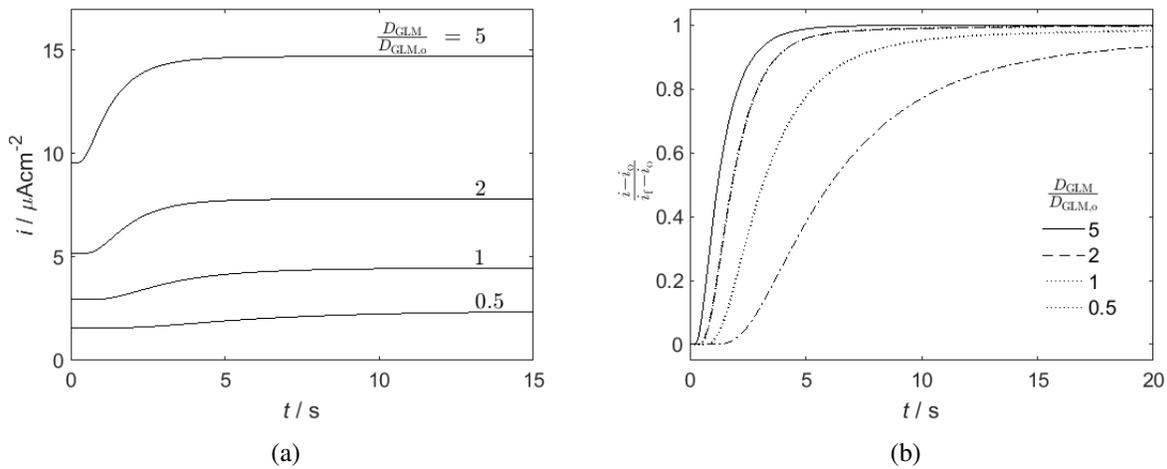


Figure 6-10. Transient (a) current and (b) normalized current calculations to a glucose perturbation from 200 to 300 mgdL<sup>-1</sup> at 0.4 V and 5 % partial pressure of oxygen with the diffusion coefficients in the GLM as a parameter. The rate of the response increases with GLM permeability. For the normalized current, subscripts o and f represent the initial and final current respectively.

### 6.3.2 Design Parameters

Design parameters studied are presented in Table 6-4. For each design variable, the influence of the parameters on the steady current, and transient current response to a glucose perturbation at an applied potential of 0.4 V are evaluated. To compliment the analysis of the current response, concentration and reaction profiles are examined to illustrate root cause of observed phenomena. These phenomena include unexpectedly slow response times, and current increase, or decrease, where the opposite behavior might be expected.

Table 6-5. Glucose sensor design parameters studied

Design Parameter	Value Range
GLM Thickness, $\delta_{\text{GLM}}$	1 to 100 $\mu\text{m}$
GOx Thickness, $\delta_{\text{GOx}}$	1 to 50 $\mu\text{m}$
Selectivity	0.1 to 10 $\times$ default diffusion coefficients

#### 6.3.2.1 GLM thickness

GLM thickness regulates the flux of glucose entering the sensor. A sufficient thickness is necessary to prevent from overwhelming the enzyme, but thin enough to allow oxygen

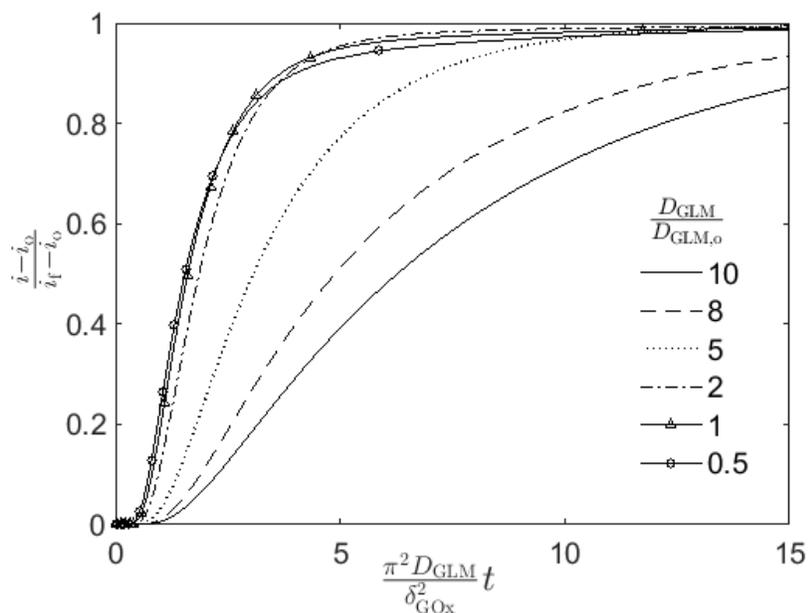


Figure 6-11. Current response as a function of the dimensionless time with the diffusion coefficients in the GLM as a parameter. When  $D_{GLM}/D_{GLM,o}$  exceeds 2, a deviation from the time constant for glucose transport through the GLM is observed. As the GLM permeability increases, the GOx region becomes the dominant diffusion barrier.

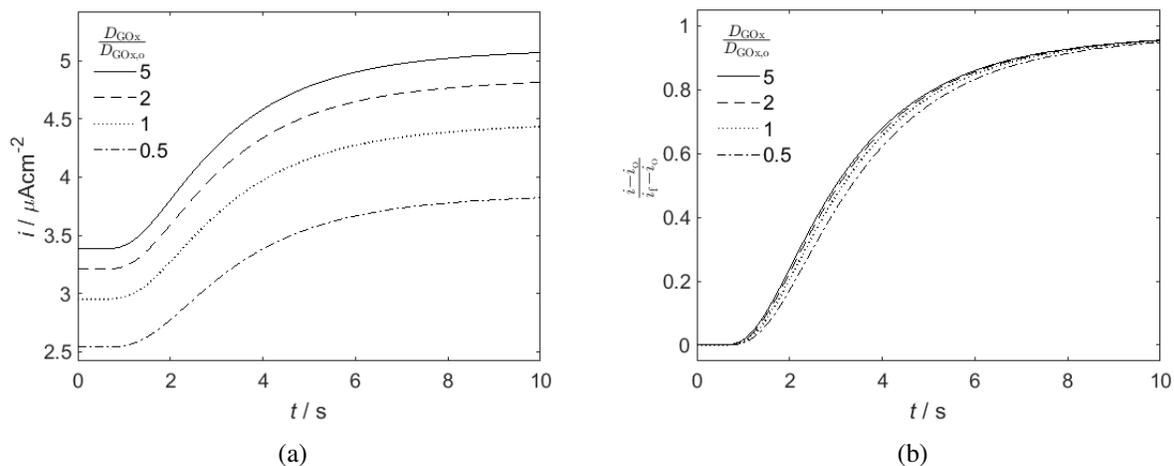


Figure 6-12. Transient (a) current and (b) normalized current calculations to a glucose perturbation from  $200$  to  $300 \text{ mgdL}^{-1}$  at  $0.4 \text{ V}$  and  $5 \%$  partial pressure of oxygen with the diffusion coefficients in the GOx as a parameter. While magnitude varies, response rate was not strongly influenced by the GOx permeability

permeability, adequate signal from reacting glucose, and not produce a large lag between true blood glucose and the sensor output. The GLM should also be less permeable than the GOx layer in order to prevent loss of hydrogen peroxide to the bulk tissue outside the sensor. A less permeable GLM also increases the detectable glucose range as a larger glucose concentration is required to produce a flux sufficient to overwhelm the enzyme.

Steady current as a function of GLM thickness is presented in Figure 6-13. Current drops rapidly when the GLM thickness is increased from 1  $\mu\text{m}$  and diminishes for continual increases. The current is proportional to the flux of glucose at the GOx/GLM interface. Assuming all the glucose is consumed at the GOx/GLM interface the current

$$i \propto \left. \frac{dc_{\text{glu}}}{dy} \right|_{y=\delta_{\text{GOx}}} = \frac{c_{\text{glu,bulk}}}{\delta_{\text{GLM}}} \quad (6-19)$$

is proportional to the bulk concentration of glucose and inverse with the GLM thickness. Steady profiles are presented in Figure 6-14 with GLM thickness as a parameter for an applied potential of 0.4 V and 200  $\text{mgdL}^{-1}$  glucose. For a 5  $\mu\text{m}$  GLM thickness, the flux of entering glucose is large, which yields a sharp increase in hydrogen peroxide and decrease in oxygen concentration. While this thickness would render a sensor highly sensitive to changes in glucose concentration, it would also be prone to hydrogen peroxide loss to the bulk and oxygen deficiency to sustain the enzyme reaction. The opposite is also true for a thick GLM region which would be less sensitive to glucose, but have sufficient oxygen to sustain the enzyme reactions. Exiting flux of the hydrogen peroxide is significantly lower for a thick GLM than a thin one, as demonstrated in Figure 6-14(c).

Transient current response to a glucose perturbation from 200 to 300  $\text{mgdL}^{-1}$  are presented in Figure 6-15 with GLM thickness as a parameter. As the GLM thickness is increased, the magnitude and rate of the response is reduced. The rate of the response is determined by the GLM thickness while it is the largest diffusion barrier to glucose. Normalized current as a function of dimensionless time is presented in Figure 6-15(b). Overlap of the current is observed for 20, 50, and 80  $\mu\text{m}$  GLM thickness. Deviation from this response rate is observed for a 5  $\mu\text{m}$  GLM. For a

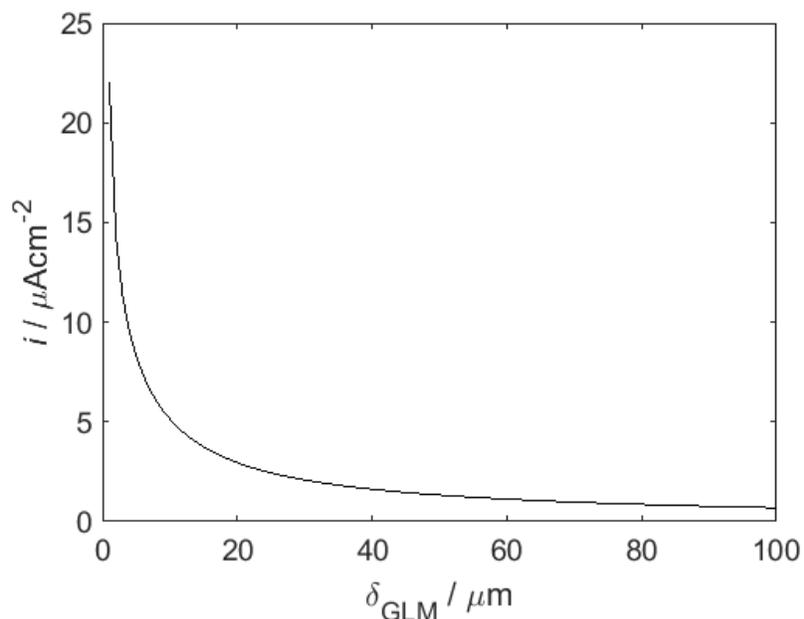


Figure 6-13. Current as a function of GLM thickness at 0.4 V and 200 mgdL<sup>-1</sup> of glucose. Upon introduction of the GLM a large drop in the steady current is observed and tapers as GLM thickness is continually increased.

thin GLM, the response is determined by diffusion-reaction rates in the GOx enzyme layer.

These results demonstrate an expected response time to steady state within seconds for a GOx thickness of 50  $\mu\text{m}$  or smaller. Because response time increases with the square of the GLM thickness, it is easier to adjust the film thickness than permeability to obtain the desired glucose flux and response time. The permeability of the GLM should not exceed that of the GOx layer as the enzyme may become more easily overwhelmed, particularly for aging sensors with decreased enzyme activity.

### 6.3.2.2 GOx thickness

Adjustments to the GOx layer directly control the total enzyme loading of the sensor for a fixed concentration of enzyme. The porous membrane with immobilized enzyme should be thick enough to react all the glucose with excess oxidized GOx remaining, but thin enough to still allow for transport of hydrogen peroxide and oxygen to and from the electrode.

Steady current as a function of GOx thickness is presented in Figure 6-16 with glucose as a

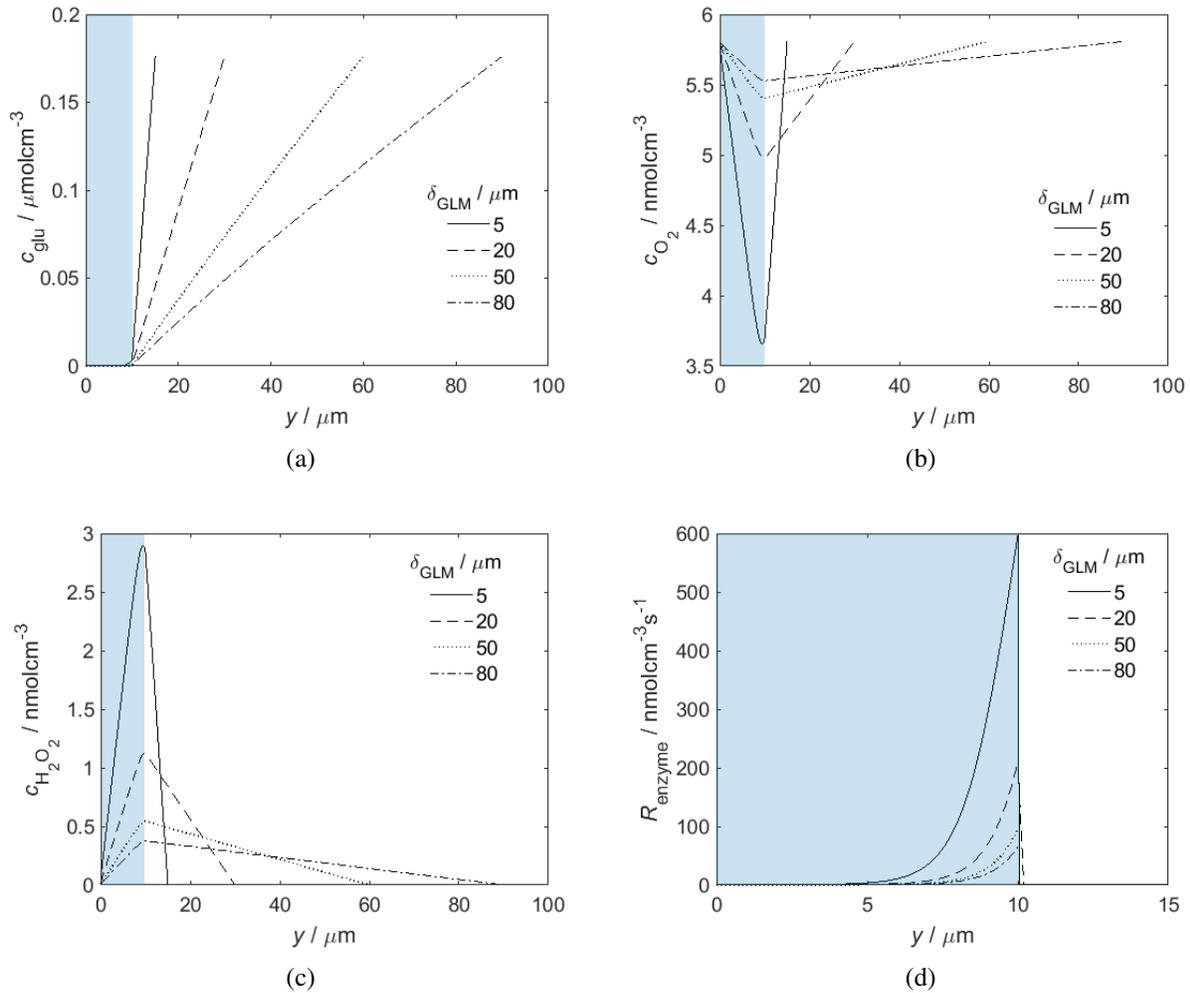


Figure 6-14. Steady profiles for the concentration of (a)  $\beta$ -glucose, (b) oxygen, (c) hydrogen peroxide, and (d) the enzyme reaction with GLM thickness as a parameter. GLM thickness values chosen are 5, 20, 50, and 80  $\mu\text{m}$ . The light blue region from 0 to 10  $\mu\text{m}$  is the GOx layer.

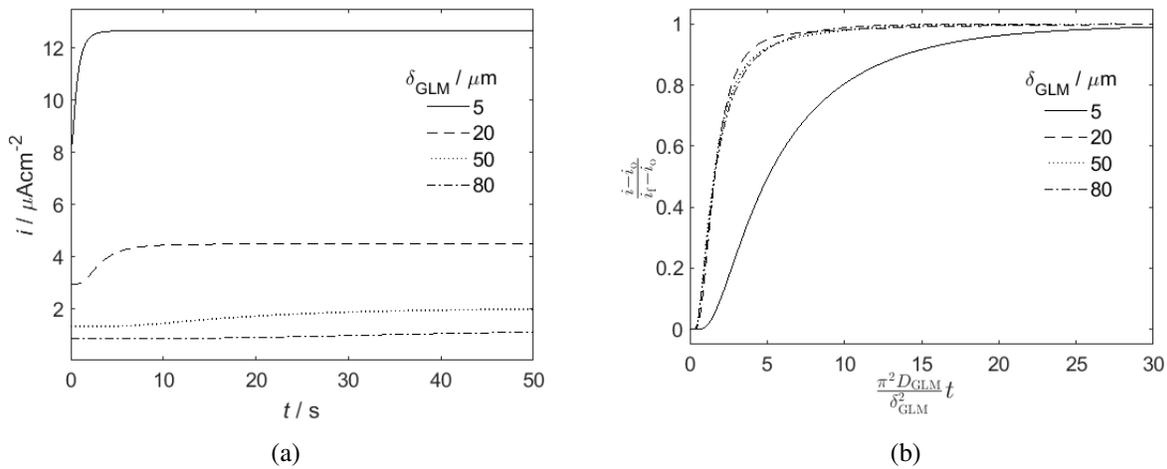


Figure 6-15. Transient current response to a step change in glucose from 200 to 300  $\text{mgdL}^{-1}$  with GLM thickness as a parameter. Results are presented as (a) current and (b) normalized current as a function of the dimensionless time relative to glucose diffusion through the GLM.

parameter. For very thin GOx regions, under 1  $\mu\text{m}$ , a steep change in current is observed for a change in GOx thickness. At these thicknesses, the sensor is limited by the total enzyme to fully react all the glucose. Glucose is fully reacted for GOx thickness greater than 1  $\mu\text{m}$ ; additional thickness will shift the peak enzyme reaction away from the electrode and the current will decrease. A 40 % current decrease was observed when GOx thickness was increased from 2  $\mu\text{m}$  to 50  $\mu\text{m}$ , independent of glucose concentration. However, some additional thickness is required to increase the detectable glucose concentration range. This also prolongs the sensor lifetime by increasing the total amount of enzyme.

Steady concentration and reaction profiles are presented in Figure 6-16 with GOx thickness as a parameter. The glucose concentration profile (Figure 6-17(a)) is presented with a log scale for concentration due to its rapid consumption in the GOx region. For the thinnest GOx region of 1  $\mu\text{m}$ , the residence time of glucose in the enzyme layer is not sufficient to fully react and minimal oxygen is consumed. For GOx layers of 10, 20 and , 40  $\mu\text{m}$  all of the glucose fully reacts and the reaction profiles are similar in shape and magnitude. However, oxygen concentration at the GOx/GLM interface decreases significantly with increasing GOx thickness. The minimal oxygen

concentration was  $5 \text{ nmolcm}^{-3}$  for a  $10 \mu\text{m}$  GOx region, but drops to  $3.3 \text{ nmolcm}^{-3}$  for a  $40 \mu\text{m}$  GOx region. As GOx thickness was increased, the diffusion resistance of hydrogen peroxide to the electrode is increased, and a heightened concentration is observed. This leads to additional loss of hydrogen peroxide to the bulk boundary and is responsible for the current decrease for the thicker GOx layers conditions in Figure 6-16.

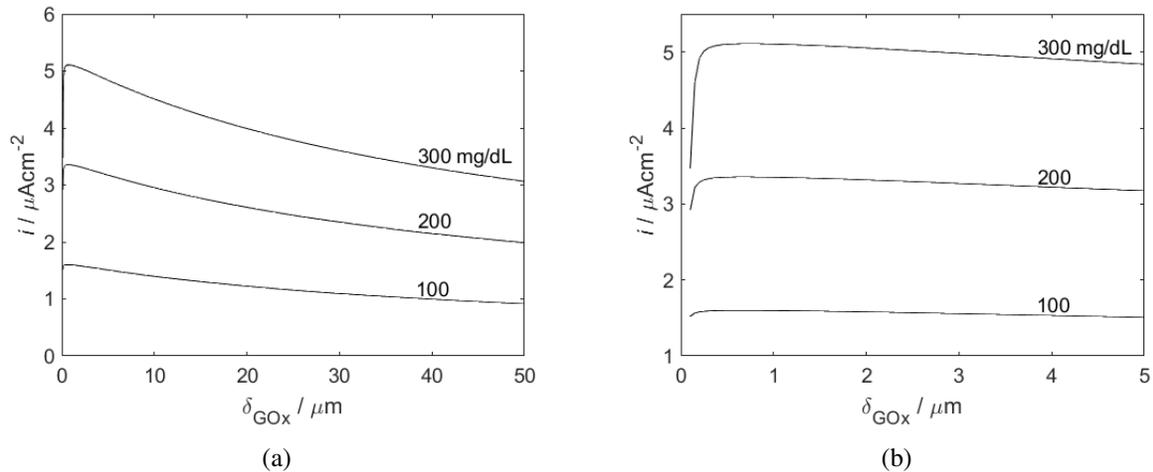


Figure 6-16. Steady current as a function of GOx layer thickness with glucose concentration as a parameter. Results shown for (a) 0.5 to 50  $\mu\text{m}$  and (b) 0.1 to 5  $\mu\text{m}$  GOx layer thickness. Current decrease is observed for thickness increases to the GOx region, except when less than 1  $\mu\text{m}$ .

Influence of the GOx thickness on the transient response to a glucose perturbation from 200 to 300  $\text{mgdL}^{-1}$  was investigated. The transient current response is presented in Figure 6-18 with GOx thickness as a parameter. The current responses roughly overlap for the first 5 seconds. There is a small ( $\approx 0.5 \text{ s}$ ) difference in the initial increase in the current. Despite the presence of unreacted glucose in the 1  $\mu\text{m}$  GOx condition, a current rise is still observed, proportional to the glucose perturbation. The enzyme is not limited in this case, but instead the residence time of the glucose is greatly reduced for the thin GOx region. Thus an increase in glucose will still demonstrate a proportional rise in current. These results raise the need to inquire about testing glucose sensors which have significantly reduced enzyme region thickness as the model demonstrates a heightened current response. However, the reduced total amount of enzyme in a

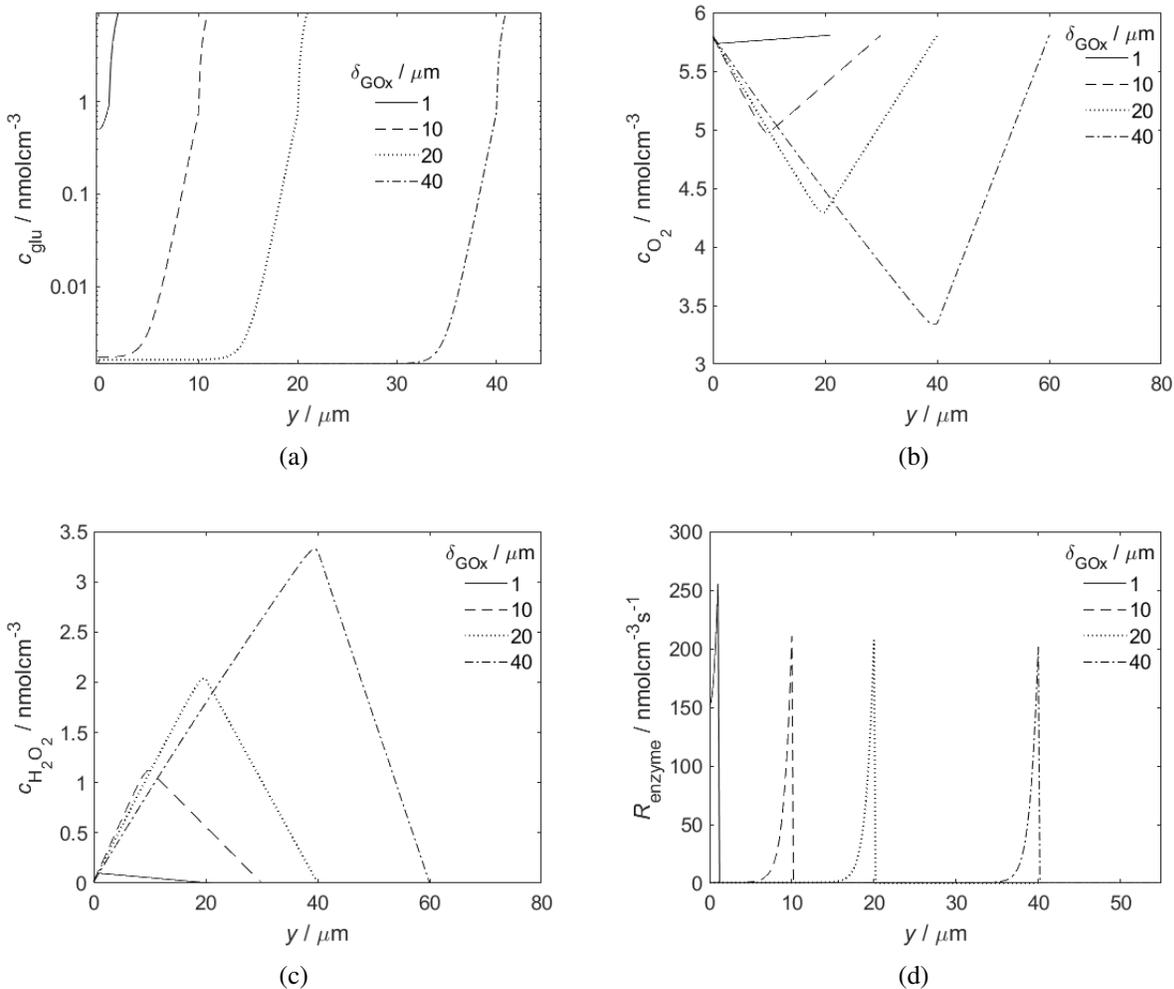


Figure 6-17. Steady profiles for the concentration of (a)  $\beta$ -glucose, (b) oxygen, (c) hydrogen peroxide, and (d) the enzyme reaction with GOx thickness as a parameter. GOx thickness values chosen are 1, 10, 20, and 40  $\mu\text{m}$ . Simulations conducted at an applied potential of 0.4 V and 200  $\text{mgdL}^{-1}$ . Note the glucose concentration is presented on a log scale, as concentration decreases rapidly within the GOx region.

thin GOx region may be more sensitive to deactivation. A slow decaying current response was observed for the 40  $\mu\text{m}$  GOx layer condition. This was found to be due to the increased degree in anomerization of  $\alpha$ -glucose to  $\beta$ -glucose as a result of glucose's significantly longer residence time in the GOx region. Reducing the rate constant for anomerization reduced, or removed, this long time behavior. Anomerization presents a potential lag in the glucose response, particularly in cases of rapidly developing hyperglycemic and hypoglycemic conditions. However, a stronger current response is produced, in theory, due to the supplementation of the reacting  $\beta$ -glucose.

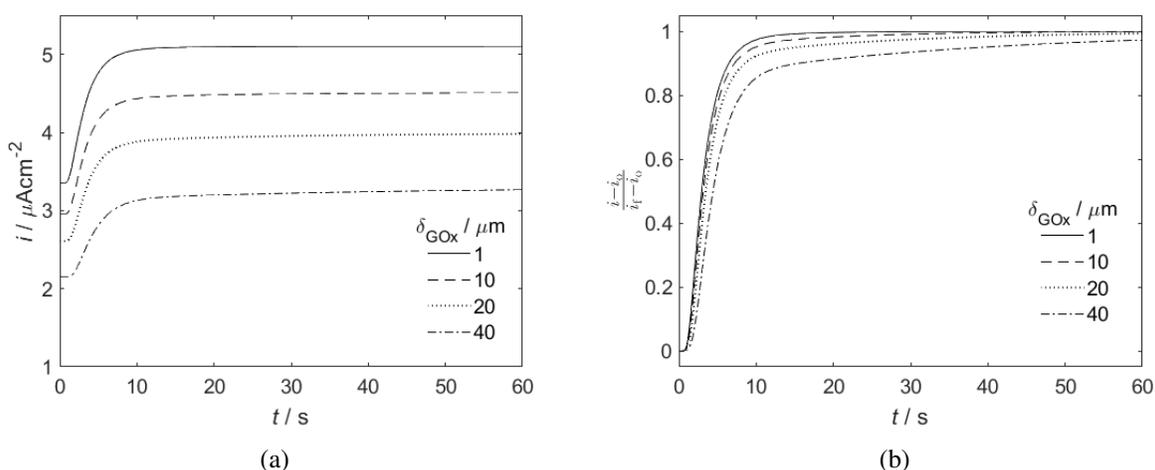


Figure 6-18. Transient current response to a glucose perturbation from 200 to 300 mgdL<sup>-1</sup> for (a) current and (b) normalized current with GOx thickness as a parameter. The long time behavior for the thickest GOx condition is due to the anomerization from  $\alpha$ -glucose to  $\beta$ -glucose, as the  $\beta$ -glucose concentration is very small in the GOx layer.

### 6.3.2.3 Membrane diffusion and selectivity

The GOx and GLM membranes of the sensor are porous membranes; permeability increases and selectivity decreases with increasing pore size. The GLM is responsible for selective diffusion of oxygen while slowing glucose diffusion. The GOx should be permeable to all species to facilitate diffusion of hydrogen peroxide and oxygen to and from the electrode, while providing sufficient residence time for glucose to fully react. Thus the GLM should be the primary barrier for selectivity in the sensor. The model was used to provide the influence of individual membrane selectivity and layer to layer permeability differences.

Current is presented as a function of individual diffusion coefficients in Figure 6-19. The influence of selectivity between the hydrogen peroxide and oxygen, in Figure 6-19(a), demonstrated dependence solely on the hydrogen peroxide diffusion coefficient. The exception is at large values of the hydrogen peroxide diffusion coefficient and small values of the oxygen diffusion coefficient, where an increase in current is observed. This effect would be more noticeable for a larger glucose concentration, or reduced oxygen partial pressure as the enzyme reaction is forced to shift closer to the electrode in this region. The selectivity between hydrogen peroxide and glucose, in Figure 6-19(b), demonstrates a stronger influence of the glucose diffusion coefficient than the hydrogen peroxide diffusion coefficient, but both influence current. Straight contour lines signify the absence of interaction between these two diffusion coefficients.

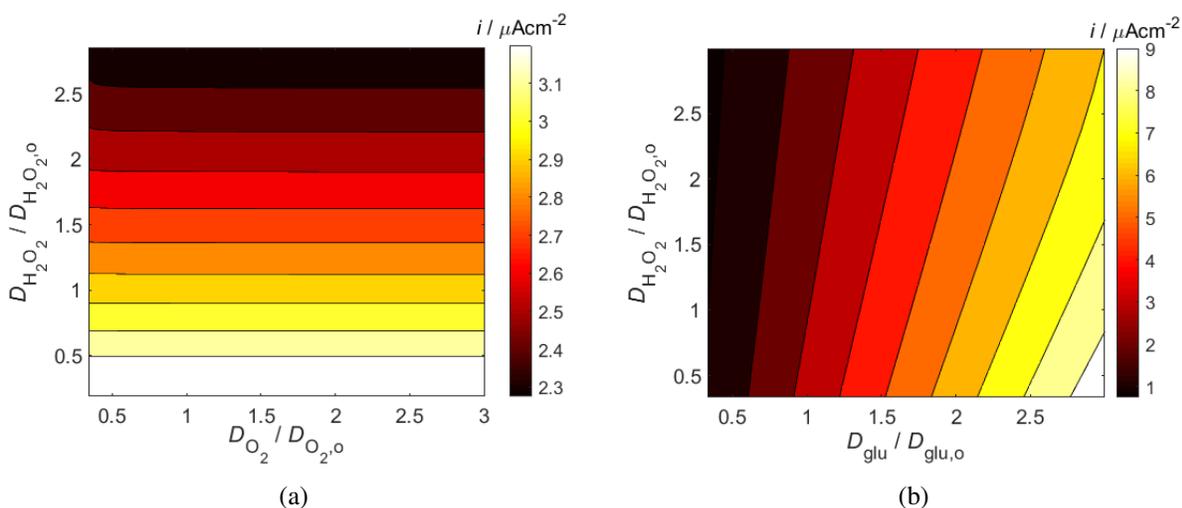


Figure 6-19. Steady current as a function of GLM diffusion coefficients for (a)  $\text{H}_2\text{O}_2$  and  $\text{O}_2$  and (b)  $\text{H}_2\text{O}_2$  and glucose. Applied potential was 0.4 V, bulk glucose was  $200\text{mgdL}^{-1}$  and oxygen partial pressure was 5 %. Oxygen is shown to have little impact on the sensor response, except at small diffusion coefficients in the GLM. Current increase was observed for an increase in glucose and decrease in hydrogen peroxide diffusivity. All diffusion coefficients are presented as a fraction of their value in Table 6-3 for the GLM layer.

In addition to selectivity, diffusion coefficients in the GOx layer relative to the GLM also influence the current. Steady current as a function of the GOx and GLM diffusion coefficients for hydrogen peroxide are presented in Figure 6-20. Current increases with increasing GOx

diffusivity and decreases with increasing GLM diffusivity for hydrogen peroxide. Increased permeability of hydrogen peroxide in the GOx layer facilitates transport to the electrode. Increased permeability in the GLM increases the exiting hydrogen peroxide flux to the bulk concentration.

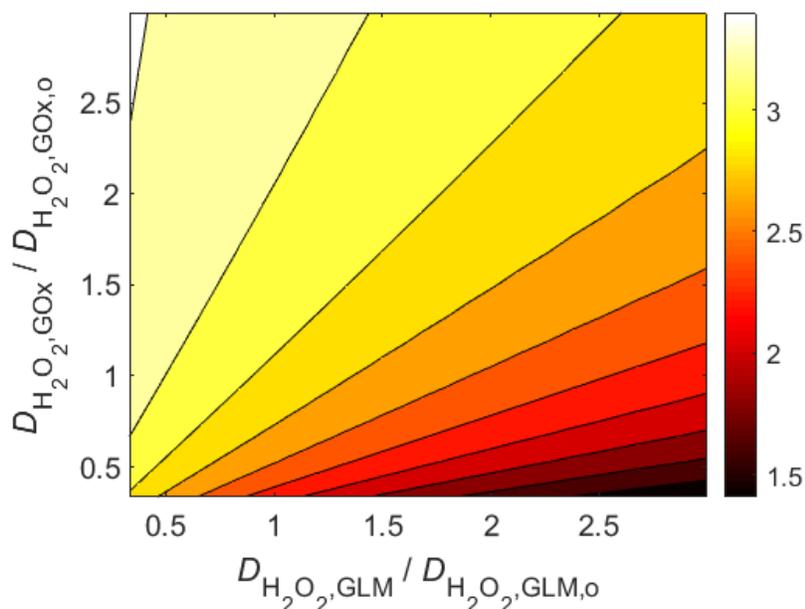


Figure 6-20. Steady current as a function of GOx and GLM diffusion coefficient for hydrogen peroxide. Current increases with increased diffusivity in the GOx layer, and decreased diffusivity in the GLM layer for hydrogen peroxide.

A difference in the GOx and GLM layer hydrogen peroxide permeability plays a less trivial role under oxygen limitation. Current as a function of oxygen partial pressure are presented in Figure 6-21 with the diffusion coefficient of hydrogen peroxide in the GLM as a parameter. The diffusion coefficient for hydrogen peroxide in the GOx layer was increased from Figures 6-21(a) to 6-21(d). The oxygen curve, as demonstrated in Figure 3-16, yields a peak in current at an intermediate value of oxygen partial pressure. As the oxygen becomes limited, the enzyme reaction slows and the peak reaction rate shifts towards the electrode, thus increasing current. The largest peak is observed in Figure 6-21(a), where the GOx diffusivity is the smallest for hydrogen peroxide. Current becomes more sensitive to where hydrogen peroxide is formed as diffusivity of

hydrogen peroxide is decreased in the GOx layer. The current peak is even more pronounced for increased permeability of hydrogen peroxide in the GLM. Thus the peak is most pronounced as the ratio,  $D_{\text{H}_2\text{O}_2,\text{GOx}}/D_{\text{H}_2\text{O}_2,\text{GLM}}$ , is reduced. GOx and GLM permeability can be adjusted relative to each other in order to minimize the oxygen curve peak, which acts as a bias on the current reading under oxygen deficiency.

The transient response to a glucose perturbation from 200 to 300 mgdL<sup>-1</sup> was made with the hydrogen peroxide diffusion coefficients in the GOx and GLM layers from the previous oxygen curve study. The current response are presented in Figure 6-22 with the diffusion coefficient of hydrogen peroxide in the GLM as a parameter. The applied potential was 0.4 V and the oxygen partial pressure was 0.15% to study the transient behavior in the vicinity of the oxygen curve peaks observed in Figure 6-21. The diffusion coefficient for hydrogen peroxide in the GOx layer was increased from Figures 6-22(a) to 6-22(d). The rate of the current response was found to slow down as the diffusion coefficient of hydrogen peroxide was increased in the GLM. This was similar to the influence of oxygen deficiency demonstrate in Section 6.3.1.2. As hydrogen peroxide diffusivity out of the GLM is increased, less oxygen is recovered at the electrode. As a result, the oxygen concentration decreases and slows the enzyme reactions which leads to observed long time behavior. An exception is seen for the transient currents with the smallest hydrogen peroxide diffusivity in the GOx layer (Figure 6-22(a)). The response slows down for the first increase to the GLM diffusion coefficient, but then stagnates for further increases. For this case, the enzyme is nearly overwhelmed and the reaction profile cannot shift much closer to the electrode before the response begins to speed up again as demonstrated in Figure 6-6(b).

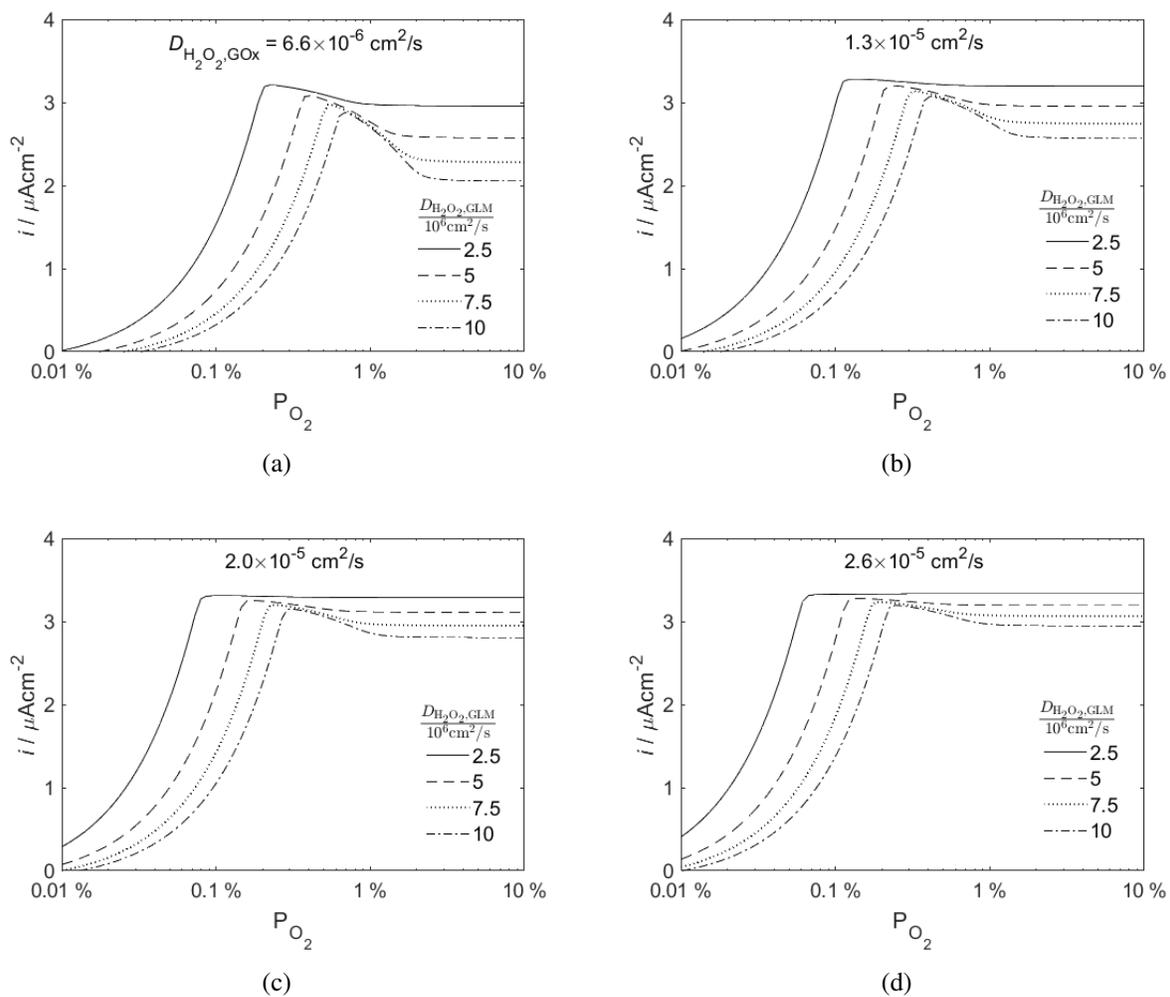


Figure 6-21. Current as a function of oxygen concentration with the GLM diffusion coefficient for hydrogen peroxide as a parameter. The diffusion coefficient for hydrogen peroxide in the GOx layer was (a) 6.6 (b) 13 (c) 20 and (d)  $26 \times 10^{-6} \text{cm}^2/\text{s}$ .

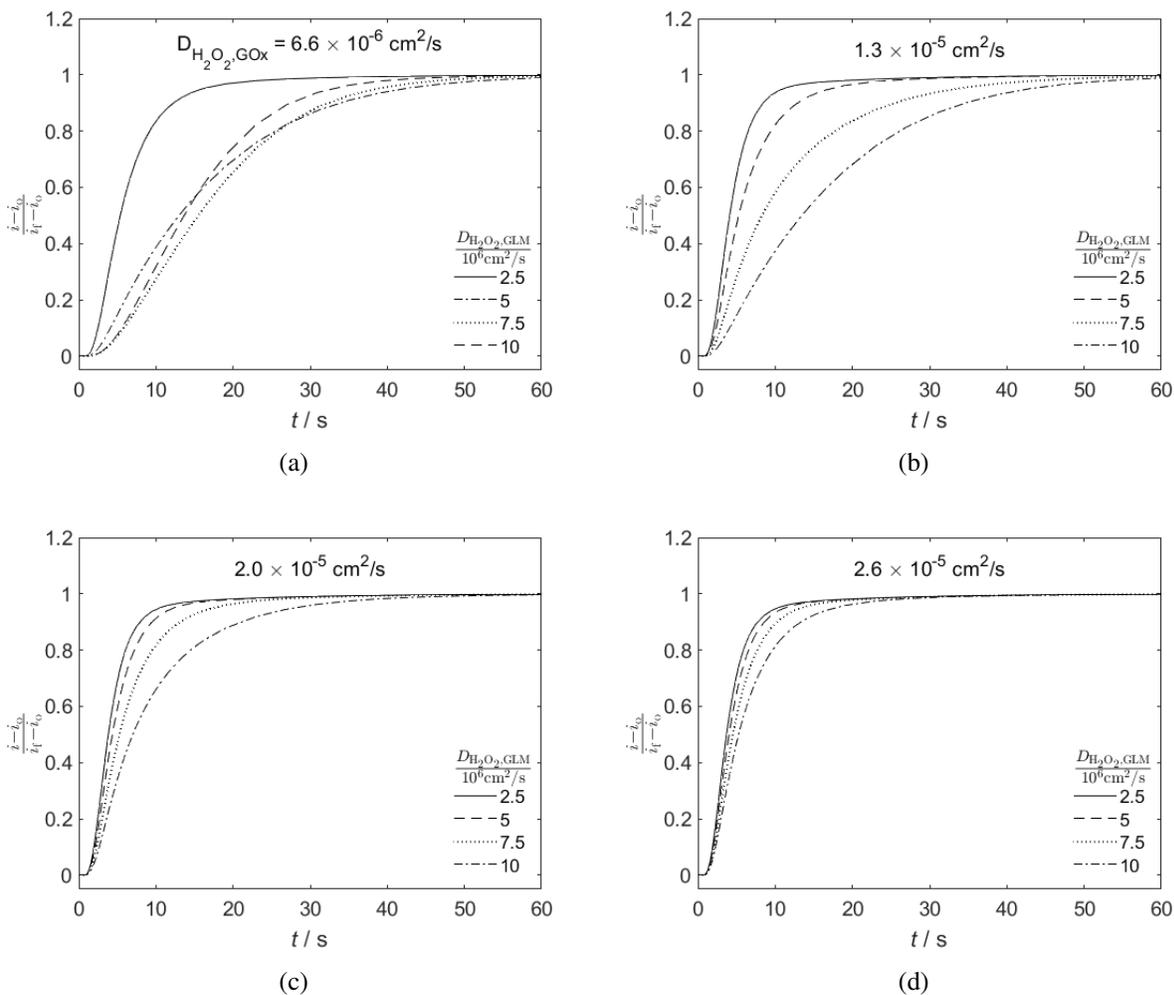


Figure 6-22. Transient current response to a glucose perturbation from  $200$  to  $300 \text{ mgdL}^{-1}$  with the GLM diffusion coefficient for hydrogen peroxide as a parameter. The diffusion coefficient for hydrogen peroxide in the GOx layer was (a)  $6.6$  (b)  $13$  (c)  $20$  and (d)  $26 \times 10^{-6} \text{ cm}^2/\text{s}$ . Applied potential was  $0.4 \text{ V}$  and the partial pressure of oxygen was  $0.15 \%$ .

## CHAPTER 7 EXPERIMENTAL ANALYSIS

This chapter includes experimental data obtained from Medtronic Guardian Sensors with the intention of obtaining parameter values for the numerical models presented in Chapters 3 through 6. Chronoamperometry was used to obtain polarization behavior of the sensor; the steady model presented in Chapter 6 was fit to the polarization curve and obtain heterogeneous rate constants. Potentiostatic holds were applied while glucose or oxygen partial pressure were varied to obtain transient current response to concentration perturbations. These methods assisted in obtaining homogeneous rate constants for the enzyme reactions. Steady current values were obtained while varying glucose to approximate a diffusion and partition coefficient for glucose in the GLM. Impedance spectroscopy was employed at multiple applied potentials and oxygen concentrations to determine values for the electrolyte resistance, capacitance, electrode roughness, and diffusion resistance. The advantage of impedance spectroscopy over steady methods was demonstrated by identifying when the sensor was oxygen deficient.

### 7.1 Experimental Setup

A glass, 200 mL sealed and jacketed vessel was used for all experimental work. The jacket had attached water inlet and outlet ports for controlling vessel temperature to 37 °C via a Fischer Scientific Model910 IsoTemp Water Recirculator. Temperature inside the vessel was validated manually with a calibrated glass thermometer. The vessel contains 1 large port for sensor insertion and 4 smaller ports which were used for additions of glucose, gas spargers, pH, and oxygen sensors. All devices inserted into the ports were isolated with surrounding rubber stoppers to prevent isolation from ambient conditions. The experimental setup is presented in Figure

A Gamry Reference 600+ Potentiostat modulated potential and recorded current with a 3-electrode circuit. Working, counter, and reference electrodes all connected directly to the glucose sensor. The grounding wire from the Gamry instrument was connected to a stainless steel faucet which was found to eliminate noise during EIS measurements. Applied potential was controlled relative to the sensor's built-in Ag/AgCl reference electrode. Steady and transient current measurements were made with in fixed channel mode, while EIS measurements were made in auto-channel mode.

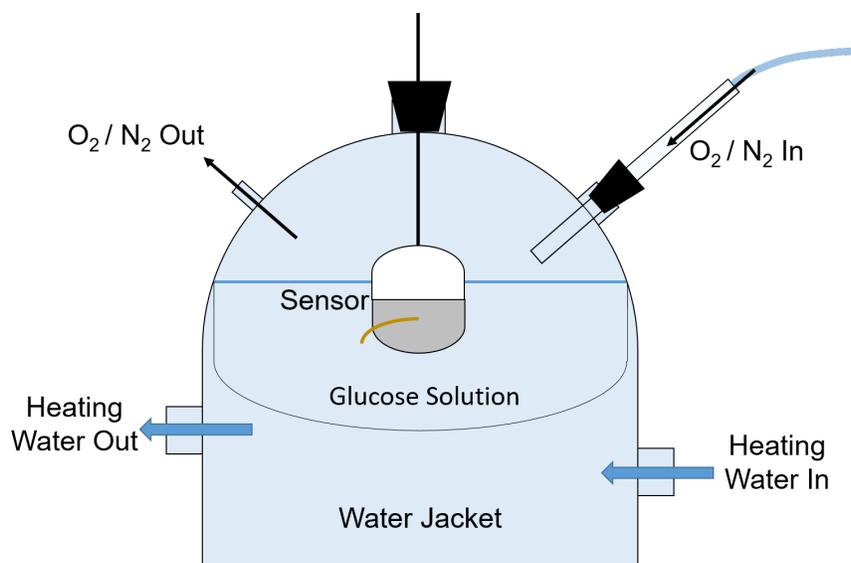


Figure 7-1. Experimental setup includes: glass temperature controlled jacket vessel, glucose solution with gas inlet and outlet, and glucose sensor.

100 mL solutions were prepared by combining a stock solution of  $2000 \text{ mgdL}^{-1}$  glucose to desired concentration, 20 mL of phosphate buffer saline (PBS) from a stock solution of 0.137 M sodium chloride and 0.01 M phosphate buffer, and the remaining volume with deionized water. For glucose perturbation measurements, the stock solution of glucose was saturated with the desired gas concentration prior to perturbing the system to minimize the perturbation of oxygen concentration. Gas mixtures of 1 or 5 % oxygen with balanced nitrogen, and pure nitrogen were supplied from compressed cylinders with an output pressure of 5 psig through the glass spherger. One of the ports was covered with PARAFILM and gas was allowed to exit via a pinhole. The spherger remained directly above the solution surface as gas bubbles were found to introduce noise in the measurements via bubble adsorption to the sensor surface, except during oxygen perturbation when a fast gas exchange rate was desired.

## 7.2 Experimental Results

This section is separated into 3 subsections: Steady Experiments, Transient Experiments, and Impedance Measurements. Steady measurements conducted were polarization behavior and glucose calibration. Transient measurements were glucose and oxygen perturbations. Application of the experimental results to the model are presented in each section.

## 7.2.1 Steady Experiments

Steady techniques rely on the current to maintain a long term steady state. Polarization behavior was obtained from a series of potential steps; while the current is transient after a potential step, the system was provided sufficient time to reach a new steady state before the next step was applied. Similarly, glucose steps were made to acquire the steady current as a function of glucose concentration. This technique requires a constant bias hold while the current approaches a steady state in response to the adjusted glucose.

### 7.2.1.1 Polarization curve

Polarization behavior of the sensor was obtained from a series of chronoamperometric steps from an applied potential of 0.65 V (Ag/AgCl) to -0.2 V in 50 mV increments. The vessel solution contained 400 mgdL<sup>-1</sup> glucose and 5% partial pressure of oxygen supplied by a compressed gas mixture. To ensure steady state current was obtained, a potential hold was applied for 4500 seconds before stepping to the next potential. The obtained polarization curve is presented in Figure 7-2. A mass transfer plateau was observed above 0.5 V. Hydrogen peroxide formed by the sensor is believed to be the only active species at anodic potentials, and this plateau is expected to be due to the mass-transfer-limited flux of hydrogen peroxide reacting at the electrode. Above 0.65 V, oxygen evolution occurs and current is increased above the mass-transfer-limited plateau. A kinetic plateau was observed between 0.2 and 0.35 V. Due to the possibility of 3 different cathodic reactions, this could be a kinetically limited region for either/both the hydrogen peroxide reduction and hydrogen evolution reaction.[29] On a bare platinum electrode, oxygen reduction contributes to the cathodic current, but the consumption of oxygen via the enzyme reaction is believed to deplete it before reacting at the electrode.[27] A steep cathodic current developed below 0.2 V. This current was attributed to hydrogen evolution due to its large magnitude which could not be explained by hydrogen peroxide reduction. The plateau observed below -0.05 V was attributed to the formation of visible bubbles which effectively reduce the electrode surface area. These bubbles are additional evidence for hydrogen evolution which may be assisted by the presence of PBS buffer.

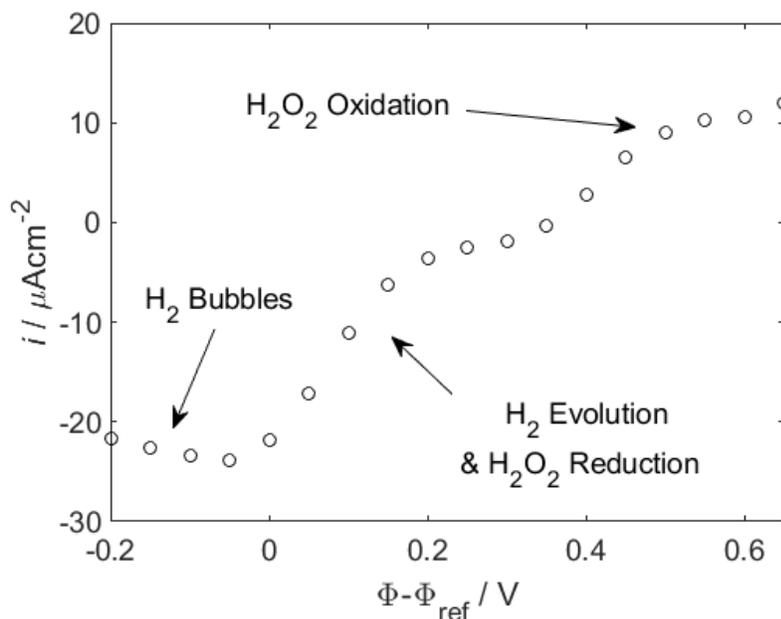


Figure 7-2. Polarization behavior obtained from a series of chronoamperometric steps from 0.65 V to -0.2 V in 50 mV increments with 4500 second potential holds between steps. Hypothesized mechanisms are provided to explain behavior along the curve.

The steady model presented in Chapter 6 was fit to the data. A comparison of the model with previous and updated parameters, and the experimentally obtained polarization behavior are presented in Figure 7-3(a). The diffusion coefficients and kinetic parameters adjusted to the data are presented in Table 7-1. The anodic plateau was shifted to more positive potentials by decreasing the rate constant for hydrogen peroxide oxidation,  $K_{\text{H}_2\text{O}_2}$ ; the slope approaching this plateau was matched by reducing the exponential electrode constant,  $b_{\text{H}_2\text{O}_2}$ . The kinetic plateau observed from 0.2 to 0.35 V was fit by increasing the rate constant for hydrogen peroxide reduction,  $K_{\text{red}}$ , and reducing the electrode constant,  $b_{\text{red}}$ . The parameters for hydrogen evolution were adjusted to accommodate the resulting change to the cathodic current. The presence of 3 cathodic reactions provides 6 variables to match the cathodic current, however the mass transfer limitation for two of these reactions requires a significant contribution of hydrogen evolution to fit the data. Electrode constants for oxygen reduction were found to have no effect as all the oxygen is consumed in the electrode reactions at cathodic potentials. The model deviates below 0.05 V

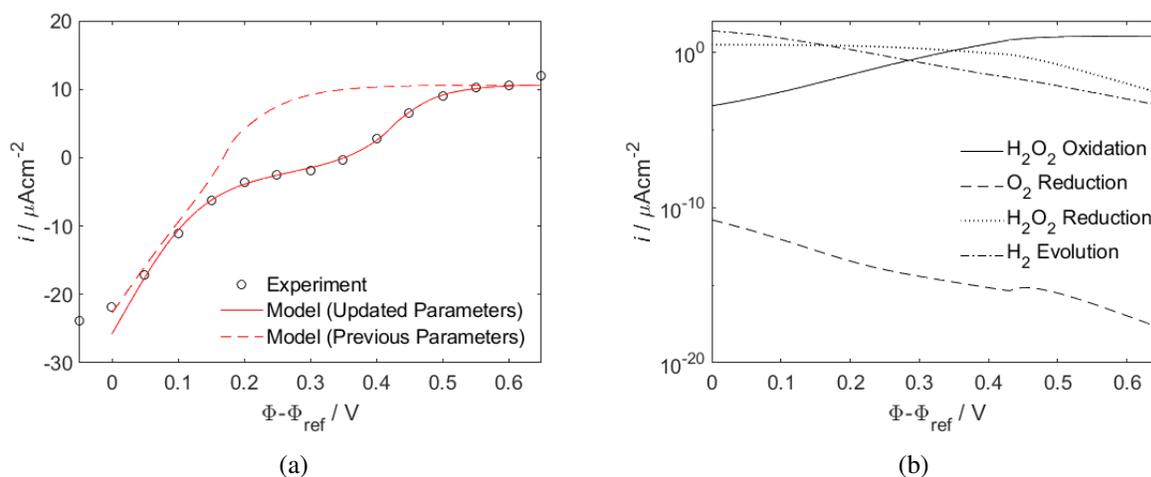


Figure 7-3. Steady model fit to experimental polarization curve. Calculated results are (a) experimental and model polarization before and after parameter adjustment and (b) individual contribution of the faradaic reactions to the total current.

and above 0.6 V due the electrode blocking, and oxygen evolution respectively. The present model does not account for these phenomena. Individual contribution of each faradaic reaction is presented in Figure 7-3(b). The contribution of oxygen reduction was insignificant at all potentials. The contribution of hydrogen peroxide reduction reached a plateau below 0.3 V, while the contribution of hydrogen evolution increased as with decreasing potential. Above 0.45 V, hydrogen peroxide oxidation was the only significant faradaic reaction remaining.

Table 7-1. Adjusted parameters to match experimental polarization curve

Parameter / Units	Updated Value	Previous Value
$D_{\text{GOx,glu}} / \text{cm}^2/\text{s}$	$3 \times 10^{-7}$	$2.13 \times 10^{-6}$
$K_{\text{H}_2\text{O}_2} / \text{Acm}/\text{mol}$	0.7	20
$K_{\text{red}} / \text{Acm}^7/\text{mol}^3$	$1 \times 10^{25}$	$7.5 \times 10^{23}$
$K_{\text{H}_2} / \text{Acm}^4/\text{mol}^2$	$3.8 \times 10^{16}$	$2.8 \times 10^{16}$
$b_{\text{H}_2\text{O}_2} / \text{V}^{-1}$	17	22.4
$b_{\text{red}} / \text{V}^{-1}$	13	30
$b_{\text{H}_2} / \text{V}^{-1}$	20	15

### 7.2.1.2 Glucose calibration

Operating the sensor on the anodic mass-transfer-limited current plateau yields a linear trend between current and glucose concentration. A series of  $100 \text{ mgdL}^{-1}$  glucose steps were

made from 100 to 900 mgdL<sup>-1</sup>. Applied potential was held at 0.5 V (Ag/AgCl) and partial pressure of oxygen was maintained at 5 %. Current was recorded once steady state was reached after each glucose perturbation. Recorded current density as a function of glucose concentration is presented in Figure 7-4. Current rise was 0.036 μAcm<sup>-2</sup>/mgdL<sup>-1</sup>. The steady model was fit with to the data by setting the glucose diffusion coefficient in the GLM to 5.1 × 10<sup>-7</sup> cm<sup>2</sup>s<sup>-1</sup>. Alternatively, the partition coefficient for glucose in the GLM could be adjusted instead. The diffusion coefficient, as opposed to the partition coefficient, will influence the response rate to a glucose perturbation in the transient model according to Equation (3-29). As sensors age, the calibration curve will gradually change and likely the diffusion coefficient of glucose as well.

### 7.2.2 Transient Experiments

Transient techniques rely on the transient current response to a system perturbation. The primary means to perturb the glucose sensor is chronoamperometry, which were conducted to acquire the polarization behavior, glucose perturbations, and oxygen perturbations. Perturbation

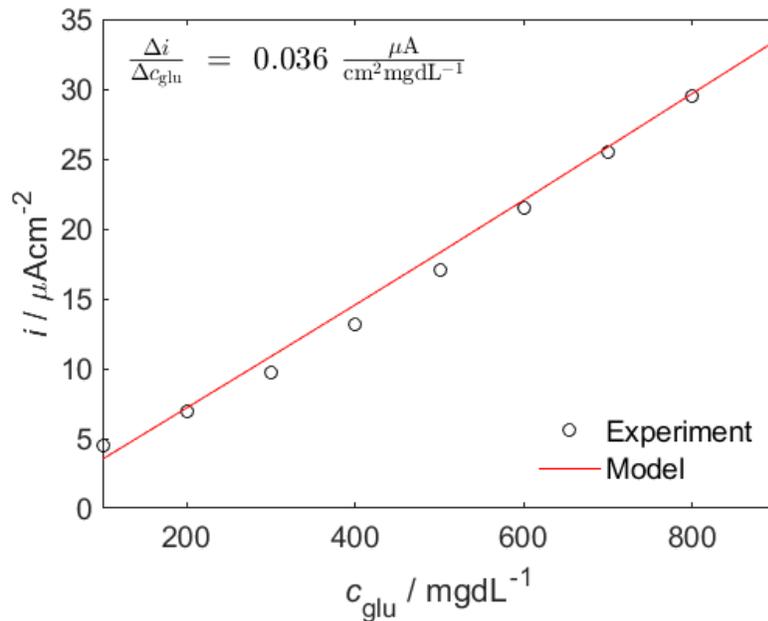


Figure 7-4. Polarization behavior obtained from a series of chronoamperometric steps from 0.65 V to -0.2 V in 50 mV increments with 4500 second potential holds between steps. Hypothesized mechanisms are provided to explain behavior along the curve.

methods include steps, ramps, cyclical sweeps, or sinusoidal sweeps, as the case in impedance spectroscopy. The transient model can simulate the current response to various, and even simultaneous, perturbations. Thus, transient experiments compliment the scope of the present work. In this section, experimental results are presented for glucose steps and oxygen ramps. The transient model is used to simulate the response to these perturbations.

### 7.2.2.1 Glucose steps

The glucose step experiment to produced the glucose calibration in Section 7.2.1.2 is presented in Figure 7-5. A series of 100 mgdL<sup>-1</sup> glucose steps were made from 100 to 700 mgdL<sup>-1</sup>, applied potential was 0.4 V and oxygen partial pressure was 5 %. Current increase at each step is approximately proportional. Referring to Figure 7-5(b), the time constant for the initial elevation in current was 4.1 seconds while a final steady state was not approached until 250 seconds. The early time behavior can be fit with the model by adjusting the glucose diffusion coefficient in the GLM and a single enzyme rate constant, as discussed in Chapter 3. The model was fit to the shorter time constant of 4.1 seconds by adjusting the enzymatic rate constants. 3 enzyme reaction rate constants were set to large value, the remaining rate constant was made

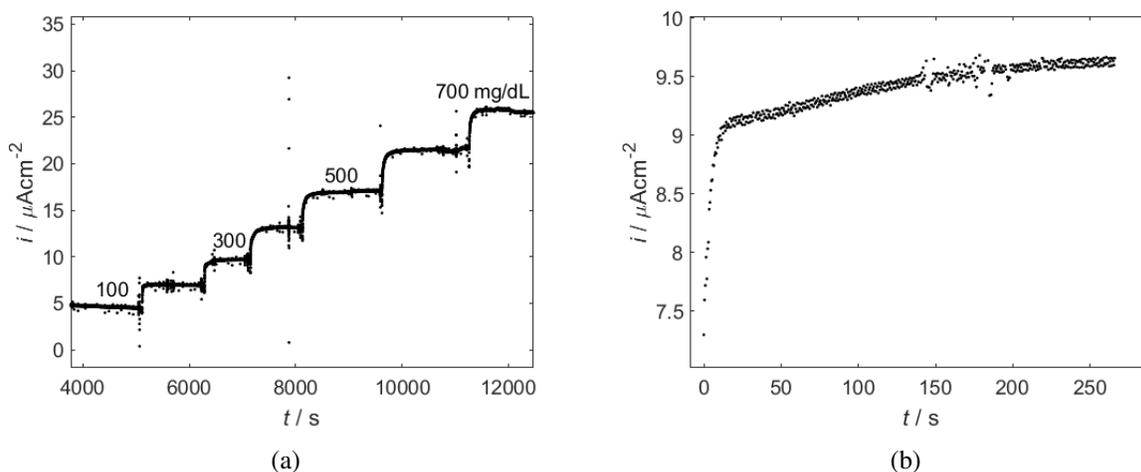


Figure 7-5. Glucose step experiments conducted from 100 to 700 mgdL<sup>-1</sup> in 100 mgdL<sup>-1</sup> increments. Current as a function of time for (a) all 6 glucose perturbations and (b) 200 to 300 mgdL<sup>-1</sup>. Applied potential was 0.4 V and oxygen partial pressure was 5 %.

small to yield the desired time constant. The rate constant for enzyme reaction 2,  $k_{f,2}$  was set to a value of  $0.245 \text{ s}^{-1}$ . The results of the model fit to the experiment are presented in Figure 7-6. The model is in agreement with the experiment from 0 to 45 seconds, but deviates afterwards. The agreement between the model and experiment only implies the enzyme reactions may be adjusted to fit the data at short times, but does not mean the chosen reaction is correct. In addition, the model assumes an instantaneous glucose perturbation outside the GLM, while the experiment response rate is limited by the rate at which glucose was added to the vessel and mixed. The measured short time constant of 4.1 seconds is an upper limit for the time constant characterizing the enzyme reactions; the actual value is likely smaller. Fitting of the model to the experiment for the first 250 seconds requires additional physics. Because the enzyme reactions all occur in series, they can only be responsible for 1 individual time constant, which was accounted for at short times. Further reduction of enzyme reaction rates will also lead to the overwhelming of the enzyme. As the sensor is relatively thin, a time constant on the order of 100 seconds is not coupled to the diffusion of the system. One possibility is the reversible activation/deactivation of the enzyme. This offers a mechanism decoupled from the mass transfer properties of the system

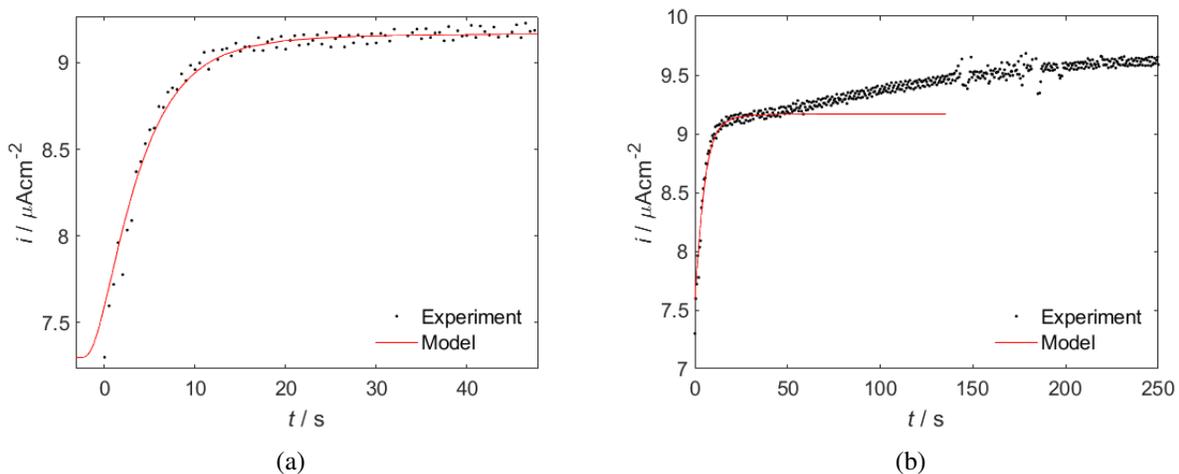
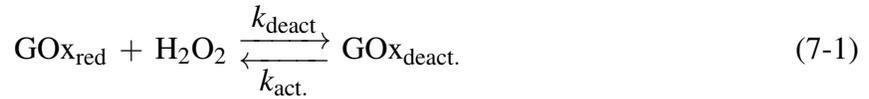


Figure 7-6. Comparison of the glucose step experiment and model fit for a perturbation from 200 to  $300 \text{ mgdL}^{-1}$ . Comparison of time scale for (a) 0 to 45 seconds and (b) 0 to 250 seconds of the current response. The model was accurate at short times, but fails to describe the continual current climb from 40 to 250 seconds

as the enzyme is immobile in the GOx layer. One hypothesis is the exposure of the reduced glucose oxidase to excess hydrogen peroxide could result in deactivation.[49] The reaction follows



where  $k_{\text{deact.}}$  and  $k_{\text{activ.}}$  are the rate constants for deactivation and activation respectively. Influence of the hypothesized reaction on the current response to a glucose perturbation is presented in Figure 7-7 with oxygen partial pressure as a parameter. Both oxygen partial pressures yield large time constants, but the oxygen deficient condition causes a shift towards the accumulation of  $\text{GOX}_{\text{red}}$ . From (7-1), the accumulation of the reduced GOx enzyme shifts the reaction towards additional deactivation and thus an even longer time constant. The change in current at long times for the 5% condition is subtle, but it is continually climbing for the duration of the simulation. The enzyme reaction peak begins at the GOx/GLM interface and shifts the reaction towards the electrode, which accounts for the observed current rise at long times. The ability of deactivation to produce large time constants observed during glucose step experiments does not confirm its presence. Another possibility is a displacement of dissolved oxygen in the stock solution prior to the glucose addition to the vessel. While the stock solution is saturated with the same gas supply as the vessel, the significantly higher glucose concentration in the stock solution may yield a different equilibrium oxygen concentration. These large time constants are observed for in vitro and in vivo.

### 7.2.2.2 Oxygen ramp

The sensor responds to changes in supplied oxygen partial pressure. For a decrease from high to low partial pressure, an initial drop in current occurs followed by recovery to a higher value than the initial value; the current is larger at reduced oxygen concentrations due to the shifting the enzyme reaction, as discussed in Section 6.3.1.2. The opposite occurs for an increase from low to high oxygen partial pressure; an initial steep rise in current is observed, followed by a decrease to a lower current value than the initial. Example calculations for the steady current as a function of oxygen concentration, and the transient current in response to a step change in oxygen

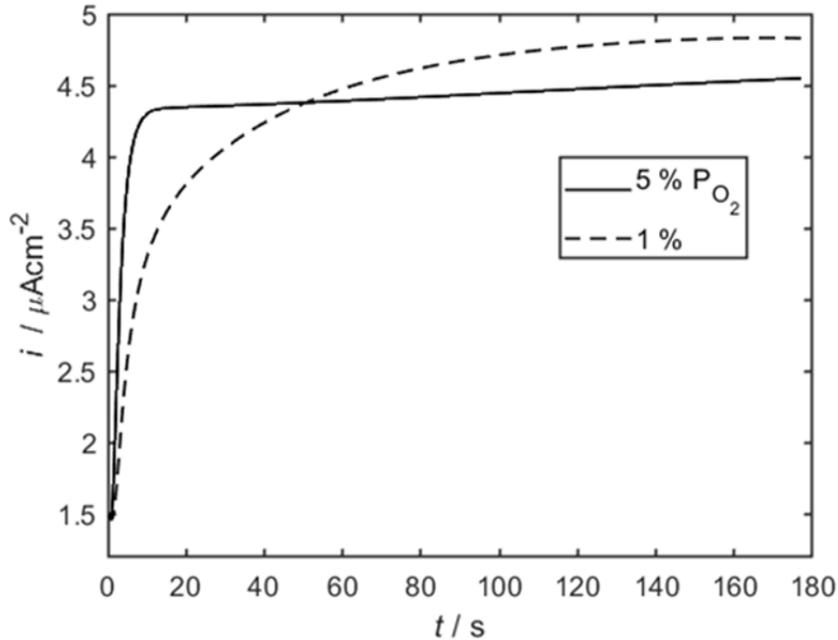


Figure 7-7. Transient current response to an arbitrary step change in glucose with oxygen partial pressure as a parameter. The introduction of enzyme deactivation into the model has the ability to produce large time constants decoupled from the rapid mass transfer time constants in the sensor.

concentration are presented in Figure 7-8. The example transient oxygen step responses in Figure 7-8(b) are made between the two steady current values highlighted in Figure 7-8(a). An oxygen deficit in the GOx layer slows enzyme reactions, and is reflected by the current response rate. In the case of a step increase, the excess oxygen present in the GOx layer speeds up the enzyme reactions; the response for an oxygen step increase is faster than a step decrease for this scenario. The large peak in current observed for the step increase is due to accumulated reduced GOx enzyme under oxygen deficient operation. When the oxygen is increased, equilibrium shifts rapidly to remove the excess enzyme, as described by Equation (3-5). Interestingly, this sharp current spike is not dependent on the glucose of the system, but instead the excess combination of oxygen and  $\text{GOx}_{\text{red}}$ . The parameter influence on the peak of the steady current as a function of oxygen was discussed in Chapter 6.3.2.3.

Oxygen perturbations were conducted experimentally. The experimentally obtained current response to changing oxygen partial pressure is presented in Figure 7-9. An initial steady state

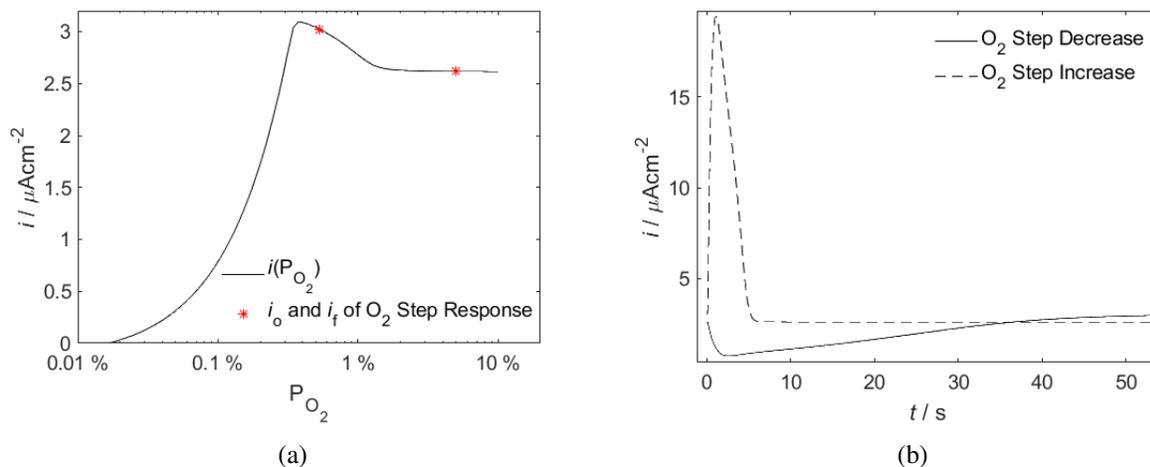


Figure 7-8. Example calculations for (a) steady current as a function of oxygen partial pressure and (b) transient current response to an oxygen step decrease and increase between the steady points highlighted in (a).

was established for a glucose sensor in a  $200 \text{ mgdL}^{-1}$  glucose solution, with an applied potential of  $0.4 \text{ V}$ , and  $5\%$  partial pressure oxygen was supplied to the vessel with a compressed gas cylinder. When current was steady, the regulator on the compressed cylinder was removed and placed onto a new compressed gas cylinder, that supplied  $1\%$  partial pressure oxygen. The current transient was recorded until a new steady value was reached, and the regulator was placed back on the original  $5\%$  cylinder. As opposed to other experiments presented, the gas sparger was placed below the solution level in the vessel to increase the rate of gas dissolution; additional noise in the current measurements are a consequence of locating the sparger below the solution level. While this method of perturbing oxygen is more similar to a ramp than a step, the results were still in qualitative agreement with the example simulation in Figure 7-8(b).

Gas is supplied to the experiment vessel at  $< 5 \text{ psig}$ . When the supply cylinder is changed, the previous gas must purge the supply line before the new gas reaches the vessel. This leads to an exponentially decaying ramp according to the mass balance

$$\frac{dP_{O_2}}{dt} = -k_{\text{gas}}(P_{O_2} - P_{O_2,o}) \quad (7-2)$$

where  $k_{\text{gas}}$  is the dissolution rate of oxygen in the supply gas and  $P_{O_2,o}$  is the initial partial

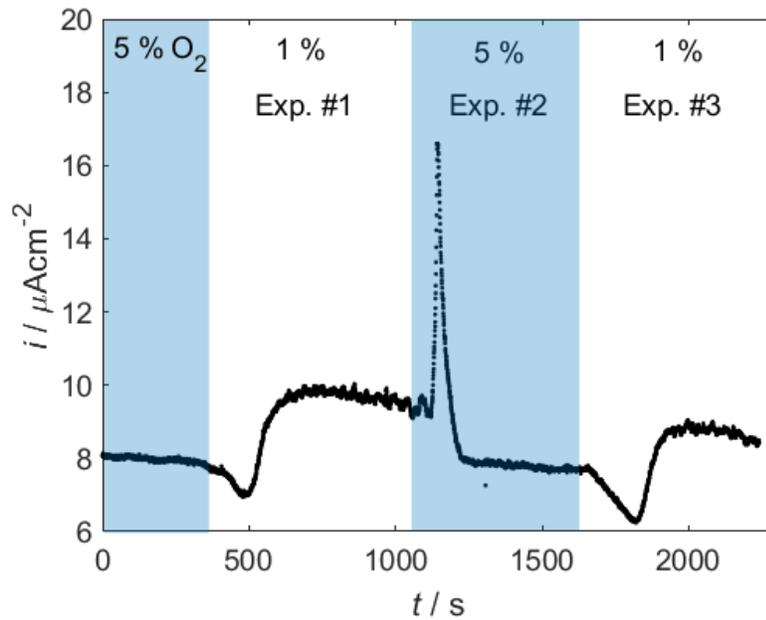


Figure 7-9. Transient current in response to changing of the oxygen partial pressure in the supply air. A decrease in oxygen yields an initial current decrease, followed by a recovery to a current value higher than the initial. The opposite occurs with an increase in oxygen, but the level of current overshoot is much more pronounced.

pressure of oxygen in the gas. Solution of the first-order ODE is

$$P_{O_2}(t) = (P_{O_2,o} - P_{O_2,f}) \exp(-k_{\text{gas}}t) + P_{O_2,f} \quad (7-3)$$

where  $P_{O_2,f}$  is the final partial pressure of oxygen in the gas. Equation (7-3) provides a transient boundary condition at the GLM/bulk tissue interface to simulate exponentially decaying oxygen ramps; this technique serves as an approximation for the time required to dissolve newly supplied gas to the vessel.

The boundary condition provided by Equation (7-3) was introduced to the advanced model presented in Chapter 6. Parameters were adjusted to match the current peak during an increasing oxygen ramp, which is experiment 2 in Figure 7-9. Parameters which had the largest impact on fitting the peak were total enzyme concentration, the limiting homogeneous rate constant for the enzyme reactions ( $k_{f,3}$  for this example), and  $k_{\text{gas}}$  the gas dissolution rate. Transient current in response to an oxygen partial pressure ramp change from 1% to 5% are presented in Figure 7-10.

The enzyme concentration controls the integral area of the current peak observed experimentally; an increase in oxygen when initially deficient yields a rapid concentration decrease in accumulated  $\text{GOx}_{\text{red}}$ . The current and integral of the peak during an oxygen ramp was found to increase proportional to the initial concentration of accumulated  $\text{GOx}_{\text{red}}$ . The enzyme rate constant,  $k_{f,3}$ , was found to adjust the peak current value without dramatically impacting the integral of the peak. It also reduced the time constant for decay of the current. Finally, the gas dissolution time constant yielded a similar effect as the enzyme rate constant, but it also controlled the lag in the peak current onset. Adjusted variables which are not shown were diffusion coefficient of glucose in the GLM, which was proportional to the current magnitude at initial and final times of the response, as well as the discrepancy in the diffusion coefficient for hydrogen peroxide between the GOx and GLM whose impact is described in Chapter 6.3.1.3. The adjusted parameters were applied to both oxygen increase and decrease perturbations to fit the experimental results.

Fitting results of the transient model are presented in Figure 7-11. For the fit to the oxygen ramp increase (Figure 7-11(a)), the current for the model were in agreement at the initial, peak, and final current. However, the model response rate while the peak development and decayed were faster than the experimental data. Additional adjustment of the oxygen dissolution rate constant could increase the current decay time; however this would require adjustment of the enzyme rate constants to compensate for the reduction in peak current and it would shift the peak to a larger time. The same set of parameter values were applied when fitting the model to the oxygen ramp decrease (Figure 7-11(b)), with the exception of the oxygen dissolution rate constant which was reduced. One explanation for this requirement was the difference in pressures between supply cylinders. Good agreement was found for the magnitude and rates of the current response between the model and both trials. The model demonstrated a faster initial rate constant and a deviation above the experimental data immediately after the current valley, between 80 and 120 seconds. The rate of the response after 120 s was in good agreement for the model and both data sets.

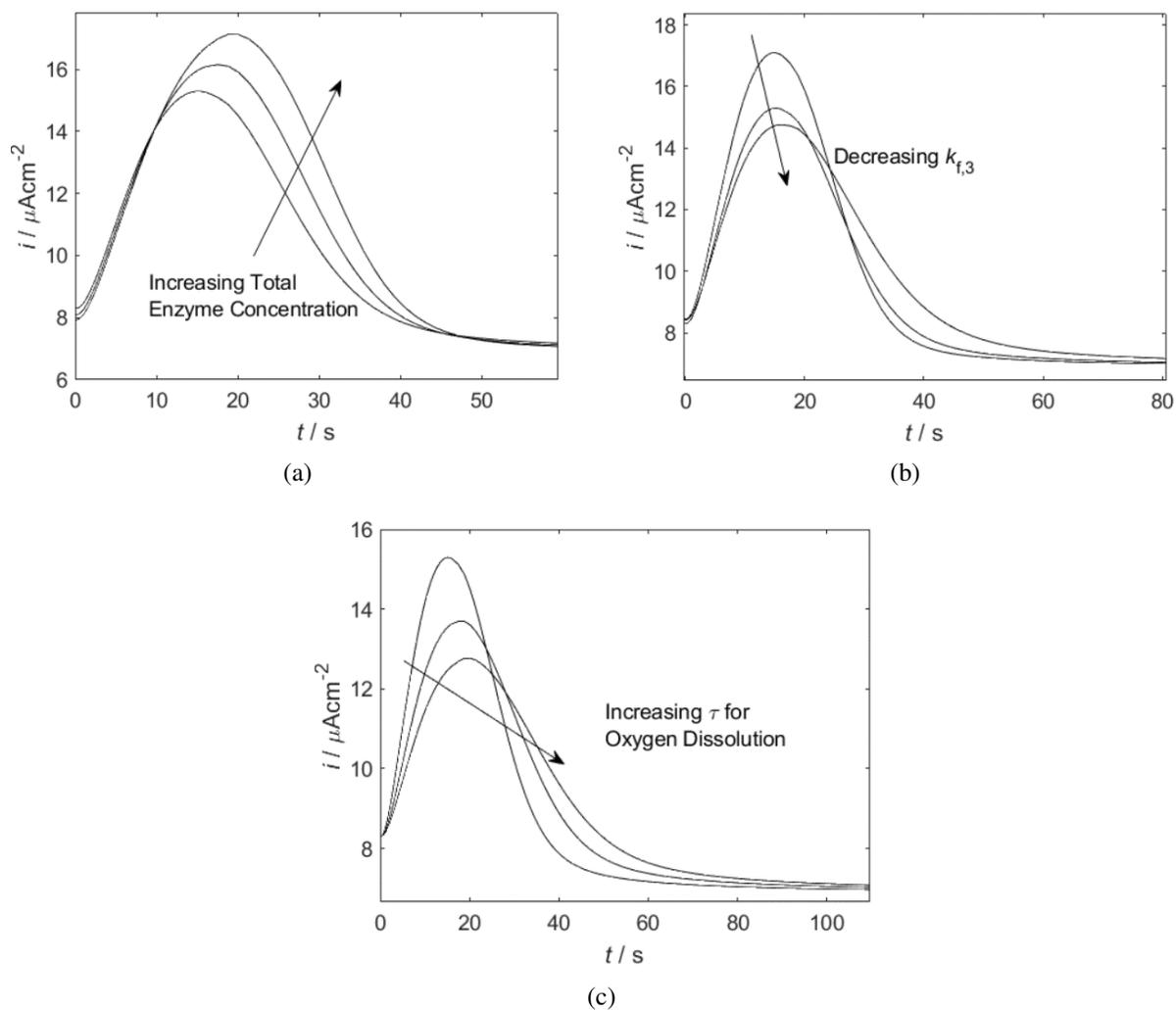


Figure 7-10. Transient current in response to an exponentially decaying oxygen ramp from 1% to 5% partial pressure with the adjusted variable as a parameter. Transient calculations for adjusted variables: (a) total enzyme concentration, (b)  $k_{f,3}$ , enzyme rate constant for reaction 3, and (c)  $k_{\text{gas}}$ , oxygen dissolution rate in the supplied gas.

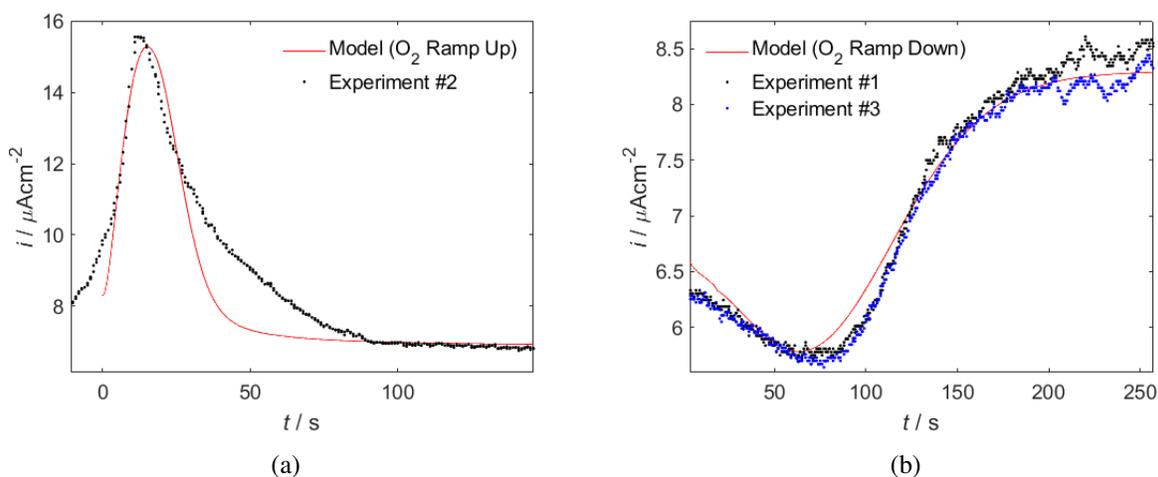


Figure 7-11. Fitting results of the model after parameter adjustment for the current response to (a) an oxygen ramp from 1% to 5% and (b) an oxygen ramp from 5% to 1%. Model parameter values for both perturbation directions were the same, with the exception of the time constant for dissolution which was smaller for the oxygen ramp decrease.

Due to the large number of parameters in the glucose sensor model, it is highly unlikely the parameters adjusted are an extraction of the physical experimental values. However, a common set of parameter values were found which are in relative agreement with the data from multiple experimental techniques including polarization, steady current as a function of glucose concentration, and transient current response to perturbations to the system glucose and oxygen. The ability to reach a set of parameter values capable of producing these phenomena observed from the physical sensor has proven the model as an important tool in understanding the underlying physics involved.

### 7.2.3 Electrochemical Impedance Spectroscopy

Electrochemical impedance spectra was measured from a MiniMed Guardian 3 Glucose Sensor obtained from Medtronic. A 100 mL solution containing 0.04 M phosphate-buffered-saline and 200 mgdL<sup>-1</sup> glucose was maintained at 37 °C and 5% partial pressure oxygen. Prior to EIS measurements, a bias hold of 300 mV was applied versus the sensor's built-in Ag-Cl reference until current did not vary within 0.5 nA for 15 minutes. Upon establishing this pseudo steady-state, EIS measurements were made at 300 mV from 10 kHz to 10

mHz with 10 points per decade and a peak-to-peak perturbation amplitude of 34 mV, or 12 mV RMS. Triplicate EIS measurements were made at this potential. Impedance analysis and fitting was made with the Measurement Model Program from Watson and Orazem.[50]

### 7.2.3.1 Measurement model

Real, imaginary and complex impedance data was fit with a series of Voigt elements, as discussed in Chapter 2.2.2.1. A complex fit was conducted with a modulus error weighting of  $\gamma = 0.002$  as a first approximation of the error structure. This was repeated for all replicates and the resulting error structure was identified from the residual errors to identify the stochastic error structure, as outlined in Section 7.2.3.2. The identified error model was used to weight regressions of the measurement model and the process model presented in Section 7.2.3.3. Frequencies from the original data were filtered based on consistency with the Kramers-Kronig relations. The real part of the impedance was fit to the data and 20 high frequency points fell outside of the 95% confidence interval from the predicted imaginary fit. The complex fit to the data yields a characteristic frequency above which data are influenced by the frequency dispersion due to a rough electrode surface; data above this frequency was eliminated to avoid the influence of dispersion on the model fitting parameters. In total, 40 data points for frequencies from 8 kHz to 0.9 Hz were omitted from the final analysis. A complex fit of the remaining data, from 0.8 Hz to 10 mHz, provided 5 significant Voigt elements. Plots of the impedance, ohmic resistance corrected phase angle, and the real and imaginary residual errors are presented in Figure 7-12.

### 7.2.3.2 Error structure

Error residuals of the real and imaginary parts of the complex fit from the measurement model were used to identify the stochastic error structure of the data. The stochastic error was identified to be

$$\sigma_{\text{stoch}} = \gamma|Z|^2 + \delta \quad (7-4)$$

where  $\gamma$  is the modulus weighting factor with units  $\Omega^{-1}$ .  $\delta$  is the proportional weight constant with units of  $\Omega$ . The values of these constants are presented in Table 7-2. The stochastic error structure was applied to the measurement model, and fits were repeated. Upon the second pass

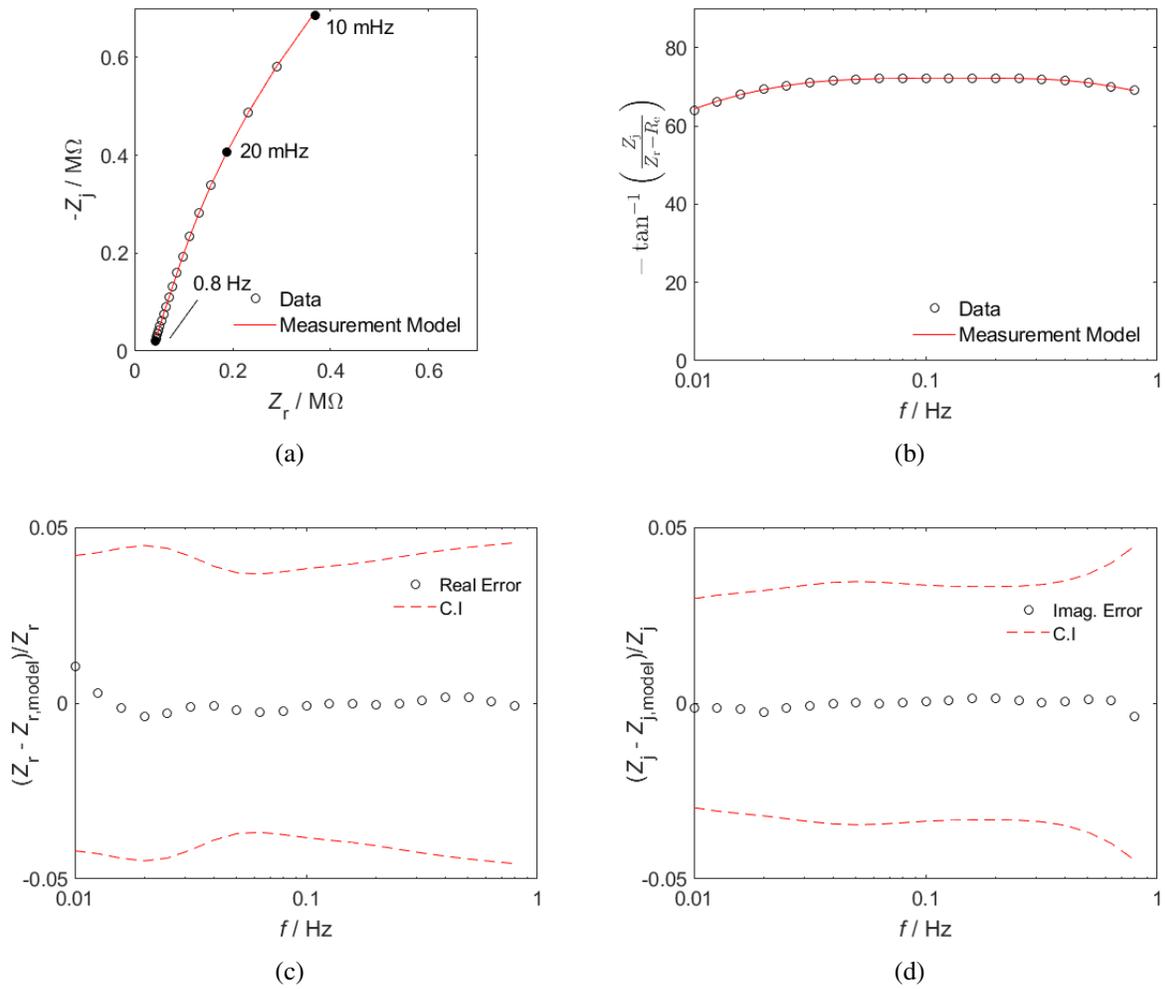


Figure 7-12. Measurement model fitting results presented for (a) Nyquist plot (b) ohmic-resistance-corrected phase angle (c) residual errors of the real fit (d) residual errors of the imaginary fit.

fitting of the measurement model points are eliminated based on Kramers-Kronig criteria for the real and imaginary fits of the impedance, as outlined in Section 7.2.3.1. For frequencies greater than 1 Hz, the residual errors of the real and imaginary impedance values do not overlap and thus the Kramers-Kronig relations are not satisfied. This was believed to be due to frequency dispersion from the large roughness of the sensor's working electrode. This is supported by the small characteristic frequency identified from the complex fit with the identified stochastic error structure weighting. The stochastic error model fitting to the residuals as a function of frequency is presented in Figure 7-13.

Table 7-2. Fitted values for the weighting constants of the stochastic error structure presented in Figure

Parameter / Units	Value ( $1\sigma$ )
$\gamma / \Omega^{-1}$	1.635E-9 (3.14E-10)
$\delta / \Omega$	26.075 (small)

### 7.2.3.3 Process Model

Gao and Harding outlined the reactions, equivalent circuit, and impedance model for the glucose sensor.[19] The equivalent circuit of the glucose sensor is presented in Figure 7-14. The faradaic impedance may be written as

$$Z_F = R_t + R_d \left( -\frac{1}{\theta'} \right) \quad (7-5)$$

where  $Z_F$  is the faradaic impedance,  $R_t$  is the charge-transfer resistance,  $R_d$  is the diffusion impedance, and  $-1/\theta'$  is the dimensionless diffusion impedance and dependent on frequency.[19] At sufficiently anodic potentials, charge-transfer resistance is assumed to be small compared to the diffusion impedance. Furthermore, following the work of Gao, at large values of the diffusion impedance and/or capacitance such that

$$R_d C_{\text{eff}} \gg \frac{\delta^2}{D_i} \quad (7-6)$$

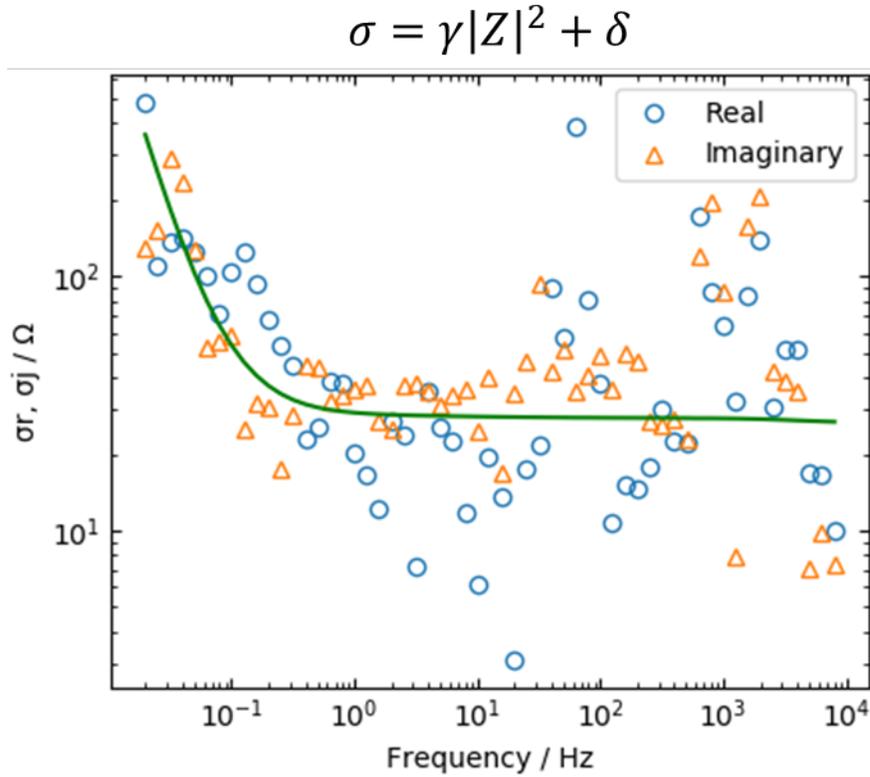


Figure 7-13. Stochastic error of the real and imaginary variation as a function of frequency. Lack of overlap of the real and imaginary variation above 1 Hz is believed to be due to frequency dispersion from a rough electrode.

where  $\delta$  is the diffusion thickness of reaction species, the diffusion impedance becomes independent of frequency. The overall impedance simplifies to

$$Z = R_e + \frac{R_d}{1 + (j\omega)^\alpha Q R_d} \quad (7-7)$$

where  $R_e$  is the electrolyte resistance,  $\alpha$  is the high frequency phase angle as a fraction of  $90^\circ$ , and  $Q$  is a constant related to the effective capacitance of a CPE.[20] This leaves 4 independent parameters used in nonlinear regression of Equation 7-7 to the impedance data:  $R_e$ ,  $R_d$ ,  $\alpha$ , and  $Q$ . The regression was conducted utilizing the weighting and error structure presented in Section 7.2.3.2. A Nyquist plot of the fit to the data is presented in Figure 7-15. Values of extracted parameters are presented in Table 7-3.

The glucose sensor is believed to produce constant-phase element behavior due to a

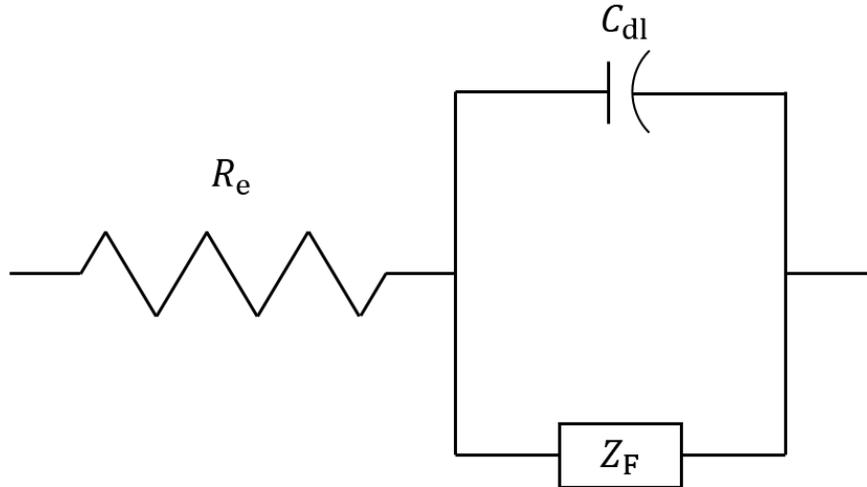


Figure 7-14. Equivalent circuit diagram for the glucose sensor. Individual faradaic reactions are not distinguished during impedance measurements and are lumped together into the circuit element,  $Z_F$ .

Table 7-3. Fitting parameters extracted from process model fitting. Effective capacitance may be extracted with the Brug formula[5].

Parameter / Units	Value ( $22\sigma_x/\bar{x}$ )
$R_e / \text{k}\Omega$	36.9 (10.7%)
$R_d / \text{M}\Omega$	3.68 (22.8%)
$Q / \mu\text{Fs}^{1-\alpha}$	12.89 (2.58%)
$\alpha$	0.852 (1.92%)

distribution of time constants on the electrode surface. Brug et al. proposed an effective capacitance in terms of CPE parameters,

$$C_{\text{eff}} = Q^{1/\alpha} R_e^{(1-\alpha)/\alpha} \quad (7-8)$$

, in the case where CPE behavior is due to a surface distribution of time constants.[5] Equation 7-8 was used to compare results from the process and measurement models. A comparison of extracted parameters are presented in Table 7-4. There is good agreement between the electrolyte resistance extracted from the 2 models, as this is the high frequency limit of the impedance data. However, there is a larger discrepancy in the extracted diffusion resistance and effective capacitance. The measurement model may be better suited to describe a distribution of time

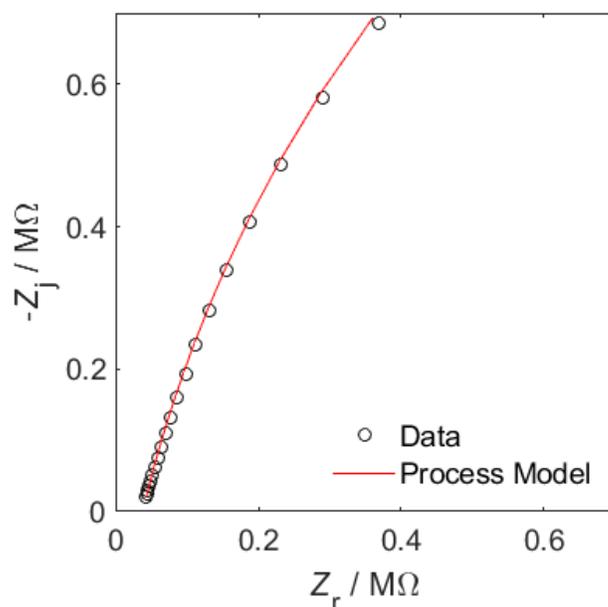


Figure 7-15. Nonlinear regression of the process model, Equation 7-7, to a Nyquist plot of the impedance data.

constants in series, while the capacitance extracted from the process model with the Brug formula is better suited for a surface distribution of time constants. Thus, the actual capacitance is likely closer to the process model. The Nyquist plot is assumed to be the beginning of a semicircle. The diffusion resistance extracted from the measurement model may be a better estimate. From the process model results, the expected  $R_d C_{\text{eff}}$  time constant yields a characteristic frequency of 4 mHz. A more accurate estimate of the diffusion resistance from the process model may require lower frequency measurements, as this characteristic frequency requires extrapolation of the model to obtain. To a first approximation, these results suggest an effective capacitance on the order of  $10 \mu\text{F}$  and a diffusion resistance of  $3 \text{ M}\Omega$ . Capacitance and ohmic resistance values were scaled by the sensor area of  $3.42 \times 10^{-3} \text{ cm}^2$  to be used in the transient model electrode charging parameters.

Table 7-4. Comparison of parameter values extracted from the measurement model and the process model, including the effective capacitance extracted from a CPE with Equation 7-8.

Parameter / Units	Measurement Model	Process Model
$R_e / \text{k}\Omega$	33.5	36.9
$R_d / \text{M}\Omega$	2.57	3.68
$C_{\text{eff}} / \mu\text{F}$	5.56	11.3

## CHAPTER 8 CONCLUSIONS

Steady and transient models were developed for the glucose sensor with varying complexity and dimensions. The model accounts for the individual reaction steps of the enzyme as opposed to the assumptions involved under Michaelis-Menten kinetics. The transient model developed is unique. The charging and subsequent lag between the applied potential and double-layer potential are accounted for via an equivalent circuit of the electrode surface which include the influence of the electrolyte resistance, double-layer capacitance, and charge transfer resistance. Simultaneous use of the steady model may be used to validate consistency when a steady-state is obtained by the transient model. The model may also be used to illustrate the effects of transient operation on the perturbed enzyme reactions and the resulting shift in enzyme profile, and the impact of this has on the current response at short and long times. The influence of concentration perturbations at the boundary may be easily calculated.

The model was used to describe many different scenarios for the glucose sensor. The simplified model was used to characterize the largest time constant of the sensor, which was found to depend on the diffusion of glucose through the sensor and homogeneous rate constants. The influence of an external diffusion layer was found to contribute significantly to the signal lag after a glucose perturbation. Incorporation of a blocking layer was determined to effectively screen acetaminophen when the layer is selective to hydrogen peroxide and oxygen permeability. 3 Failure modes and Design parameters were studied in the context of the steady and transient response; these studies provide valuable information on understanding the sensor behavior under varied operating conditions.

Experimental work was presented for steady, transient and impedance measurements. The most detailed model described was fit to the data for the steady and transient techniques. These fits provide knowledge on the influence of individual parameters on the current response of the sensor. Application of the experimental work was also used to update the values of the model which improves its utility.

## APPENDIX A MESH REFINEMENT STUDY

The second-order accuracy of the model was confirmed in the spatial and temporal mesh spacing. Presented in Figure A-1 are calculated concentrations for hydrogen peroxide at a fixed position and time as a function of the spatial and temporal mesh spacing squared. A linear fit of both studies yield intercepts which are in 99.99996 % agreement.

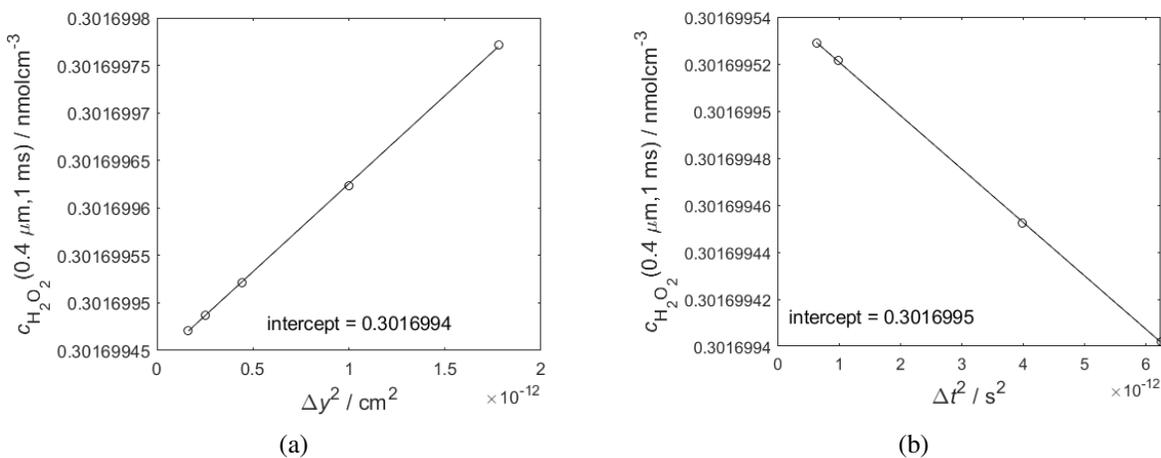


Figure A-1. Calculated hydrogen peroxide concentration  $0.4 \mu\text{m}$  from electrode and 1 ms after potential perturbation as a function of (a) spatial-mesh spacing squared,  $\Delta y^2$  and (b) temporal-mesh spacing squared,  $\Delta t^2$ .

## APPENDIX B FINITE DIFFERENCE CODE FOR THE TRANSIENT RESPONSE OF THE CONTINUOUS GLUCOSE SENSOR

The finite-difference equations for transient calculations in the system for the glucose sensor with the blocking and diffusion layer were solved by use of Newman's BAND algorithm in FORTRAN.[36] Input file shown in Appendix B.1 is corresponding to the parameters shown in Table 5-1. The FORTRAN code for the calculation of the transient glucose sensor model is presented in B.2. There are individual subroutines for the electrode, blocking layer, rough and fine mesh regions for the GOx layer, GLM layer, diffusion layer, external boundary conditions, and coupling routines between these regions. Subroutines called MATINV and BAND were used to solve the non-linear partial differential equations.

Listing B.1. Input File for the Parameters Used in the steady and transient glucose sensor model

```
1 21
2 501
3 301
4 201
5 0.0003
6 0.0007
7 0.002
8 0.8
9 0.42
10 0.169
11 1
12 0.11
13 0.025
14 1e+09
15 1e+07
16 1000
17 1e+09
18 1e+07
19 1e+09
20 0.006
21 1.7397
22 0.0002
23 0.0017
24 5.26e-07
25 1e-20
26 20
27 22.4
28 5e+15
29 38.4
30 7.5e+23
31 30
32 2.8e+16
33 15
34 1e-14
35 101
36 0.0001
37 20
38 22.4
39 401
40 0.01
41 0.7
42 0.15
```

## Listing B.2. FORTRAN Code for the calculation of the transient glucose model

```

1 C Convective Diffusion Equation with Homogeneous Reaction
2 C Enzyme kinetics added
3 C 8 species system
4 C SPECIES 1 = glucose , SPECIES 2 = GOx-FAD, SPECIES 3 = Gluconic acid
5 C SPECIES 4 = GOx-FADH2, SPECIES 5 = O2, SPECIES 6 = H2O2
6 C SPECIES 7 = GOx-FADH2-GA, SPECIES 8 = GOx-FAD-H2O2
7 C Species 6 is the reacting species
8 C This is the steady state solution only
9 C It should be ran prior to cdhgox_os.for
10 C The input file is the same for both
11 C This version of the code is reversible normal kinetics for reactions 1
and 3
12 C Reactions 2 and 4 are irreversible
13
14 C Copy and paste the appropriate lines to create the executable
15 C cd D:\0006 - Simple Transient Sensor Part 2
16 C gfortran -static FullTransCGMvA.for -o FullTransCGMvA.exe
17
18 PROGRAM FullTransCGMvA
19 IMPLICIT DOUBLE PRECISION (A-H, O-Z)
20 COMMON/BAB/ A(22,22),B(22,22),C(22,80001),D(22,45),G(22),X(22,22)
21 1 ,Y(22,22)
22 COMMON/NSN/ N, NJ
23 COMMON/GLC/ NTIME,LL
24 COMMON/VAR/ DIFF(16),H,EBIG,HH,IJ,KJ,TT,VAP,HHH,DT,RE,AKB,BB,CDL
25 COMMON/VARR/ HHHH,HHHHH,MJ,LJ
26 COMMON/DIN/ DGOX(16),DGLM(16),DIRM(16),DBULK(16)
27 COMMON/SPCI/ GLU(2,80001),GOX(2,80001),GLA(2,80001),GOR(2,80001)
28 COMMON/SPCII/ OXY(2,80001),HPR(2,80001),GOA(2,80001),GOP(2,80001)
29 COMMON/RXT/ EQ1(2,80001),RGA(2,80001),EQ2(2,80001),RHP(2,80001)
30 COMMON/SPCIII/ ANM(2,80001),GLUA(2,80001),GLI(2,80001)
31 COMMON/SPCIV/ HYD(2,80001),OHI(2,80001),CO2(2,80001),CBA(2,80001)
32 COMMON/SPCV/ CBI(2,80001),ACE(2,80001)
33 COMMON/VOL/ VDL(2,80001)
34 COMMON/POR/ POR1,POR2,PORGLU,PARION,PARACE
35 COMMON/BCI/ FLUX,FLUX2,FLUX3,FLUX4,FLUX5,AKO,BO,AKR,BR,AKH,BH
36 COMMON/BCII/ AKA,BA
37 COMMON/RTE/ ratef1,equilib1,ratef2,ratef3,equilib3,ratef4
38 COMMON/RTD/ ratef5,equilib5,equilib6,equilib7,equilib8,equilib9
39 COMMON/BUL/ CBULK(16),PARH2O2,PARO2,PARGLUCESE,JCOUNT
40 COMMON/EXTRA/ REF(16)
41 CHARACTER REF*16
42
43
44 102 FORMAT (/30H THE NEXT RUN DID NOT CONVERGE)
45 103 FORMAT ('Error=',E16.6/(1X,'Species=',A6,2X,'C at Electrode=',
46 1 E12.5,2X,'C at Bulk=',E12.5))
47 300 FORMAT (18x,'Glucose'14x,'GOx'14x,'GA'14x,'GOx2'14x,'O2'14x,
48 1 'H2O2'14x,'CX-GOx2'14x,'CX-GOx'14x,'EQ1'14x,'RGA'14x,
49 1 'EQ2'14x,'RHP'14x,'VDL')
50 301 FORMAT (5x,'J=' I5, 13E18.9)
51 334 FORMAT (21(D25.15,5X))
52 302 FORMAT ('Iteration=' I4)
53
54 OPEN(UNIT=13, FILE='cdhGLU_out.txt')
55 CLOSE(UNIT=13, STATUS='DELETE')
56 OPEN(UNIT=13, FILE='cdhGLU_out.txt')

```

```

57
58 OPEN(UNIT=17, FILE='cdhGOX_out.txt')
59 CLOSE(UNIT=17, STATUS='DELETE')
60 OPEN(UNIT=17, FILE='cdhGOX_out.txt')
61
62 OPEN(UNIT=19, FILE='cdhGLA_out.txt')
63 CLOSE(UNIT=19, STATUS='DELETE')
64 OPEN(UNIT=19, FILE='cdhGLA_out.txt')
65
66 OPEN(UNIT=20, FILE='cdhGOR_out.txt')
67 CLOSE(UNIT=20, STATUS='DELETE')
68 OPEN(UNIT=20, FILE='cdhGOR_out.txt')
69
70 OPEN(UNIT=26, FILE='cdhOXY_out.txt')
71 CLOSE(UNIT=26, STATUS='DELETE')
72 OPEN(UNIT=26, FILE='cdhOXY_out.txt')
73
74 OPEN(UNIT=27, FILE='cdhHPR_out.txt')
75 CLOSE(UNIT=27, STATUS='DELETE')
76 OPEN(UNIT=27, FILE='cdhHPR_out.txt')
77
78 OPEN(UNIT=28, FILE='cdhGOA_out.txt')
79 CLOSE(UNIT=28, STATUS='DELETE')
80 OPEN(UNIT=28, FILE='cdhGOA_out.txt')
81
82 OPEN(UNIT=29, FILE='cdhGOP_out.txt')
83 CLOSE(UNIT=29, STATUS='DELETE')
84 OPEN(UNIT=29, FILE='cdhGOP_out.txt')
85
86 OPEN(UNIT=30, FILE='cdhEQ1_out.txt')
87 CLOSE(UNIT=30, STATUS='DELETE')
88 OPEN(UNIT=30, FILE='cdhEQ1_out.txt')
89
90 OPEN(UNIT=31, FILE='cdhRGA_out.txt')
91 CLOSE(UNIT=31, STATUS='DELETE')
92 OPEN(UNIT=31, FILE='cdhRGA_out.txt')
93
94 OPEN(UNIT=32, FILE='cdhEQ2_out.txt')
95 CLOSE(UNIT=32, STATUS='DELETE')
96 OPEN(UNIT=32, FILE='cdhEQ2_out.txt')
97
98 OPEN(UNIT=34, FILE='cdhRHP_out.txt')
99 CLOSE(UNIT=34, STATUS='DELETE')
100 OPEN(UNIT=34, FILE='cdhRHP_out.txt')
101
102 OPEN(UNIT=38, FILE='cdhANM_out.txt')
103 CLOSE(UNIT=38, STATUS='DELETE')
104 OPEN(UNIT=38, FILE='cdhANM_out.txt')
105
106 OPEN(UNIT=39, FILE='cdhGLUA_out.txt')
107 CLOSE(UNIT=39, STATUS='DELETE')
108 OPEN(UNIT=39, FILE='cdhGLUA_out.txt')
109
110 OPEN(UNIT=40, FILE='cdhGLI_out.txt')
111 CLOSE(UNIT=40, STATUS='DELETE')
112 OPEN(UNIT=40, FILE='cdhGLI_out.txt')
113
114 OPEN(UNIT=41, FILE='cdhHYD_out.txt')

```

```

115 CLOSE(UNIT=41, STATUS='DELETE')
116 OPEN(UNIT=41, FILE='cdhHYD_out.txt')
117
118 OPEN(UNIT=42, FILE='cdhOHI_out.txt')
119 CLOSE(UNIT=42, STATUS='DELETE')
120 OPEN(UNIT=42, FILE='cdhOHI_out.txt')
121
122 OPEN(UNIT=43, FILE='cdhCO2_out.txt')
123 CLOSE(UNIT=43, STATUS='DELETE')
124 OPEN(UNIT=43, FILE='cdhCO2_out.txt')
125
126 OPEN(UNIT=44, FILE='cdhCBA_out.txt')
127 CLOSE(UNIT=44, STATUS='DELETE')
128 OPEN(UNIT=44, FILE='cdhCBA_out.txt')
129
130 OPEN(UNIT=45, FILE='cdhCBI_out.txt')
131 CLOSE(UNIT=45, STATUS='DELETE')
132 OPEN(UNIT=45, FILE='cdhCBI_out.txt')
133
134 OPEN(UNIT=53, FILE='cdhACE_out.txt')
135 CLOSE(UNIT=53, STATUS='DELETE')
136 OPEN(UNIT=53, FILE='cdhACE_out.txt')
137
138 OPEN(UNIT=35, FILE='cdhVDL_out.txt')
139 CLOSE(UNIT=35, STATUS='DELETE')
140 OPEN(UNIT=35, FILE='cdhVDL_out.txt')
141
142 OPEN(UNIT=36, FILE='cdhTIME_out.txt')
143 CLOSE(UNIT=36, STATUS='DELETE')
144 OPEN(UNIT=36, FILE='cdhTIME_out.txt')
145
146 OPEN(12, FILE='cdhgox_G_out.txt')
147 CLOSE(12, STATUS='DELETE')
148 OPEN(12, FILE='cdhgox_G_out.txt')
149 WRITE(12,300)
150
151 open(14, file='cdhgox_inFastKineticsAcid.txt', status='old')
152 106 FORMAT (I2/I7/I7/E15.4/E15.4/E15.4/E15.4/E15.4/E15.4/E15.4/E15.4)
153 1 /E15.4/E15.4/E15.4/E15.4/E15.4/E15.4/E15.4/E15.4)
154 print *, 'does this work'
155 read(14,*) N,NJ,IJ,KJ,Y1,Y2,Y3,POR1,POR2,POR3,PARH2O2,PARO2,
156 1 PARGLUCOSE,ratef1,equilib1,ratef2,ratef3,equilib3,ratef4,
157 2 ratef5,equilib5,equilib6,equilib7,equilib8,equilib9,
158 3 AKB,BB,AKO,BO,AKR,BR,AKH,BH,EBIG,MJ,Y4,AKA,BA,LJ,Y5,PARION,
159 4 PARACE
160
161 N=N+1
162
163 open(55, file='DiffBulk_in.txt', status='old')
164 read(55,*) (DBULK(I),I=1,(N-6))
165
166 open(47, file='DiffGox_in.txt', status='old')
167 read(47,*) (DGOX(I),I=1,(N-6))
168
169 open(48, file='DiffGLM_in.txt', status='old')
170 read(48,*) (DGLM(I),I=1,(N-6))
171
172 open(54, file='DiffIRM_in.txt', status='old')

```

```

173 read(54,*) (DIRM(I),I=1,(N-6))
174
175 open(49,file='CBulk_in.txt',status='old')
176 read(49,*) (CBULK(I),I=1,(N-6))
177
178 open(50,file='REF_in.txt',status='old')
179 read(50,*) (REF(I),I=1,(N-6))
180
181
182
183
184 print *, 'CBULK(1)=',CBULK(1)
185 PRINT *, 'CBULK(13)=',CBULK(13)
186 open(37,file='cdhgoxSS_out.txt',status='old')
187 read(37,334) (GLU(1,J),GOX(1,J),GLA(1,J),GOR(1,J),OXY(1,J),
188 1 HPR(1,J),GOA(1,J),GOP(1,J),GLUA(1,J),GLI(1,J),HYD(1,J),
189 2 CO2(1,J),CBA(1,J),CBI(1,J),OHI(1,J),ACE(1,J),
190 3 EQ1(1,J),RGA(1,J),EQ2(1,J),RHP(1,J),ANM(1,J),J=1,NJ)
191
192 print *, GLU(1,NJ)
193 print *, GOX(1,NJ)
194 print *, GLA(1,NJ)
195 print *, GOR(1,NJ)
196 print *, OXY(1,NJ)
197 print *, HPR(1,NJ)
198
199 open(51,file='potTrans_in.txt',status='old')
200 read(51,*) VAP
201 PRINT*, 'Vapplied = ',VAP
202
203 open(52,file='pot_in.txt',status='old')
204 read(52,*) VDL(1,1)
205
206 open(16,file='O2_in.txt',status='old')
207 305 FORMAT (E25.15E3)
208 read(16,305) CBULK(5)
209
210 open(46,file='pH_in.txt',status='old')
211 read(46,*) CBULK(11)
212
213
214 POR1=1.
215 POR2=1.
216 PORGLU=1.
217 CBULK(1)=equilib5/(equilib5+1.)*CBULK(1)
218 CBULK(9)=CBULK(1)/equilib5
219
220 CBULK(11)=10*(-CBULK(11))/1000.
221 CBULK(15)=equilib9/CBULK(11)
222
223 C Constants
224 F=96487.
225
226 c THIS IS SPACING FOR OUTER LAYER, BCNJ
227 HHHHH=Y5/(NJ-LJ)
228 PRINT *, 'HHHHH=', HHHHH
229 PRINT *, 'Y3=', Y5
230 PRINT *, 'NJ-IJ=', NJ-LJ

```

```

231
232 c   THIS IS SPACING FOR OUTER LAYER, GLM
233     H=Y3/(LJ-IJ)
234     PRINT *, 'H=', H
235     PRINT *, 'Y3=', Y3
236     PRINT *, 'NJ-IJ=', LJ-IJ
237
238 c   THIS IS SPACING FOR INNER LAYER
239     HH=(Y2)/(IJ-KJ)
240     PRINT *, 'HH=', HH
241     PRINT *, 'Y2=', Y2
242     PRINT *, 'IJ-KJ=', IJ-KJ
243
244 c   THIS IS SPACING FOR REACTION LAYER
245     HHH=(Y1)/(KJ-MJ)
246     PRINT *, 'Y1=', Y1
247     PRINT *, 'KJ-1=', KJ-MJ
248     PRINT *, 'HHH=', HHH
249
250 c   THIS IS SPACING FOR INSULATION LAYER
251     HHHH=(Y4)/(MJ-1.)
252     PRINT *, 'Y1=', Y4
253     PRINT *, 'KJ-1=', MJ-1.
254     PRINT *, 'HHHH=', HHHH
255
256
257     OPEN(15, FILE='cdhgox_ssvalues_out.txt')
258     CLOSE(15, STATUS='DELETE')
259     OPEN(15, FILE='cdhgox_ssvalues_out.txt')
260 337 FORMAT (I2/I7/I7/I7/E25.15/E25.15/E25.15/E15.8/E15.8/E15.4/E15.4
261 1 /E15.4/E15.4/E25.15)
262     WRITE (15,337) N,NJ,IJ,KJ,H,HH,HHH,DIFF(6),AKB,BB,VAP,POR1
263
264 C     TIME DEPENDENCE PARAMTERS (TIME STEP & # STEPS
265     NTIME = 3001
266     DT = 1.E-8
267     TT=0.0
268
269 C     DBL CAPACITANCE F/cm^2 & ELECTROLYTE RESISTANCE ohm-cm^2
270     CDL=(6E-6/(3.429E-3))
271     RE = (5.E4)*(3.429E-3)
272
273 C     Create flux of the reacting species constants
274     FLUX=AKB/F/2.
275     FLUX2=AKO/F/2.
276     FLUX3=AKR/F/2.
277     FLUX4=AKH/F/2.
278     FLUX5=AKA/F/2.
279     PRINT *, 'FLUX=', FLUX
280     PRINT *, 'FLUX2=', FLUX2
281     PRINT *, 'FLUX3=', FLUX3
282     PRINT *, 'VAP=', VAP
283     PRINT *, 'RE=', RE
284     PRINT *, 'CDL', CDL
285     PRINT *, ''
286
287 c   THIS IS THE MAIN PART OF THE PROGRAM
288     GLU(1,NJ)=CBULK(1)

```

```

289     GLUA(1 ,NJ)=CBULK(9)
290     OXY(1 ,NJ)=CBULK(5)
291     ACE(1 ,NJ)=CBULK(16)
292
293     DO 111 LL=2 ,NTIME
294     IF (MOD(LL,1000).EQ.0) PRINT *, 'N=' , LL
295     IF (MOD(LL,1000).EQ.0) PRINT *, 'VAP=' , VAP
296         IF (LL.LT.1000) DT=1.E-3
297         IF (LL.GE.1000 .AND. LL.LT.1600) DT=5.E-3
298         IF (LL.GE.1600 .AND. LL.LT.1800) DT=5.E-3
299         IF (LL.GE.1800 .AND. LL.LT.2000) DT=5.E-3
300         IF (LL.GE.2000 .AND. LL.LT.2200) DT=5.E-3
301         IF (LL.GE.2200 .AND. LL.LT.2400) DT=5.E-2
302         IF (LL.GE.2400 .AND. LL.LT.3002) DT=2.E-1
303
304 C     RECORD CURRENT TIME
305     TT=TT+DT
306
307     DO 113 J=1 ,NJ
308     IF (LL.GT.2) GLU(1 ,J)=GLU(2 ,J)
309     IF (LL.GT.2) GOX(1 ,J)=GOX(2 ,J)
310     IF (LL.GT.2) GLA(1 ,J)=GLA(2 ,J)
311     IF (LL.GT.2) GOR(1 ,J)=GOR(2 ,J)
312     IF (LL.GT.2) OXY(1 ,J)=OXY(2 ,J)
313     IF (LL.GT.2) HPR(1 ,J)=HPR(2 ,J)
314     IF (LL.GT.2) GOA(1 ,J)=GOA(2 ,J)
315     IF (LL.GT.2) GOP(1 ,J)=GOP(2 ,J)
316     IF (LL.GT.2) EQ1(1 ,J)=EQ1(2 ,J)
317     IF (LL.GT.2) RGA(1 ,J)=RGA(2 ,J)
318     IF (LL.GT.2) EQ2(1 ,J)=EQ2(2 ,J)
319     IF (LL.GT.2) RHP(1 ,J)=RHP(2 ,J)
320     IF (LL.GT.2) ANM(1 ,J)=ANM(2 ,J)
321     IF (LL.GT.2) GLUA(1 ,J)=GLUA(2 ,J)
322     IF (LL.GT.2) GLI(1 ,J)=GLI(2 ,J)
323     IF (LL.GT.2) HYD(1 ,J)=HYD(2 ,J)
324     IF (LL.GT.2) OHI(1 ,J)=OHI(2 ,J)
325     IF (LL.GT.2) CO2(1 ,J)=CO2(2 ,J)
326     IF (LL.GT.2) CBA(1 ,J)=CBA(2 ,J)
327     IF (LL.GT.2) CBI(1 ,J)=CBI(2 ,J)
328     IF (LL.GT.2) ACE(1 ,J)=ACE(2 ,J)
329     IF (LL.GT.2) VDL(1 ,J)=VDL(2 ,J)
330     GLU(2 ,J)=GLU(1 ,J)
331     GOX(2 ,J)=GOX(1 ,J)
332     GLA(2 ,J)=GLA(1 ,J)
333     GOR(2 ,J)=GOR(1 ,J)
334     OXY(2 ,J)=OXY(1 ,J)
335     HPR(2 ,J)=HPR(1 ,J)
336     GOA(2 ,J)=GOA(1 ,J)
337     GOP(2 ,J)=GOP(1 ,J)
338     EQ1(2 ,J)=EQ1(1 ,J)
339     RGA(2 ,J)=RGA(1 ,J)
340     EQ2(2 ,J)=EQ2(1 ,J)
341     RHP(2 ,J)=RHP(1 ,J)
342     ANM(2 ,J)=ANM(1 ,J)
343     GLUA(2 ,J)=GLUA(1 ,J)
344     GLI(2 ,J)=GLI(1 ,J)
345     HYD(2 ,J)=HYD(1 ,J)
346     OHI(2 ,J)=OHI(1 ,J)

```

```

347     CO2(2,J)=CO2(1,J)
348     CBA(2,J)=CBA(1,J)
349     CBI(2,J)=CBI(1,J)
350     ACE(2,J)=ACE(1,J)
351 113 VDL(2,J)=VDL(1,J)
352
353     JCOUNT=0
354     TOL=1.E-10*N*NJ/1.E6
355 C     PRINT *, 'TOL=', TOL
356
357 22 JCOUNT=JCOUNT+1
358     AMP=0.0
359     J=0
360     DO 23 I=1,N
361     DO 23 K=1,N
362     Y(I,K)=0.0
363 23 X(I,K)=0.0
364 24 J=J+1
365     DO 25 I=1,N
366     G(I)=0.0
367     DO 25 K=1,N
368     A(I,K)=0.0
369     B(I,K)=0.0
370 25 D(I,K)=0.0
371
372
373     IF (J.EQ.1) CALL BC1(J)
374     IF (J.GT.1 .AND. J.LT.MJ) CALL INSULATION(J)
375     IF (J.EQ.MJ) CALL COUPLERINS(J)
376     IF (J.GT.MJ .AND. J.LT.KJ) CALL REACTION(J)
377     IF (J.EQ.KJ) CALL COUPLER1(J)
378     IF (J.GT.KJ .AND. J.LT.IJ) CALL INNER(J)
379     IF (J.EQ.IJ) CALL COUPLER2(J)
380     IF (J.GT.IJ .AND. J.LT.(LJ-1)) CALL OUTER(J)
381     IF (J.EQ.(LJ-1)) CALL FORCEC(J)
382     IF (J.EQ.LJ) CALL COUPLER3(J)
383     IF (J.GT.LJ .AND. J.LT.NJ) CALL BULKDIFF(J)
384     IF (J.EQ.NJ) CALL BCNJ(J)
385     CALL BAND(J)
386
387     AMP=AMP+DABS(G(1))+DABS(G(2))+DABS(G(3))+DABS(G(4))+DABS(G(5))
388 1     +DABS(G(6))+DABS(G(7))+DABS(G(8))+DABS(G(9))+DABS(G(10))
389 2     +DABS(G(11))+DABS(G(12))+DABS(G(13))+DABS(G(14))+DABS(G(15))
390 3     +DABS(G(16))+DABS(G(17))+DABS(G(18))+DABS(G(19))+DABS(G(20))
391 4     +DABS(G(21))+DABS(G(22))
392
393     IF (J.LT.NJ) GO TO 24
394
395     IF (MOD(LL,100).EQ.0) PRINT *, 'ERROR=', AMP
396
397     DO 16 K=1,NJ
398     IF (C(1,K).LT.-0.999*GLU(2,K)) C(1,K)=-0.999*GLU(2,K)
399     IF (C(1,K).GT. 999.*GLU(2,K)) C(1,K)= 999.*GLU(2,K)
400     IF (C(2,K).LT.-0.999*GOX(2,K)) C(2,K)=-0.999*GOX(2,K)
401     IF (C(2,K).GT. 999.*GOX(2,K)) C(2,K)= 999.*GOX(2,K)
402     IF (C(3,K).LT.-0.999*GLA(2,K)) C(3,K)=-0.999*GLA(2,K)
403     IF (C(3,K).GT. 999.*GLA(2,K)) C(3,K)= 999.*GLA(2,K)
404     IF (C(4,K).LT.-0.999*GOR(2,K)) C(4,K)=-0.999*GOR(2,K)

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405 IF (C(4,K).GT. 999.*GOR(2,K)) C(4,K)= 999.*GOR(2,K)
406 IF (C(5,K).LT. -0.999*OXY(2,K)) C(5,K)=-0.999*OXY(2,K)
407 IF (C(5,K).GT. 999.*OXY(2,K)) C(5,K)= 999.*OXY(2,K)
408 IF (C(6,K).LT. -0.999*HPR(2,K)) C(6,K)=-0.999*HPR(2,K)
409 IF (C(6,K).GT. 999.*HPR(2,K)) C(6,K)= 999.*HPR(2,K)
410 IF (C(7,K).LT. -0.999*GOA(2,K)) C(7,K)=-0.999*GOA(2,K)
411 IF (C(7,K).GT. 999.*GOA(2,K)) C(7,K)= 999.*GOA(2,K)
412 IF (C(8,K).LT. -0.999*GOP(2,K)) C(8,K)=-0.999*GOP(2,K)
413 IF (C(8,K).GT. 999.*GOP(2,K)) C(8,K)= 999.*GOP(2,K)
414 IF (C(14,K).LT. -0.999*GLUA(2,K)) C(14,K)=-0.999*GLUA(2,K)
415 IF (C(14,K).GT. 999.*GLUA(2,K)) C(14,K)= 999.*GLUA(2,K)
416 IF (C(15,K).LT. -0.999*GLI(2,K)) C(15,K)=-0.999*GLI(2,K)
417 IF (C(15,K).GT. 999.*GLI(2,K)) C(15,K)= 999.*GLI(2,K)
418 IF (C(16,K).LT. -0.999*HYD(2,K)) C(16,K)=-0.999*HYD(2,K)
419 IF (C(16,K).GT. 999.*HYD(2,K)) C(16,K)= 999.*HYD(2,K)
420 IF (C(17,K).LT. -0.999*OHI(2,K)) C(17,K)=-0.999*OHI(2,K)
421 IF (C(17,K).GT. 999.*OHI(2,K)) C(17,K)= 999.*OHI(2,K)
422 IF (C(18,K).LT. -0.999*CO2(2,K)) C(18,K)=-0.999*CO2(2,K)
423 IF (C(18,K).GT. 999.*CO2(2,K)) C(18,K)= 999.*CO2(2,K)
424 IF (C(19,K).LT. -0.999*CBA(2,K)) C(19,K)=-0.999*CBA(2,K)
425 IF (C(19,K).GT. 999.*CBA(2,K)) C(19,K)= 999.*CBA(2,K)
426 IF (C(20,K).LT. -0.999*CBI(2,K)) C(20,K)=-0.999*CBI(2,K)
427 IF (C(20,K).GT. 999.*CBI(2,K)) C(20,K)= 999.*CBI(2,K)
428 IF (C(21,K).LT. -0.999*ACE(2,K)) C(21,K)=-0.999*ACE(2,K)
429 IF (C(21,K).GT. 999.*ACE(2,K)) C(21,K)= 999.*ACE(2,K)
430 GLU(2,K)=GLU(2,K)+C(1,K)
431 GOX(2,K)=GOX(2,K)+C(2,K)
432 GLA(2,K)=GLA(2,K)+C(3,K)
433 GOR(2,K)=GOR(2,K)+C(4,K)
434 OXY(2,K)=OXY(2,K)+C(5,K)
435 HPR(2,K)=HPR(2,K)+C(6,K)
436 GOA(2,K)=GOA(2,K)+C(7,K)
437 GOP(2,K)=GOP(2,K)+C(8,K)
438 EQ1(2,K)=EQ1(2,K)+C(9,K)
439 RGA(2,K)=RGA(2,K)+C(10,K)
440 EQ2(2,K)=EQ2(2,K)+C(11,K)
441 RHP(2,K)=RHP(2,K)+C(12,K)
442 ANM(2,K)=ANM(2,K)+C(13,K)
443 GLUA(2,K)=GLUA(2,K)+C(14,K)
444 GLI(2,K)=GLI(2,K)+C(15,K)
445 HYD(2,K)=HYD(2,K)+C(16,K)
446 OHI(2,K)=OHI(2,K)+C(17,K)
447 CO2(2,K)=CO2(2,K)+C(18,K)
448 CBA(2,K)=CBA(2,K)+C(19,K)
449 CBI(2,K)=CBI(2,K)+C(20,K)
450 ACE(2,K)=ACE(2,K)+C(21,K)
451 VDL(2,K)=VDL(2,K)+C(22,K)
452
453 16 CONTINUE
454
455
456 WRITE(12,302) (JCOUNT)
457
458 c If the error is less then the tolerance , finish program
459 IF (DABS(AMP).LT.DABS(TOL)) GO TO 15
460
461 c If the error is greater then tolerance , do another iteration
462 33 IF (JCOUNT.LE.100) GO TO 22

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463      PRINT 102
464
465 C    15 PRINT 103, AMP,(REF(I),CONC(I,1),CONC(I,NJ),I=1,N-4)
466      15 CONTINUE
467 C      PRINT *,'JCOUNT=',JCOUNT
468
469
470      IF (MOD(LL,2).EQ.0) WRITE(13,305)((GLU(2,J)), J=1,NJ)
471      IF (MOD(LL,2).EQ.0) WRITE(17,305)((GOX(2,J)), J=1,NJ)
472      IF (MOD(LL,2).EQ.0) WRITE(19,305)((GLA(2,J)), J=1,NJ)
473      IF (MOD(LL,2).EQ.0) WRITE(20,305)((GOR(2,J)), J=1,NJ)
474      IF (MOD(LL,2).EQ.0) WRITE(26,305)((OXY(2,J)), J=1,NJ)
475      IF (MOD(LL,2).EQ.0) WRITE(27,305)((HPR(2,J)), J=1,NJ)
476      IF (MOD(LL,2).EQ.0) WRITE(28,305)((GOA(2,J)), J=1,NJ)
477      IF (MOD(LL,2).EQ.0) WRITE(29,305)((GOP(2,J)), J=1,NJ)
478      IF (MOD(LL,2).EQ.0) WRITE(30,305)((EQ1(2,J)), J=1,NJ)
479      IF (MOD(LL,2).EQ.0) WRITE(31,305)((RGA(2,J)), J=1,NJ)
480      IF (MOD(LL,2).EQ.0) WRITE(32,305)((EQ2(2,J)), J=1,NJ)
481      IF (MOD(LL,2).EQ.0) WRITE(34,305)((RHP(2,J)), J=1,NJ)
482      IF (MOD(LL,2).EQ.0) WRITE(38,305)((ANM(2,J)), J=1,NJ)
483      IF (MOD(LL,2).EQ.0) WRITE(39,305)((GLUA(2,J)), J=1,NJ)
484      IF (MOD(LL,2).EQ.0) WRITE(40,305)((GLI(2,J)), J=1,NJ)
485      IF (MOD(LL,2).EQ.0) WRITE(41,305)((HYD(2,J)), J=1,NJ)
486      IF (MOD(LL,2).EQ.0) WRITE(42,305)((OHI(2,J)), J=1,NJ)
487      IF (MOD(LL,2).EQ.0) WRITE(43,305)((CO2(2,J)), J=1,NJ)
488      IF (MOD(LL,2).EQ.0) WRITE(44,305)((CBA(2,J)), J=1,NJ)
489      IF (MOD(LL,2).EQ.0) WRITE(45,305)((CBI(2,J)), J=1,NJ)
490      IF (MOD(LL,2).EQ.0) WRITE(53,305)((ACE(2,J)), J=1,NJ)
491      IF (MOD(LL,2).EQ.0) WRITE(35,305)(VDL(2,1))
492      IF (MOD(LL,2).EQ.0) WRITE(36,305)(TT)
493
494      111 CONTINUE
495      END PROGRAM FullTransCGMvA
496
497      SUBROUTINE BC1(J)
498      IMPLICIT DOUBLE PRECISION (A-H, O-Z)
499      COMMON/BAB/ A(22,22),B(22,22),C(22,80001),D(22,45),G(22),X(22,22)
500      1 ,Y(22,22)
501      COMMON/NSN/ N, NJ
502      COMMON/GLC/ NTIME,LL
503      COMMON/VAR/ DIFF(16),H,EBIG,HH,IJ,KJ,TT,VAP,HHH,DT,RE,AKB,BB,CDL
504      COMMON/VARR/ HHHH,HHHHH,MJ,LJ
505      COMMON/DIN/ DGOX(16),DGLM(16),DIRM(16),DBULK(16)
506      COMMON/SPCI/ GLU(2,80001),GOX(2,80001),GLA(2,80001),GOR(2,80001)
507      COMMON/SPCII/ OXY(2,80001),HPR(2,80001),GOA(2,80001),GOP(2,80001)
508      COMMON/RXT/ EQ1(2,80001),RGA(2,80001),EQ2(2,80001),RHP(2,80001)
509      COMMON/SPCIII/ ANM(2,80001),GLUA(2,80001),GLI(2,80001)
510      COMMON/SPCIV/ HYD(2,80001),OHI(2,80001),CO2(2,80001),CBA(2,80001)
511      COMMON/SPCV/ CBI(2,80001),ACE(2,80001)
512      COMMON/VOL/ VDL(2,80001)
513      COMMON/POR/ POR1,POR2,PORGLU,PARION,PARACE
514      COMMON/BCI/ FLUX,FLUX2,FLUX3,FLUX4,FLUX5,AKO,BO,AKR,BR,AKH,BH
515      COMMON/BCII/ AKA,BA
516      COMMON/RTE/ ratef1,equilib1,ratef2,ratef3,equilib3,ratef4
517      COMMON/RTD/ ratef5,equilib5,equilib6,equilib7,equilib8,equilib9
518      COMMON/BUL/ CBULK(16),PARH2O2,PARO2,PARGLUCOSE,JCOUNT
519
520      301 FORMAT (5x,'J=' I5, 22E18.9)

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521
522 C   For Glucose , being consumed only
523     G(1)=DIRM(1)
524     1 *(GLU(2 , J+1)-GLU(2 , J)+GLU(1 , J+1)-GLU(1 , J) )/HHHH**2.
525     3 +(3.*(ANM(2 , J)+ANM(1 , J) )+(ANM(2 , J+1)+ANM(1 , J+1) ) )/8.
526     4 -(3.*(GLU(2 , J)-GLU(1 , J) )+(GLU(2 , J+1)-GLU(1 , J+1) ) )/(4.*DT)
527
528     B(1 , 1)=DIRM(1)/HHHH**2.+3./(4.*DT)
529     D(1 , 1)=-DIRM(1)/HHHH**2.+1./(4.*DT)
530     B(1 , 13)=-3./8.
531     D(1 , 13)=-1./8.
532
533     BIG=ABS(DIRM(1)*GLU(2 , J+1)/HHHH**2.)
534 C   PRINT *, "BIG=", BIG
535     BIG2=ABS(DIRM(1)*GLU(2 , J)/HHHH**2.)
536 C   PRINT *, "BIG2=", BIG2
537     IF (BIG2.GT.BIG) BIG=BIG2
538     BIG3=ABS(DIRM(1)*GLU(1 , J+1)/HHHH**2.)
539     IF (BIG3.GT.BIG) BIG=BIG3
540     BIG4=ABS(DIRM(1)*GLU(1 , J)/HHHH**2.)
541     IF (BIG4.GT.BIG) BIG=BIG4
542     BIG13=ABS(3.*GLU(2 , J)/(4.*DT))
543     IF (BIG13.GT.BIG) BIG=BIG13
544     BIG14=ABS(3.*GLU(1 , J)/(4.*DT))
545     IF (BIG14.GT.BIG) BIG=BIG14
546     BIG15=ABS(GLU(2 , J+1)/(4.*DT))
547     IF (BIG15.GT.BIG) BIG=BIG15
548     BIG16=ABS(GLU(1 , J+1)/(4.*DT))
549     IF (BIG16.GT.BIG) BIG=BIG16
550
551 C   PRINT *, "G(1)=", ABS(G(1))
552     IF (ABS(G(1)).LT.BIG*EBIG) G(1)=0
553
554 C   For GOx, enzyme
555     G(2)=(GOX(2 , J)+GOX(1 , J))/2.
556     B(2 , 2)=-1./2.
557
558
559 C   For Gluconic Acid , being produced only
560     G(3)=DIRM(3)
561     1 *(GLA(2 , J+1)-GLA(2 , J)+GLA(1 , J+1)-GLA(1 , J) )/HHHH**2.
562     2 +DIRM(10)*(GLI(2 , J+1)-GLI(2 , J)+GLI(1 , J+1)-GLI(1 , J) )/HHHH**2.
563     4 -(3.*(GLA(2 , J)-GLA(1 , J) )+(GLA(2 , J+1)-GLA(1 , J+1) ) )/(4.*DT)
564     5 -(3.*(GLI(2 , J)-GLI(1 , J) )+(GLI(2 , J+1)-GLI(1 , J+1) ) )/(4.*DT)
565
566     B(3 , 3)=DIRM(3)/HHHH**2.+3./(4.*DT)
567     D(3 , 3)=-DIRM(3)/HHHH**2.+1./(4.*DT)
568     B(3 , 15)=DIRM(10)/HHHH**2.+3./(4.*DT)
569     D(3 , 15)=-DIRM(10)/HHHH**2.+1./(4.*DT)
570
571     BIG=ABS(DIRM(3)*GLA(2 , J+1)/HHHH**2.)
572     BIG2=ABS(DIRM(3)*GLA(2 , J)/HHHH**2.)
573     IF (BIG2.GT.BIG) BIG=BIG2
574     BIG3=ABS(DIRM(3)*GLA(1 , J+1)/HHHH**2.)
575     IF (BIG3.GT.BIG) BIG=BIG3
576     BIG4=ABS(DIRM(3)*GLA(1 , J)/HHHH**2.)
577     IF (BIG4.GT.BIG) BIG=BIG4
578     BIG5=ABS(DIRM(10)*GLI(2 , J+1)/HHHH**2.)

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579 IF (BIG5.GT.BIG) BIG=BIG5
580 BIG6=ABS(DIRM(10)*GLI(2,J)/HHHH**2.)
581 IF (BIG6.GT.BIG) BIG=BIG6
582 BIG7=ABS(DIRM(10)*GLI(1,J+1)/HHHH**2.)
583 IF (BIG7.GT.BIG) BIG=BIG7
584 BIG8=ABS(DIRM(10)*GLI(1,J)/HHHH**2.)
585 IF (BIG8.GT.BIG) BIG=BIG8
586 BIG13=ABS(3.*GLA(2,J)/(4.*DT))
587 IF (BIG13.GT.BIG) BIG=BIG13
588 BIG14=ABS(3.*GLA(1,J)/(4.*DT))
589 IF (BIG14.GT.BIG) BIG=BIG14
590 BIG15=ABS(GLA(2,J+1)/(4.*DT))
591 IF (BIG15.GT.BIG) BIG=BIG15
592 BIG16=ABS(GLA(1,J+1)/(4.*DT))
593 IF (BIG16.GT.BIG) BIG=BIG16
594 BIG17=ABS(3.*GLI(2,J)/(4.*DT))
595 IF (BIG17.GT.BIG) BIG=BIG17
596 BIG18=ABS(3.*GLI(1,J)/(4.*DT))
597 IF (BIG18.GT.BIG) BIG=BIG18
598 BIG19=ABS(GLI(2,J+1)/(4.*DT))
599 IF (BIG19.GT.BIG) BIG=BIG19
600 BIG20=ABS(GLI(1,J+1)/(4.*DT))
601 IF (BIG20.GT.BIG) BIG=BIG20
602 IF (ABS(G(3)).LT.BIG*EBIG) G(3)=0
603
604 C For GOx2, enzyme
605 G(4)=(GOR(2,J)+GOR(1,J))/2.
606 B(4,4)=-1./2.
607
608
609 C For O2, being consumed only. *NOTES G 5 DIFF 5 CONC 5 (FLUX DEPENDS ON
CONC 6) RXN(3)
610
611 G(5)=DIRM(5)
612 1 *(OXY(2,J+1)-OXY(2,J)+OXY(1,J+1)-OXY(1,J))/HHHH**2.
613 2 +FLUX*EXP(BB*(VDL(2,J)+VDL(1,J))/2.)*(HPR(2,J)+HPR(1,J))/(HHHH)
614 3 -FLUX2*EXP(-BO*(VDL(2,J)+VDL(1,J))/2.)*(OXY(2,J)+OXY(1,J))
615 4 *((HYD(2,J)+HYD(1,J))/2.)*2./HHHH
616 6 -(3.*(OXY(2,J)-OXY(1,J))+(OXY(2,J+1)-OXY(1,J+1)))/(4.*DT)
617
618 B(5,5)=DIRM(5)/HHHH**2.+3./(4.*DT)
619 1 +FLUX2*EXP(-BO*(VDL(2,J)+VDL(1,J))/2.)
620 2 *((HYD(2,J)+HYD(1,J))/2.)*2./HHHH
621 D(5,5)=-DIRM(5)/HHHH**2.+1./(4.*DT)
622 B(5,6)=-FLUX*EXP(BB*(VDL(2,J)+VDL(1,J))/2.)/HHHH
623 B(5,16)=+FLUX2*EXP(-BO*(VDL(2,J)+VDL(1,J))/2.)*(OXY(2,J)+OXY(1,J))
624 1 *(HYD(2,J)+HYD(1,J))/2./HHHH
625 B(5,22)=-FLUX*EXP(BB*(VDL(2,J)+VDL(1,J))/2.)*(HPR(2,J)+HPR(1,J))
626 1 *(BB/2.)/HHHH-FLUX2*EXP(-BO*(VDL(2,J)+VDL(1,J))/2.)*
627 2 (OXY(2,J)+OXY(1,J))*((HYD(2,J)+HYD(1,J))/2.)*2.*(BO/2.)/HHHH
628
629 BIG=ABS(DIRM(5)*OXY(2,J+1)/HHHH**2.)
630 BIG2=ABS(DIRM(5)*OXY(2,J)/HHHH**2.)
631 IF (BIG2.GT.BIG) BIG=BIG2
632 BIG3=ABS(DIRM(5)*OXY(1,J+1)/HHHH**2.)
633 IF (BIG3.GT.BIG) BIG=BIG3
634 BIG4=ABS(DIRM(5)*OXY(1,J)/HHHH**2.)
635 IF (BIG4.GT.BIG) BIG=BIG4

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636 C      BIG5=ABS(FLUX*EXP(BB*(VDL(2,J)+VDL(1,J))/2.)*(HPR(2,J))/(HHHH))
637 C      IF (BIG5.GT.BIG) BIG=BIG5
638 C      BIG6=ABS(FLUX*EXP(BB*(VDL(2,J)+VDL(1,J))/2.)*(HPR(1,J))/(HHHH))
639 C      IF (BIG6.GT.BIG) BIG=BIG6
640      BIG11=ABS(3.*OXY(2,J)/(4.*DT))
641      IF (BIG11.GT.BIG) BIG=BIG11
642      BIG12=ABS(3.*OXY(1,J)/(4.*DT))
643      IF (BIG12.GT.BIG) BIG=BIG12
644      BIG13=ABS(OXY(2,J+1)/(4.*DT))
645      IF (BIG13.GT.BIG) BIG=BIG13
646      BIG14=ABS(OXY(1,J+1)/(4.*DT))
647      IF (BIG14.GT.BIG) BIG=BIG14
648 C      BIG15=ABS(FLUX2*EXP(-BO*(VDL(2,J)+VDL(1,J))/2.)*(OXY(2,J))/(HHHH))
649 C      IF (BIG15.GT.BIG) BIG=BIG15
650 C      BIG16=ABS(FLUX2*EXP(-BO*(VDL(2,J)+VDL(1,J))/2.)*(OXY(1,J))/(HHHH))
651 C      IF (BIG16.GT.BIG) BIG=BIG16
652      IF (ABS(G(5)).LT.BIG*EBIG) G(5)=0
653
654 C      For H2O2, reacting species *NOTES G 6 DIFF 6 CONC 6 (INCLUDING IN FLUX)
RXN(4
655      G(6)=DIRM(6)
656      1 *(HPR(2,J+1)-HPR(2,J)+HPR(1,J+1)-HPR(1,J))/HHHH**2.
657      2 -FLUX*EXP(BB*(VDL(2,J)+VDL(1,J))/2.)*(HPR(2,J)+HPR(1,J))/(HHHH)
658      3 +FLUX2*EXP(-BO*(VDL(2,J)+VDL(1,J))/2.)*(OXY(2,J)+OXY(1,J))
659      4 *((HYD(2,J)+HYD(1,J))/2.)*2./(HHHH)
660      5 -FLUX3*EXP(-BR*(VDL(2,J)+VDL(1,J))/2.)*(HPR(2,J)+HPR(1,J))
661      6 *((HYD(2,J)+HYD(1,J))/2.)*2./(HHHH)
662      8 -(3.*(HPR(2,J)-HPR(1,J))+(HPR(2,J+1)-HPR(1,J+1)))/(4.*DT)
663
664      B(6,6)=DIRM(6)/HHHH**2.+FLUX*EXP(BB*(VDL(2,J)+VDL(1,J))/2.)
665      1 /HHHH+FLUX3*EXP(-BR*(VDL(2,J)+VDL(1,J))/2.)
666      2 *((HYD(2,J)+HYD(1,J))/2.)*2./HHHH+3./(4.*DT)
667      D(6,6)=-DIRM(6)/HHHH**2.+1./(4.*DT)
668      B(6,5)=-FLUX2*EXP(-BO*(VDL(2,J)+VDL(1,J))/2.)
669      1 *((HYD(2,J)+HYD(1,J))/2.)*2./HHHH
670      B(6,16)=-FLUX2*EXP(-BO*(VDL(2,J)+VDL(1,J))/2.)*(OXY(2,J)+OXY(1,J))
671      1 *((HYD(2,J)+HYD(1,J))/2.)/(HHHH)
672      2 +FLUX3*EXP(-BR*(VDL(2,J)+VDL(1,J))/2.)*(HPR(2,J)+HPR(1,J))
673      3 *((HYD(2,J)+HYD(1,J))/2.)/(HHHH)
674      B(6,22)=FLUX*EXP(BB*(VDL(2,J)+VDL(1,J))/2.)*(HPR(2,J)+HPR(1,J))
675      1 *(BB/2.)/HHHH+FLUX2*EXP(-BO*(VDL(2,J)+VDL(1,J))/2.)*
676      2 (OXY(2,J)+OXY(1,J))*((HYD(2,J)+HYD(1,J))/2.)*2.*(BO/2)/HHHH
677      3 -FLUX3*EXP(-BR*(VDL(2,J)+VDL(1,J))/2.)*(HPR(2,J)+HPR(1,J))
678      4 *((HYD(2,J)+HYD(1,J))/2.)*2.*(BR/2)/HHHH
679
680      BIG=ABS(DIRM(6)*HPR(2,J+1)/HHHH**2.)
681      BIG2=ABS(DIRM(6)*HPR(2,J)/HHHH**2.)
682      IF (BIG2.GT.BIG) BIG=BIG2
683      BIG3=ABS(DIRM(6)*HPR(1,J+1)/HHHH**2.)
684      IF (BIG3.GT.BIG) BIG=BIG3
685      BIG4=ABS(DIRM(6)*HPR(1,J)/HHHH**2.)
686      IF (BIG4.GT.BIG) BIG=BIG4
687      BIG11=ABS(3.*HPR(2,J)/(4.*DT))
688      IF (BIG11.GT.BIG) BIG=BIG11
689      BIG12=ABS(3.*HPR(1,J)/(4.*DT))
690      IF (BIG12.GT.BIG) BIG=BIG12
691      BIG13=ABS(HPR(2,J+1)/(4.*DT))
692      IF (BIG13.GT.BIG) BIG=BIG13

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693     BIG14=ABS(HPR(1,J+1)/(4.*DT))
694     IF (BIG14.GT.BIG) BIG=BIG14
695     IF (ABS(G(6)).LT.BIG*EBIG) G(6)=0
696
697 C     For CX-GOx2, enzyme complex
698     G(7)=(GOA(2,J)+GOA(1,J))/2.
699     B(7,7)=-1./2.
700
701 C     For CX-GOx, enzyme complex
702     G(8)=(GOP(2,J)+GOP(1,J))/2.
703     B(8,8)=-1./2.
704
705 C     For Reaction 1 Enzymatic Catalysis
706     G(9)=(EQ1(2,J)+EQ1(1,J))/2.
707     B(9,9)=-1./2.
708
709
710 C     For Reaction 2
711     G(10)=(RGA(2,J)+RGA(1,J))/2.
712     B(10,10)=-1./2.
713
714 C     For Reaction 3 Meditation/regeneration
715     G(11)=(EQ2(2,J)+EQ2(1,J))/2.
716     B(11,11)=-1./2.
717
718 C     For Reaction 4
719     G(12)=(RHP(2,J)+RHP(1,J))/2.
720     B(12,12)=-1./2.
721
722 C     REACTIONS
723 218 G(13)=-((ANM(2,J)+ANM(1,J))/2.+ratef5*((GLUA(2,J)+GLUA(1,J))/2.
724 1 -(GLU(2,J)+GLU(1,J))/2./equilib5)
725     B(13,1)=ratef5/2./equilib5
726     B(13,14)=-ratef5/2.
727     B(13,13)=+1./2.
728
729     BIG=ABS(ANM(2,J)/2.)
730     BIG2=ABS(ANM(1,J)/2.)
731     IF (BIG2.GT.BIG) BIG=BIG2
732     BIG3=ABS(ratef5*GLUA(2,J)/2.)
733     IF (BIG3.GT.BIG) BIG=BIG3
734     BIG4=ABS(ratef5*GLUA(1,J)/2.)
735     IF (BIG4.GT.BIG) BIG=BIG4
736     BIG5=ABS(ratef5*GLU(2,J)/2./equilib5)
737     IF (BIG5.GT.BIG) BIG=BIG5
738     BIG6=ABS(ratef5*GLU(1,J)/2./equilib5)
739     IF (BIG6.GT.BIG) BIG=BIG6
740     IF (ABS(G(13)).LT.BIG*EBIG) G(13)=0
741 C For alpha glucose, being consumed only
742
743     G(14)=DIRM(9)*(GLUA(2,J+1)-GLUA(2,J)+GLUA(1,J+1)-GLUA(1,J))
744 1 /HHHH**2.-(3.*(ANM(2,J)+ANM(1,J))+(ANM(2,J+1)+ANM(1,J+1)))/8.
745 2 -(3.*(GLUA(2,J)-GLUA(1,J))+(GLUA(2,J+1)-GLUA(1,J+1)))/(4.*DT)
746
747     B(14,14)=DIRM(9)/HHHH**2.+3./(4.*DT)
748     D(14,14)=-DIRM(9)/HHHH**2.+1./(4.*DT)
749     B(14,13)=3./8.
750     D(14,13)=1./8.

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751
752     BIG=ABS(DIRM(9)*GLUA(2,J+1)/HHHH**2.)
753     BIG2=ABS(DIRM(9)*GLUA(2,J)/HHHH**2.)
754     IF (BIG2.GT.BIG) BIG=BIG2
755     BIG3=ABS(DIRM(9)*GLUA(1,J+1)/HHHH**2.)
756     IF (BIG3.GT.BIG) BIG=BIG3
757     BIG4=ABS(DIRM(9)*GLUA(1,J)/HHHH**2.)
758     IF (BIG4.GT.BIG) BIG=BIG4
759     BIG5=ABS(3.*ANM(2,J)/8.)
760     IF (BIG5.GT.BIG) BIG=BIG5
761     BIG6=ABS(3.*ANM(1,J)/8.)
762     IF (BIG6.GT.BIG) BIG=BIG6
763     BIG7=ABS(ANM(2,J+1)/8.)
764     IF (BIG7.GT.BIG) BIG=BIG7
765     BIG8=ABS(ANM(1,J+1)/8.)
766     IF (BIG8.GT.BIG) BIG=BIG8
767     BIG9=ABS(3.*GLUA(2,J)/(4.*DT))
768     IF (BIG9.GT.BIG) BIG=BIG9
769     BIG10=ABS(3.*GLUA(1,J)/(4.*DT))
770     IF (BIG10.GT.BIG) BIG=BIG10
771     BIG11=ABS(GLUA(2,J+1)/(4.*DT))
772     IF (BIG11.GT.BIG) BIG=BIG11
773     BIG12=ABS(GLUA(2,J+1)/(4.*DT))
774     IF (BIG12.GT.BIG) BIG=BIG12
775     IF (ABS(G(14)).LT.BIG*EBIG) G(14)=0
776
777 C Gluconic acid dissociation
778
779     G(15)=equilib6*(GLA(2,J)+GLA(1,J))/2.-(GLI(2,J)+GLI(1,J))*
780     1 (HYD(2,J)+HYD(1,J))/4.
781     B(15,3)=-equilib6/2.
782     B(15,15)=(HYD(2,J)+HYD(1,J))/4.
783     B(15,16)=(GLI(2,J)+GLI(1,J))/4.
784
785     BIG=ABS(equilib6*GLA(2,J)/2.)
786     BIG2=ABS(equilib6*GLA(1,J)/2.)
787     IF (BIG2.GT.BIG) BIG=BIG2
788     BIG3=ABS(GLI(2,J)*HYD(2,J)/4.)
789     IF (BIG3.GT.BIG) BIG=BIG3
790     BIG4=ABS(GLI(2,J)*HYD(1,J)/4.)
791     IF (BIG4.GT.BIG) BIG=BIG4
792     BIG5=ABS(GLI(1,J)*HYD(2,J)/4.)
793     IF (BIG5.GT.BIG) BIG=BIG5
794     BIG6=ABS(GLI(1,J)*HYD(1,J)/4.)
795     IF (BIG6.GT.BIG) BIG=BIG6
796     IF (ABS(G(15)).LT.BIG*EBIG) G(15)=0
797
798 C Flux of Hydrogen ion, Hydroxide ion, gluconate ion, and bicarbonate ion
799 C *Note flux4 has a factor of 4 in nom and denominator which cancels out
800
801     G(16)=DIRM(11)*(HYD(2,J+1)-HYD(2,J)+HYD(1,J+1)-HYD(1,J))
802     1 /HHHH**2.-DIRM(15)*(OHI(2,J+1)-OHI(2,J)+OHI(1,J+1)-OHI(1,J))
803     2 /HHHH**2.-DIRM(10)*(GLI(2,J+1)-GLI(2,J)+GLI(1,J+1)-GLI(1,J))
804     3 /HHHH**2.-DIRM(14)*(CBI(2,J+1)-CBI(2,J)+CBI(1,J+1)-CBI(1,J))
805     4 /HHHH**2.-(3.*(HYD(2,J)-HYD(1,J))+(HYD(2,J+1)-HYD(1,J+1)))
806     4 /(4.*DT)
807     5 +(3.*(OHI(2,J)-OHI(1,J))+(OHI(2,J+1)-OHI(1,J+1)))/(4.*DT)
808     6 +(3.*(GLI(2,J)-GLI(1,J))+(GLI(2,J+1)-GLI(1,J+1)))/(4.*DT)

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809 7 +(3.*(CBI(2,J)-CBI(1,J))+(CBI(2,J+1)-CBI(1,J+1)))/(4.*DT)
810 8 +2.*FLUX*EXP(BB*(VDL(2,J)+VDL(1,J))/2.)*(HPR(2,J)+HPR(1,J))
811 8 /(HHHH)
812 9 -2.*FLUX2*EXP(-BO*(VDL(2,J)+VDL(1,J))/2.)*(OXY(2,J)+OXY(1,J))
813 1 *((HYD(2,J)+HYD(1,J))/2.)*2./(HHHH)
814 2 -2.*FLUX3*EXP(-BR*(VDL(2,J)+VDL(1,J))/2.)*(HPR(2,J)+HPR(1,J))
815 3 *((HYD(2,J)+HYD(1,J))/2.)*2./(HHHH)
816 4 -FLUX4*((HYD(2,J)+HYD(1,J)))*2.
817 5 *EXP(-BH*(VDL(2,J)+VDL(1,J))/2.)/(HHHH)
818
819 B(16,16)=DIRM(11)/HHHH*2.+3./(4.*DT)
820 1 +FLUX2*EXP(-BO*(VDL(2,J)+VDL(1,J))/2.)*(OXY(2,J)+OXY(1,J))
821 2 *(HYD(2,J)+HYD(1,J))/HHHH
822 3 +FLUX3*EXP(-BR*(VDL(2,J)+VDL(1,J))/2.)*(HPR(2,J)+HPR(1,J))
823 4 *((HYD(2,J)+HYD(1,J)))/(HHHH)
824 5 +FLUX4*2.*(HYD(2,J)+HYD(1,J))
825 6 *EXP(-BH*(VDL(2,J)+VDL(1,J))/2.)/(HHHH)
826
827 D(16,16)=-DIRM(11)/HHHH*2.+1./(4.*DT)
828 B(16,17)=-DIRM(15)/HHHH*2.-3./(4.*DT)
829 D(16,17)=DIRM(15)/HHHH*2.-1./(4.*DT)
830 B(16,15)=-DIRM(10)/HHHH*2.-3./(4.*DT)
831 D(16,15)=DIRM(10)/HHHH*2.-1./(4.*DT)
832 B(16,20)=-DIRM(14)/HHHH*2.-3./(4.*DT)
833 D(16,20)=DIRM(14)/HHHH*2.-1./(4.*DT)
834
835 B(16,5)=+2.*FLUX2*EXP(-BO*(VDL(2,J)+VDL(1,J))/2.)
836 1 *((HYD(2,J)+HYD(1,J))/2.)*2./(HHHH)
837
838 B(16,6)=-2.*FLUX*EXP(BB*(VDL(2,J)+VDL(1,J))/2.)/(HHHH)
839 1 +2.*FLUX3*EXP(-BR*(VDL(2,J)+VDL(1,J))/2.)
840 2 *((HYD(2,J)+HYD(1,J))/2.)*2./(HHHH)
841
842 B(16,22)=-2.*FLUX*EXP(BB*(VDL(2,J)+VDL(1,J))/2.)
843 1 *(HPR(2,J)+HPR(1,J))*(BB/2.)/HHHH
844 2 -2.*FLUX2*EXP(-BO*(VDL(2,J)+VDL(1,J))/2.)
845 3 *(OXY(2,J)+OXY(1,J))*((HYD(2,J)+HYD(1,J))/2.)*2.*(BO/2.)/HHHH
846 4 -2.*FLUX3*EXP(-BR*(VDL(2,J)+VDL(1,J))/2.)*(HPR(2,J)+HPR(1,J))
847 5 *((HYD(2,J)+HYD(1,J))/2.)*2.*(BR/2)/HHHH
848 6 -FLUX4*((HYD(2,J)+HYD(1,J)))*2.
849 5 *EXP(-BH*(VDL(2,J)+VDL(1,J))/2.)*(BH/2.)/(HHHH)
850
851 BIG=ABS(DIRM(11)*HYD(2,J+1)/HHHH*2.)
852 BIG2=ABS(DIRM(11)*HYD(2,J)/HHHH*2.)
853 IF (BIG2.GT.BIG) BIG=BIG2
854 BIG3=ABS(DIRM(11)*HYD(1,J+1)/HHHH*2.)
855 IF (BIG3.GT.BIG) BIG=BIG3
856 BIG4=ABS(DIRM(11)*HYD(1,J)/HHHH*2.)
857 IF (BIG4.GT.BIG) BIG=BIG4
858 BIG5=ABS(DIRM(15)*OHI(2,J+1)/HHHH*2.)
859 IF (BIG5.GT.BIG) BIG=BIG5
860 BIG6=ABS(DIRM(15)*OHI(2,J)/HHHH*2.)
861 IF (BIG6.GT.BIG) BIG=BIG6
862 BIG7=ABS(DIRM(15)*OHI(1,J+1)/HHHH*2.)
863 IF (BIG7.GT.BIG) BIG=BIG7
864 BIG8=ABS(DIRM(15)*OHI(1,J)/HHHH*2.)
865 IF (BIG8.GT.BIG) BIG=BIG8
866 BIG9=ABS(DIRM(10)*GLI(2,J+1)/HHHH*2.)

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867 IF (BIG9.GT.BIG) BIG=BIG9
868 BIG10=ABS(DIRM(10)*GLI(2,J)/HHHH**2.)
869 IF (BIG10.GT.BIG) BIG=BIG10
870 BIG11=ABS(DIRM(10)*GLI(1,J+1)/HHHH**2.)
871 IF (BIG11.GT.BIG) BIG=BIG11
872 BIG12=ABS(DIRM(10)*GLI(1,J)/HHHH**2.)
873 IF (BIG12.GT.BIG) BIG=BIG12
874 BIG13=ABS(DIRM(14)*CBI(2,J+1)/HHHH**2.)
875 IF (BIG13.GT.BIG) BIG=BIG13
876 BIG14=ABS(DIRM(14)*CBI(2,J)/HHHH**2.)
877 IF (BIG14.GT.BIG) BIG=BIG14
878 BIG15=ABS(DIRM(14)*CBI(1,J+1)/HHHH**2.)
879 IF (BIG15.GT.BIG) BIG=BIG15
880 BIG16=ABS(DIRM(14)*CBI(1,J)/HHHH**2.)
881 IF (BIG16.GT.BIG) BIG=BIG16
882 BIG17=ABS(3.*HYD(2,J)/(4.*DT))
883 IF (BIG17.GT.BIG) BIG=BIG17
884 BIG18=ABS(3.*HYD(1,J)/(4.*DT))
885 IF (BIG18.GT.BIG) BIG=BIG18
886 BIG19=ABS(HYD(2,J+1)/(4.*DT))
887 IF (BIG19.GT.BIG) BIG=BIG19
888 BIG20=ABS(HYD(1,J+1)/(4.*DT))
889 IF (BIG20.GT.BIG) BIG=BIG20
890 BIG21=ABS(3.*OHI(2,J)/(4.*DT))
891 IF (BIG21.GT.BIG) BIG=BIG21
892 BIG22=ABS(3.*OHI(1,J)/(4.*DT))
893 IF (BIG22.GT.BIG) BIG=BIG22
894 BIG23=ABS(OHI(2,J+1)/(4.*DT))
895 IF (BIG23.GT.BIG) BIG=BIG23
896 BIG24=ABS(OHI(1,J+1)/(4.*DT))
897 IF (BIG24.GT.BIG) BIG=BIG24
898 BIG25=ABS(3.*GLI(2,J)/(4.*DT))
899 IF (BIG25.GT.BIG) BIG=BIG25
900 BIG26=ABS(3.*GLI(1,J)/(4.*DT))
901 IF (BIG26.GT.BIG) BIG=BIG26
902 BIG27=ABS(GLI(2,J+1)/(4.*DT))
903 IF (BIG27.GT.BIG) BIG=BIG27
904 BIG28=ABS(GLI(1,J+1)/(4.*DT))
905 IF (BIG28.GT.BIG) BIG=BIG28
906 BIG29=ABS(3.*CBI(2,J)/(4.*DT))
907 IF (BIG29.GT.BIG) BIG=BIG29
908 BIG30=ABS(3.*CBI(1,J)/(4.*DT))
909 IF (BIG30.GT.BIG) BIG=BIG30
910 BIG31=ABS(CBI(2,J+1)/(4.*DT))
911 IF (BIG31.GT.BIG) BIG=BIG31
912 BIG32=ABS(CBI(1,J+1)/(4.*DT))
913 IF (BIG32.GT.BIG) BIG=BIG32
914 IF (ABS(G(16)).LT.BIG*EBIG) G(16)=0
915 C Water dissociation
916
917 G(17)=equilib9 -(HYD(2,J)+HYD(1,J))*(OHI(2,J)+OHI(1,J))/4.
918 B(17,17)=(HYD(2,J)+HYD(1,J))/4.
919 B(17,16)=(OHI(2,J)+OHI(1,J))/4.
920
921 BIG=ABS(equilib9)
922 BIG2=ABS(HYD(2,J)*OHI(2,J)/4.)
923 IF (BIG2.GT.BIG) BIG=BIG2
924 BIG3=ABS(HYD(2,J)*OHI(1,J)/4.)

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925 IF (BIG3.GT.BIG) BIG=BIG3
926 BIG4=ABS(HYD(1,J)*OHI(2,J)/4.)
927 IF (BIG4.GT.BIG) BIG=BIG4
928 BIG5=ABS(HYD(1,J)*OHI(1,J)/4.)
929 IF (BIG5.GT.BIG) BIG=BIG5
930 IF (ABS(G(17)).LT.BIG*EBIG) G(17)=0
931 C CO2 Hydration
932
933 G(18)=equilib7*(CO2(2,J)+CO2(1,J))/2.-(CBA(2,J)+CBA(1,J))/2.
934 B(18,18)=-equilib7/2.
935 B(18,19)=1./2.
936
937 BIG=ABS(equilib7*CO2(2,J)/2.)
938 BIG2=ABS(equilib7*CO2(1,J)/2.)
939 IF (BIG2.GT.BIG) BIG=BIG2
940 BIG3=ABS(CBA(2,J)/2.)
941 IF (BIG3.GT.BIG) BIG=BIG3
942 BIG4=ABS(CBA(1,J)/2.)
943 IF (BIG4.GT.BIG) BIG=BIG4
944 IF (ABS(G(18)).LT.BIG*EBIG) G(18)=0
945
946 C Carbonic acid dissociation
947
948 G(19)=equilib8*(CBA(2,J)+CBA(1,J))/2.-(CBI(2,J)+CBI(1,J))
949 1*(HYD(2,J)+HYD(1,J))/4.
950 B(19,19)=-equilib8/2.
951 B(19,20)=(HYD(2,J)+HYD(1,J))/4.
952 B(19,16)=(CBI(2,J)+CBI(1,J))/4.
953
954 BIG=ABS(equilib8*CBA(2,J)/2.)
955 BIG2=ABS(equilib8*CBA(1,J)/2.)
956 IF (BIG2.GT.BIG) BIG=BIG2
957 BIG3=ABS(CBI(2,J)*HYD(2,J)/4.)
958 IF (BIG3.GT.BIG) BIG=BIG3
959 BIG4=ABS(CBI(2,J)*HYD(1,J)/4.)
960 IF (BIG4.GT.BIG) BIG=BIG4
961 BIG5=ABS(CBI(1,J)*HYD(2,J)/4.)
962 IF (BIG5.GT.BIG) BIG=BIG5
963 BIG6=ABS(CBI(1,J)*HYD(1,J)/4.)
964 IF (BIG6.GT.BIG) BIG=BIG6
965 IF (ABS(G(19)).LT.BIG*EBIG) G(19)=0
966
967 C FLUX OF CO2, CARBONIC ACID, BICARBONATE ION
968
969 G(20)=DIRM(12)*(CO2(2,J+1)-CO2(2,J)+CO2(1,J+1)-CO2(1,J))
970 1/HHHH**2.+DIRM(13)*(CBA(2,J+1)-CBA(2,J)+CBA(1,J+1)-CBA(1,J))
971 2/HHHH**2.+DIRM(14)*(CBI(2,J+1)-CBI(2,J)+CBI(1,J+1)-CBI(1,J))
972 3/HHHH**2.-(3.*(CO2(2,J)-CO2(1,J))+CO2(2,J+1)-CO2(1,J+1))
973 3/(4.*DT)
974 4-(3.*(CBA(2,J)-CBA(1,J))+CBA(2,J+1)-CBA(1,J+1))/(4.*DT)
975 5-(3.*(CBI(2,J)-CBI(1,J))+CBI(2,J+1)-CBI(1,J+1))/(4.*DT)
976
977 B(20,20)=DIRM(14)/HHHH**2.+3./(4.*DT)
978 D(20,20)=-DIRM(14)/HHHH**2.+1./(4.*DT)
979 B(20,18)=DIRM(12)/HHHH**2.+3./(4.*DT)
980 D(20,18)=-DIRM(12)/HHHH**2.+1./(4.*DT)
981 B(20,19)=DIRM(13)/HHHH**2.+3./(4.*DT)
982 D(20,19)=-DIRM(13)/HHHH**2.+1./(4.*DT)

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983
984     BIG=ABS(DIRM(12)*CO2(2,J+1)/HHHH**2.)
985     BIG2=ABS(DIRM(12)*CO2(2,J)/HHHH**2.)
986     IF (BIG2.GT.BIG) BIG=BIG2
987     BIG3=ABS(DIRM(12)*CO2(1,J+1)/HHHH**2.)
988     IF (BIG3.GT.BIG) BIG=BIG3
989     BIG4=ABS(DIRM(12)*CO2(1,J)/HHHH**2.)
990     IF (BIG4.GT.BIG) BIG=BIG4
991     BIG5=ABS(DIRM(13)*CBA(2,J+1)/HHHH**2.)
992     IF (BIG5.GT.BIG) BIG=BIG5
993     BIG6=ABS(DIRM(13)*CBA(2,J)/HHHH**2.)
994     IF (BIG6.GT.BIG) BIG=BIG6
995     BIG7=ABS(DIRM(13)*CBA(1,J+1)/HHHH**2.)
996     IF (BIG7.GT.BIG) BIG=BIG7
997     BIG8=ABS(DIRM(13)*CBA(1,J)/HHHH**2.)
998     IF (BIG8.GT.BIG) BIG=BIG8
999     BIG9=ABS(DIRM(14)*CBI(2,J+1)/HHHH**2.)
1000    IF (BIG9.GT.BIG) BIG=BIG9
1001    BIG10=ABS(DIRM(14)*CBI(2,J)/HHHH**2.)
1002    IF (BIG10.GT.BIG) BIG=BIG10
1003    BIG11=ABS(DIRM(14)*CBI(1,J+1)/HHHH**2.)
1004    IF (BIG11.GT.BIG) BIG=BIG11
1005    BIG12=ABS(DIRM(14)*CBI(1,J)/HHHH**2.)
1006    IF (BIG12.GT.BIG) BIG=BIG12
1007    BIG13=ABS(3.*CO2(2,J)/(4.*DT))
1008    IF (BIG13.GT.BIG) BIG=BIG13
1009    BIG14=ABS(3.*CO2(1,J)/(4.*DT))
1010    IF (BIG14.GT.BIG) BIG=BIG14
1011    BIG15=ABS(CO2(2,J+1)/(4.*DT))
1012    IF (BIG15.GT.BIG) BIG=BIG15
1013    BIG16=ABS(CO2(1,J+1)/(4.*DT))
1014    IF (BIG16.GT.BIG) BIG=BIG16
1015    BIG17=ABS(3.*CBA(2,J)/(4.*DT))
1016    IF (BIG17.GT.BIG) BIG=BIG17
1017    BIG18=ABS(3.*CBA(1,J)/(4.*DT))
1018    IF (BIG18.GT.BIG) BIG=BIG18
1019    BIG19=ABS(CBA(2,J+1)/(4.*DT))
1020    IF (BIG19.GT.BIG) BIG=BIG19
1021    BIG20=ABS(CBA(1,J+1)/(4.*DT))
1022    IF (BIG20.GT.BIG) BIG=BIG20
1023    BIG21=ABS(3.*CBI(2,J)/(4.*DT))
1024    IF (BIG21.GT.BIG) BIG=BIG21
1025    BIG22=ABS(3.*CBI(1,J)/(4.*DT))
1026    IF (BIG22.GT.BIG) BIG=BIG22
1027    BIG23=ABS(CBI(2,J+1)/(4.*DT))
1028    IF (BIG23.GT.BIG) BIG=BIG23
1029    BIG24=ABS(CBI(1,J+1)/(4.*DT))
1030    IF (BIG24.GT.BIG) BIG=BIG24
1031    IF (ABS(G(20)).LT.BIG*EBIG) G(20)=0
1032
1033 C   flux OF Acetaminophen
1034
1035     G(21)=DIRM(16)
1036     1 *(ACE(2,J+1)-ACE(2,J)+ACE(1,J+1)-ACE(1,J))/HHHH**2.
1037     2 -FLUX5*EXP(BA*(VDL(2,J)+VDL(1,J))/2.)*(ACE(2,J)+ACE(1,J))/(HHHH)
1038     8 -(3.*(ACE(2,J)-ACE(1,J))+(ACE(2,J+1)-ACE(1,J+1)))/(4.*DT)
1039
1040     B(21,21)=DIRM(16)/HHHH**2.+FLUX5*EXP(BA*(VDL(2,J)+VDL(1,J))/2.)

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```

1041 1 /HHHH+3./(4.*DT)
1042
1043 D(21,21)=-DIRM(16)/HHHH**2.+1./(4.*DT)
1044
1045 B(21,22)=FLUX5*EXP(BA*(VDL(2,J)+VDL(1,J))/2.)*(ACE(2,J)+ACE(1,J))
1046 1 *(BA/2.)/HHHHH
1047
1048 BIG=ABS(DIRM(16)*ACE(2,J+1)/HHHH**2.)
1049 BIG2=ABS(DIRM(16)*ACE(2,J)/HHHH**2.)
1050 IF (BIG2.GT.BIG) BIG=BIG2
1051 BIG3=ABS(DIRM(16)*ACE(1,J+1)/HHHH**2.)
1052 IF (BIG3.GT.BIG) BIG=BIG3
1053 BIG4=ABS(DIRM(16)*ACE(1,J)/HHHH**2.)
1054 IF (BIG4.GT.BIG) BIG=BIG4
1055 BIG11=ABS(3.*ACE(2,J)/(4.*DT))
1056 IF (BIG11.GT.BIG) BIG=BIG11
1057 BIG12=ABS(3.*ACE(1,J)/(4.*DT))
1058 IF (BIG12.GT.BIG) BIG=BIG12
1059 BIG13=ABS(ACE(2,J+1)/(4.*DT))
1060 IF (BIG13.GT.BIG) BIG=BIG13
1061 BIG14=ABS(ACE(1,J+1)/(4.*DT))
1062 IF (BIG14.GT.BIG) BIG=BIG14
1063 IF (ABS(G(21)).LT.BIG*EBIG) G(21)=0
1064 C For Voltage drop across double layer
1065
1066 G(22)= VAP-RE*(AKB*EXP(BB*(VDL(2,J)+VDL(1,J))/2.)
1067 1 *(HPR(2,J)+HPR(1,J))/2.-AKO*EXP(-BO*(VDL(2,J)+VDL(1,J))/2.)
1068 2 *(OXY(2,J)+OXY(1,J))/2.*((HYD(2,J)+HYD(1,J))/2.）**2.
1069 3 -AKR*EXP(-BR*(VDL(2,J)+VDL(1,J))/2.)*(HPR(2,J)+HPR(1,J))/2.
1070 4 *((HYD(2,J)+HYD(1,J))/2.）**2.
1071 5 -AKH*EXP(-BH*(VDL(2,J)+VDL(1,J))/2.)*((HYD(2,J)+HYD(1,J))/2.）**2.
1072 6 +AKA*EXP(BA*(VDL(2,J)+VDL(1,J))/2.)*(ACE(2,J)+ACE(1,J))/2.
1073 6 +CDL*(VDL(2,J)-VDL(1,J))/DT)-(VDL(2,J)+VDL(1,J))/2.
1074
1075 B(22,22)= RE*AKB*(BB/2.)*EXP(BB*(VDL(2,J)+VDL(1,J))/2.)
1076 1 *(HPR(2,J)+HPR(1,J))/2.+RE*AKO*(BO/2.)
1077 2 *EXP(-BO*(VDL(2,J)+VDL(1,J))/2.)*(OXY(2,J)+OXY(1,J))/2.
1078 3 *((HYD(2,J)+HYD(1,J))/2.）**2.
1079 4 +RE*AKR*(BR/2.)*EXP(-BR*(VDL(2,J)+VDL(1,J))/2.)
1080 5 *(HPR(2,J)+HPR(1,J))/2.*((HYD(2,J)+HYD(1,J))/2.）**2.
1081 6 +RE*AKH*(BH/2.)*EXP(-BH*(VDL(2,J)+VDL(1,J))/2.)
1082 7 *((HYD(2,J)+HYD(1,J))/2.）**2.
1083 8 +RE*AKA*(BA/2.)*EXP(BA*(VDL(2,J)+VDL(1,J))/2.)
1084 9 *(ACE(2,J)+ACE(1,J))/2.+RE*CDL/DT+1./2.
1085
1086
1087 B(22,5)=-RE*AKO*EXP(-BO*(VDL(2,J)+VDL(1,J))/2.)/2.
1088 1 *((HYD(2,J)+HYD(1,J))/2.）**2.
1089 B(22,6)=RE*AKB*EXP(BB*(VDL(2,J)+VDL(1,J))/2.)/2.
1090 1 -RE*AKR*EXP(-BR*(VDL(2,J)+VDL(1,J))/2.)/2.
1091 2 *((HYD(2,J)+HYD(1,J))/2.）**2.
1092 B(22,16)=-AKO*EXP(-BO*(VDL(2,J)+VDL(1,J))/2.)
1093 1 *(OXY(2,J)+OXY(1,J))/2.*((HYD(2,J)+HYD(1,J))/2.)
1094 2 -AKR*EXP(-BR*(VDL(2,J)+VDL(1,J))/2.)*(HPR(2,J)+HPR(1,J))/2.
1095 3 *((HYD(2,J)+HYD(1,J))/2.)
1096 4 -AKH*EXP(-BH*(VDL(2,J)+VDL(1,J))/2.)*((HYD(2,J)+HYD(1,J))/2.)
1097 B(22,21)=RE*AKA*EXP(BA*(VDL(2,J)+VDL(1,J))/2.)/2.
1098

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1099 RETURN
1100 END
1101
1102 SUBROUTINE INSULATION(J)
1103 IMPLICIT DOUBLE PRECISION (A-H, O-Z)
1104 COMMON/BAB/ A(22,22),B(22,22),C(22,80001),D(22,45),G(22),X(22,22)
1105 1 ,Y(22,22)
1106 COMMON/NSN/ N, NJ
1107 COMMON/GLC/ NTIME,LL
1108 COMMON/VAR/ DIFF(16),H,EBIG,HH,IJ,KJ,TT,VAP,HHH,DT,RE,AKB,BB,CDL
1109 COMMON/VARR/ HHHH,HHHHH,MJ,LJ
1110 COMMON/DIN/ DGOX(16),DGLM(16),DIRM(16),DBULK(16)
1111 COMMON/SPCI/ GLU(2,80001),GOX(2,80001),GLA(2,80001),GOR(2,80001)
1112 COMMON/SPCII/ OXY(2,80001),HPR(2,80001),GOA(2,80001),GOP(2,80001)
1113 COMMON/RXT/ EQ1(2,80001),RGA(2,80001),EQ2(2,80001),RHP(2,80001)
1114 COMMON/SPCIII/ ANM(2,80001),GLUA(2,80001),GLI(2,80001)
1115 COMMON/SPCIV/ HYD(2,80001),OHI(2,80001),CO2(2,80001),CBA(2,80001)
1116 COMMON/SPCV/ CBI(2,80001),ACE(2,80001)
1117 COMMON/VOL/ VDL(2,80001)
1118 COMMON/POR/ POR1,POR2,PORGLU,PARION,PARACE
1119 COMMON/RTE/ ratef1,equilib1,ratef2,ratef3,equilib3,ratef4
1120 COMMON/RTD/ ratef5,equilib5,equilib6,equilib7,equilib8,equilib9
1121 COMMON/BUL/ CBULK(16),PARH2O2,PARO2,PARGLUCE,JCOUNT
1122
1123 301 FORMAT (5x,'J=' I5, 12E18.9)
1124
1125 C For Glucose, being consumed only
1126 G(1)=DIRM(1)*(GLU(2,J+1)-2.*GLU(2,J)+GLU(2,J-1)
1127 1 +GLU(1,J+1)-2.*GLU(1,J)+GLU(1,J-1))/(2.*HHHH**2.)
1128 2 +(ANM(2,J)+ANM(1,J))/2.-(GLU(2,J)-GLU(1,J))/DT
1129
1130 B(1,1)=DIRM(1)/HHHH**2.+1./DT
1131 D(1,1)=-DIRM(1)/(2.*HHHH**2.)
1132 A(1,1)=-DIRM(1)/(2.*HHHH**2.)
1133 B(1,13)=-1./2.
1134
1135
1136 BIG=ABS(DIRM(1)*(GLU(2,J+1))/(2.*HHHH**2.))
1137 BIG2=ABS(DIRM(1)*(GLU(2,J))/(HHHH**2.))
1138 IF (BIG2.GT.BIG) BIG=BIG2
1139 BIG3=ABS(DIRM(1)*(GLU(2,J-1))/(2.*HHHH**2.))
1140 IF (BIG3.GT.BIG) BIG=BIG3
1141 BIG4=ABS(DIRM(1)*(GLU(1,J+1))/(2.*HHHH**2.))
1142 IF (BIG4.GT.BIG) BIG=BIG4
1143 BIG5=ABS(DIRM(1)*(GLU(1,J))/(HHHH**2.))
1144 IF (BIG5.GT.BIG) BIG=BIG5
1145 BIG6=ABS(DIRM(1)*(GLU(1,J-1))/(2.*HHHH**2.))
1146 IF (BIG6.GT.BIG) BIG=BIG6
1147 BIG7=ABS(GLU(2,J)/DT)
1148 IF (BIG7.GT.BIG) BIG=BIG7
1149 BIG8=ABS(GLU(1,J)/DT)
1150 IF (BIG8.GT.BIG) BIG=BIG8
1151 BIG9=ABS(ANM(2,J)/2.)
1152 IF (BIG9.GT.BIG) BIG=BIG9
1153 BIG10=ABS(ANM(1,J)/2.)
1154 IF (BIG10.GT.BIG) BIG=BIG10
1155 IF (ABS(G(1)).LT.BIG*EBIG) G(1)=0
1156

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1157
1158
1159 C   For GOx, enzyme
1160     G(2)=(GOX(2,J)+GOX(1,J))/2.
1161     B(2,2)=-1./2.
1162
1163
1164 C   For Gluconic Acid, being produced only
1165     G(3)=DIRM(3)*(GLA(2,J+1)-2.*GLA(2,J)+GLA(2,J-1)
1166     1   +GLA(1,J+1)-2.*GLA(1,J)+GLA(1,J-1))/(2.*HHHH**2.)
1167     2   +DIRM(10)*(GLI(2,J+1)-2.*GLI(2,J)+GLI(2,J-1)
1168     3   +GLI(1,J+1)-2.*GLI(1,J)+GLI(1,J-1))/(2.*HHHH**2.)
1169     2   -(GLA(2,J)-GLA(1,J))/DT-(GLI(2,J)-GLI(1,J))/DT
1170
1171     B(3,3)=DIRM(3)/HHHH**2.+1./DT
1172     D(3,3)=-DIRM(3)/(2.*HHHH**2.)
1173     A(3,3)=-DIRM(3)/(2.*HHHH**2.)
1174     B(3,15)=DIRM(10)/HHHH**2.+1./DT
1175     D(3,15)=-DIRM(10)/(2.*HHHH**2.)
1176     A(3,15)=-DIRM(10)/(2.*HHHH**2.)
1177
1178
1179     BIG=ABS(DIRM(3)*(GLA(2,J+1))/(2.*HHHH**2.))
1180     BIG2=ABS(DIRM(3)*(GLA(2,J))/(HHHH**2.))
1181     IF (BIG2.GT.BIG) BIG=BIG2
1182     BIG3=ABS(DIRM(3)*(GLA(2,J-1))/(2.*HHHH**2.))
1183     IF (BIG3.GT.BIG) BIG=BIG3
1184     BIG4=ABS(DIRM(3)*(GLA(1,J+1))/(2.*HHHH**2.))
1185     IF (BIG4.GT.BIG) BIG=BIG4
1186     BIG5=ABS(DIRM(3)*(GLA(1,J))/(HHHH**2.))
1187     IF (BIG5.GT.BIG) BIG=BIG5
1188     BIG6=ABS(DIRM(3)*(GLA(1,J-1))/(2.*HHHH**2.))
1189     IF (BIG6.GT.BIG) BIG=BIG6
1190     BIG7=ABS(GLA(2,J)/DT)
1191     IF (BIG7.GT.BIG) BIG=BIG7
1192     BIG8=ABS(GLA(1,J)/DT)
1193     IF (BIG8.GT.BIG) BIG=BIG8
1194     BIG9=ABS(DIRM(10)*(GLI(2,J+1))/(2.*HHHH**2.))
1195     IF (BIG9.GT.BIG) BIG=BIG9
1196     BIG10=ABS(DIRM(10)*(GLI(2,J))/(HHHH**2.))
1197     IF (BIG10.GT.BIG) BIG=BIG10
1198     BIG11=ABS(DIRM(10)*(GLI(2,J-1))/(2.*HHHH**2.))
1199     IF (BIG11.GT.BIG) BIG=BIG11
1200     BIG12=ABS(DIRM(10)*(GLI(1,J+1))/(2.*HHHH**2.))
1201     IF (BIG12.GT.BIG) BIG=BIG12
1202     BIG13=ABS(DIRM(10)*(GLI(1,J))/(HHHH**2.))
1203     IF (BIG13.GT.BIG) BIG=BIG13
1204     BIG14=ABS(DIRM(10)*(GLI(1,J-1))/(2.*HHHH**2.))
1205     IF (BIG14.GT.BIG) BIG=BIG14
1206     BIG15=ABS(GLI(2,J)/DT)
1207     IF (BIG15.GT.BIG) BIG=BIG15
1208     BIG16=ABS(GLI(1,J)/DT)
1209     IF (BIG16.GT.BIG) BIG=BIG16
1210     IF (ABS(G(3)).LT.BIG*EBIG) G(3)=0
1211
1212 C   For GOx2, enzyme
1213     G(4)=(GOR(2,J)+GOR(1,J))/2.
1214     B(4,4)=-1./2.

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1215
1216 C   For O2, being consumed only
1217     G(5)=DIRM(5)*(OXY(2,J+1)-2.*OXY(2,J)+OXY(2,J-1)
1218     1   +OXY(1,J+1)-2.*OXY(1,J)+OXY(1,J-1))/(2.*HHHH**2.)
1219     2   -(OXY(2,J)-OXY(1,J))/DT
1220
1221     B(5,5)=DIRM(5)/HHHH**2.+1./DT
1222     D(5,5)=-DIRM(5)/(2.*HHHH**2.)
1223     A(5,5)=-DIRM(5)/(2.*HHHH**2.)
1224
1225
1226     BIG=ABS(DIRM(5)*(OXY(2,J+1))/(2.*HHHH**2.))
1227     BIG2=ABS(DIRM(5)*(OXY(2,J))/(HHHH**2.))
1228     IF (BIG2.GT.BIG) BIG=BIG2
1229     BIG3=ABS(DIRM(5)*(OXY(2,J-1))/(2.*HHHH**2.))
1230     IF (BIG3.GT.BIG) BIG=BIG3
1231     BIG4=ABS(DIRM(5)*(OXY(1,J+1))/(2.*HHHH**2.))
1232     IF (BIG4.GT.BIG) BIG=BIG4
1233     BIG5=ABS(DIRM(5)*(OXY(1,J))/(HHHH**2.))
1234     IF (BIG5.GT.BIG) BIG=BIG5
1235     BIG6=ABS(DIRM(5)*(OXY(1,J-1))/(2.*HHHH**2.))
1236     IF (BIG6.GT.BIG) BIG=BIG6
1237     BIG7=ABS(OXY(2,J)/DT)
1238     IF (BIG7.GT.BIG) BIG=BIG7
1239     BIG8=ABS(OXY(1,J)/DT)
1240     IF (BIG8.GT.BIG) BIG=BIG8
1241     IF (ABS(G(5)).LT.BIG*EBIG) G(5)=0
1242
1243 C   For H2O2, reacting species
1244     G(6)=DIRM(6)*(HPR(2,J+1)-2.*HPR(2,J)+HPR(2,J-1)
1245     1   +HPR(1,J+1)-2.*HPR(1,J)+HPR(1,J-1))/(2.*HHHH**2.)
1246     2   -(HPR(2,J)-HPR(1,J))/DT
1247
1248     B(6,6)=DIRM(6)/HHHH**2.+1./DT
1249     D(6,6)=-DIRM(6)/(2.*HHHH**2.)
1250     A(6,6)=-DIRM(6)/(2.*HHHH**2.)
1251
1252
1253     BIG=ABS(DIRM(6)*(HPR(2,J+1))/(2.*HHHH**2.))
1254     BIG2=ABS(DIRM(6)*(HPR(2,J))/(HHHH**2.))
1255     IF (BIG2.GT.BIG) BIG=BIG2
1256     BIG3=ABS(DIRM(6)*(HPR(2,J-1))/(2.*HHHH**2.))
1257     IF (BIG3.GT.BIG) BIG=BIG3
1258     BIG4=ABS(DIRM(6)*(HPR(1,J+1))/(2.*HHHH**2.))
1259     IF (BIG4.GT.BIG) BIG=BIG4
1260     BIG5=ABS(DIRM(6)*(HPR(1,J))/(HHHH**2.))
1261     IF (BIG5.GT.BIG) BIG=BIG5
1262     BIG6=ABS(DIRM(6)*(HPR(1,J-1))/(2.*HHHH**2.))
1263     IF (BIG6.GT.BIG) BIG=BIG6
1264     BIG7=ABS(HPR(2,J)/DT)
1265     IF (BIG7.GT.BIG) BIG=BIG7
1266     BIG8=ABS(HPR(1,J)/DT)
1267     IF (BIG8.GT.BIG) BIG=BIG8
1268     IF (ABS(G(6)).LT.BIG*EBIG) G(6)=0
1269
1270 C   For CX-GOx2, enzyme complex
1271     G(7)=(GOA(2,J)+GOA(1,J))/2.
1272     B(7,7)=-1./2.

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1273
1274 C   For CX-GOx, enzyme complex
1275     G(8)=(GOP(2,J)+GOP(1,J))/2.
1276     B(8,8)=-1./2.
1277
1278 C   For Reaction 1 Enzymatic Catalysis
1279     G(9)=(EQ1(2,J)+EQ1(1,J))/2.
1280     B(9,9)=-1./2.
1281
1282 C   For Reaction 2
1283     G(10)=(RGA(2,J)+RGA(1,J))/2.
1284     B(10,10)=-1./2.
1285
1286 C   For Reaction 3 Meditation/regeneration
1287     G(11)=(EQ2(2,J)+EQ2(1,J))/2.
1288     B(11,11)=-1./2.
1289
1290 C   For Reaction 4
1291     G(12)=(RHP(2,J)+RHP(1,J))/2.
1292     B(12,12)=-1./2.
1293
1294 C   REACTION5
1295 218 G(13)=- (ANM(2,J)+ANM(1,J))/2.+ratef5*((GLUA(2,J)+GLUA(1,J))/2.
1296 1   -(GLU(2,J)+GLU(1,J))/2./equilib5)
1297     B(13,1)=ratef5/2./equilib5
1298     B(13,14)=-ratef5/2.
1299     B(13,13)=+1./2.
1300
1301     BIG=ABS(ANM(2,J)/2.)
1302     BIG2=ABS(ANM(1,J)/2.)
1303     IF (BIG2.GT.BIG) BIG=BIG2
1304     BIG3=ABS(ratef5*GLUA(2,J)/2.)
1305     IF (BIG3.GT.BIG) BIG=BIG3
1306     BIG4=ABS(ratef5*GLUA(1,J)/2.)
1307     IF (BIG4.GT.BIG) BIG=BIG4
1308     BIG5=ABS(ratef5*GLU(2,J)/2./equilib5)
1309     IF (BIG5.GT.BIG) BIG=BIG5
1310     BIG6=ABS(ratef5*GLU(1,J)/2./equilib5)
1311     IF (BIG6.GT.BIG) BIG=BIG6
1312     IF (ABS(G(13)).LT.BIG*EBIG) G(13)=0.0
1313
1314 C   For alpha Glucose, being consumed only
1315     G(14)=DIRM(9)*(GLUA(2,J+1)-2.*GLUA(2,J)+GLUA(2,J-1)
1316 1   +GLUA(1,J+1)-2.*GLUA(1,J)+GLUA(1,J-1))/(2.*HHHH**2.)
1317 2   -(ANM(2,J)+ANM(1,J))/2.-(GLUA(2,J)-GLUA(1,J))/DT
1318     B(14,14)=DIRM(9)/HHHH**2.+1./DT
1319     D(14,14)=-DIRM(9)/(2.*HHHH**2.)
1320     A(14,14)=-DIRM(9)/(2.*HHHH**2.)
1321     B(14,13)=1./2.
1322
1323     BIG=ABS(DIRM(9)*(GLUA(2,J+1))/(2.*HHHH**2.))
1324     BIG2=ABS(DIRM(9)*(GLUA(2,J))/(HHHH**2.))
1325     IF (BIG2.GT.BIG) BIG=BIG2
1326     BIG3=ABS(DIRM(9)*(GLUA(2,J-1))/(2.*HHHH**2.))
1327     IF (BIG3.GT.BIG) BIG=BIG3
1328     BIG4=ABS(DIRM(9)*(GLUA(1,J+1))/(2.*HHHH**2.))
1329     IF (BIG4.GT.BIG) BIG=BIG4
1330     BIG5=ABS(DIRM(9)*(GLUA(1,J))/(HHHH**2.))

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1331 IF (BIG5.GT.BIG) BIG=BIG5
1332 BIG6=ABS(DIRM(9)*(GLUA(1,J-1))/(2.*HHHH**2.))
1333 IF (BIG6.GT.BIG) BIG=BIG6
1334 BIG7=ABS(ANM(2,J)/2.)
1335 IF (BIG7.GT.BIG) BIG=BIG7
1336 BIG8=ABS(ANM(1,J)/2.)
1337 IF (BIG8.GT.BIG) BIG=BIG8
1338 BIG9=ABS(GLUA(2,J)/DT)
1339 IF (BIG9.GT.BIG) BIG=BIG9
1340 BIG10=ABS(GLUA(1,J)/DT)
1341 IF (BIG10.GT.BIG) BIG=BIG10
1342 IF (ABS(G(14)).LT.BIG*EBIG) G(14)=0.0
1343
1344 C Gluconic acid dissociation
1345
1346 G(15)=equilib6*(GLA(2,J)+GLA(1,J))/2.-(GLI(2,J)+GLI(1,J))*
1347 1 (HYD(2,J)+HYD(1,J))/4.
1348 B(15,3)=-equilib6/2.
1349 B(15,15)=(HYD(2,J)+HYD(1,J))/4.
1350 B(15,16)=(GLI(2,J)+GLI(1,J))/4.
1351
1352 BIG=ABS(equilib6*GLA(2,J)/2.)
1353 BIG2=ABS(equilib6*GLA(1,J)/2.)
1354 IF (BIG2.GT.BIG) BIG=BIG2
1355 BIG3=ABS(GLI(2,J)*HYD(2,J)/4.)
1356 IF (BIG3.GT.BIG) BIG=BIG3
1357 BIG4=ABS(GLI(2,J)*HYD(1,J)/4)
1358 IF (BIG4.GT.BIG) BIG=BIG4
1359 BIG5=ABS(GLI(1,J)*HYD(2,J)/4)
1360 IF (BIG5.GT.BIG) BIG=BIG5
1361 BIG6=ABS(GLI(1,J)*HYD(1,J)/4)
1362 IF (BIG6.GT.BIG) BIG=BIG6
1363 IF (ABS(G(15)).LT.BIG*EBIG) G(15)=0
1364 C Hydrogen ion, hydroxide ion, gluconate ion, bicarbonate ion flux
1365 G(16)=DIRM(11)*(HYD(2,J+1)-2.*HYD(2,J)+HYD(2,J-1)
1366 1 +HYD(1,J+1)-2.*HYD(1,J)+HYD(1,J-1))/(2.*HHHH**2.)
1367 2 -DIRM(15)*(OHI(2,J+1)-2.*OHI(2,J)+OHI(2,J-1)
1368 3 +OHI(1,J+1)-2.*OHI(1,J)+OHI(1,J-1))/(2.*HHHH**2.)
1369 4 -DIRM(10)*(GLI(2,J+1)-2.*GLI(2,J)+GLI(2,J-1)
1370 5 +GLI(1,J+1)-2.*GLI(1,J)+GLI(1,J-1))/(2.*HHHH**2.)
1371 6 -DIRM(14)*(CBI(2,J+1)-2.*CBI(2,J)+CBI(2,J-1)
1372 7 +CBI(1,J+1)-2.*CBI(1,J)+CBI(1,J-1))/(2.*HHHH**2.)
1373 8 -(HYD(2,J)-HYD(1,J))/DT+(OHI(2,J)-OHI(1,J))/DT
1374 9 +(GLI(2,J)-GLI(1,J))/DT+(CBI(2,J)-CBI(1,J))/DT
1375
1376 B(16,16)=DIRM(11)/HHHH**2.+1./DT
1377 D(16,16)=-DIRM(11)/(2.*HHHH**2.)
1378 A(16,16)=-DIRM(11)/(2.*HHHH**2.)
1379 B(16,17)=-DIRM(15)/HHHH**2.-1./DT
1380 D(16,17)=DIRM(15)/(2.*HHHH**2.)
1381 A(16,17)=DIRM(15)/(2.*HHHH**2.)
1382 B(16,15)=-DIRM(10)/HHHH**2.-1./DT
1383 D(16,15)=DIRM(10)/(2.*HHHH**2.)
1384 A(16,15)=DIRM(10)/(2.*HHHH**2.)
1385 B(16,20)=-DIRM(14)/HHHH**2.-1./DT
1386 D(16,20)=DIRM(14)/(2.*HHHH**2.)
1387 A(16,20)=DIRM(14)/(2.*HHHH**2.)
1388

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1389 BIG=ABS(DIRM(11)*(HYD(2,J+1))/(2.*HHHH**2.))
1390 BIG2=ABS(DIRM(11)*(HYD(2,J))/(HHHH**2.))
1391 IF (BIG2.GT.BIG) BIG=BIG2
1392 BIG3=ABS(DIRM(11)*(HYD(2,J-1))/(2.*HHHH**2.))
1393 IF (BIG3.GT.BIG) BIG=BIG3
1394 BIG4=ABS(DIRM(11)*(HYD(1,J+1))/(2.*HHHH**2.))
1395 IF (BIG4.GT.BIG) BIG=BIG4
1396 BIG5=ABS(DIRM(11)*(HYD(1,J))/(HHHH**2.))
1397 IF (BIG5.GT.BIG) BIG=BIG5
1398 BIG6=ABS(DIRM(11)*(HYD(1,J-1))/(2.*HHHH**2.))
1399 IF (BIG6.GT.BIG) BIG=BIG6
1400 BIG7=ABS(DIRM(15)*OHI(2,J+1)/(2.*HHHH**2.))
1401 IF (BIG7.GT.BIG) BIG=BIG7
1402 BIG8=ABS(DIRM(15)*OHI(2,J)/(HHHH**2.))
1403 IF (BIG8.GT.BIG) BIG=BIG8
1404 BIG9=ABS(DIRM(15)*OHI(2,J-1)/(2.*HHHH**2.))
1405 IF (BIG9.GT.BIG) BIG=BIG9
1406 BIG10=ABS(DIRM(15)*OHI(1,J+1)/(2.*HHHH**2.))
1407 IF (BIG10.GT.BIG) BIG=BIG10
1408 BIG11=ABS(DIRM(15)*OHI(1,J)/(HHHH**2.))
1409 IF (BIG11.GT.BIG) BIG=BIG11
1410 BIG12=ABS(DIRM(15)*OHI(1,J-1)/(2.*HHHH**2.))
1411 IF (BIG12.GT.BIG) BIG=BIG12
1412 BIG13=ABS(DIRM(10)*GLI(2,J+1)/(2.*HHHH**2.))
1413 IF (BIG13.GT.BIG) BIG=BIG13
1414 BIG14=ABS(DIRM(10)*GLI(2,J)/(HHHH**2.))
1415 IF (BIG14.GT.BIG) BIG=BIG14
1416 BIG15=ABS(DIRM(10)*GLI(2,J-1)/(2.*HHHH**2.))
1417 IF (BIG15.GT.BIG) BIG=BIG15
1418 BIG16=ABS(DIRM(10)*GLI(1,J+1)/(2.*HHHH**2.))
1419 IF (BIG16.GT.BIG) BIG=BIG16
1420 BIG17=ABS(DIRM(10)*GLI(1,J)/(HHHH**2.))
1421 IF (BIG17.GT.BIG) BIG=BIG17
1422 BIG18=ABS(DIRM(10)*GLI(1,J-1)/(2.*HHHH**2.))
1423 IF (BIG18.GT.BIG) BIG=BIG18
1424 BIG19=ABS(DIRM(14)*CBI(2,J+1)/(2.*HHHH**2.))
1425 IF (BIG19.GT.BIG) BIG=BIG19
1426 BIG20=ABS(DIRM(14)*CBI(2,J)/(HHHH**2.))
1427 IF (BIG20.GT.BIG) BIG=BIG20
1428 BIG21=ABS(DIRM(14)*CBI(2,J-1)/(2.*HHHH**2.))
1429 IF (BIG21.GT.BIG) BIG=BIG21
1430 BIG22=ABS(DIRM(14)*CBI(1,J+1)/(2.*HHHH**2.))
1431 IF (BIG22.GT.BIG) BIG=BIG22
1432 BIG23=ABS(DIRM(14)*CBI(1,J)/(HHHH**2.))
1433 IF (BIG23.GT.BIG) BIG=BIG23
1434 BIG24=ABS(DIRM(14)*CBI(1,J-1)/(2.*HHHH**2.))
1435 IF (BIG24.GT.BIG) BIG=BIG24
1436 BIG25=ABS(HYD(2,J)/DT)
1437 IF (BIG25.GT.BIG) BIG=BIG25
1438 BIG26=ABS(HYD(1,J)/DT)
1439 IF (BIG26.GT.BIG) BIG=BIG26
1440 BIG27=ABS(OHI(2,J)/DT)
1441 IF (BIG27.GT.BIG) BIG=BIG27
1442 BIG28=ABS(OHI(1,J)/DT)
1443 IF (BIG28.GT.BIG) BIG=BIG28
1444 BIG29=ABS(GLI(2,J)/DT)
1445 IF (BIG29.GT.BIG) BIG=BIG29
1446 BIG30=ABS(GLI(1,J)/DT)

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1447 IF (BIG30.GT.BIG) BIG=BIG30
1448 BIG31=ABS(CBI(2,J)/DT)
1449 IF (BIG31.GT.BIG) BIG=BIG31
1450 BIG32=ABS(CBI(1,J)/DT)
1451 IF (BIG32.GT.BIG) BIG=BIG32
1452 IF (ABS(G(16)).LT.BIG*EBIG) G(16)=0
1453
1454 c Water Dissociation
1455 G(17)=equilib9 -(HYD(2,J)+HYD(1,J))*(OHI(2,J)+OHI(1,J))/4.
1456 B(17,17)=(HYD(2,J)+HYD(1,J))/4.
1457 B(17,16)=(OHI(2,J)+OHI(1,J))/4.
1458
1459 BIG=ABS(equilib9)
1460 BIG2=ABS(HYD(2,J)*OHI(2,J)/4.)
1461 IF (BIG2.GT.BIG) BIG=BIG2
1462 BIG3=ABS(HYD(2,J)*OHI(1,J)/4.)
1463 IF (BIG3.GT.BIG) BIG=BIG3
1464 BIG4=ABS(HYD(1,J)*OHI(2,J)/4.)
1465 IF (BIG4.GT.BIG) BIG=BIG4
1466 BIG5=ABS(HYD(1,J)*OHI(1,J)/4.)
1467 IF (BIG5.GT.BIG) BIG=BIG5
1468 IF (ABS(G(17)).LT.BIG*EBIG) G(17)=0
1469
1470 C CO2 Hydration
1471
1472 G(18)=equilib7 *(CO2(2,J)+CO2(1,J))/2. -(CBA(2,J)+CBA(1,J))/2.
1473 B(18,18)=-equilib7/2.
1474 B(18,19)=1./2.
1475
1476 BIG=ABS(equilib7*CO2(2,J)/2.)
1477 BIG2=ABS(equilib7*CO2(1,J)/2.)
1478 IF (BIG2.GT.BIG) BIG=BIG2
1479 BIG3=ABS(CBA(2,J)/2.)
1480 IF (BIG3.GT.BIG) BIG=BIG3
1481 BIG4=ABS(CBA(1,J)/2.)
1482 IF (BIG4.GT.BIG) BIG=BIG4
1483 IF (ABS(G(18)).LT.BIG*EBIG) G(18)=0
1484
1485 C Carbonic acid dissociation
1486
1487 G(19)=equilib8 *(CBA(2,J)+CBA(1,J))/2. -(CBI(2,J)+CBI(1,J))
1488 1 *(HYD(2,J)+HYD(1,J))/4.
1489 B(19,19)=-equilib8/2.
1490 B(19,20)=(HYD(2,J)+HYD(1,J))/4.
1491 B(19,16)=(CBI(2,J)+CBI(1,J))/4.
1492
1493 BIG=ABS(equilib8*CBA(2,J)/2.)
1494 BIG2=ABS(equilib8*CBA(1,J)/2.)
1495 IF (BIG2.GT.BIG) BIG=BIG2
1496 BIG3=ABS(CBI(2,J)*HYD(2,J)/4.)
1497 IF (BIG3.GT.BIG) BIG=BIG3
1498 BIG4=ABS(CBI(2,J)*HYD(1,J)/4.)
1499 IF (BIG4.GT.BIG) BIG=BIG4
1500 BIG5=ABS(CBI(1,J)*HYD(2,J)/4.)
1501 IF (BIG5.GT.BIG) BIG=BIG5
1502 BIG6=ABS(CBI(1,J)*HYD(1,J)/4.)
1503 IF (BIG6.GT.BIG) BIG=BIG6
1504 IF (ABS(G(19)).LT.BIG*EBIG) G(19)=0

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1505
1506 C FLUX OF CO2, CARBONIC ACID, BICARBONATE ION
1507     G(20)=DIRM(12)*(CO2(2,J+1)-2.*CO2(2,J)+CO2(2,J-1)
1508     1   +CO2(1,J+1)-2.*CO2(1,J)+CO2(1,J-1))/(2.*HHHH**2.)
1509     2   +DIRM(13)*(CBA(2,J+1)-2.*CBA(2,J)+CBA(2,J-1)
1510     3   +CBA(1,J+1)-2.*CBA(1,J)+CBA(1,J-1))/(2.*HHHH**2.)
1511     4   +DIRM(14)*(CBI(2,J+1)-2.*CBI(2,J)+CBI(2,J-1)
1512     5   +CBI(1,J+1)-2.*CBI(1,J)+CBI(1,J-1))/(2.*HHHH**2.)
1513     8   -(CO2(2,J)-CO2(1,J))/DT-(CBA(2,J)-CBA(1,J))/DT
1514     9   -(CBI(2,J)-CBI(1,J))/DT
1515
1516     B(20,20)=DIRM(14)/HHHH**2.+1./DT
1517     D(20,20)=-DIRM(14)/(2.*HHHH**2.)
1518     A(20,20)=-DIRM(14)/(2.*HHHH**2.)
1519     B(20,18)=DIRM(12)/HHHH**2.+1./DT
1520     D(20,18)=-DIRM(12)/(2.*HHHH**2.)
1521     A(20,18)=-DIRM(12)/(2.*HHHH**2.)
1522     B(20,19)=DIRM(13)/HHHH**2.+1./DT
1523     D(20,19)=-DIRM(13)/(2.*HHHH**2.)
1524     A(20,19)=-DIRM(13)/(2.*HHHH**2.)
1525
1526
1527     BIG=ABS(DIRM(12)*(CO2(2,J+1))/(2.*HHHH**2.))
1528     BIG2=ABS(DIRM(12)*(CO2(2,J))/(HHHH**2.))
1529     IF (BIG2.GT.BIG) BIG=BIG2
1530
1531     BIG3=ABS(DIRM(12)*(CO2(2,J-1))/(2.*HHHH**2.))
1532     IF (BIG3.GT.BIG) BIG=BIG3
1533
1534     BIG4=ABS(DIRM(12)*(CO2(1,J+1))/(2.*HHHH**2.))
1535     IF (BIG4.GT.BIG) BIG=BIG4
1536
1537     BIG5=ABS(DIRM(12)*(CO2(1,J))/(HHHH**2.))
1538     IF (BIG5.GT.BIG) BIG=BIG5
1539
1540     BIG6=ABS(DIRM(12)*(CO2(1,J-1))/(2.*HHHH**2.))
1541     IF (BIG6.GT.BIG) BIG=BIG6
1542
1543     BIG7=ABS(DIRM(13)*CBA(2,J+1)/(2.*HHHH**2.))
1544     IF (BIG7.GT.BIG) BIG=BIG7
1545
1546     BIG8=ABS(DIRM(13)*CBA(2,J)/(HHHH**2.))
1547     IF (BIG8.GT.BIG) BIG=BIG8
1548
1549     BIG9=ABS(DIRM(13)*CBA(2,J-1)/(2.*HHHH**2.))
1550     IF (BIG9.GT.BIG) BIG=BIG9
1551
1552     BIG10=ABS(DIRM(13)*CBA(1,J+1)/(2.*HHHH**2.))
1553     IF (BIG10.GT.BIG) BIG=BIG10
1554
1555     BIG11=ABS(DIRM(13)*CBA(1,J)/(HHHH**2.))
1556     IF (BIG11.GT.BIG) BIG=BIG11
1557
1558     BIG12=ABS(DIRM(13)*CBA(1,J-1)/(2.*HHHH**2.))
1559     IF (BIG12.GT.BIG) BIG=BIG12
1560
1561     BIG13=ABS(DIRM(14)*CBI(2,J+1)/(2.*HHHH**2.))
1562     IF (BIG13.GT.BIG) BIG=BIG13
1563
1564     BIG14=ABS(DIRM(14)*CBI(2,J)/(HHHH**2.))
1565     IF (BIG14.GT.BIG) BIG=BIG14
1566
1567     BIG15=ABS(DIRM(14)*CBI(2,J-1)/(2.*HHHH**2.))
1568     IF (BIG15.GT.BIG) BIG=BIG15
1569
1570     BIG16=ABS(DIRM(14)*CBI(1,J+1)/(2.*HHHH**2.))
1571     IF (BIG16.GT.BIG) BIG=BIG16
1572
1573     BIG17=ABS(DIRM(14)*CBI(1,J)/(HHHH**2.))
1574     IF (BIG17.GT.BIG) BIG=BIG17
1575
1576     BIG18=ABS(DIRM(14)*CBI(1,J-1)/(2.*HHHH**2.))
1577     IF (BIG18.GT.BIG) BIG=BIG18
1578
1579     BIG19=ABS(CO2(2,J)/DT)

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1563 IF (BIG19.GT.BIG) BIG=BIG19
1564 BIG20=ABS(CO2(1,J)/DT)
1565 IF (BIG20.GT.BIG) BIG=BIG20
1566 BIG21=ABS(CBA(2,J)/DT)
1567 IF (BIG21.GT.BIG) BIG=BIG21
1568 BIG22=ABS(CBA(1,J)/DT)
1569 IF (BIG22.GT.BIG) BIG=BIG22
1570 BIG23=ABS(CBI(2,J)/DT)
1571 IF (BIG23.GT.BIG) BIG=BIG23
1572 BIG24=ABS(CBI(1,J)/DT)
1573 IF (BIG24.GT.BIG) BIG=BIG24
1574 IF (ABS(G(20)).LT.BIG*EBIG) G(20)=0
1575
1576 C For Acetaminophen
1577 G(21)=DIRM(16)*(ACE(2,J+1)-2.*ACE(2,J)+ACE(2,J-1)
1578 1 +ACE(1,J+1)-2.*ACE(1,J)+ACE(1,J-1))/(2.*HHHH**2.)
1579 2 -(ACE(2,J)-ACE(1,J))/DT
1580
1581 B(21,21)=DIRM(16)/HHHH**2.+1./DT
1582 D(21,21)=-DIRM(16)/(2.*HHHH**2.)
1583 A(21,21)=-DIRM(16)/(2.*HHHH**2.)
1584
1585
1586 BIG=ABS(DIRM(16)*(ACE(2,J+1))/(2.*HHHH**2.))
1587 BIG2=ABS(DIRM(16)*(ACE(2,J))/(HHHH**2.))
1588 IF (BIG2.GT.BIG) BIG=BIG2
1589 BIG3=ABS(DIRM(16)*(ACE(2,J-1))/(2.*HHHH**2.))
1590 IF (BIG3.GT.BIG) BIG=BIG3
1591 BIG4=ABS(DIRM(16)*(ACE(1,J+1))/(2.*HHHH**2.))
1592 IF (BIG4.GT.BIG) BIG=BIG4
1593 BIG5=ABS(DIRM(16)*(ACE(1,J))/(HHHH**2.))
1594 IF (BIG5.GT.BIG) BIG=BIG5
1595 BIG6=ABS(DIRM(16)*(ACE(1,J-1))/(2.*HHHH**2.))
1596 IF (BIG6.GT.BIG) BIG=BIG6
1597 BIG7=ABS(ACE(2,J)/DT)
1598 IF (BIG7.GT.BIG) BIG=BIG7
1599 BIG8=ABS(ACE(1,J)/DT)
1600 IF (BIG8.GT.BIG) BIG=BIG8
1601 IF (ABS(G(21)).LT.BIG*EBIG) G(21)=0
1602
1603 c INTERFACE VOLTAGE - DUMMY
1604 G(22)=(VDL(2,J)+VDL(1,J))/2.
1605
1606 B(22,22)=-1./2.
1607
1608 BIG=ABS(VDL(2,J)/2.)
1609 BIG2=ABS(VDL(1,J)/2.)
1610 IF (BIG2.GT.BIG) BIG=BIG2
1611 IF (ABS(G(22)).LT.BIG*EBIG) G(22)=0
1612
1613 RETURN
1614 END
1615
1616 SUBROUTINE COUPLERINS(J)
1617 IMPLICIT DOUBLE PRECISION (A-H, O-Z)
1618 COMMON/BAB/ A(22,22),B(22,22),C(22,80001),D(22,45),G(22),X(22,22)
1619 1 ,Y(22,22)
1620 COMMON/NSN/ N, NJ

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1621 COMMON/GLC/ NTIME, LL
1622 COMMON/VAR/ DIFF(16), H, EBIG, HH, IJ, KJ, TT, VAP, HHH, DT, RE, AKB, BB, CDL
1623 COMMON/VARR/ HHHH, HHHHH, MJ, LJ
1624 COMMON/DIN/ DGOX(16), DGLM(16), DIRM(16), DBULK(16)
1625 COMMON/SPCI/ GLU(2,80001), GOX(2,80001), GLA(2,80001), GOR(2,80001)
1626 COMMON/SPCII/ OXY(2,80001), HPR(2,80001), GOA(2,80001), GOP(2,80001)
1627 COMMON/RXT/ EQ1(2,80001), RGA(2,80001), EQ2(2,80001), RHP(2,80001)
1628 COMMON/SPCIII/ ANM(2,80001), GLUA(2,80001), GLI(2,80001)
1629 COMMON/SPCIV/ HYD(2,80001), OHI(2,80001), CO2(2,80001), CBA(2,80001)
1630 COMMON/SPCV/ CBI(2,80001), ACE(2,80001)
1631 COMMON/VOL/ VDL(2,80001)
1632 COMMON/POR/ POR1, POR2, PORGLU, PARION, PARACE
1633 COMMON/RTE/ ratef1, equilb1, ratef2, ratef3, equilb3, ratef4
1634 COMMON/RTD/ ratef5, equilb5, equilb6, equilb7, equilb8, equilb9
1635 COMMON/BUL/ CBULK(16), PARH2O2, PARO2, PARGLUCOSE, JCOUNT

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1636

1637

1638 C DIMENSION COEFF1, COEFF3, COEFF5, COEFF6

1639

1640 301 FORMAT (5x, 'J=' I5, 12E18.9)

1641

1642 COEFF1HHH=DGOX(1)/(HHH)

1643 COEFF1HHHH=DIRM(1)/(HHHH)

1644 COEFF3HHH=DGOX(3)/(HHH)

1645 COEFF3HHHH=DIRM(3)/(HHHH)

1646 COEFF5HHH=DGOX(5)/(HHH)

1647 COEFF5HHHH=DIRM(5)/(HHHH)

1648 COEFF6HHH=DGOX(6)/(HHH)

1649 COEFF6HHHH=DIRM(6)/(HHHH)

1650 COEFF9HHH=DGOX(9)/(HHH)

1651 COEFF9HHHH=DIRM(9)/(HHHH)

1652 COEFF10HHH=DGOX(10)/(HHH)

1653 COEFF10HHHH=DIRM(10)/(HHHH)

1654 COEFF11HHH=DGOX(11)/(HHH)

1655 COEFF11HHHH=DIRM(11)/(HHHH)

1656 COEFF12HHH=DGOX(12)/(HHH)

1657 COEFF12HHHH=DIRM(12)/(HHHH)

1658 COEFF13HHH=DGOX(13)/(HHH)

1659 COEFF13HHHH=DIRM(13)/(HHHH)

1660 COEFF14HHH=DGOX(14)/(HHH)

1661 COEFF14HHHH=DIRM(14)/(HHHH)

1662 COEFF15HHH=DGOX(15)/(HHH)

1663 COEFF15HHHH=DIRM(15)/(HHHH)

1664 COEFF16HHH=DGOX(16)/(HHH)

1665 COEFF16HHHH=DIRM(16)/(HHHH)

1666

1667 C For Glucose, being consumed only

1668 G(1)=COEFF1HHH/2.\*(GLU(2,J+1)+GLU(1,J+1)-GLU(2,J)-GLU(1,J))

1669 1 -COEFF1HHHH/2.\*(GLU(2,J)+GLU(1,J)-GLU(2,J-1)-GLU(1,J-1))

1670 2 -(HHH/2.)\*(3.\*(EQ1(2,J)+EQ1(1,J))+(EQ1(2,J+1)+EQ1(1,J+1)))/8.

1671 2 +(HHH/2.)\*(3.\*(ANM(2,J)+ANM(1,J))+(ANM(2,J+1)+ANM(1,J+1)))/8.

1672 3 +(HHHH/2.)\*(3.\*(ANM(2,J)+ANM(1,J))+(ANM(2,J-1)+ANM(1,J-1)))/8.

1673 4 -HHH/2.\*(3.\*(GLU(2,J)-GLU(1,J))+(GLU(2,J+1)-GLU(1,J+1)))/(4.\*DT)

1674 5 -HHHH/2.\*(3.\*(GLU(2,J)-GLU(1,J))+(GLU(2,J-1)-GLU(1,J-1)))/(4.\*DT)

1675

1676 B(1,1)=COEFF1HHH/2.+COEFF1HHHH/2.

1677 1 +HHH/2.\*3./(4.\*DT)+HHHH/2.\*3./(4.\*DT)

1678 D(1,1)=-COEFF1HHH/2.+HHH/2./(4.\*DT)

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1679 A(1,1)=-COEFF1HHHH/2.+HHHH/2./(4.*DT)
1680 B(1,9)=+(HHH/2.)*(3./8.)
1681 D(1,9)=+(HHH/2.)*(1./8.)
1682 B(1,13)=-((HHH/2.)*(3./8.))-((HHHH/2.)*(3./8.))
1683 D(1,13)=-((HHH/2.)*(1./8.))
1684 A(1,13)=-((HHHH/2.)*(1./8.))
1685
1686 BIG=ABS(COEFF1HHH/2.*GLU(2,J+1))
1687 BIG2=ABS(COEFF1HHH/2.*GLU(1,J+1))
1688 IF (BIG2.GT.BIG) BIG=BIG2
1689 BIG3=ABS(COEFF1HHH/2.*GLU(2,J))
1690 IF (BIG3.GT.BIG) BIG=BIG3
1691 BIG4=ABS(COEFF1HHH/2.*GLU(1,J))
1692 IF (BIG4.GT.BIG) BIG=BIG4
1693 BIG5=ABS(COEFF1HHHH/2.*GLU(2,J))
1694 IF (BIG5.GT.BIG) BIG=BIG5
1695 BIG6=ABS(COEFF1HHHH/2.*GLU(1,J))
1696 IF (BIG6.GT.BIG) BIG=BIG6
1697 BIG7=ABS(COEFF1HHHH/2.*GLU(2,J-1))
1698 IF (BIG7.GT.BIG) BIG=BIG7
1699 BIG8=ABS(COEFF1HHHH/2.*GLU(1,J-1))
1700 IF (BIG8.GT.BIG) BIG=BIG8
1701 BIG9=ABS(HHH/2.*3.*EQ1(2,J)/8.)
1702 IF (BIG9.GT.BIG) BIG=BIG9
1703 BIG10=ABS(HHH/2.*3.*EQ1(1,J)/8.)
1704 IF (BIG10.GT.BIG) BIG=BIG10
1705 BIG11=ABS(HHH/2.*EQ1(2,J+1)/8.)
1706 IF (BIG11.GT.BIG) BIG=BIG11
1707 BIG12=ABS(HHH/2.*EQ1(1,J+1)/8.)
1708 IF (BIG12.GT.BIG) BIG=BIG12
1709 BIG17=ABS(HHH/2.*3.*GLU(2,J)/(4.*DT))
1710 IF (BIG17.GT.BIG) BIG=BIG17
1711 BIG18=ABS(HHH/2.*3.*GLU(1,J)/(4.*DT))
1712 IF (BIG18.GT.BIG) BIG=BIG18
1713 BIG19=ABS(HHH/2.*GLU(2,J+1)/(4.*DT))
1714 IF (BIG19.GT.BIG) BIG=BIG19
1715 BIG20=ABS(HHH/2.*GLU(1,J+1)/(4.*DT))
1716 IF (BIG20.GT.BIG) BIG=BIG20
1717 BIG21=ABS(HHHH/2.*3.*GLU(2,J)/(4.*DT))
1718 IF (BIG21.GT.BIG) BIG=BIG21
1719 BIG22=ABS(HHHH/2.*3.*GLU(1,J)/(4.*DT))
1720 IF (BIG22.GT.BIG) BIG=BIG22
1721 BIG23=ABS(HHHH/2.*GLU(2,J-1)/(4.*DT))
1722 IF (BIG23.GT.BIG) BIG=BIG23
1723 BIG24=ABS(HHHH/2.*GLU(1,J-1)/(4.*DT))
1724 IF (BIG24.GT.BIG) BIG=BIG24
1725 BIG25=ABS(HHH/2.*3.*ANM(2,J)/8.)
1726 IF (BIG25.GT.BIG) BIG=BIG25
1727 BIG26=ABS(HHH/2.*3.*ANM(1,J)/8.)
1728 IF (BIG26.GT.BIG) BIG=BIG26
1729 BIG27=ABS(HHH/2.*ANM(2,J+1)/8.)
1730 IF (BIG27.GT.BIG) BIG=BIG27
1731 BIG28=ABS(HHH/2.*ANM(1,J+1)/8.)
1732 IF (BIG28.GT.BIG) BIG=BIG28
1733 BIG29=ABS(HHHH/2.*3.*ANM(2,J)/8.)
1734 IF (BIG29.GT.BIG) BIG=BIG29
1735 BIG30=ABS(HHHH/2.*3.*ANM(1,J)/8.)
1736 IF (BIG30.GT.BIG) BIG=BIG30

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1737 BIG31=ABS(HHHH/2.*ANM(2,J-1)/8.)
1738 IF (BIG31.GT.BIG) BIG=BIG31
1739 BIG32=ABS(HHHH/2.*ANM(1,J-1)/8.)
1740 IF (BIG32.GT.BIG) BIG=BIG32
1741 IF (ABS(G(1)).LT.BIG*EBIG) G(1)=0
1742
1743 C For GOx, enzyme
1744 G(2)=- (EQ1(2,J)+EQ1(1,J))/2.+(RHP(2,J)+RHP(1,J))/2.
1745 1 -(GOX(2,J)-GOX(1,J))/DT
1746 B(2,2)=+1./DT
1747 B(2,9)=+1./2.
1748 B(2,12)=-1./2.
1749
1750
1751 IF (ABS(EQ1(2,J)).GT.BIG) BIG=ABS(EQ1(2,J))
1752 IF (ABS(EQ1(1,J)).GT.BIG) BIG=ABS(EQ1(1,J))
1753 IF (ABS(RHP(2,J)).GT.BIG) BIG=ABS(RHP(2,J))
1754 IF (ABS(RHP(1,J)).GT.BIG) BIG=ABS(RHP(1,J))
1755 IF (ABS(GOX(2,J)/DT).GT.BIG) BIG=ABS(GOX(2,J)/DT)
1756 IF (ABS(GOX(1,J)/DT).GT.BIG) BIG=ABS(GOX(1,J)/DT)
1757 IF (ABS(G(2)).LT.BIG*EBIG) G(2)=0
1758
1759 C For Gluconic Acid, being produced only Balanced by Gluconate Ion
1760 G(3)=COEFF3HHH/2.*(GLA(2,J+1)+GLA(1,J+1)-GLA(2,J)-GLA(1,J))
1761 1 -COEFF3HHHH/2.*(GLA(2,J)+GLA(1,J)-GLA(2,J-1)-GLA(1,J-1))
1762 2 +COEFF10HHH/2.*(GLI(2,J+1)+GLI(1,J+1)-GLI(2,J)-GLI(1,J))
1763 3 -COEFF10HHHH/2.*(GLI(2,J)+GLI(1,J)-GLI(2,J-1)-GLI(1,J-1))
1764 4 +(HHH/2.)*(3.*(RGA(2,J)+RGA(1,J))+(RGA(2,J+1)+RGA(1,J+1)))/8.
1765 6 -HHH/2.*(3.*(GLA(2,J)-GLA(1,J))+(GLA(2,J+1)-GLA(1,J+1)))/(4.*DT)
1766 7 -HHHH/2.*(3.*(GLA(2,J)-GLA(1,J))+(GLA(2,J-1)-GLA(1,J-1)))/(4.*DT)
1767 8 -HHH/2.*(3.*(GLI(2,J)-GLI(1,J))+(GLI(2,J+1)-GLI(1,J+1)))/(4.*DT)
1768 9 -HHHH/2.*(3.*(GLI(2,J)-GLI(1,J))+(GLI(2,J-1)-GLI(1,J-1)))/(4.*DT)
1769
1770 B(3,3)=COEFF3HHH/2.+COEFF3HHHH/2.
1771 1 +HHH/2.*3./(4.*DT)+HHHH/2.*3./(4.*DT)
1772 D(3,3)=-COEFF3HHH/2.+HHH/2./(4.*DT)
1773 A(3,3)=-COEFF3HHHH/2.+HHHH/2./(4.*DT)
1774 B(3,10)=- (HHH/2.)*(3./8.)
1775 D(3,10)=- (HHH/2.)*(1./8.)
1776 B(3,15)=COEFF10HHH/2.+COEFF10HHHH/2.+HHH/2.*3./(4.*DT)
1777 1 +HHHH/2.*3./(4.*DT)
1778 D(3,15)=-COEFF10HHH/2.+HHH/2./(4.*DT)
1779 A(3,15)=-COEFF10HHHH/2.+HHHH/2./(4.*DT)
1780
1781
1782 BIG=ABS(COEFF3HHH/2.*GLA(2,J+1))
1783 BIG2=ABS(COEFF3HHH/2.*GLA(1,J+1))
1784 IF (BIG2.GT.BIG) BIG=BIG2
1785 BIG3=ABS(COEFF3HHH/2.*GLA(2,J))
1786 IF (BIG3.GT.BIG) BIG=BIG3
1787 BIG4=ABS(COEFF3HHH/2.*GLA(1,J))
1788 IF (BIG4.GT.BIG) BIG=BIG4
1789 BIG5=ABS(COEFF3HHHH/2.*GLA(2,J))
1790 IF (BIG5.GT.BIG) BIG=BIG5
1791 BIG6=ABS(COEFF3HHHH/2.*GLA(1,J))
1792 IF (BIG6.GT.BIG) BIG=BIG6
1793 BIG7=ABS(COEFF3HHHH/2.*GLA(2,J-1))
1794 IF (BIG7.GT.BIG) BIG=BIG7

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1795 BIG8=ABS(COEFF3HHHH/2.*GLA(1,J-1))
1796 IF (BIG8.GT.BIG) BIG=BIG8
1797 BIG9=ABS(HHH/2.*3.*RGA(2,J)/8.)
1798 IF (BIG9.GT.BIG) BIG=BIG9
1799 BIG10=ABS(HHH/2.*3.*RGA(1,J)/8.)
1800 IF (BIG10.GT.BIG) BIG=BIG10
1801 BIG11=ABS(HHH/2.*RGA(2,J+1)/8.)
1802 IF (BIG11.GT.BIG) BIG=BIG11
1803 BIG12=ABS(HHH/2.*RGA(1,J+1)/8.)
1804 IF (BIG12.GT.BIG) BIG=BIG12
1805 BIG17=ABS(HHH/2.*3.*GLA(2,J)/(4.*DT))
1806 IF (BIG17.GT.BIG) BIG=BIG17
1807 BIG18=ABS(HHH/2.*3.*GLA(1,J)/(4.*DT))
1808 IF (BIG18.GT.BIG) BIG=BIG18
1809 BIG19=ABS(HHH/2.*GLA(2,J+1)/(4.*DT))
1810 IF (BIG19.GT.BIG) BIG=BIG19
1811 BIG20=ABS(HHH/2.*GLA(1,J+1)/(4.*DT))
1812 IF (BIG20.GT.BIG) BIG=BIG20
1813 BIG21=ABS(HHHH/2.*3.*GLA(2,J)/(4.*DT))
1814 IF (BIG21.GT.BIG) BIG=BIG21
1815 BIG22=ABS(HHHH/2.*3.*GLA(1,J)/(4.*DT))
1816 IF (BIG22.GT.BIG) BIG=BIG22
1817 BIG23=ABS(HHHH/2.*GLA(2,J-1)/(4.*DT))
1818 IF (BIG23.GT.BIG) BIG=BIG23
1819 BIG24=ABS(HHHH/2.*GLA(1,J-1)/(4.*DT))
1820 IF (BIG24.GT.BIG) BIG=BIG24
1821 BIG25=ABS(COEFF10HHH/2.*GLI(2,J+1))
1822 IF (BIG25.GT.BIG) BIG=BIG25
1823 BIG26=ABS(COEFF10HHH/2.*GLI(1,J+1))
1824 IF (BIG26.GT.BIG) BIG=BIG26
1825 BIG27=ABS(COEFF10HHH/2.*GLI(2,J))
1826 IF (BIG27.GT.BIG) BIG=BIG27
1827 BIG28=ABS(COEFF10HHH/2.*GLI(1,J))
1828 IF (BIG28.GT.BIG) BIG=BIG28
1829 BIG29=ABS(COEFF10HHHH/2.*GLI(2,J))
1830 IF (BIG29.GT.BIG) BIG=BIG29
1831 BIG30=ABS(COEFF10HHHH/2.*GLI(1,J))
1832 IF (BIG30.GT.BIG) BIG=BIG30
1833 BIG31=ABS(COEFF10HHHH/2.*GLI(2,J-1))
1834 IF (BIG31.GT.BIG) BIG=BIG31
1835 BIG32=ABS(COEFF10HHHH/2.*GLI(1,J-1))
1836 IF (BIG32.GT.BIG) BIG=BIG32
1837 BIG33=ABS(HHH/2.*3.*GLI(2,J)/(4.*DT))
1838 IF (BIG33.GT.BIG) BIG=BIG33
1839 BIG34=ABS(HHH/2.*3.*GLI(1,J)/(4.*DT))
1840 IF (BIG34.GT.BIG) BIG=BIG34
1841 BIG35=ABS(HHH/2.*GLI(2,J+1)/(4.*DT))
1842 IF (BIG35.GT.BIG) BIG=BIG35
1843 BIG36=ABS(HHH/2.*GLI(1,J+1)/(4.*DT))
1844 IF (BIG36.GT.BIG) BIG=BIG36
1845 BIG37=ABS(HHHH/2.*3.*GLI(2,J)/(4.*DT))
1846 IF (BIG37.GT.BIG) BIG=BIG37
1847 BIG38=ABS(HHHH/2.*3.*GLI(1,J)/(4.*DT))
1848 IF (BIG38.GT.BIG) BIG=BIG38
1849 BIG39=ABS(HHHH/2.*GLI(2,J-1)/(4.*DT))
1850 IF (BIG39.GT.BIG) BIG=BIG39
1851 BIG40=ABS(HHHH/2.*GLI(1,J-1)/(4.*DT))
1852 IF (BIG40.GT.BIG) BIG=BIG40

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1853     IF (ABS(G(3)) .LT. BIG*EBIG) G(3)=0
1854
1855 C     For GOx2, enzyme
1856     G(4)=CBULK(2)+CBULK(4)+CBULK(7)+CBULK(8) -(GOX(2, J)+GOX(1, J)) /2.
1857     1 -(GOR(2, J)+GOR(1, J)) /2. -(GOA(2, J)+GOA(1, J)) /2.
1858     2 -(GOP(2, J)+GOP(1, J)) /2.
1859     B(4, 4) =+1./2.
1860     B(4, 2) =+1./2.
1861     B(4, 7) =+1./2.
1862     B(4, 8) =+1./2.
1863
1864     BIG=ABS(CBULK(2))
1865     IF (ABS(CBULK(4)) .GT. BIG) BIG=ABS(CBULK(4))
1866     IF (ABS(CBULK(7)) .GT. BIG) BIG=ABS(CBULK(7))
1867     IF (ABS(CBULK(8)) .GT. BIG) BIG=ABS(CBULK(8))
1868     IF (ABS(GOX(2, J) /2.) .GT. BIG) BIG=ABS(GOX(2, J) /2.)
1869     IF (ABS(GOX(1, J) /2.) .GT. BIG) BIG=ABS(GOX(1, J) /2.)
1870     IF (ABS(GOR(2, J) /2.) .GT. BIG) BIG=ABS(GOR(2, J) /2.)
1871     IF (ABS(GOR(1, J) /2.) .GT. BIG) BIG=ABS(GOR(1, J) /2.)
1872     IF (ABS(GOA(2, J) /2.) .GT. BIG) BIG=ABS(GOA(2, J) /2.)
1873     IF (ABS(GOA(1, J) /2.) .GT. BIG) BIG=ABS(GOA(1, J) /2.)
1874     IF (ABS(GOP(2, J) /2.) .GT. BIG) BIG=ABS(GOP(2, J) /2.)
1875     IF (ABS(GOP(1, J) /2.) .GT. BIG) BIG=ABS(GOP(1, J) /2.)
1876     IF (ABS(G(4)) .LT. BIG*EBIG) G(4)=0
1877
1878 C     For O2, being consumed only
1879     G(5)=COEFF5HHH/2. *(OXY(2, J+1)+OXY(1, J+1)-OXY(2, J)-OXY(1, J))
1880     1 -COEFF5HHHH/2. *(OXY(2, J)+OXY(1, J)-OXY(2, J-1)-OXY(1, J-1))
1881     2 -(HHH/2.) *(3. *(EQ2(2, J)+EQ2(1, J)) +(EQ2(2, J+1)+EQ2(1, J+1))) /8.
1882     4 -HHH/2. *(3. *(OXY(2, J)-OXY(1, J)) +(OXY(2, J+1)-OXY(1, J+1))) / (4. *DT)
1883     5 -HHHH/2. *(3. *(OXY(2, J)-OXY(1, J)) +(OXY(2, J-1)-OXY(1, J-1))) / (4. *DT)
1884
1885     B(5, 5)=COEFF5HHH/2. +COEFF5HHHH/2.
1886     1 +HHH/2. *3. / (4. *DT)+HHHH/2. *3. / (4. *DT)
1887     D(5, 5)=-COEFF5HHHH/2. +HHH/2. / (4. *DT)
1888     A(5, 5)=-COEFF5HHHH/2. +HHHH/2. / (4. *DT)
1889     B(5, 11)=+(HHH/2.) *(3. /8.)
1890     D(5, 11)=+(HHH/2.) *(1. /8.)
1891
1892
1893     BIG=ABS(COEFF5HHH/2. *OXY(2, J+1))
1894     BIG2=ABS(COEFF5HHH/2. *OXY(1, J+1))
1895     IF (BIG2 .GT. BIG) BIG=BIG2
1896     BIG3=ABS(COEFF5HHH/2. *OXY(2, J))
1897     IF (BIG3 .GT. BIG) BIG=BIG3
1898     BIG4=ABS(COEFF5HHH/2. *OXY(1, J))
1899     IF (BIG4 .GT. BIG) BIG=BIG4
1900     BIG5=ABS(COEFF5HHHH/2. *OXY(2, J))
1901     IF (BIG5 .GT. BIG) BIG=BIG5
1902     BIG6=ABS(COEFF5HHHH/2. *OXY(1, J))
1903     IF (BIG6 .GT. BIG) BIG=BIG6
1904     BIG7=ABS(COEFF5HHHH/2. *OXY(2, J-1))
1905     IF (BIG7 .GT. BIG) BIG=BIG7
1906     BIG8=ABS(COEFF5HHHH/2. *OXY(1, J-1))
1907     IF (BIG8 .GT. BIG) BIG=BIG8
1908     BIG9=ABS(HHH/2. *3. *EQ2(2, J) /8.)
1909     IF (BIG9 .GT. BIG) BIG=BIG9
1910     BIG10=ABS(HHH/2. *3. *EQ2(1, J) /8.)

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1911 IF (BIG10.GT.BIG) BIG=BIG10
1912 BIG11=ABS(HHH/2.*EQ2(2,J+1)/8.)
1913 IF (BIG11.GT.BIG) BIG=BIG11
1914 BIG12=ABS(HHH/2.*EQ2(1,J+1)/8.)
1915 IF (BIG12.GT.BIG) BIG=BIG12
1916 BIG17=ABS(HHH/2.*3.*OXY(2,J)/(4.*DT))
1917 IF (BIG17.GT.BIG) BIG=BIG17
1918 BIG18=ABS(HHH/2.*3.*OXY(1,J)/(4.*DT))
1919 IF (BIG18.GT.BIG) BIG=BIG18
1920 BIG19=ABS(HHH/2.*OXY(2,J+1)/(4.*DT))
1921 IF (BIG19.GT.BIG) BIG=BIG19
1922 BIG20=ABS(HHH/2.*OXY(1,J+1)/(4.*DT))
1923 IF (BIG20.GT.BIG) BIG=BIG20
1924 BIG21=ABS(HHHH/2.*3.*OXY(2,J)/(4.*DT))
1925 IF (BIG21.GT.BIG) BIG=BIG21
1926 BIG22=ABS(HHHH/2.*3.*OXY(1,J)/(4.*DT))
1927 IF (BIG22.GT.BIG) BIG=BIG22
1928 BIG23=ABS(HHHH/2.*OXY(2,J-1)/(4.*DT))
1929 IF (BIG23.GT.BIG) BIG=BIG23
1930 BIG24=ABS(HHHH/2.*OXY(1,J-1)/(4.*DT))
1931 IF (BIG24.GT.BIG) BIG=BIG24
1932 IF (ABS(G(5)).LT.BIG*EBIG) G(5)=0
1933
1934 C For H2O2, reacting species
1935 G(6)=COEFF6HHH/2.*(HPR(2,J+1)+HPR(1,J+1)-HPR(2,J)-HPR(1,J))
1936 1 -COEFF6HHHH/2.*(HPR(2,J)+HPR(1,J)-HPR(2,J-1)-HPR(1,J-1))
1937 2 +(HHH/2.)*(3.*(RHP(2,J)+RHP(1,J))+(RHP(2,J+1)+RHP(1,J+1)))/8.
1938 4 -HHH/2.*(3.*(HPR(2,J)-HPR(1,J))+(HPR(2,J+1)-HPR(1,J+1)))/(4.*DT)
1939 5 -HHHH/2.*(3.*(HPR(2,J)-HPR(1,J))+(HPR(2,J-1)-HPR(1,J-1)))/(4.*DT)
1940
1941 B(6,6)=COEFF6HHH/2.+COEFF6HHHH/2.
1942 1 +HHH/2.*3./(4.*DT)+HHHH/2.*3./(4.*DT)
1943 D(6,6)=-COEFF6HHH/2.+HHH/2./(4.*DT)
1944 A(6,6)=-COEFF6HHHH/2.+HHHH/2./(4.*DT)
1945 B(6,12)=-((HHH/2.)*(3./8.))
1946 D(6,12)=-((HHH/2.)*(1./8.))
1947
1948 BIG=ABS(COEFF6HHH/2.*HPR(2,J+1))
1949 BIG2=ABS(COEFF6HHH/2.*HPR(1,J+1))
1950 IF (BIG2.GT.BIG) BIG=BIG2
1951 BIG3=ABS(COEFF6HHH/2.*HPR(2,J))
1952 IF (BIG3.GT.BIG) BIG=BIG3
1953 BIG4=ABS(COEFF6HHH/2.*HPR(1,J))
1954 IF (BIG4.GT.BIG) BIG=BIG4
1955 BIG5=ABS(COEFF6HHHH/2.*HPR(2,J))
1956 IF (BIG5.GT.BIG) BIG=BIG5
1957 BIG6=ABS(COEFF6HHHH/2.*HPR(1,J))
1958 IF (BIG6.GT.BIG) BIG=BIG6
1959 BIG7=ABS(COEFF6HHHH/2.*HPR(2,J-1))
1960 IF (BIG7.GT.BIG) BIG=BIG7
1961 BIG8=ABS(COEFF6HHHH/2.*HPR(1,J-1))
1962 IF (BIG8.GT.BIG) BIG=BIG8
1963 BIG9=ABS(HHH/2.*3.*RHP(2,J)/8.)
1964 IF (BIG9.GT.BIG) BIG=BIG9
1965 BIG10=ABS(HHH/2.*3.*RHP(1,J)/8.)
1966 IF (BIG10.GT.BIG) BIG=BIG10
1967 BIG11=ABS(HHH/2.*RHP(2,J+1)/8.)
1968 IF (BIG11.GT.BIG) BIG=BIG11

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1969 BIG12=ABS(HHH/2.*RHP(1,J+1)/8.)
1970 IF (BIG12.GT.BIG) BIG=BIG12
1971 BIG17=ABS(HHH/2.*3.*HPR(2,J)/(4.*DT))
1972 IF (BIG17.GT.BIG) BIG=BIG17
1973 BIG18=ABS(HHH/2.*3.*HPR(1,J)/(4.*DT))
1974 IF (BIG18.GT.BIG) BIG=BIG18
1975 BIG19=ABS(HHH/2.*HPR(2,J+1)/(4.*DT))
1976 IF (BIG19.GT.BIG) BIG=BIG19
1977 BIG20=ABS(HHH/2.*HPR(1,J+1)/(4.*DT))
1978 IF (BIG20.GT.BIG) BIG=BIG20
1979 BIG21=ABS(HHHH/2.*3.*HPR(2,J)/(4.*DT))
1980 IF (BIG21.GT.BIG) BIG=BIG21
1981 BIG22=ABS(HHHH/2.*3.*HPR(1,J)/(4.*DT))
1982 IF (BIG22.GT.BIG) BIG=BIG22
1983 BIG23=ABS(HHHH/2.*HPR(2,J-1)/(4.*DT))
1984 IF (BIG23.GT.BIG) BIG=BIG23
1985 BIG24=ABS(HHHH/2.*HPR(1,J-1)/(4.*DT))
1986 IF (BIG24.GT.BIG) BIG=BIG24
1987 IF (ABS(G(6)).LT.BIG*EBIG) G(6)=0
1988
1989 C For CX-GOx2, enzyme
1990 G(7)=(EQ1(2,J)+EQ1(1,J))/2.-(RGA(2,J)+RGA(1,J))/2.
1991 1 -(GOA(2,J)-GOA(1,J))/DT
1992
1993 B(7,7)=+1./DT
1994 B(7,9)=-1./2.
1995 B(7,10)=1./2.
1996
1997 IF (ABS(EQ1(2,J)).GT.BIG) BIG=ABS(EQ1(2,J))
1998 IF (ABS(EQ1(1,J)).GT.BIG) BIG=ABS(EQ1(1,J))
1999 IF (ABS(RGA(2,J)).GT.BIG) BIG=ABS(RGA(2,J))
2000 IF (ABS(RGA(1,J)).GT.BIG) BIG=ABS(RGA(1,J))
2001 IF (ABS(GOA(2,J)/DT).GT.BIG) BIG=ABS(GOA(2,J)/DT)
2002 IF (ABS(GOA(1,J)/DT).GT.BIG) BIG=ABS(GOA(1,J)/DT)
2003 IF (ABS(G(7)).LT.BIG*EBIG) G(7)=0
2004
2005
2006 C For CX-GOx, enzyme
2007 G(8)=(EQ2(2,J)+EQ2(1,J))/2.-(RHP(2,J)+RHP(1,J))/2.
2008 1 -(GOP(2,J)-GOP(1,J))/DT
2009 B(8,8)=+1./DT
2010 B(8,11)=-1./2.
2011 B(8,12)=1./2.
2012
2013 IF (ABS(EQ2(2,J)).GT.BIG) BIG=ABS(EQ2(2,J))
2014 IF (ABS(EQ2(1,J)).GT.BIG) BIG=ABS(EQ2(1,J))
2015 IF (ABS(RHP(2,J)).GT.BIG) BIG=ABS(RHP(2,J))
2016 IF (ABS(RHP(1,J)).GT.BIG) BIG=ABS(RHP(1,J))
2017 IF (ABS(GOP(2,J)/DT).GT.BIG) BIG=ABS(GOP(2,J)/DT)
2018 IF (ABS(GOP(1,J)/DT).GT.BIG) BIG=ABS(GOP(1,J)/DT)
2019 IF (ABS(G(8)).LT.BIG*EBIG) G(8)=0
2020
2021
2022 C REACTION1
2023 214 G(9)=-((EQ1(2,J)+EQ1(1,J))/2.
2024 1 +ratef1*((GLU(2,J)+GLU(1,J))*(GOX(2,J)+GOX(1,J))/4.
2025 2 -(GOA(2,J)+GOA(1,J))/2./equilib1)
2026 B(9,1)=-ratef1*(GOX(2,J)+GOX(1,J))/4.

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2027 B(9,2)=-ratef1*(GLU(2,J)+GLU(1,J))/4.
2028 B(9,7)=ratef1/2./equilib1
2029 B(9,9)=+1./2.
2030
2031 BIG=ABS(EQ1(2,J)/2.)
2032 BIG2=ABS(EQ1(1,J)/2.)
2033 IF (BIG2.GT.BIG) BIG=BIG2
2034 BIG3=ABS(ratef1*GLU(2,J)*GOX(2,J)/4.)
2035 IF (BIG3.GT.BIG) BIG=BIG3
2036 BIG4=ABS(ratef1*GLU(1,J)*GOX(2,J)/4)
2037 IF (BIG4.GT.BIG) BIG=BIG4
2038 BIG5=ABS(ratef1*GLU(2,J)*GOX(1,J)/4)
2039 IF (BIG5.GT.BIG) BIG=BIG5
2040 BIG6=ABS(ratef1*GLU(1,J)*GOX(1,J)/4)
2041 IF (BIG6.GT.BIG) BIG=BIG6
2042 BIG7=ABS(ratef1*GOA(2,J)/2./equilib1)
2043 IF (BIG7.GT.BIG) BIG=BIG7
2044 BIG8=ABS(ratef1*GOA(1,J)/2./equilib1)
2045 IF (BIG8.GT.BIG) BIG=BIG8
2046 IF (ABS(G(9)).LT.BIG*EBIG) G(9)=0
2047
2048 C REACTION2
2049 215 G(10)=- (RGA(2,J)+RGA(1,J))/2.+ratef2*(GOA(2,J)+GOA(1,J))/2.
2050 B(10,7)=-ratef2/2.
2051 B(10,10)=+1./2.
2052
2053 BIG=ABS(RGA(2,J)/2.)
2054 BIG2=ABS(RGA(1,J)/2.)
2055 IF (BIG2.GT.BIG) BIG=BIG2
2056 BIG3=ABS(ratef2*GOA(2,J)/2.)
2057 IF (BIG3.GT.BIG) BIG=BIG3
2058 BIG4=ABS(ratef2*GOA(1,J)/2.)
2059 IF (BIG4.GT.BIG) BIG=BIG4
2060 IF (ABS(G(10)).LT.BIG*EBIG) G(10)=0
2061
2062 C REACTION3
2063 216 G(11)=- (EQ2(2,J)+EQ2(1,J))/2.
2064 1 +ratef3*((GOR(2,J)+GOR(1,J))*(OXY(2,J)+OXY(1,J))/4.
2065 2 -(GOP(2,J)+GOP(1,J))/2./equilib3)
2066 B(11,4)=-ratef3*(OXY(2,J)+OXY(1,J))/4.
2067 B(11,5)=-ratef3*(GOR(2,J)+GOR(1,J))/4.
2068 B(11,8)=ratef3/2./equilib3
2069 B(11,11)=+1./2.
2070
2071 BIG=ABS(EQ2(2,J)/2.)
2072 BIG2=ABS(EQ2(1,J)/2.)
2073 IF (BIG2.GT.BIG) BIG=BIG2
2074 BIG3=ABS(ratef3*GOR(2,J)*OXY(2,J)/4.)
2075 IF (BIG3.GT.BIG) BIG=BIG3
2076 BIG4=ABS(ratef3*GOR(1,J)*OXY(2,J)/4)
2077 IF (BIG4.GT.BIG) BIG=BIG4
2078 BIG5=ABS(ratef3*GOR(2,J)*OXY(1,J)/4)
2079 IF (BIG5.GT.BIG) BIG=BIG5
2080 BIG6=ABS(ratef3*GOR(1,J)*OXY(1,J)/4)
2081 IF (BIG6.GT.BIG) BIG=BIG6
2082 BIG7=ABS(ratef3*GOP(2,J)/2./EQUILIB3)
2083 IF (BIG7.GT.BIG) BIG=BIG7
2084 BIG8=ABS(ratef3*GOP(1,J)/2./EQUILIB3)

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2085 IF (BIG8.GT.BIG) BIG=BIG8
2086 IF (ABS(G(11)).LT.BIG*EBIG) G(11)=0
2087
2088 C REACTION4
2089 217 G(12)=-((RHP(2,J)+RHP(1,J))/2.+ratef4*(GOP(2,J)+GOP(1,J))/2.
2090 B(12,8)=-ratef4/2.
2091 B(12,12)=+1./2.
2092
2093 BIG=ABS(RHP(2,J)/2.)
2094 BIG2=ABS(RHP(1,J)/2.)
2095 IF (BIG2.GT.BIG) BIG=BIG2
2096 BIG3=ABS(ratef4*GOP(2,J)/2.)
2097 IF (BIG3.GT.BIG) BIG=BIG3
2098 BIG4=ABS(ratef4*GOP(1,J)/2.)
2099 IF (BIG4.GT.BIG) BIG=BIG4
2100 IF (ABS(G(12)).LT.BIG*EBIG) G(12)=0
2101
2102 C REACTION5
2103 218 G(13)=-((ANM(2,J)+ANM(1,J))/2.+ratef5*((GLUA(2,J)+GLUA(1,J))/2.
2104 1 -(GLU(2,J)+GLU(1,J))/2./equilib5)
2105 B(13,1)=ratef5/2./equilib5
2106 B(13,14)=-ratef5/2.
2107 B(13,13)=+1./2.
2108
2109 BIG=ABS(ANM(2,J)/2.)
2110 BIG2=ABS(ANM(1,J)/2.)
2111 IF (BIG2.GT.BIG) BIG=BIG2
2112 BIG3=ABS(ratef5*GLUA(2,J)/2.)
2113 IF (BIG3.GT.BIG) BIG=BIG3
2114 BIG4=ABS(ratef5*GLUA(1,J)/2.)
2115 IF (BIG4.GT.BIG) BIG=BIG4
2116 BIG5=ABS(ratef5*GLU(2,J)/2./equilib5)
2117 IF (BIG5.GT.BIG) BIG=BIG5
2118 BIG6=ABS(ratef5*GLU(1,J)/2./equilib5)
2119 IF (BIG6.GT.BIG) BIG=BIG6
2120 IF (ABS(G(13)).LT.BIG*EBIG) G(13)=0.0
2121
2122 C For alpha Glucose , being consumed only
2123 G(14)=COEFF9HHH/2.*(GLUA(2,J+1)+GLUA(1,J+1)-GLUA(2,J)-GLUA(1,J))
2124 1 -COEFF9HHHH/2.*(GLUA(2,J)+GLUA(1,J)-GLUA(2,J-1)-GLUA(1,J-1))
2125 2 -(HHH/2.)*(3.*(ANM(2,J)+ANM(1,J))+(ANM(2,J+1)+ANM(1,J+1)))/8.
2126 3 -(HHHH/2.)*(3.*(ANM(2,J)+ANM(1,J))+(ANM(2,J-1)+ANM(1,J-1)))/8.
2127 4 -HHH/2.
2128 5 *(3.*(GLUA(2,J)-GLUA(1,J))+(GLUA(2,J+1)-GLUA(1,J+1)))/(4.*DT)
2129 6 -HHHH/2.
2130 7 *(3.*(GLUA(2,J)-GLUA(1,J))+(GLUA(2,J-1)-GLUA(1,J-1)))/(4.*DT)
2131
2132 B(14,14)=COEFF9HHH/2.+COEFF9HHHH/2.+HHH/2.*3./(4.*DT)
2133 1 +HHHH/2.*3./(4.*DT)
2134 D(14,14)=-COEFF9HHH/2.+HHH/2./(4.*DT)
2135 A(14,14)=-COEFF9HHHH/2.+HHHH/2./(4.*DT)
2136 B(14,13)=+(HHH/2.)*(3./8.)+(HHHH/2.)*(3./8.)
2137 D(14,13)=+(HHH/2.)*(1./8.)
2138 A(14,13)=+(HHHH/2.)*(1./8.)
2139
2140 BIG=ABS(COEFF9HHH/2.*GLUA(2,J+1))
2141 BIG2=ABS(COEFF9HHH/2.*GLUA(1,J+1))
2142 IF (BIG2.GT.BIG) BIG=BIG2

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2143 BIG3=ABS(COEFF9HHH/2.*GLUA(2,J))
2144 IF (BIG3.GT.BIG) BIG=BIG3
2145 BIG4=ABS(COEFF9HHH/2.*GLUA(1,J))
2146 IF (BIG4.GT.BIG) BIG=BIG4
2147 BIG5=ABS(COEFF9HHHH/2.*GLUA(2,J))
2148 IF (BIG5.GT.BIG) BIG=BIG5
2149 BIG6=ABS(COEFF9HHHH/2.*GLUA(1,J))
2150 IF (BIG6.GT.BIG) BIG=BIG6
2151 BIG7=ABS(COEFF9HHHH/2.*GLUA(2,J-1))
2152 IF (BIG7.GT.BIG) BIG=BIG7
2153 BIG8=ABS(COEFF9HHHH/2.*GLUA(1,J-1))
2154 IF (BIG8.GT.BIG) BIG=BIG8
2155 BIG9=ABS(HHH/2.*3.*GLUA(2,J)/(4.*DT))
2156 IF (BIG9.GT.BIG) BIG=BIG9
2157 BIG10=ABS(HHH/2.*3.*GLUA(1,J)/(4.*DT))
2158 IF (BIG10.GT.BIG) BIG=BIG10
2159 BIG11=ABS(HHH/2.*GLUA(2,J+1)/(4.*DT))
2160 IF (BIG11.GT.BIG) BIG=BIG11
2161 BIG12=ABS(HHH/2.*GLUA(1,J+1)/(4.*DT))
2162 IF (BIG12.GT.BIG) BIG=BIG12
2163 BIG13=ABS(HHHH/2.*3.*GLUA(2,J)/(4.*DT))
2164 IF (BIG13.GT.BIG) BIG=BIG13
2165 BIG14=ABS(HHHH/2.*3.*GLUA(1,J)/(4.*DT))
2166 IF (BIG14.GT.BIG) BIG=BIG14
2167 BIG15=ABS(HHHH/2.*GLUA(2,J-1)/(4.*DT))
2168 IF (BIG15.GT.BIG) BIG=BIG15
2169 BIG16=ABS(HHHH/2.*GLUA(1,J-1)/(4.*DT))
2170 IF (BIG16.GT.BIG) BIG=BIG16
2171 BIG17=ABS(HHH/2.*3.*ANM(2,J)/8.)
2172 IF (BIG17.GT.BIG) BIG=BIG17
2173 BIG18=ABS(HHH/2.*3.*ANM(1,J)/8.)
2174 IF (BIG18.GT.BIG) BIG=BIG18
2175 BIG19=ABS(HHH/2.*ANM(2,J+1)/8.)
2176 IF (BIG19.GT.BIG) BIG=BIG19
2177 BIG20=ABS(HHH/2.*ANM(1,J+1)/8.)
2178 IF (BIG20.GT.BIG) BIG=BIG20
2179 BIG21=ABS(HHHH/2.*3.*ANM(2,J)/8.)
2180 IF (BIG21.GT.BIG) BIG=BIG21
2181 BIG22=ABS(HHHH/2.*3.*ANM(1,J)/8.)
2182 IF (BIG22.GT.BIG) BIG=BIG22
2183 BIG23=ABS(HHHH/2.*ANM(2,J-1)/8.)
2184 IF (BIG23.GT.BIG) BIG=BIG23
2185 BIG24=ABS(HHHH/2.*ANM(1,J-1)/8.)
2186 IF (BIG24.GT.BIG) BIG=BIG24
2187 IF (ABS(G(14)).LT.BIG*EBIG) G(14)=0
2188
2189 C Gluconic acid dissociation
2190
2191 G(15)=equilib6*(GLA(2,J)+GLA(1,J))/2.-(GLI(2,J)+GLI(1,J))*
2192 1 (HYD(2,J)+HYD(1,J))/4.
2193 B(15,3)=-equilib6/2.
2194 B(15,15)=(HYD(2,J)+HYD(1,J))/4.
2195 B(15,16)=(GLI(2,J)+GLI(1,J))/4.
2196
2197 BIG=ABS(equilib6*GLA(2,J)/2.)
2198 BIG2=ABS(equilib6*GLA(1,J)/2.)
2199 IF (BIG2.GT.BIG) BIG=BIG2
2200 BIG3=ABS(GLI(2,J)*HYD(2,J)/4.)

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2201 IF (BIG3.GT.BIG) BIG=BIG3
2202 BIG4=ABS(GLI(2,J)*HYD(1,J)/4)
2203 IF (BIG4.GT.BIG) BIG=BIG4
2204 BIG5=ABS(GLI(1,J)*HYD(2,J)/4)
2205 IF (BIG5.GT.BIG) BIG=BIG5
2206 BIG6=ABS(GLI(1,J)*HYD(1,J)/4)
2207 IF (BIG6.GT.BIG) BIG=BIG6
2208 IF (ABS(G(15)).LT.BIG*EBIG) G(15)=0
2209
2210 C Hydrogen ion, hydroxide ion, gluconate ion, bicarbonate ion flux
2211 G(16)=COEFF11HHH/2.*(HYD(2,J+1)+HYD(1,J+1)-HYD(2,J)-HYD(1,J))
2212 1 -COEFF11HHHH/2.*(HYD(2,J)+HYD(1,J)-HYD(2,J-1)-HYD(1,J-1))
2213 2 -COEFF15HHH/2.*(OHI(2,J+1)+OHI(1,J+1)-OHI(2,J)-OHI(1,J))
2214 3 +COEFF15HHHH/2.*(OHI(2,J)+OHI(1,J)-OHI(2,J-1)-OHI(1,J-1))
2215 4 -COEFF10HHH/2.*(GLI(2,J+1)+GLI(1,J+1)-GLI(2,J)-GLI(1,J))
2216 5 +COEFF10HHHH/2.*(GLI(2,J)+GLI(1,J)-GLI(2,J-1)-GLI(1,J-1))
2217 6 -COEFF14HHH/2.*(CBI(2,J+1)+CBI(1,J+1)-CBI(2,J)-CBI(1,J))
2218 7 +COEFF14HHHH/2.*(CBI(2,J)+CBI(1,J)-CBI(2,J-1)-CBI(1,J-1))
2219 8 -HHH/2.*(3.*(HYD(2,J)-HYD(1,J))+(HYD(2,J+1)-HYD(1,J+1)))/(4.*DT)
2220 9 -HHHH/2.*(3.*(HYD(2,J)-HYD(1,J))+(HYD(2,J-1)-HYD(1,J-1)))/(4.*DT)
2221 1 +HHH/2.*(3.*(OHI(2,J)-OHI(1,J))+(OHI(2,J+1)-OHI(1,J+1)))/(4.*DT)
2222 2 +HHHH/2.*(3.*(OHI(2,J)-OHI(1,J))+(OHI(2,J-1)-OHI(1,J-1)))/(4.*DT)
2223 3 +HHH/2.*(3.*(GLI(2,J)-GLI(1,J))+(GLI(2,J+1)-GLI(1,J+1)))/(4.*DT)
2224 4 +HHHH/2.*(3.*(GLI(2,J)-GLI(1,J))+(GLI(2,J-1)-GLI(1,J-1)))/(4.*DT)
2225 5 +HHH/2.*(3.*(CBI(2,J)-CBI(1,J))+(CBI(2,J+1)-CBI(1,J+1)))/(4.*DT)
2226 6 +HHHH/2.*(3.*(CBI(2,J)-CBI(1,J))+(CBI(2,J-1)-CBI(1,J-1)))/(4.*DT)
2227
2228 B(16,16)=COEFF11HHH/2.+COEFF11HHHH/2.+HHH/2.*3./(4.*DT)
2229 1 +HHHH/2.*3./(4.*DT)
2230 D(16,16)=-COEFF11HHH/2.+HHH/2./(4.*DT)
2231 A(16,16)=-COEFF11HHHH/2.+HHHH/2./(4.*DT)
2232
2233 B(16,17)=-COEFF15HHH/2.-COEFF15HHHH/2.-HHH/2.*3./(4.*DT)
2234 1 -HHHH/2.*3./(4.*DT)
2235 D(16,17)=+COEFF15HHH/2.-HHH/2./(4.*DT)
2236 A(16,17)=+COEFF15HHHH/2.-HHHH/2./(4.*DT)
2237
2238 B(16,15)=-COEFF10HHH/2.-COEFF10HHHH/2.-HHH/2.*3./(4.*DT)
2239 1 -HHHH/2.*3./(4.*DT)
2240 D(16,15)=+COEFF10HHH/2.-HHH/2./(4.*DT)
2241 A(16,15)=+COEFF10HHHH/2.-HHHH/2./(4.*DT)
2242
2243 B(16,20)=-COEFF14HHH/2.-COEFF14HHHH/2.-HHH/2.*3./(4.*DT)
2244 1 -HHHH/2.*3./(4.*DT)
2245 D(16,20)=+COEFF14HHH/2.-HHH/2./(4.*DT)
2246 A(16,20)=+COEFF14HHHH/2.-HHHH/2./(4.*DT)
2247
2248 BIG=ABS(COEFF11HHH/2.*HYD(2,J+1))
2249 BIG2=ABS(COEFF11HHH/2.*HYD(1,J+1))
2250 IF (BIG2.GT.BIG) BIG=BIG2
2251 BIG3=ABS(COEFF11HHH/2.*HYD(2,J))
2252 IF (BIG3.GT.BIG) BIG=BIG3
2253 BIG4=ABS(COEFF11HHH/2.*HYD(1,J))
2254 IF (BIG4.GT.BIG) BIG=BIG4
2255 BIG5=ABS(COEFF11HHHH/2.*HYD(2,J))
2256 IF (BIG5.GT.BIG) BIG=BIG5
2257 BIG6=ABS(COEFF11HHHH/2.*HYD(1,J))
2258 IF (BIG6.GT.BIG) BIG=BIG6

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2259 BIG7=ABS(COEFF11HHHH/2.*HYD(2,J-1))
2260 IF (BIG7.GT.BIG) BIG=BIG7
2261 BIG8=ABS(COEFF11HHHH/2.*HYD(1,J-1))
2262 IF (BIG8.GT.BIG) BIG=BIG8
2263 BIG9=ABS(HHH/2.*3.*HYD(2,J)/(4.*DT))
2264 IF (BIG9.GT.BIG) BIG=BIG9
2265 BIG10=ABS(HHH/2.*3.*HYD(1,J)/(4.*DT))
2266 IF (BIG10.GT.BIG) BIG=BIG10
2267 BIG11=ABS(HHH/2.*HYD(2,J+1)/(4.*DT))
2268 IF (BIG11.GT.BIG) BIG=BIG11
2269 BIG12=ABS(HHH/2.*HYD(1,J+1)/(4.*DT))
2270 IF (BIG12.GT.BIG) BIG=BIG12
2271 BIG13=ABS(HHHH/2.*3.*HYD(2,J)/(4.*DT))
2272 IF (BIG13.GT.BIG) BIG=BIG13
2273 BIG14=ABS(HHHH/2.*3.*HYD(1,J)/(4.*DT))
2274 IF (BIG14.GT.BIG) BIG=BIG14
2275 BIG15=ABS(HHHH/2.*HYD(2,J-1)/(4.*DT))
2276 IF (BIG15.GT.BIG) BIG=BIG15
2277 BIG16=ABS(HHHH/2.*HYD(1,J-1)/(4.*DT))
2278 IF (BIG16.GT.BIG) BIG=BIG16
2279 BIG17=ABS(COEFF15HHH/2.*OHI(2,J+1))
2280 IF (BIG17.GT.BIG) BIG=BIG17
2281 BIG18=ABS(COEFF15HHH/2.*OHI(1,J+1))
2282 IF (BIG18.GT.BIG) BIG=BIG18
2283 BIG19=ABS(COEFF15HHH/2.*OHI(2,J))
2284 IF (BIG19.GT.BIG) BIG=BIG19
2285 BIG20=ABS(COEFF15HHH/2.*OHI(1,J))
2286 IF (BIG20.GT.BIG) BIG=BIG20
2287 BIG21=ABS(COEFF15HHHH/2.*OHI(2,J))
2288 IF (BIG21.GT.BIG) BIG=BIG21
2289 BIG22=ABS(COEFF15HHHH/2.*OHI(1,J))
2290 IF (BIG22.GT.BIG) BIG=BIG22
2291 BIG23=ABS(COEFF15HHHH/2.*OHI(2,J-1))
2292 IF (BIG23.GT.BIG) BIG=BIG23
2293 BIG24=ABS(COEFF15HHHH/2.*OHI(1,J-1))
2294 IF (BIG24.GT.BIG) BIG=BIG24
2295 BIG25=ABS(HHH/2.*3.*OHI(2,J)/(4.*DT))
2296 IF (BIG25.GT.BIG) BIG=BIG25
2297 BIG26=ABS(HHH/2.*3.*OHI(1,J)/(4.*DT))
2298 IF (BIG26.GT.BIG) BIG=BIG26
2299 BIG27=ABS(HHH/2.*OHI(2,J+1)/(4.*DT))
2300 IF (BIG27.GT.BIG) BIG=BIG27
2301 BIG28=ABS(HHH/2.*OHI(1,J+1)/(4.*DT))
2302 IF (BIG28.GT.BIG) BIG=BIG28
2303 BIG29=ABS(HHHH/2.*3.*OHI(2,J)/(4.*DT))
2304 IF (BIG29.GT.BIG) BIG=BIG29
2305 BIG30=ABS(HHHH/2.*3.*OHI(1,J)/(4.*DT))
2306 IF (BIG30.GT.BIG) BIG=BIG30
2307 BIG31=ABS(HHHH/2.*OHI(2,J-1)/(4.*DT))
2308 IF (BIG31.GT.BIG) BIG=BIG31
2309 BIG32=ABS(HHHH/2.*OHI(1,J-1)/(4.*DT))
2310 IF (BIG32.GT.BIG) BIG=BIG32
2311 BIG33=ABS(COEFF10HHH/2.*GLI(2,J+1))
2312 IF (BIG33.GT.BIG) BIG=BIG33
2313 BIG34=ABS(COEFF10HHH/2.*GLI(1,J+1))
2314 IF (BIG34.GT.BIG) BIG=BIG34
2315 BIG35=ABS(COEFF10HHH/2.*GLI(2,J))
2316 IF (BIG35.GT.BIG) BIG=BIG35

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2317 BIG36=ABS(COEFF10HHH/2.*GLI(1,J))
2318 IF (BIG36.GT.BIG) BIG=BIG36
2319 BIG37=ABS(COEFF10HHHH/2.*GLI(2,J))
2320 IF (BIG37.GT.BIG) BIG=BIG37
2321 BIG38=ABS(COEFF10HHHH/2.*GLI(1,J))
2322 IF (BIG38.GT.BIG) BIG=BIG38
2323 BIG39=ABS(COEFF10HHHH/2.*GLI(2,J-1))
2324 IF (BIG39.GT.BIG) BIG=BIG39
2325 BIG40=ABS(COEFF10HHHH/2.*GLI(1,J-1))
2326 IF (BIG40.GT.BIG) BIG=BIG40
2327 BIG41=ABS(HHH/2.*3.*GLI(2,J)/(4.*DT))
2328 IF (BIG41.GT.BIG) BIG=BIG41
2329 BIG42=ABS(HHH/2.*3.*GLI(1,J)/(4.*DT))
2330 IF (BIG42.GT.BIG) BIG=BIG42
2331 BIG43=ABS(HHH/2.*GLI(2,J+1)/(4.*DT))
2332 IF (BIG43.GT.BIG) BIG=BIG43
2333 BIG44=ABS(HHH/2.*GLI(1,J+1)/(4.*DT))
2334 IF (BIG44.GT.BIG) BIG=BIG44
2335 BIG45=ABS(HHHH/2.*3.*GLI(2,J)/(4.*DT))
2336 IF (BIG45.GT.BIG) BIG=BIG45
2337 BIG46=ABS(HHHH/2.*3.*GLI(1,J)/(4.*DT))
2338 IF (BIG46.GT.BIG) BIG=BIG46
2339 BIG47=ABS(HHHH/2.*GLI(2,J-1)/(4.*DT))
2340 IF (BIG47.GT.BIG) BIG=BIG47
2341 BIG48=ABS(HHHH/2.*GLI(1,J-1)/(4.*DT))
2342 IF (BIG48.GT.BIG) BIG=BIG48
2343 BIG49=ABS(COEFF14HHH/2.*CBI(2,J+1))
2344 IF (BIG49.GT.BIG) BIG=BIG49
2345 BIG50=ABS(COEFF14HHH/2.*CBI(1,J+1))
2346 IF (BIG50.GT.BIG) BIG=BIG50
2347 BIG51=ABS(COEFF14HHH/2.*CBI(2,J))
2348 IF (BIG51.GT.BIG) BIG=BIG51
2349 BIG52=ABS(COEFF14HHH/2.*CBI(1,J))
2350 IF (BIG52.GT.BIG) BIG=BIG52
2351 BIG53=ABS(COEFF14HHHH/2.*CBI(2,J))
2352 IF (BIG53.GT.BIG) BIG=BIG53
2353 BIG54=ABS(COEFF14HHHH/2.*CBI(1,J))
2354 IF (BIG54.GT.BIG) BIG=BIG54
2355 BIG55=ABS(COEFF14HHHH/2.*CBI(2,J-1))
2356 IF (BIG55.GT.BIG) BIG=BIG55
2357 BIG56=ABS(COEFF14HHHH/2.*CBI(1,J-1))
2358 IF (BIG56.GT.BIG) BIG=BIG56
2359 BIG57=ABS(HHH/2.*3.*CBI(2,J)/(4.*DT))
2360 IF (BIG57.GT.BIG) BIG=BIG57
2361 BIG58=ABS(HHH/2.*3.*CBI(1,J)/(4.*DT))
2362 IF (BIG58.GT.BIG) BIG=BIG58
2363 BIG59=ABS(HHH/2.*CBI(2,J+1)/(4.*DT))
2364 IF (BIG59.GT.BIG) BIG=BIG59
2365 BIG60=ABS(HHH/2.*CBI(1,J+1)/(4.*DT))
2366 IF (BIG60.GT.BIG) BIG=BIG60
2367 BIG61=ABS(HHHH/2.*3.*CBI(2,J)/(4.*DT))
2368 IF (BIG61.GT.BIG) BIG=BIG61
2369 BIG62=ABS(HHHH/2.*3.*CBI(1,J)/(4.*DT))
2370 IF (BIG62.GT.BIG) BIG=BIG62
2371 BIG63=ABS(HHHH/2.*CBI(2,J-1)/(4.*DT))
2372 IF (BIG63.GT.BIG) BIG=BIG63
2373 BIG64=ABS(HHHH/2.*CBI(1,J-1)/(4.*DT))
2374 IF (BIG64.GT.BIG) BIG=BIG64

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2375     IF (ABS(G(16)).LT.BIG*EBIG) G(16)=0
2376
2377 c Water Dissociation
2378     G(17)=equilib9 -(HYD(2,J)+HYD(1,J))*(OHI(2,J)+OHI(1,J))/4.
2379     B(17,17)=(HYD(2,J)+HYD(1,J))/4.
2380     B(17,16)=(OHI(2,J)+OHI(1,J))/4.
2381
2382     BIG=ABS(equilib9)
2383     BIG2=ABS(HYD(2,J)*OHI(2,J)/4.)
2384     IF (BIG2.GT.BIG) BIG=BIG2
2385     BIG3=ABS(HYD(2,J)*OHI(1,J)/4.)
2386     IF (BIG3.GT.BIG) BIG=BIG3
2387     BIG4=ABS(HYD(1,J)*OHI(2,J)/4.)
2388     IF (BIG4.GT.BIG) BIG=BIG4
2389     BIG5=ABS(HYD(1,J)*OHI(1,J)/4.)
2390     IF (BIG5.GT.BIG) BIG=BIG5
2391     IF (ABS(G(17)).LT.BIG*EBIG) G(17)=0
2392
2393 C CO2 Hydration
2394
2395     G(18)=equilib7 *(CO2(2,J)+CO2(1,J))/2. -(CBA(2,J)+CBA(1,J))/2.
2396     B(18,18)=-equilib7/2.
2397     B(18,19)=1./2.
2398
2399     BIG=ABS(equilib7*CO2(2,J)/2.)
2400     BIG2=ABS(equilib7*CO2(1,J)/2.)
2401     IF (BIG2.GT.BIG) BIG=BIG2
2402     BIG3=ABS(CBA(2,J)/2.)
2403     IF (BIG3.GT.BIG) BIG=BIG3
2404     BIG4=ABS(CBA(1,J)/2.)
2405     IF (BIG4.GT.BIG) BIG=BIG4
2406     IF (ABS(G(18)).LT.BIG*EBIG) G(18)=0
2407
2408 C Carbonic acid dissociation
2409
2410     G(19)=equilib8 *(CBA(2,J)+CBA(1,J))/2. -(CBI(2,J)+CBI(1,J))
2411 1 *(HYD(2,J)+HYD(1,J))/4.
2412     B(19,19)=-equilib8/2.
2413     B(19,20)=(HYD(2,J)+HYD(1,J))/4.
2414     B(19,16)=(CBI(2,J)+CBI(1,J))/4.
2415
2416     BIG=ABS(equilib8*CBA(2,J)/2.)
2417     BIG2=ABS(equilib8*CBA(1,J)/2.)
2418     IF (BIG2.GT.BIG) BIG=BIG2
2419     BIG3=ABS(CBI(2,J)*HYD(2,J)/4.)
2420     IF (BIG3.GT.BIG) BIG=BIG3
2421     BIG4=ABS(CBI(2,J)*HYD(1,J)/4.)
2422     IF (BIG4.GT.BIG) BIG=BIG4
2423     BIG5=ABS(CBI(1,J)*HYD(2,J)/4.)
2424     IF (BIG5.GT.BIG) BIG=BIG5
2425     BIG6=ABS(CBI(1,J)*HYD(1,J)/4.)
2426     IF (BIG6.GT.BIG) BIG=BIG6
2427     IF (ABS(G(19)).LT.BIG*EBIG) G(19)=0
2428
2429 C FLUX OF CO2, CARBONIC ACID, BICARBONATE ION
2430     G(20)=COEFF12HHH/2. *(CO2(2,J+1)+CO2(1,J+1)-CO2(2,J)-CO2(1,J))
2431 1 -COEFF12HHHH/2. *(CO2(2,J)+CO2(1,J)-CO2(2,J-1)-CO2(1,J-1))
2432 2 +COEFF13HHH/2. *(CBA(2,J+1)+CBA(1,J+1)-CBA(2,J)-CBA(1,J))

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2433 3 -COEFF13HHHH/2. *(CBA(2, J)+CBA(1, J)-CBA(2, J-1)-CBA(1, J-1))
2434 4 +COEFF14HHH/2. *(CBI(2, J+1)+CBI(1, J+1)-CBI(2, J)-CBI(1, J))
2435 5 -COEFF14HHHH/2. *(CBI(2, J)+CBI(1, J)-CBI(2, J-1)-CBI(1, J-1))
2436 6 -HHH/2. *(3. *(CO2(2, J)-CO2(1, J))+(CO2(2, J+1)-CO2(1, J+1)))/(4. *DT)
2437 7 -HHHH/2. *(3. *(CO2(2, J)-CO2(1, J))+(CO2(2, J-1)-CO2(1, J-1)))/(4. *DT)
2438 8 -HHH/2. *(3. *(CBA(2, J)-CBA(1, J))+(CBA(2, J+1)-CBA(1, J+1)))/(4. *DT)
2439 9 -HHHH/2. *(3. *(CBA(2, J)-CBA(1, J))+(CBA(2, J-1)-CBA(1, J-1)))/(4. *DT)
2440 1 -HHH/2. *(3. *(CBI(2, J)-CBI(1, J))+(CBI(2, J+1)-CBI(1, J+1)))/(4. *DT)
2441 2 -HHHH/2. *(3. *(CBI(2, J)-CBI(1, J))+(CBI(2, J-1)-CBI(1, J-1)))/(4. *DT)
2442
2443 B(20,20)=COEFF14HHH/2. +COEFF14HHHH/2. +HHH/2. *3./(4. *DT)
2444 1 +HHHH/2. *3./(4. *DT)
2445 D(20,20)=-COEFF14HHH/2. +HHH/2./(4. *DT)
2446 A(20,20)=-COEFF14HHHH/2. +HHHH/2./(4. *DT)
2447 B(20,18)=COEFF12HHH/2. +COEFF12HHHH/2. +HHH/2. *3./(4. *DT)
2448 1 +HHHH/2. *3./(4. *DT)
2449 D(20,18)=-COEFF12HHH/2. +HHH/2./(4. *DT)
2450 A(20,18)=-COEFF12HHHH/2. +HHHH/2./(4. *DT)
2451 B(20,19)=COEFF13HHH/2. +COEFF13HHHH/2. +HHH/2. *3./(4. *DT)
2452 1 +HHHH/2. *3./(4. *DT)
2453 D(20,19)=-COEFF13HHH/2. +HHH/2./(4. *DT)
2454 A(20,19)=-COEFF13HHHH/2. +HHHH/2./(4. *DT)
2455
2456 BIG=ABS(COEFF12HHH/2. *CO2(2, J+1))
2457 BIG2=ABS(COEFF12HHH/2. *CO2(1, J+1))
2458 IF (BIG2.GT. BIG) BIG=BIG2
2459 BIG3=ABS(COEFF12HHH/2. *CO2(2, J))
2460 IF (BIG3.GT. BIG) BIG=BIG3
2461 BIG4=ABS(COEFF12HHH/2. *CO2(1, J))
2462 IF (BIG4.GT. BIG) BIG=BIG4
2463 BIG5=ABS(COEFF12HHHH/2. *CO2(2, J))
2464 IF (BIG5.GT. BIG) BIG=BIG5
2465 BIG6=ABS(COEFF12HHHH/2. *CO2(1, J))
2466 IF (BIG6.GT. BIG) BIG=BIG6
2467 BIG7=ABS(COEFF12HHHH/2. *CO2(2, J-1))
2468 IF (BIG7.GT. BIG) BIG=BIG7
2469 BIG8=ABS(COEFF12HHHH/2. *CO2(1, J-1))
2470 IF (BIG8.GT. BIG) BIG=BIG8
2471 BIG9=ABS(HHH/2. *3. *CO2(2, J)/(4. *DT))
2472 IF (BIG9.GT. BIG) BIG=BIG9
2473 BIG10=ABS(HHH/2. *3. *CO2(1, J)/(4. *DT))
2474 IF (BIG10.GT. BIG) BIG=BIG10
2475 BIG11=ABS(HHH/2. *CO2(2, J+1)/(4. *DT))
2476 IF (BIG11.GT. BIG) BIG=BIG11
2477 BIG12=ABS(HHH/2. *CO2(1, J+1)/(4. *DT))
2478 IF (BIG12.GT. BIG) BIG=BIG12
2479 BIG13=ABS(HHHH/2. *3. *CO2(2, J)/(4. *DT))
2480 IF (BIG13.GT. BIG) BIG=BIG13
2481 BIG14=ABS(HHHH/2. *3. *CO2(1, J)/(4. *DT))
2482 IF (BIG14.GT. BIG) BIG=BIG14
2483 BIG15=ABS(HHHH/2. *CO2(2, J-1)/(4. *DT))
2484 IF (BIG15.GT. BIG) BIG=BIG15
2485 BIG16=ABS(HHHH/2. *CO2(1, J-1)/(4. *DT))
2486 IF (BIG16.GT. BIG) BIG=BIG16
2487 BIG17=ABS(COEFF13HHH/2. *CBA(2, J+1))
2488 IF (BIG17.GT. BIG) BIG=BIG17
2489 BIG18=ABS(COEFF13HHH/2. *CBA(1, J+1))
2490 IF (BIG18.GT. BIG) BIG=BIG18

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2491 BIG19=ABS(COEFF13HHH/2.*CBA(2,J))
2492 IF (BIG19.GT.BIG) BIG=BIG19
2493 BIG20=ABS(COEFF13HHH/2.*CBA(1,J))
2494 IF (BIG20.GT.BIG) BIG=BIG20
2495 BIG21=ABS(COEFF13HHHH/2.*CBA(2,J))
2496 IF (BIG21.GT.BIG) BIG=BIG21
2497 BIG22=ABS(COEFF13HHHH/2.*CBA(1,J))
2498 IF (BIG22.GT.BIG) BIG=BIG22
2499 BIG23=ABS(COEFF13HHHH/2.*CBA(2,J-1))
2500 IF (BIG23.GT.BIG) BIG=BIG23
2501 BIG24=ABS(COEFF13HHHH/2.*CBA(1,J-1))
2502 IF (BIG24.GT.BIG) BIG=BIG24
2503 BIG25=ABS(HHH/2.*3.*CBA(2,J)/(4.*DT))
2504 IF (BIG25.GT.BIG) BIG=BIG25
2505 BIG26=ABS(HHH/2.*3.*CBA(1,J)/(4.*DT))
2506 IF (BIG26.GT.BIG) BIG=BIG26
2507 BIG27=ABS(HHH/2.*CBA(2,J+1)/(4.*DT))
2508 IF (BIG27.GT.BIG) BIG=BIG27
2509 BIG28=ABS(HHH/2.*CBA(1,J+1)/(4.*DT))
2510 IF (BIG28.GT.BIG) BIG=BIG28
2511 BIG29=ABS(HHHH/2.*3.*CBA(2,J)/(4.*DT))
2512 IF (BIG29.GT.BIG) BIG=BIG29
2513 BIG30=ABS(HHHH/2.*3.*CBA(1,J)/(4.*DT))
2514 IF (BIG30.GT.BIG) BIG=BIG30
2515 BIG31=ABS(HHHH/2.*CBA(2,J-1)/(4.*DT))
2516 IF (BIG31.GT.BIG) BIG=BIG31
2517 BIG32=ABS(HHHH/2.*CBA(1,J-1)/(4.*DT))
2518 IF (BIG32.GT.BIG) BIG=BIG32
2519 BIG33=ABS(COEFF14HHH/2.*CBI(2,J+1))
2520 IF (BIG33.GT.BIG) BIG=BIG33
2521 BIG34=ABS(COEFF14HHH/2.*CBI(1,J+1))
2522 IF (BIG34.GT.BIG) BIG=BIG34
2523 BIG35=ABS(COEFF14HHH/2.*CBI(2,J))
2524 IF (BIG35.GT.BIG) BIG=BIG35
2525 BIG36=ABS(COEFF14HHH/2.*CBI(1,J))
2526 IF (BIG36.GT.BIG) BIG=BIG36
2527 BIG37=ABS(COEFF14HHHH/2.*CBI(2,J))
2528 IF (BIG37.GT.BIG) BIG=BIG37
2529 BIG38=ABS(COEFF14HHHH/2.*CBI(1,J))
2530 IF (BIG38.GT.BIG) BIG=BIG38
2531 BIG39=ABS(COEFF14HHHH/2.*CBI(2,J-1))
2532 IF (BIG39.GT.BIG) BIG=BIG39
2533 BIG40=ABS(COEFF14HHHH/2.*CBI(1,J-1))
2534 IF (BIG40.GT.BIG) BIG=BIG40
2535 BIG41=ABS(HHH/2.*3.*CBI(2,J)/(4.*DT))
2536 IF (BIG41.GT.BIG) BIG=BIG41
2537 BIG42=ABS(HHH/2.*3.*CBI(1,J)/(4.*DT))
2538 IF (BIG42.GT.BIG) BIG=BIG42
2539 BIG43=ABS(HHH/2.*CBI(2,J+1)/(4.*DT))
2540 IF (BIG43.GT.BIG) BIG=BIG43
2541 BIG44=ABS(HHH/2.*CBI(1,J+1)/(4.*DT))
2542 IF (BIG44.GT.BIG) BIG=BIG44
2543 BIG45=ABS(HHHH/2.*3.*CBI(2,J)/(4.*DT))
2544 IF (BIG45.GT.BIG) BIG=BIG45
2545 BIG46=ABS(HHHH/2.*3.*CBI(1,J)/(4.*DT))
2546 IF (BIG46.GT.BIG) BIG=BIG46
2547 BIG47=ABS(HHHH/2.*CBI(2,J-1)/(4.*DT))
2548 IF (BIG47.GT.BIG) BIG=BIG47

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2549     BIG48=ABS(HHHH/2.*CBI(1,J-1)/(4.*DT))
2550     IF (BIG48.GT.BIG) BIG=BIG48
2551     IF (ABS(G(20)).LT.BIG*EBIG) G(20)=0
2552
2553 C FOR ACETAMINOPHEN
2554
2555     G(21)=COEFF16HHH/2.*(ACE(2,J+1)+ACE(1,J+1)-ACE(2,J)-ACE(1,J))
2556     1 -COEFF16HHHH/2.*(ACE(2,J)+ACE(1,J)-ACE(2,J-1)-ACE(1,J-1))
2557     4 -HHH/2.*(3.*(ACE(2,J)-ACE(1,J))+(ACE(2,J+1)-ACE(1,J+1)))/(4.*DT)
2558     5 -HHHH/2.*(3.*(ACE(2,J)-ACE(1,J))+(ACE(2,J-1)-ACE(1,J-1)))/(4.*DT)
2559
2560     B(21,21)=COEFF16HHH/2.+COEFF16HHHH/2.
2561     1 +HHH/2.*3./(4.*DT)+HHHH/2.*3./(4.*DT)
2562     D(21,21)=-COEFF16HHH/2.+HHH/2./(4.*DT)
2563     A(21,21)=-COEFF16HHHH/2.+HHHH/2./(4.*DT)
2564
2565
2566
2567     BIG=ABS(COEFF16HHH/2.*ACE(2,J+1))
2568     BIG2=ABS(COEFF16HHH/2.*ACE(1,J+1))
2569     IF (BIG2.GT.BIG) BIG=BIG2
2570     BIG3=ABS(COEFF16HHH/2.*ACE(2,J))
2571     IF (BIG3.GT.BIG) BIG=BIG3
2572     BIG4=ABS(COEFF16HHH/2.*ACE(1,J))
2573     IF (BIG4.GT.BIG) BIG=BIG4
2574     BIG5=ABS(COEFF16HHHH/2.*ACE(2,J))
2575     IF (BIG5.GT.BIG) BIG=BIG5
2576     BIG6=ABS(COEFF16HHHH/2.*ACE(1,J))
2577     IF (BIG6.GT.BIG) BIG=BIG6
2578     BIG7=ABS(COEFF16HHHH/2.*ACE(2,J-1))
2579     IF (BIG7.GT.BIG) BIG=BIG7
2580     BIG8=ABS(COEFF16HHHH/2.*ACE(1,J-1))
2581     IF (BIG8.GT.BIG) BIG=BIG8
2582     BIG17=ABS(HHH/2.*3.*ACE(2,J)/(4.*DT))
2583     IF (BIG17.GT.BIG) BIG=BIG17
2584     BIG18=ABS(HHH/2.*3.*ACE(1,J)/(4.*DT))
2585     IF (BIG18.GT.BIG) BIG=BIG18
2586     BIG19=ABS(HHH/2.*ACE(2,J+1)/(4.*DT))
2587     IF (BIG19.GT.BIG) BIG=BIG19
2588     BIG20=ABS(HHH/2.*ACE(1,J+1)/(4.*DT))
2589     IF (BIG20.GT.BIG) BIG=BIG20
2590     BIG21=ABS(HHHH/2.*3.*ACE(2,J)/(4.*DT))
2591     IF (BIG21.GT.BIG) BIG=BIG21
2592     BIG22=ABS(HHHH/2.*3.*ACE(1,J)/(4.*DT))
2593     IF (BIG22.GT.BIG) BIG=BIG22
2594     BIG23=ABS(HHHH/2.*ACE(2,J-1)/(4.*DT))
2595     IF (BIG23.GT.BIG) BIG=BIG23
2596     BIG24=ABS(HHHH/2.*ACE(1,J-1)/(4.*DT))
2597     IF (BIG24.GT.BIG) BIG=BIG24
2598     IF (ABS(G(21)).LT.BIG*EBIG) G(21)=0
2599
2600 C     DOUBLE LAYER VOLTAGE DUMMY VARIABLE
2601
2602     G(22)=(VDL(2,J)+VDL(1,J))/2.
2603
2604     B(22,22)=-1./2.
2605
2606     BIG=ABS(VDL(2,J)/2.)

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2607     BIG2=ABS(VDL(1,J)/2.)
2608     IF (BIG2.GT.BIG) BIG=BIG2
2609     IF (ABS(G(22)).LT.BIG*EBIG) G(22)=0
2610
2611
2612 C   212 WRITE(12,301) J, (G(K),K=1,N)
2613     RETURN
2614     END
2615
2616
2617     SUBROUTINE REACTION(J)
2618     IMPLICIT DOUBLE PRECISION (A-H, O-Z)
2619     COMMON/BAB/ A(22,22),B(22,22),C(22,80001),D(22,45),G(22),X(22,22)
2620     1 ,Y(22,22)
2621     COMMON/NSN/ N, NJ
2622     COMMON/GLC/ NTIME,LL
2623     COMMON/VAR/ DIFF(16),H,EBIG,HH,IJ,KJ,TT,VAP,HHH,DT,RE,AKB,BB,CDL
2624     COMMON/VARR/ HHHH,HHHHH,MJ,LJ
2625     COMMON/DIN/ DGOX(16),DGLM(16),DIRM(16),DBULK(16)
2626     COMMON/SPCI/ GLU(2,80001),GOX(2,80001),GLA(2,80001),GOR(2,80001)
2627     COMMON/SPCII/ OXY(2,80001),HPR(2,80001),GOA(2,80001),GOP(2,80001)
2628     COMMON/RXT/ EQ1(2,80001),RGA(2,80001),EQ2(2,80001),RHP(2,80001)
2629     COMMON/SPCIII/ ANM(2,80001),GLUA(2,80001),GLI(2,80001)
2630     COMMON/SPCIV/ HYD(2,80001),OHI(2,80001),CO2(2,80001),CBA(2,80001)
2631     COMMON/SPCV/ CBI(2,80001),ACE(2,80001)
2632     COMMON/VOL/ VDL(2,80001)
2633     COMMON/POR/ POR1,POR2,PORGLU,PARION,PARACE
2634     COMMON/RTE/ ratef1,equilib1,ratef2,ratef3,equilib3,ratef4
2635     COMMON/RTD/ ratef5,equilib5,equilib6,equilib7,equilib8,equilib9
2636     COMMON/BUL/ CBULK(16),PARH2O2,PARO2,PARGLUOSE,JCOUNT
2637
2638     301 FORMAT (5x,'J=' I5, 13E18.9)
2639
2640 C   For Glucose, being consumed only
2641     G(1)=DGOX(1)*(GLU(2,J+1)-2.*GLU(2,J)+GLU(2,J-1)
2642     1 +GLU(1,J+1)-2.*GLU(1,J)+GLU(1,J-1))/(2.*HHH**2.)
2643     2 +(ANM(2,J)+ANM(1,J))/2.
2644     3 -(EQ1(2,J)+EQ1(1,J))/2.-(GLU(2,J)-GLU(1,J))/DT
2645
2646     B(1,1)=DGOX(1)/HHH**2.+1./DT
2647     D(1,1)=-DGOX(1)/(2.*HHH**2.)
2648     A(1,1)=-DGOX(1)/(2.*HHH**2.)
2649     B(1,9)=+1./2.
2650     B(1,13)=-1./2.
2651
2652     BIG=ABS(DGOX(1)*(GLU(2,J+1))/(2.*HHH**2.))
2653     BIG2=ABS(DGOX(1)*(GLU(2,J))/(HHH**2.))
2654     IF (BIG2.GT.BIG) BIG=BIG2
2655     BIG3=ABS(DGOX(1)*(GLU(2,J-1))/(2.*HHH**2.))
2656     IF (BIG3.GT.BIG) BIG=BIG3
2657     BIG4=ABS(DGOX(1)*(GLU(1,J+1))/(2.*HHH**2.))
2658     IF (BIG4.GT.BIG) BIG=BIG4
2659     BIG5=ABS(DGOX(1)*(GLU(1,J))/(HHH**2.))
2660     IF (BIG5.GT.BIG) BIG=BIG5
2661     BIG6=ABS(DGOX(1)*(GLU(1,J-1))/(2.*HHH**2.))
2662     IF (BIG6.GT.BIG) BIG=BIG6
2663     BIG7=ABS(EQ1(2,J)/2.)
2664     IF (BIG7.GT.BIG) BIG=BIG7

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2665     BIG8=ABS(EQ1(1,J)/2.)
2666     IF (BIG8.GT.BIG) BIG=BIG8
2667     BIG9=ABS(GLU(2,J)/DT)
2668     IF (BIG9.GT.BIG) BIG=BIG9
2669     BIG10=ABS(GLU(1,J)/DT)
2670     IF (BIG10.GT.BIG) BIG=BIG10
2671     BIG11=ABS(ANM(2,J)/2.)
2672     IF (BIG11.GT.BIG) BIG=BIG11
2673     BIG12=ABS(ANM(1,J)/2.)
2674     IF (BIG12.GT.BIG) BIG=BIG12
2675     IF (ABS(G(1)).LT.BIG*EBIG) G(1)=0
2676
2677 C     For GOx, enzyme
2678     G(2)=-((EQ1(2,J)+EQ1(1,J))/2.+(RHP(2,J)+RHP(1,J))/2.
2679 1  -(GOX(2,J)-GOX(1,J))/DT
2680     B(2,2)=+1./DT
2681     B(2,9)=+1./2.
2682     B(2,12)=-1./2.
2683
2684
2685     IF (ABS(EQ1(2,J)).GT.BIG) BIG=ABS(EQ1(2,J))
2686     IF (ABS(EQ1(1,J)).GT.BIG) BIG=ABS(EQ1(1,J))
2687     IF (ABS(RHP(2,J)).GT.BIG) BIG=ABS(RHP(2,J))
2688     IF (ABS(RHP(1,J)).GT.BIG) BIG=ABS(RHP(1,J))
2689     IF (ABS(GOX(2,J)/DT).GT.BIG) BIG=ABS(GOX(2,J)/DT)
2690     IF (ABS(GOX(1,J)/DT).GT.BIG) BIG=ABS(GOX(1,J)/DT)
2691     IF (ABS(G(2)).LT.BIG*EBIG) G(2)=0
2692
2693 C     For Gluconic Acid, being produced only
2694     G(3)=DGOX(3)*(GLA(2,J+1)-2.*GLA(2,J)+GLA(2,J-1)
2695 1  +GLA(1,J+1)-2.*GLA(1,J)+GLA(1,J-1))/(2.*HHH**2.)
2696 2  +DGOX(10)*(GLI(2,J+1)-2.*GLI(2,J)+GLI(2,J-1)
2697 3  +GLI(1,J+1)-2.*GLI(1,J)+GLI(1,J-1))/(2.*HHH**2.)
2698 4  +(RGA(2,J)+RGA(1,J))/2.-(GLA(2,J)-GLA(1,J))/DT
2699 5  -(GLI(2,J)-GLI(1,J))/DT
2700
2701     B(3,3)=DGOX(3)/HHH**2.+1./DT
2702     B(3,10)=-1./2.
2703     D(3,3)=-DGOX(3)/(2.*HHH**2.)
2704     A(3,3)=-DGOX(3)/(2.*HHH**2.)
2705     B(3,15)=DGOX(10)/HHH**2.+1./DT
2706     D(3,15)=-DGOX(10)/(2.*HHH**2.)
2707     A(3,15)=-DGOX(10)/(2.*HHH**2.)
2708
2709     BIG=ABS(DGOX(3)*GLA(2,J+1)/(2.*HHH**2.))
2710     BIG2=ABS(DGOX(3)*GLA(2,J)/(HHH**2.))
2711     IF (BIG2.GT.BIG) BIG=BIG2
2712     BIG3=ABS(DGOX(3)*GLA(2,J-1)/(2.*HHH**2.))
2713     IF (BIG3.GT.BIG) BIG=BIG3
2714     BIG4=ABS(DGOX(3)*GLA(1,J+1)/(2.*HHH**2.))
2715     IF (BIG4.GT.BIG) BIG=BIG4
2716     BIG5=ABS(DGOX(3)*GLA(1,J)/(HHH**2.))
2717     IF (BIG5.GT.BIG) BIG=BIG5
2718     BIG6=ABS(DGOX(3)*GLA(1,J-1)/(2.*HHH**2.))
2719     IF (BIG6.GT.BIG) BIG=BIG6
2720     BIG7=ABS(DGOX(10)*GLI(2,J+1)/(2.*HHH**2.))
2721     IF (BIG7.GT.BIG) BIG=BIG7
2722     BIG8=ABS(DGOX(10)*GLI(2,J)/(HHH**2.))

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2723 IF (BIG8.GT.BIG) BIG=BIG8
2724 BIG9=ABS(DGOX(10)*GLI(2,J-1)/(2.*HHH**2.))
2725 IF (BIG9.GT.BIG) BIG=BIG9
2726 BIG10=ABS(DGOX(10)*GLI(1,J+1)/(2.*HHH**2.))
2727 IF (BIG10.GT.BIG) BIG=BIG10
2728 BIG11=ABS(DGOX(10)*GLI(1,J)/(HHH**2.))
2729 IF (BIG11.GT.BIG) BIG=BIG11
2730 BIG12=ABS(DGOX(10)*GLI(1,J-1)/(2.*HHH**2.))
2731 IF (BIG12.GT.BIG) BIG=BIG12
2732 BIG13=ABS(RGA(2,J)/2.)
2733 IF (BIG13.GT.BIG) BIG=BIG13
2734 BIG14=ABS(RGA(1,J)/2)
2735 IF (BIG14.GT.BIG) BIG=BIG14
2736 BIG15=ABS(GLA(2,J)/DT)
2737 IF (BIG15.GT.BIG) BIG=BIG15
2738 BIG16=ABS(GLA(1,J)/DT)
2739 IF (BIG16.GT.BIG) BIG=BIG16
2740 BIG17=ABS(GLI(2,J)/DT)
2741 IF (BIG17.GT.BIG) BIG=BIG17
2742 BIG18=ABS(GLI(1,J)/DT)
2743 IF (BIG18.GT.BIG) BIG=BIG18
2744 IF (ABS(G(3)).LT.BIG*EBIG) G(3)=0
2745
2746 G(4)=CBULK(2)+CBULK(4)+CBULK(7)+CBULK(8)-(GOX(2,J)+GOX(1,J))/2.
2747 1 -(GOR(2,J)+GOR(1,J))/2.-(GOA(2,J)+GOA(1,J))/2.
2748 2 -(GOP(2,J)+GOP(1,J))/2.
2749 B(4,4)=+1./2.
2750 B(4,2)=+1./2.
2751 B(4,7)=+1./2.
2752 B(4,8)=+1./2.
2753
2754 BIG=ABS(CBULK(2))
2755 IF (ABS(CBULK(4)).GT.BIG) BIG=ABS(CBULK(4))
2756 IF (ABS(CBULK(7)).GT.BIG) BIG=ABS(CBULK(7))
2757 IF (ABS(CBULK(8)).GT.BIG) BIG=ABS(CBULK(8))
2758 IF (ABS(GOX(2,J)/2.).GT.BIG) BIG=ABS(GOX(2,J)/2.)
2759 IF (ABS(GOX(1,J)/2.).GT.BIG) BIG=ABS(GOX(1,J)/2.)
2760 IF (ABS(GOR(2,J)/2.).GT.BIG) BIG=ABS(GOR(2,J)/2.)
2761 IF (ABS(GOR(1,J)/2.).GT.BIG) BIG=ABS(GOR(1,J)/2.)
2762 IF (ABS(GOA(2,J)/2.).GT.BIG) BIG=ABS(GOA(2,J)/2.)
2763 IF (ABS(GOA(1,J)/2.).GT.BIG) BIG=ABS(GOA(1,J)/2.)
2764 IF (ABS(GOP(2,J)/2.).GT.BIG) BIG=ABS(GOP(2,J)/2.)
2765 IF (ABS(GOP(1,J)/2.).GT.BIG) BIG=ABS(GOP(1,J)/2.)
2766 IF (ABS(G(4)).LT.BIG*EBIG) G(4)=0
2767
2768
2769 C For O2, being consumed only, Diff(5), OXY,G5,EQ2
2770 G(5)=DGOX(5)*(OXY(2,J+1)-2.*OXY(2,J)+OXY(2,J-1)
2771 1 +OXY(1,J+1)-2.*OXY(1,J)+OXY(1,J-1))/(2.*HHH**2.)
2772 2 -(EQ2(2,J)+EQ2(1,J))/2.-(OXY(2,J)-OXY(1,J))/DT
2773
2774
2775 B(5,5)=DGOX(5)/HHH**2.+1./DT
2776 B(5,11)=1./2.
2777 D(5,5)=-DGOX(5)/(2.*HHH**2.)
2778 A(5,5)=-DGOX(5)/(2.*HHH**2.)
2779
2780

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2781 BIG=ABS(DGOX(5)*OXY(2,J+1)/(2.*HHH**2.))
2782 BIG2=ABS(DGOX(5)*OXY(2,J)/(HHH**2.))
2783 IF (BIG2.GT.BIG) BIG=BIG2
2784 BIG3=ABS(DGOX(5)*OXY(2,J-1)/(2.*HHH**2.))
2785 IF (BIG3.GT.BIG) BIG=BIG3
2786 BIG4=ABS(DGOX(5)*OXY(1,J+1)/(2.*HHH**2.))
2787 IF (BIG4.GT.BIG) BIG=BIG4
2788 BIG5=ABS(DGOX(5)*OXY(1,J)/(HHH**2.))
2789 IF (BIG5.GT.BIG) BIG=BIG5
2790 BIG6=ABS(DGOX(5)*OXY(1,J-1)/(2.*HHH**2.))
2791 IF (BIG6.GT.BIG) BIG=BIG6
2792 BIG7=ABS(EQ2(2,J)/2.)
2793 IF (BIG7.GT.BIG) BIG=BIG7
2794 BIG8=ABS(EQ2(1,J)/2)
2795 IF (BIG8.GT.BIG) BIG=BIG8
2796 BIG9=ABS(OXY(2,J)/DT)
2797 IF (BIG9.GT.BIG) BIG=BIG9
2798 BIG10=ABS(OXY(1,J)/DT)
2799 IF (BIG10.GT.BIG) BIG=BIG10
2800 IF (ABS(G(5)).LT.BIG*EBIG) G(5)=0
2801
2802 C For H2O2, reacting species ,DIFF(6),H2O2,RHP,G6
2803 G(6)=DGOX(6)*(HPR(2,J+1)-2.*HPR(2,J)+HPR(2,J-1)
2804 1 +HPR(1,J+1)-2.*HPR(1,J)+HPR(1,J-1))/(2.*HHH**2.)
2805 2 +(RHP(2,J)+RHP(1,J))/2.-(HPR(2,J)-HPR(1,J))/DT
2806
2807
2808 B(6,6)=DGOX(6)/HHH**2.+1./DT
2809 B(6,12)=-1./2.
2810 D(6,6)=-DGOX(6)/(2.*HHH**2.)
2811 A(6,6)=-DGOX(6)/(2.*HHH**2.)
2812
2813
2814 BIG=ABS(DGOX(6)*HPR(2,J+1)/(2.*HHH**2.))
2815 BIG2=ABS(DGOX(6)*HPR(2,J)/(HHH**2.))
2816 IF (BIG2.GT.BIG) BIG=BIG2
2817 BIG3=ABS(DGOX(6)*HPR(2,J-1)/(2.*HHH**2.))
2818 IF (BIG3.GT.BIG) BIG=BIG3
2819 BIG4=ABS(DGOX(6)*HPR(1,J+1)/(2.*HHH**2.))
2820 IF (BIG4.GT.BIG) BIG=BIG4
2821 BIG5=ABS(DGOX(6)*HPR(1,J)/(HHH**2.))
2822 IF (BIG5.GT.BIG) BIG=BIG5
2823 BIG6=ABS(DGOX(6)*HPR(1,J-1)/(2.*HHH**2.))
2824 IF (BIG6.GT.BIG) BIG=BIG6
2825 BIG7=ABS(RHP(2,J)/2.)
2826 IF (BIG7.GT.BIG) BIG=BIG7
2827 BIG8=ABS(RHP(1,J)/2)
2828 IF (BIG8.GT.BIG) BIG=BIG8
2829 BIG9=ABS(HPR(2,J)/DT)
2830 IF (BIG9.GT.BIG) BIG=BIG9
2831 BIG10=ABS(HPR(1,J)/DT)
2832 IF (BIG10.GT.BIG) BIG=BIG10
2833 IF (ABS(G(6)).LT.BIG*EBIG) G(6)=0
2834
2835 C For CX-GOx2, enzyme
2836 G(7)=(EQ1(2,J)+EQ1(1,J))/2.-(RGA(2,J)+RGA(1,J))/2.
2837 1 -(GOA(2,J)-GOA(1,J))/DT
2838

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2839 B(7,7)=+1./DT
2840 B(7,9)=-1./2.
2841 B(7,10)=1./2.
2842
2843 IF (ABS(EQ1(2,J)).GT.BIG) BIG=ABS(EQ1(2,J))
2844 IF (ABS(EQ1(1,J)).GT.BIG) BIG=ABS(EQ1(1,J))
2845 IF (ABS(RGA(2,J)).GT.BIG) BIG=ABS(RGA(2,J))
2846 IF (ABS(RGA(1,J)).GT.BIG) BIG=ABS(RGA(1,J))
2847 IF (ABS(GOA(2,J)/DT).GT.BIG) BIG=ABS(GOA(2,J)/DT)
2848 IF (ABS(GOA(1,J)/DT).GT.BIG) BIG=ABS(GOA(1,J)/DT)
2849 IF (ABS(G(7)).LT.BIG*EBIG) G(7)=0
2850
2851 C For CX-GOx, enzyme
2852 G(8)=(EQ2(2,J)+EQ2(1,J))/2.-(RHP(2,J)+RHP(1,J))/2.
2853 1 -(GOP(2,J)-GOP(1,J))/DT
2854 B(8,8)=+1./DT
2855 B(8,11)=-1./2.
2856 B(8,12)=1./2.
2857
2858 IF (ABS(EQ2(2,J)).GT.BIG) BIG=ABS(EQ2(2,J))
2859 IF (ABS(EQ2(1,J)).GT.BIG) BIG=ABS(EQ2(1,J))
2860 IF (ABS(RHP(2,J)).GT.BIG) BIG=ABS(RHP(2,J))
2861 IF (ABS(RHP(1,J)).GT.BIG) BIG=ABS(RHP(1,J))
2862 IF (ABS(GOP(2,J)/DT).GT.BIG) BIG=ABS(GOP(2,J)/DT)
2863 IF (ABS(GOP(1,J)/DT).GT.BIG) BIG=ABS(GOP(1,J)/DT)
2864 IF (ABS(G(8)).LT.BIG*EBIG) G(8)=0
2865
2866
2867 C REACTION1
2868 214 G(9)=-((EQ1(2,J)+EQ1(1,J))/2.
2869 1 +ratef1*((GLU(2,J)+GLU(1,J))*(GOX(2,J)+GOX(1,J))/4.
2870 2 -(GOA(2,J)+GOA(1,J))/2./equilib1)
2871 B(9,1)=-ratef1*(GOX(2,J)+GOX(1,J))/4.
2872 B(9,2)=-ratef1*(GLU(2,J)+GLU(1,J))/4.
2873 B(9,7)=ratef1/2./equilib1
2874 B(9,9)=+1./2.
2875
2876 BIG=ABS(EQ1(2,J)/2.)
2877 BIG2=ABS(EQ1(1,J)/2.)
2878 IF (BIG2.GT.BIG) BIG=BIG2
2879 BIG3=ABS(ratef1*GLU(2,J)*GOX(2,J)/4.)
2880 IF (BIG3.GT.BIG) BIG=BIG3
2881 BIG4=ABS(ratef1*GLU(1,J)*GOX(2,J)/4)
2882 IF (BIG4.GT.BIG) BIG=BIG4
2883 BIG5=ABS(ratef1*GLU(2,J)*GOX(1,J)/4)
2884 IF (BIG5.GT.BIG) BIG=BIG5
2885 BIG6=ABS(ratef1*GLU(1,J)*GOX(1,J)/4)
2886 IF (BIG6.GT.BIG) BIG=BIG6
2887 BIG7=ABS(ratef1*GOA(2,J)/2./equilib1)
2888 IF (BIG7.GT.BIG) BIG=BIG7
2889 BIG8=ABS(ratef1*GOA(1,J)/2./equilib1)
2890 IF (BIG8.GT.BIG) BIG=BIG8
2891 IF (ABS(G(9)).LT.BIG*EBIG) G(9)=0
2892
2893
2894 C REACTION2
2895 215 G(10)=-((RGA(2,J)+RGA(1,J))/2.+ratef2*(GOA(2,J)+GOA(1,J))/2.
2896 B(10,7)=-ratef2/2.

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2897 B(10,10)=+1./2.
2898
2899 BIG=ABS(RGA(2,J)/2.)
2900 BIG2=ABS(RGA(1,J)/2.)
2901 IF (BIG2.GT.BIG) BIG=BIG2
2902 BIG3=ABS(ratef2*GOA(2,J)/2.)
2903 IF (BIG3.GT.BIG) BIG=BIG3
2904 BIG4=ABS(ratef2*GOA(1,J)/2.)
2905 IF (BIG4.GT.BIG) BIG=BIG4
2906 IF (ABS(G(10)).LT.BIG*EBIG) G(10)=0
2907
2908 C REACTION3
2909 216 G(11)=- (EQ2(2,J)+EQ2(1,J))/2.
2910 1 +ratef3*((GOR(2,J)+GOR(1,J))*(OXY(2,J)+OXY(1,J))/4.
2911 2 -(GOP(2,J)+GOP(1,J))/2./equilib3)
2912 B(11,4)=-ratef3*(OXY(2,J)+OXY(1,J))/4.
2913 B(11,5)=-ratef3*(GOR(2,J)+GOR(1,J))/4.
2914 B(11,8)=ratef3/2./equilib3
2915 B(11,11)=+1./2.
2916
2917 BIG=ABS(EQ2(2,J)/2.)
2918 BIG2=ABS(EQ2(1,J)/2.)
2919 IF (BIG2.GT.BIG) BIG=BIG2
2920 BIG3=ABS(ratef3*GOR(2,J)*OXY(2,J)/4.)
2921 IF (BIG3.GT.BIG) BIG=BIG3
2922 BIG4=ABS(ratef3*GOR(1,J)*OXY(2,J)/4)
2923 IF (BIG4.GT.BIG) BIG=BIG4
2924 BIG5=ABS(ratef3*GOR(2,J)*OXY(1,J)/4)
2925 IF (BIG5.GT.BIG) BIG=BIG5
2926 BIG6=ABS(ratef3*GOR(1,J)*OXY(1,J)/4)
2927 IF (BIG6.GT.BIG) BIG=BIG6
2928 BIG7=ABS(ratef3*GOP(2,J)/2./EQUILIB3)
2929 IF (BIG7.GT.BIG) BIG=BIG7
2930 BIG8=ABS(ratef3*GOP(1,J)/2./EQUILIB3)
2931 IF (BIG8.GT.BIG) BIG=BIG8
2932 IF (ABS(G(11)).LT.BIG*EBIG) G(11)=0.0
2933
2934 C REACTION4
2935 217 G(12)=- (RHP(2,J)+RHP(1,J))/2.+ratef4*(GOP(2,J)+GOP(1,J))/2.
2936 B(12,8)=-ratef4/2.
2937 B(12,12)=+1./2.
2938
2939 BIG=ABS(RHP(2,J)/2.)
2940 BIG2=ABS(RHP(1,J)/2.)
2941 IF (BIG2.GT.BIG) BIG=BIG2
2942 BIG3=ABS(ratef4*GOP(2,J)/2.)
2943 IF (BIG3.GT.BIG) BIG=BIG3
2944 BIG4=ABS(ratef4*GOP(1,J)/2.)
2945 IF (BIG4.GT.BIG) BIG=BIG4
2946 IF (ABS(G(12)).LT.BIG*EBIG) G(12)=0.0
2947
2948 C REACTION5
2949 218 G(13)=- (ANM(2,J)+ANM(1,J))/2.+ratef5*((GLUA(2,J)+GLUA(1,J))/2.
2950 1 -(GLU(2,J)+GLU(1,J))/2./equilib5)
2951 B(13,1)=ratef5/2./equilib5
2952 B(13,14)=-ratef5/2.
2953 B(13,13)=+1./2.
2954

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2955 BIG=ABS(ANM(2,J)/2.)
2956 BIG2=ABS(ANM(1,J)/2.)
2957 IF (BIG2.GT.BIG) BIG=BIG2
2958 BIG3=ABS(ratef5*GLUA(2,J)/2.)
2959 IF (BIG3.GT.BIG) BIG=BIG3
2960 BIG4=ABS(ratef5*GLUA(1,J)/2.)
2961 IF (BIG4.GT.BIG) BIG=BIG4
2962 BIG5=ABS(ratef5*GLU(2,J)/2./equilib5)
2963 IF (BIG5.GT.BIG) BIG=BIG5
2964 BIG6=ABS(ratef5*GLU(1,J)/2./equilib5)
2965 IF (BIG6.GT.BIG) BIG=BIG6
2966 IF (ABS(G(13)).LT.BIG*EBIG) G(13)=0.0
2967
2968 C For alpha Glucose, being consumed only
2969 G(14)=DGOX(9)*(GLUA(2,J+1)-2.*GLUA(2,J)+GLUA(2,J-1)
2970 1 +GLUA(1,J+1)-2.*GLUA(1,J)+GLUA(1,J-1))/(2.*HHH**2.)
2971 2 -(ANM(2,J)+ANM(1,J))/2.-(GLUA(2,J)-GLUA(1,J))/DT
2972 B(14,14)=DGOX(9)/HHH**2.+1./DT
2973 D(14,14)=-DGOX(9)/(2.*HHH**2.)
2974 A(14,14)=-DGOX(9)/(2.*HHH**2.)
2975 B(14,13)=1./2.
2976
2977 BIG=ABS(DGOX(9)*(GLUA(2,J+1))/(2.*HHH**2.))
2978 BIG2=ABS(DGOX(9)*(GLUA(2,J))/(HHH**2.))
2979 IF (BIG2.GT.BIG) BIG=BIG2
2980 BIG3=ABS(DGOX(9)*(GLUA(2,J-1))/(2.*HHH**2.))
2981 IF (BIG3.GT.BIG) BIG=BIG3
2982 BIG4=ABS(DGOX(9)*(GLUA(1,J+1))/(2.*HHH**2.))
2983 IF (BIG4.GT.BIG) BIG=BIG4
2984 BIG5=ABS(DGOX(9)*(GLUA(1,J))/(HHH**2.))
2985 IF (BIG5.GT.BIG) BIG=BIG5
2986 BIG6=ABS(DGOX(9)*(GLUA(1,J-1))/(2.*HHH**2.))
2987 IF (BIG6.GT.BIG) BIG=BIG6
2988 BIG7=ABS(ANM(2,J)/2.)
2989 IF (BIG7.GT.BIG) BIG=BIG7
2990 BIG8=ABS(ANM(1,J)/2.)
2991 IF (BIG8.GT.BIG) BIG=BIG8
2992 BIG9=ABS(GLUA(2,J)/DT)
2993 IF (BIG9.GT.BIG) BIG=BIG9
2994 BIG10=ABS(GLUA(1,J)/DT)
2995 IF (BIG10.GT.BIG) BIG=BIG10
2996 IF (ABS(G(14)).LT.BIG*EBIG) G(14)=0.0
2997
2998 C Gluconic acid dissociation
2999
3000 G(15)=equilib6*(GLA(2,J)+GLA(1,J))/2.-(GLI(2,J)+GLI(1,J))*
3001 1 (HYD(2,J)+HYD(1,J))/4.
3002 B(15,3)=-equilib6/2.
3003 B(15,15)=(HYD(2,J)+HYD(1,J))/4.
3004 B(15,16)=(GLI(2,J)+GLI(1,J))/4.
3005
3006 BIG=ABS(equilib6*GLA(2,J)/2.)
3007 BIG2=ABS(equilib6*GLA(1,J)/2.)
3008 IF (BIG2.GT.BIG) BIG=BIG2
3009 BIG3=ABS(GLI(2,J)*HYD(2,J)/4.)
3010 IF (BIG3.GT.BIG) BIG=BIG3
3011 BIG4=ABS(GLI(2,J)*HYD(1,J)/4.)
3012 IF (BIG4.GT.BIG) BIG=BIG4

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3013     BIG5=ABS(GLI(1,J)*HYD(2,J)/4)
3014     IF (BIG5.GT.BIG) BIG=BIG5
3015     BIG6=ABS(GLI(1,J)*HYD(1,J)/4)
3016     IF (BIG6.GT.BIG) BIG=BIG6
3017     IF (ABS(G(15)).LT.BIG*EBIG) G(15)=0
3018
3019 C Hydrogen ion , hydroxide ion , gluconate ion , bicarbonate ion flux
3020     G(16)=DGOX(11)*(HYD(2,J+1)-2.*HYD(2,J)+HYD(2,J-1)
3021     1     +HYD(1,J+1)-2.*HYD(1,J)+HYD(1,J-1))/(2.*HHH**2.)
3022     2     -DGOX(15)*(OHI(2,J+1)-2.*OHI(2,J)+OHI(2,J-1)
3023     3     +OHI(1,J+1)-2.*OHI(1,J)+OHI(1,J-1))/(2.*HHH**2.)
3024     4     -DGOX(10)*(GLI(2,J+1)-2.*GLI(2,J)+GLI(2,J-1)
3025     5     +GLI(1,J+1)-2.*GLI(1,J)+GLI(1,J-1))/(2.*HHH**2.)
3026     6     -DGOX(14)*(CBI(2,J+1)-2.*CBI(2,J)+CBI(2,J-1)
3027     7     +CBI(1,J+1)-2.*CBI(1,J)+CBI(1,J-1))/(2.*HHH**2.)
3028     8     -(HYD(2,J)-HYD(1,J))/DT+(OHI(2,J)-OHI(1,J))/DT
3029     9     +(GLI(2,J)-GLI(1,J))/DT+(CBI(2,J)-CBI(1,J))/DT
3030
3031     B(16,16)=DGOX(11)/HHH**2.+1./DT
3032     D(16,16)=-DGOX(11)/(2.*HHH**2.)
3033     A(16,16)=-DGOX(11)/(2.*HHH**2.)
3034     B(16,17)=-DGOX(15)/HHH**2.-1./DT
3035     D(16,17)=DGOX(15)/(2.*HHH**2.)
3036     A(16,17)=DGOX(15)/(2.*HHH**2.)
3037     B(16,15)=-DGOX(10)/HHH**2.-1./DT
3038     D(16,15)=DGOX(10)/(2.*HHH**2.)
3039     A(16,15)=DGOX(10)/(2.*HHH**2.)
3040     B(16,20)=-DGOX(14)/HHH**2.-1./DT
3041     D(16,20)=DGOX(14)/(2.*HHH**2.)
3042     A(16,20)=DGOX(14)/(2.*HHH**2.)
3043
3044     BIG=ABS(DGOX(11)*(HYD(2,J+1))/(2.*HHH**2.))
3045     BIG2=ABS(DGOX(11)*(HYD(2,J))/(HHH**2.))
3046     IF (BIG2.GT.BIG) BIG=BIG2
3047     BIG3=ABS(DGOX(11)*(HYD(2,J-1))/(2.*HHH**2.))
3048     IF (BIG3.GT.BIG) BIG=BIG3
3049     BIG4=ABS(DGOX(11)*(HYD(1,J+1))/(2.*HHH**2.))
3050     IF (BIG4.GT.BIG) BIG=BIG4
3051     BIG5=ABS(DGOX(11)*(HYD(1,J))/(HHH**2.))
3052     IF (BIG5.GT.BIG) BIG=BIG5
3053     BIG6=ABS(DGOX(11)*(HYD(1,J-1))/(2.*HHH**2.))
3054     IF (BIG6.GT.BIG) BIG=BIG6
3055     BIG7=ABS(DGOX(15)*OHI(2,J+1)/(2.*HHH**2.))
3056     IF (BIG7.GT.BIG) BIG=BIG7
3057     BIG8=ABS(DGOX(15)*OHI(2,J)/(HHH**2.))
3058     IF (BIG8.GT.BIG) BIG=BIG8
3059     BIG9=ABS(DGOX(15)*OHI(2,J-1)/(2.*HHH**2.))
3060     IF (BIG9.GT.BIG) BIG=BIG9
3061     BIG10=ABS(DGOX(15)*OHI(1,J+1)/(2.*HHH**2.))
3062     IF (BIG10.GT.BIG) BIG=BIG10
3063     BIG11=ABS(DGOX(15)*OHI(1,J)/(HHH**2.))
3064     IF (BIG11.GT.BIG) BIG=BIG11
3065     BIG12=ABS(DGOX(15)*OHI(1,J-1)/(2.*HHH**2.))
3066     IF (BIG12.GT.BIG) BIG=BIG12
3067     BIG13=ABS(DGOX(10)*GLI(2,J+1)/(2.*HHH**2.))
3068     IF (BIG13.GT.BIG) BIG=BIG13
3069     BIG14=ABS(DGOX(10)*GLI(2,J)/(HHH**2.))
3070     IF (BIG14.GT.BIG) BIG=BIG14

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3071 BIG15=ABS(DGOX(10)*GLI(2,J-1)/(2.*HHH**2.))
3072 IF (BIG15.GT.BIG) BIG=BIG15
3073 BIG16=ABS(DGOX(10)*GLI(1,J+1)/(2.*HHH**2.))
3074 IF (BIG16.GT.BIG) BIG=BIG16
3075 BIG17=ABS(DGOX(10)*GLI(1,J)/(HHH**2.))
3076 IF (BIG17.GT.BIG) BIG=BIG17
3077 BIG18=ABS(DGOX(10)*GLI(1,J-1)/(2.*HHH**2.))
3078 IF (BIG18.GT.BIG) BIG=BIG18
3079 BIG19=ABS(DGOX(14)*CBI(2,J+1)/(2.*HHH**2.))
3080 IF (BIG19.GT.BIG) BIG=BIG19
3081 BIG20=ABS(DGOX(14)*CBI(2,J)/(HHH**2.))
3082 IF (BIG20.GT.BIG) BIG=BIG20
3083 BIG21=ABS(DGOX(14)*CBI(2,J-1)/(2.*HHH**2.))
3084 IF (BIG21.GT.BIG) BIG=BIG21
3085 BIG22=ABS(DGOX(14)*CBI(1,J+1)/(2.*HHH**2.))
3086 IF (BIG22.GT.BIG) BIG=BIG22
3087 BIG23=ABS(DGOX(14)*CBI(1,J)/(HHH**2.))
3088 IF (BIG23.GT.BIG) BIG=BIG23
3089 BIG24=ABS(DGOX(14)*CBI(1,J-1)/(2.*HHH**2.))
3090 IF (BIG24.GT.BIG) BIG=BIG24
3091 BIG25=ABS(HYD(2,J)/DT)
3092 IF (BIG25.GT.BIG) BIG=BIG25
3093 BIG26=ABS(HYD(1,J)/DT)
3094 IF (BIG26.GT.BIG) BIG=BIG26
3095 BIG27=ABS(OHI(2,J)/DT)
3096 IF (BIG27.GT.BIG) BIG=BIG27
3097 BIG28=ABS(OHI(1,J)/DT)
3098 IF (BIG28.GT.BIG) BIG=BIG28
3099 BIG29=ABS(GLI(2,J)/DT)
3100 IF (BIG29.GT.BIG) BIG=BIG29
3101 BIG30=ABS(GLI(1,J)/DT)
3102 IF (BIG30.GT.BIG) BIG=BIG30
3103 BIG31=ABS(CBI(2,J)/DT)
3104 IF (BIG31.GT.BIG) BIG=BIG31
3105 BIG32=ABS(CBI(1,J)/DT)
3106 IF (BIG32.GT.BIG) BIG=BIG32
3107 IF (ABS(G(16)).LT.BIG*EBIG) G(16)=0
3108
3109 c Water Dissociation
3110 G(17)=equilib9 -(HYD(2,J)+HYD(1,J))*(OHI(2,J)+OHI(1,J))/4.
3111 B(17,17)=(HYD(2,J)+HYD(1,J))/4.
3112 B(17,16)=(OHI(2,J)+OHI(1,J))/4.
3113
3114 BIG=ABS(equilib9)
3115 BIG2=ABS(HYD(2,J)*OHI(2,J)/4.)
3116 IF (BIG2.GT.BIG) BIG=BIG2
3117 BIG3=ABS(HYD(2,J)*OHI(1,J)/4.)
3118 IF (BIG3.GT.BIG) BIG=BIG3
3119 BIG4=ABS(HYD(1,J)*OHI(2,J)/4.)
3120 IF (BIG4.GT.BIG) BIG=BIG4
3121 BIG5=ABS(HYD(1,J)*OHI(1,J)/4.)
3122 IF (BIG5.GT.BIG) BIG=BIG5
3123 IF (ABS(G(17)).LT.BIG*EBIG) G(17)=0
3124
3125 C CO2 Hydration
3126
3127 G(18)=equilib7 *(CO2(2,J)+CO2(1,J))/2. -(CBA(2,J)+CBA(1,J))/2.
3128 B(18,18)=-equilib7/2.

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3129      B(18,19)=1./2.
3130
3131      BIG=ABS(equilib7*CO2(2,J)/2.)
3132      BIG2=ABS(equilib7*CO2(1,J)/2.)
3133      IF (BIG2.GT.BIG) BIG=BIG2
3134      BIG3=ABS(CBA(2,J)/2.)
3135      IF (BIG3.GT.BIG) BIG=BIG3
3136      BIG4=ABS(CBA(1,J)/2.)
3137      IF (BIG4.GT.BIG) BIG=BIG4
3138      IF (ABS(G(18)).LT.BIG*EBIG) G(18)=0
3139
3140 C Carbonic acid dissociation
3141
3142      G(19)=equilib8*(CBA(2,J)+CBA(1,J))/2.-(CBI(2,J)+CBI(1,J))
3143      1 *(HYD(2,J)+HYD(1,J))/4.
3144      B(19,19)=-equilib8/2.
3145      B(19,20)=(HYD(2,J)+HYD(1,J))/4.
3146      B(19,16)=(CBI(2,J)+CBI(1,J))/4.
3147
3148      BIG=ABS(equilib8*CBA(2,J)/2.)
3149      BIG2=ABS(equilib8*CBA(1,J)/2.)
3150      IF (BIG2.GT.BIG) BIG=BIG2
3151      BIG3=ABS(CBI(2,J)*HYD(2,J)/4.)
3152      IF (BIG3.GT.BIG) BIG=BIG3
3153      BIG4=ABS(CBI(2,J)*HYD(1,J)/4.)
3154      IF (BIG4.GT.BIG) BIG=BIG4
3155      BIG5=ABS(CBI(1,J)*HYD(2,J)/4.)
3156      IF (BIG5.GT.BIG) BIG=BIG5
3157      BIG6=ABS(CBI(1,J)*HYD(1,J)/4.)
3158      IF (BIG6.GT.BIG) BIG=BIG6
3159      IF (ABS(G(19)).LT.BIG*EBIG) G(19)=0
3160
3161 C FLUX OF CO2, CARBONIC ACID, BICARBONATE ION
3162      G(20)=DGOX(12)*(CO2(2,J+1)-2.*CO2(2,J)+CO2(2,J-1)
3163      1 +CO2(1,J+1)-2.*CO2(1,J)+CO2(1,J-1))/(2.*HHH**2.)
3164      2 +DGOX(13)*(CBA(2,J+1)-2.*CBA(2,J)+CBA(2,J-1)
3165      3 +CBA(1,J+1)-2.*CBA(1,J)+CBA(1,J-1))/(2.*HHH**2.)
3166      4 +DGOX(14)*(CBI(2,J+1)-2.*CBI(2,J)+CBI(2,J-1)
3167      5 +CBI(1,J+1)-2.*CBI(1,J)+CBI(1,J-1))/(2.*HHH**2.)
3168      8 -(CO2(2,J)-CO2(1,J))/DT-(CBA(2,J)-CBA(1,J))/DT
3169      9 -(CBI(2,J)-CBI(1,J))/DT
3170
3171      B(20,20)=DGOX(14)/HHH**2.+1./DT
3172      D(20,20)=-DGOX(14)/(2.*HHH**2.)
3173      A(20,20)=-DGOX(14)/(2.*HHH**2.)
3174      B(20,18)=DGOX(12)/HHH**2.+1./DT
3175      D(20,18)=-DGOX(12)/(2.*HHH**2.)
3176      A(20,18)=-DGOX(12)/(2.*HHH**2.)
3177      B(20,19)=DGOX(13)/HHH**2.+1./DT
3178      D(20,19)=-DGOX(13)/(2.*HHH**2.)
3179      A(20,19)=-DGOX(13)/(2.*HHH**2.)
3180
3181
3182      BIG=ABS(DGOX(12)*(CO2(2,J+1))/(2.*HHH**2.))
3183      BIG2=ABS(DGOX(12)*(CO2(2,J))/(HHH**2.))
3184      IF (BIG2.GT.BIG) BIG=BIG2
3185      BIG3=ABS(DGOX(12)*(CO2(2,J-1))/(2.*HHH**2.))
3186      IF (BIG3.GT.BIG) BIG=BIG3

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3187 BIG4=ABS(DGOX(12)*(CO2(1,J+1))/(2.*HHH**2.))
3188 IF (BIG4.GT.BIG) BIG=BIG4
3189 BIG5=ABS(DGOX(12)*(CO2(1,J))/(HHH**2.))
3190 IF (BIG5.GT.BIG) BIG=BIG5
3191 BIG6=ABS(DGOX(12)*(CO2(1,J-1))/(2.*HHH**2.))
3192 IF (BIG6.GT.BIG) BIG=BIG6
3193 BIG7=ABS(DGOX(13)*CBA(2,J+1)/(2.*HHH**2.))
3194 IF (BIG7.GT.BIG) BIG=BIG7
3195 BIG8=ABS(DGOX(13)*CBA(2,J)/(HHH**2.))
3196 IF (BIG8.GT.BIG) BIG=BIG8
3197 BIG9=ABS(DGOX(13)*CBA(2,J-1)/(2.*HHH**2.))
3198 IF (BIG9.GT.BIG) BIG=BIG9
3199 BIG10=ABS(DGOX(13)*CBA(1,J+1)/(2.*HHH**2.))
3200 IF (BIG10.GT.BIG) BIG=BIG10
3201 BIG11=ABS(DGOX(13)*CBA(1,J)/(HHH**2.))
3202 IF (BIG11.GT.BIG) BIG=BIG11
3203 BIG12=ABS(DGOX(13)*CBA(1,J-1)/(2.*HHH**2.))
3204 IF (BIG12.GT.BIG) BIG=BIG12
3205 BIG13=ABS(DGOX(14)*CBI(2,J+1)/(2.*HHH**2.))
3206 IF (BIG13.GT.BIG) BIG=BIG13
3207 BIG14=ABS(DGOX(14)*CBI(2,J)/(HHH**2.))
3208 IF (BIG14.GT.BIG) BIG=BIG14
3209 BIG15=ABS(DGOX(14)*CBI(2,J-1)/(2.*HHH**2.))
3210 IF (BIG15.GT.BIG) BIG=BIG15
3211 BIG16=ABS(DGOX(14)*CBI(1,J+1)/(2.*HHH**2.))
3212 IF (BIG16.GT.BIG) BIG=BIG16
3213 BIG17=ABS(DGOX(14)*CBI(1,J)/(HHH**2.))
3214 IF (BIG17.GT.BIG) BIG=BIG17
3215 BIG18=ABS(DGOX(14)*CBI(1,J-1)/(2.*HHH**2.))
3216 IF (BIG18.GT.BIG) BIG=BIG18
3217 BIG19=ABS(CO2(2,J)/DT)
3218 IF (BIG19.GT.BIG) BIG=BIG19
3219 BIG20=ABS(CO2(1,J)/DT)
3220 IF (BIG20.GT.BIG) BIG=BIG20
3221 BIG21=ABS(CBA(2,J)/DT)
3222 IF (BIG21.GT.BIG) BIG=BIG21
3223 BIG22=ABS(CBA(1,J)/DT)
3224 IF (BIG22.GT.BIG) BIG=BIG22
3225 BIG23=ABS(CBI(2,J)/DT)
3226 IF (BIG23.GT.BIG) BIG=BIG23
3227 BIG24=ABS(CBI(1,J)/DT)
3228 IF (BIG24.GT.BIG) BIG=BIG24
3229 IF (ABS(G(20)).LT.BIG*EBIG) G(20)=0
3230
3231 C For Acetaminophen
3232 G(21)=DGOX(16)*(ACE(2,J+1)-2.*ACE(2,J)+ACE(2,J-1)
3233 1 +ACE(1,J+1)-2.*ACE(1,J)+ACE(1,J-1))/(2.*HHH**2.)
3234 2 -(ACE(2,J)-ACE(1,J))/DT
3235
3236 B(21,21)=DGOX(16)/HHH**2.+1./DT
3237 D(21,21)=-DGOX(16)/(2.*HHH**2.)
3238 A(21,21)=-DGOX(16)/(2.*HHH**2.)
3239
3240
3241 BIG=ABS(DGOX(16)*(ACE(2,J+1))/(2.*HHH**2.))
3242 BIG2=ABS(DGOX(16)*(ACE(2,J))/(HHH**2.))
3243 IF (BIG2.GT.BIG) BIG=BIG2
3244 BIG3=ABS(DGOX(16)*(ACE(2,J-1))/(2.*HHH**2.))

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3245     IF (BIG3.GT.BIG) BIG=BIG3
3246     BIG4=ABS(DGOX(16)*(ACE(1,J+1))/(2.*HHH**2.))
3247     IF (BIG4.GT.BIG) BIG=BIG4
3248     BIG5=ABS(DGOX(16)*(ACE(1,J))/(HHH**2.))
3249     IF (BIG5.GT.BIG) BIG=BIG5
3250     BIG6=ABS(DGOX(16)*(ACE(1,J-1))/(2.*HHH**2.))
3251     IF (BIG6.GT.BIG) BIG=BIG6
3252     BIG7=ABS(ACE(2,J)/DT)
3253     IF (BIG7.GT.BIG) BIG=BIG7
3254     BIG8=ABS(ACE(1,J)/DT)
3255     IF (BIG8.GT.BIG) BIG=BIG8
3256     IF (ABS(G(21)).LT.BIG*EBIG) G(21)=0
3257
3258 C     DOUBLE IAYER voLTAGE - DUMMY
3259
3260     G(22)=(VDL(2,J)+VDL(1,J))/2.
3261
3262     B(22,22)=-1./2.
3263
3264     BIG=ABS(VDL(2,J)/2.)
3265     BIG2=ABS(VDL(1,J)/2.)
3266     IF (BIG2.GT.BIG) BIG=BIG2
3267     IF (ABS(G(22)).LT.BIG*EBIG) G(22)=0
3268
3269     RETURN
3270     END
3271
3272     SUBROUTINE COUPLER1(J)
3273     IMPLICIT DOUBLE PRECISION (A-H, O-Z)
3274     COMMON/BAB/ A(22,22),B(22,22),C(22,80001),D(22,45),G(22),X(22,22)
3275     1 ,Y(22,22)
3276     COMMON/NSN/ N, NJ
3277     COMMON/GLC/ NTIME,LL
3278     COMMON/VAR/ DIFF(16),H,EBIG,HH,IJ,KJ,TT,VAP,HHH,DT,RE,AKB,BB,CDL
3279     COMMON/VARR/ HHHH,HHHHH,MJ,LJ
3280     COMMON/DIN/ DGOX(16),DGLM(16),DIRM(16),DBULK(16)
3281     COMMON/SPCI/ GLU(2,80001),GOX(2,80001),GLA(2,80001),GOR(2,80001)
3282     COMMON/SPCII/ OXY(2,80001),HPR(2,80001),GOA(2,80001),GOP(2,80001)
3283     COMMON/RXT/ EQ1(2,80001),RGA(2,80001),EQ2(2,80001),RHP(2,80001)
3284     COMMON/SPCIII/ ANM(2,80001),GLUA(2,80001),GLI(2,80001)
3285     COMMON/SPCIV/ HYD(2,80001),OHI(2,80001),CO2(2,80001),CBA(2,80001)
3286     COMMON/SPCV/ CBI(2,80001),ACE(2,800001)
3287     COMMON/VOL/ VDL(2,80001)
3288     COMMON/POR/ POR1,POR2,PORGLU,PARION,PARACE
3289     COMMON/RTE/ ratef1,equilib1,ratef2,ratef3,equilib3,ratef4
3290     COMMON/RTD/ ratef5,equilib5,equilib6,equilib7,equilib8,equilib9
3291     COMMON/BUL/ CBULK(16),PARH2O2,PAR02,PARGLUCE,JCOUNT
3292
3293
3294 C     DIMENSION COEFF1, COEFF3, COEFF5, COEFF6
3295
3296     301 FORMAT (5x,'J=' I5, 12E18.9)
3297
3298     COEFF1HH=DGOX(1)/(HH)
3299     COEFF1HHH=DGOX(1)/(HHH)
3300     COEFF3HH=DGOX(3)/(HH)
3301     COEFF3HHH=DGOX(3)/(HHH)
3302     COEFF5HH=DGOX(5)/(HH)

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3303 COEFF5HHH=DGOX(5)/(HHH)
3304 COEFF6HH=DGOX(6)/(HH)
3305 COEFF6HHH=DGOX(6)/(HHH)
3306 COEFF9HH=DGOX(9)/(HH)
3307 COEFF9HHH=DGOX(9)/(HHH)
3308 COEFF10HH=DGOX(10)/(HH)
3309 COEFF10HHH=DGOX(10)/(HHH)
3310 COEFF11HH=DGOX(11)/(HH)
3311 COEFF11HHH=DGOX(11)/(HHH)
3312 COEFF12HH=DGOX(12)/(HH)
3313 COEFF12HHH=DGOX(12)/(HHH)
3314 COEFF13HH=DGOX(13)/(HH)
3315 COEFF13HHH=DGOX(13)/(HHH)
3316 COEFF14HH=DGOX(14)/(HH)
3317 COEFF14HHH=DGOX(14)/(HHH)
3318 COEFF15HH=DGOX(15)/(HH)
3319 COEFF15HHH=DGOX(15)/(HHH)
3320 COEFF16HH=DGOX(16)/(HH)
3321 COEFF16HHH=DGOX(16)/(HHH)
3322
3323 C For Glucose, being consumed only
3324 G(1)=COEFF1HH/2.*(GLU(2,J+1)+GLU(1,J+1)-GLU(2,J)-GLU(1,J))
3325 1 -COEFF1HHH/2.*(GLU(2,J)+GLU(1,J)-GLU(2,J-1)-GLU(1,J-1))
3326 2 -(HH/2.)*(3.*(EQ1(2,J)+EQ1(1,J))+(EQ1(2,J+1)+EQ1(1,J+1)))/8.
3327 3 -(HHH/2.)*(3.*(EQ1(2,J)+EQ1(1,J))+(EQ1(2,J-1)+EQ1(1,J-1)))/8.
3328 2 +(HH/2.)*(3.*(ANM(2,J)+ANM(1,J))+(ANM(2,J+1)+ANM(1,J+1)))/8.
3329 3 +(HHH/2.)*(3.*(ANM(2,J)+ANM(1,J))+(ANM(2,J-1)+ANM(1,J-1)))/8.
3330 4 -HH/2.*(3.*(GLU(2,J)-GLU(1,J))+(GLU(2,J+1)-GLU(1,J+1)))/(4.*DT)
3331 5 -HHH/2.*(3.*(GLU(2,J)-GLU(1,J))+(GLU(2,J-1)-GLU(1,J-1)))/(4.*DT)
3332
3333 B(1,1)=COEFF1HH/2.+COEFF1HHH/2.+HH/2.*3./(4.*DT)+HHH/2.*3./(4.*DT)
3334 D(1,1)=-COEFF1HH/2.+HH/2./(4.*DT)
3335 A(1,1)=-COEFF1HHH/2.+HHH/2./(4.*DT)
3336 B(1,9)=+(HH/2.)*(3./8.)+(HHH/2.)*(3./8.)
3337 D(1,9)=+(HH/2.)*(1./8.)
3338 A(1,9)=+(HHH/2.)*(1./8.)
3339 B(1,13)=-((HH/2.)*(3./8.)-(HHH/2.)*(3./8.))
3340 D(1,13)=-((HH/2.)*(1./8.))
3341 A(1,13)=-((HHH/2.)*(1./8.))
3342
3343 BIG=ABS(COEFF1HH/2.*GLU(2,J+1))
3344 BIG2=ABS(COEFF1HH/2.*GLU(1,J+1))
3345 IF (BIG2.GT.BIG) BIG=BIG2
3346 BIG3=ABS(COEFF1HH/2.*GLU(2,J))
3347 IF (BIG3.GT.BIG) BIG=BIG3
3348 BIG4=ABS(COEFF1HH/2.*GLU(1,J))
3349 IF (BIG4.GT.BIG) BIG=BIG4
3350 BIG5=ABS(COEFF1HHH/2.*GLU(2,J))
3351 IF (BIG5.GT.BIG) BIG=BIG5
3352 BIG6=ABS(COEFF1HHH/2.*GLU(1,J))
3353 IF (BIG6.GT.BIG) BIG=BIG6
3354 BIG7=ABS(COEFF1HHH/2.*GLU(2,J-1))
3355 IF (BIG7.GT.BIG) BIG=BIG7
3356 BIG8=ABS(COEFF1HHH/2.*GLU(1,J-1))
3357 IF (BIG8.GT.BIG) BIG=BIG8
3358 BIG9=ABS(HH/2.*3.*EQ1(2,J)/8.)
3359 IF (BIG9.GT.BIG) BIG=BIG9
3360 BIG10=ABS(HH/2.*3.*EQ1(1,J)/8.)

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3361 IF (BIG10.GT.BIG) BIG=BIG10
3362 BIG11=ABS(HH/2.*EQ1(2,J+1)/8.)
3363 IF (BIG11.GT.BIG) BIG=BIG11
3364 BIG12=ABS(HH/2.*EQ1(1,J+1)/8.)
3365 IF (BIG12.GT.BIG) BIG=BIG12
3366 BIG13=ABS(HHH/2.*3.*EQ1(2,J)/8.)
3367 IF (BIG13.GT.BIG) BIG=BIG13
3368 BIG14=ABS(HHH/2.*3.*EQ1(1,J)/8.)
3369 IF (BIG14.GT.BIG) BIG=BIG14
3370 BIG15=ABS(HHH/2.*EQ1(2,J-1)/8.)
3371 IF (BIG15.GT.BIG) BIG=BIG15
3372 BIG16=ABS(HHH/2.*EQ1(1,J-1)/8.)
3373 IF (BIG16.GT.BIG) BIG=BIG16
3374 BIG17=ABS(HH/2.*3.*GLU(2,J)/(4.*DT))
3375 IF (BIG17.GT.BIG) BIG=BIG17
3376 BIG18=ABS(HH/2.*3.*GLU(1,J)/(4.*DT))
3377 IF (BIG18.GT.BIG) BIG=BIG18
3378 BIG19=ABS(HH/2.*GLU(2,J+1)/(4.*DT))
3379 IF (BIG19.GT.BIG) BIG=BIG19
3380 BIG20=ABS(HH/2.*GLU(1,J+1)/(4.*DT))
3381 IF (BIG20.GT.BIG) BIG=BIG20
3382 BIG21=ABS(HHH/2.*3.*GLU(2,J)/(4.*DT))
3383 IF (BIG21.GT.BIG) BIG=BIG21
3384 BIG22=ABS(HHH/2.*3.*GLU(1,J)/(4.*DT))
3385 IF (BIG22.GT.BIG) BIG=BIG22
3386 BIG23=ABS(HHH/2.*GLU(2,J-1)/(4.*DT))
3387 IF (BIG23.GT.BIG) BIG=BIG23
3388 BIG24=ABS(HHH/2.*GLU(1,J-1)/(4.*DT))
3389 IF (BIG24.GT.BIG) BIG=BIG24
3390 BIG25=ABS(HH/2.*3.*ANM(2,J)/8.)
3391 IF (BIG25.GT.BIG) BIG=BIG25
3392 BIG26=ABS(HH/2.*3.*ANM(1,J)/8.)
3393 IF (BIG26.GT.BIG) BIG=BIG26
3394 BIG27=ABS(HH/2.*ANM(2,J+1)/8.)
3395 IF (BIG27.GT.BIG) BIG=BIG27
3396 BIG28=ABS(HH/2.*ANM(1,J+1)/8.)
3397 IF (BIG28.GT.BIG) BIG=BIG28
3398 BIG29=ABS(HHH/2.*3.*ANM(2,J)/8.)
3399 IF (BIG29.GT.BIG) BIG=BIG29
3400 BIG30=ABS(HHH/2.*3.*ANM(1,J)/8.)
3401 IF (BIG30.GT.BIG) BIG=BIG30
3402 BIG31=ABS(HHH/2.*ANM(2,J-1)/8.)
3403 IF (BIG31.GT.BIG) BIG=BIG31
3404 BIG32=ABS(HHH/2.*ANM(1,J-1)/8.)
3405 IF (BIG32.GT.BIG) BIG=BIG32
3406 IF (ABS(G(1)).LT.BIG*EBIG) G(1)=0
3407
3408 C For GOx, enzyme
3409 G(2)=- (EQ1(2,J)+EQ1(1,J))/2.+(RHP(2,J)+RHP(1,J))/2.
3410 1 -(GOX(2,J)-GOX(1,J))/DT
3411 B(2,2)=+1./DT
3412 B(2,9)=+1./2.
3413 B(2,12)=-1./2.
3414
3415
3416 IF (ABS(EQ1(2,J)).GT.BIG) BIG=ABS(EQ1(2,J))
3417 IF (ABS(EQ1(1,J)).GT.BIG) BIG=ABS(EQ1(1,J))
3418 IF (ABS(RHP(2,J)).GT.BIG) BIG=ABS(RHP(2,J))

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3419 IF (ABS(RHP(1,J)).GT.BIG) BIG=ABS(RHP(1,J))
3420 IF (ABS(GOX(2,J)/DT).GT.BIG) BIG=ABS(GOX(2,J)/DT)
3421 IF (ABS(GOX(1,J)/DT).GT.BIG) BIG=ABS(GOX(1,J)/DT)
3422 IF (ABS(G(2)).LT.BIG*EBIG) G(2)=0
3423
3424 C For Gluconic Acid, being produced only Balanced by Gluconate Ion
3425 G(3)=COEFF3HH/2.*(GLA(2,J+1)+GLA(1,J+1)-GLA(2,J)-GLA(1,J))
3426 1 -COEFF3HHH/2.*(GLA(2,J)+GLA(1,J)-GLA(2,J-1)-GLA(1,J-1))
3427 2 +COEFF10HH/2.*(GLI(2,J+1)+GLI(1,J+1)-GLI(2,J)-GLI(1,J))
3428 3 -COEFF10HHH/2.*(GLI(2,J)+GLI(1,J)-GLI(2,J-1)-GLI(1,J-1))
3429 4 +(HH/2.)*(3.*(RGA(2,J)+RGA(1,J))+(RGA(2,J+1)+RGA(1,J+1)))/8.
3430 5 +(HHH/2.)*(3.*(RGA(2,J)+RGA(1,J))+(RGA(2,J-1)+RGA(1,J-1)))/8.
3431 6 -HH/2.*(3.*(GLA(2,J)-GLA(1,J))+(GLA(2,J+1)-GLA(1,J+1)))/(4.*DT)
3432 7 -HHH/2.*(3.*(GLA(2,J)-GLA(1,J))+(GLA(2,J-1)-GLA(1,J-1)))/(4.*DT)
3433 8 -HH/2.*(3.*(GLI(2,J)-GLI(1,J))+(GLI(2,J+1)-GLI(1,J+1)))/(4.*DT)
3434 9 -HHH/2.*(3.*(GLI(2,J)-GLI(1,J))+(GLI(2,J-1)-GLI(1,J-1)))/(4.*DT)
3435
3436 B(3,3)=COEFF3HH/2.+COEFF3HHH/2.+HH/2.*3./(4.*DT)+HHH/2.*3./(4.*DT)
3437 D(3,3)=-COEFF3HH/2.+HH/2./(4.*DT)
3438 A(3,3)=-COEFF3HHH/2.+HHH/2./(4.*DT)
3439 B(3,10)=-((HH/2.)*(3./8.))-((HHH/2.)*(3./8.))
3440 D(3,10)=-((HH/2.)*(1./8.))
3441 A(3,10)=-((HHH/2.)*(1./8.))
3442 B(3,15)=COEFF10HH/2.+COEFF10HHH/2.+HH/2.*3./(4.*DT)
3443 1 +HHH/2.*3./(4.*DT)
3444 D(3,15)=-COEFF10HH/2.+HH/2./(4.*DT)
3445 A(3,15)=-COEFF10HHH/2.+HHH/2./(4.*DT)
3446
3447
3448 BIG=ABS(COEFF3HH/2.*GLA(2,J+1))
3449 BIG2=ABS(COEFF3HH/2.*GLA(1,J+1))
3450 IF (BIG2.GT.BIG) BIG=BIG2
3451 BIG3=ABS(COEFF3HH/2.*GLA(2,J))
3452 IF (BIG3.GT.BIG) BIG=BIG3
3453 BIG4=ABS(COEFF3HH/2.*GLA(1,J))
3454 IF (BIG4.GT.BIG) BIG=BIG4
3455 BIG5=ABS(COEFF3HHH/2.*GLA(2,J))
3456 IF (BIG5.GT.BIG) BIG=BIG5
3457 BIG6=ABS(COEFF3HHH/2.*GLA(1,J))
3458 IF (BIG6.GT.BIG) BIG=BIG6
3459 BIG7=ABS(COEFF3HHH/2.*GLA(2,J-1))
3460 IF (BIG7.GT.BIG) BIG=BIG7
3461 BIG8=ABS(COEFF3HHH/2.*GLA(1,J-1))
3462 IF (BIG8.GT.BIG) BIG=BIG8
3463 BIG9=ABS(HH/2.*3.*RGA(2,J)/8.)
3464 IF (BIG9.GT.BIG) BIG=BIG9
3465 BIG10=ABS(HH/2.*3.*RGA(1,J)/8.)
3466 IF (BIG10.GT.BIG) BIG=BIG10
3467 BIG11=ABS(HH/2.*RGA(2,J+1)/8.)
3468 IF (BIG11.GT.BIG) BIG=BIG11
3469 BIG12=ABS(HH/2.*RGA(1,J+1)/8.)
3470 IF (BIG12.GT.BIG) BIG=BIG12
3471 BIG13=ABS(HHH/2.*3.*RGA(2,J)/8.)
3472 IF (BIG13.GT.BIG) BIG=BIG13
3473 BIG14=ABS(HHH/2.*3.*RGA(1,J)/8.)
3474 IF (BIG14.GT.BIG) BIG=BIG14
3475 BIG15=ABS(HHH/2.*RGA(2,J-1)/8.)
3476 IF (BIG15.GT.BIG) BIG=BIG15

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3477 BIG16=ABS(HHH/2.*RGA(1,J-1)/8.)
3478 IF (BIG16.GT.BIG) BIG=BIG16
3479 BIG17=ABS(HH/2.*3.*GLA(2,J)/(4.*DT))
3480 IF (BIG17.GT.BIG) BIG=BIG17
3481 BIG18=ABS(HH/2.*3.*GLA(1,J)/(4.*DT))
3482 IF (BIG18.GT.BIG) BIG=BIG18
3483 BIG19=ABS(HH/2.*GLA(2,J+1)/(4.*DT))
3484 IF (BIG19.GT.BIG) BIG=BIG19
3485 BIG20=ABS(HH/2.*GLA(1,J+1)/(4.*DT))
3486 IF (BIG20.GT.BIG) BIG=BIG20
3487 BIG21=ABS(HHH/2.*3.*GLA(2,J)/(4.*DT))
3488 IF (BIG21.GT.BIG) BIG=BIG21
3489 BIG22=ABS(HHH/2.*3.*GLA(1,J)/(4.*DT))
3490 IF (BIG22.GT.BIG) BIG=BIG22
3491 BIG23=ABS(HHH/2.*GLA(2,J-1)/(4.*DT))
3492 IF (BIG23.GT.BIG) BIG=BIG23
3493 BIG24=ABS(HHH/2.*GLA(1,J-1)/(4.*DT))
3494 IF (BIG24.GT.BIG) BIG=BIG24
3495 BIG25=ABS(COEFF10HH/2.*GLI(2,J+1))
3496 IF (BIG25.GT.BIG) BIG=BIG25
3497 BIG26=ABS(COEFF10HH/2.*GLI(1,J+1))
3498 IF (BIG26.GT.BIG) BIG=BIG26
3499 BIG27=ABS(COEFF10HH/2.*GLI(2,J))
3500 IF (BIG27.GT.BIG) BIG=BIG27
3501 BIG28=ABS(COEFF10HH/2.*GLI(1,J))
3502 IF (BIG28.GT.BIG) BIG=BIG28
3503 BIG29=ABS(COEFF10HHH/2.*GLI(2,J))
3504 IF (BIG29.GT.BIG) BIG=BIG29
3505 BIG30=ABS(COEFF10HHH/2.*GLI(1,J))
3506 IF (BIG30.GT.BIG) BIG=BIG30
3507 BIG31=ABS(COEFF10HHH/2.*GLI(2,J-1))
3508 IF (BIG31.GT.BIG) BIG=BIG31
3509 BIG32=ABS(COEFF10HHH/2.*GLI(1,J-1))
3510 IF (BIG32.GT.BIG) BIG=BIG32
3511 BIG33=ABS(HH/2.*3.*GLI(2,J)/(4.*DT))
3512 IF (BIG33.GT.BIG) BIG=BIG33
3513 BIG34=ABS(HH/2.*3.*GLI(1,J)/(4.*DT))
3514 IF (BIG34.GT.BIG) BIG=BIG34
3515 BIG35=ABS(HH/2.*GLI(2,J+1)/(4.*DT))
3516 IF (BIG35.GT.BIG) BIG=BIG35
3517 BIG36=ABS(HH/2.*GLI(1,J+1)/(4.*DT))
3518 IF (BIG36.GT.BIG) BIG=BIG36
3519 BIG37=ABS(HHH/2.*3.*GLI(2,J)/(4.*DT))
3520 IF (BIG37.GT.BIG) BIG=BIG37
3521 BIG38=ABS(HHH/2.*3.*GLI(1,J)/(4.*DT))
3522 IF (BIG38.GT.BIG) BIG=BIG38
3523 BIG39=ABS(HHH/2.*GLI(2,J-1)/(4.*DT))
3524 IF (BIG39.GT.BIG) BIG=BIG39
3525 BIG40=ABS(HHH/2.*GLI(1,J-1)/(4.*DT))
3526 IF (BIG40.GT.BIG) BIG=BIG40
3527 IF (ABS(G(3)).LT.BIG*EBIG) G(3)=0
3528
3529 C For GOx2, enzyme
3530 G(4)=CBULK(2)+CBULK(4)+CBULK(7)+CBULK(8)-(GOX(2,J)+GOX(1,J))/2.
3531 1 -(GOR(2,J)+GOR(1,J))/2.-(GOA(2,J)+GOA(1,J))/2.
3532 2 -(GOP(2,J)+GOP(1,J))/2.
3533 B(4,4)=+1./2.
3534 B(4,2)=+1./2.

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3535 B(4,7)=+1./2.
3536 B(4,8)=+1./2.
3537
3538 BIG=ABS(CBULK(2))
3539 IF (ABS(CBULK(4)).GT.BIG) BIG=ABS(CBULK(4))
3540 IF (ABS(CBULK(7)).GT.BIG) BIG=ABS(CBULK(7))
3541 IF (ABS(CBULK(8)).GT.BIG) BIG=ABS(CBULK(8))
3542 IF (ABS(GOX(2,J)/2.).GT.BIG) BIG=ABS(GOX(2,J)/2.)
3543 IF (ABS(GOX(1,J)/2.).GT.BIG) BIG=ABS(GOX(1,J)/2.)
3544 IF (ABS(GOR(2,J)/2.).GT.BIG) BIG=ABS(GOR(2,J)/2.)
3545 IF (ABS(GOR(1,J)/2.).GT.BIG) BIG=ABS(GOR(1,J)/2.)
3546 IF (ABS(GOA(2,J)/2.).GT.BIG) BIG=ABS(GOA(2,J)/2.)
3547 IF (ABS(GOA(1,J)/2.).GT.BIG) BIG=ABS(GOA(1,J)/2.)
3548 IF (ABS(GOP(2,J)/2.).GT.BIG) BIG=ABS(GOP(2,J)/2.)
3549 IF (ABS(GOP(1,J)/2.).GT.BIG) BIG=ABS(GOP(1,J)/2.)
3550 IF (ABS(G(4)).LT.BIG*EBIG) G(4)=0
3551
3552 C For O2, being consumed only
3553 G(5)=COEFF5HH/2.*(OXY(2,J+1)+OXY(1,J+1)-OXY(2,J)-OXY(1,J))
3554 1 -COEFF5HHH/2.*(OXY(2,J)+OXY(1,J)-OXY(2,J-1)-OXY(1,J-1))
3555 2 -(HH/2.)*(3.*(EQ2(2,J)+EQ2(1,J))+(EQ2(2,J+1)+EQ2(1,J+1)))/8.
3556 3 -(HHH/2.)*(3.*(EQ2(2,J)+EQ2(1,J))+(EQ2(2,J-1)+EQ2(1,J-1)))/8.
3557 4 -HH/2.*(3.*(OXY(2,J)-OXY(1,J))+(OXY(2,J+1)-OXY(1,J+1)))/(4.*DT)
3558 5 -HHH/2.*(3.*(OXY(2,J)-OXY(1,J))+(OXY(2,J-1)-OXY(1,J-1)))/(4.*DT)
3559
3560 B(5,5)=COEFF5HH/2.+COEFF5HHH/2.+HH/2.*3./(4.*DT)+HHH/2.*3./(4.*DT)
3561 D(5,5)=-COEFF5HH/2.+HH/2./(4.*DT)
3562 A(5,5)=-COEFF5HHH/2.+HHH/2./(4.*DT)
3563 B(5,11)=+(HH/2.)*(3./8.)+(HHH/2.)*(3./8.)
3564 D(5,11)=+(HH/2.)*(1./8.)
3565 A(5,11)=+(HHH/2.)*(1./8.)
3566
3567 BIG=ABS(COEFF5HH/2.*OXY(2,J+1))
3568 BIG2=ABS(COEFF5HH/2.*OXY(1,J+1))
3569 IF (BIG2.GT.BIG) BIG=BIG2
3570 BIG3=ABS(COEFF5HH/2.*OXY(2,J))
3571 IF (BIG3.GT.BIG) BIG=BIG3
3572 BIG4=ABS(COEFF5HH/2.*OXY(1,J))
3573 IF (BIG4.GT.BIG) BIG=BIG4
3574 BIG5=ABS(COEFF5HHH/2.*OXY(2,J))
3575 IF (BIG5.GT.BIG) BIG=BIG5
3576 BIG6=ABS(COEFF5HHH/2.*OXY(1,J))
3577 IF (BIG6.GT.BIG) BIG=BIG6
3578 BIG7=ABS(COEFF5HHH/2.*OXY(2,J-1))
3579 IF (BIG7.GT.BIG) BIG=BIG7
3580 BIG8=ABS(COEFF5HHH/2.*OXY(1,J-1))
3581 IF (BIG8.GT.BIG) BIG=BIG8
3582 BIG9=ABS(HH/2.*3.*EQ2(2,J)/8.)
3583 IF (BIG9.GT.BIG) BIG=BIG9
3584 BIG10=ABS(HH/2.*3.*EQ2(1,J)/8.)
3585 IF (BIG10.GT.BIG) BIG=BIG10
3586 BIG11=ABS(HH/2.*EQ2(2,J+1)/8.)
3587 IF (BIG11.GT.BIG) BIG=BIG11
3588 BIG12=ABS(HH/2.*EQ2(1,J+1)/8.)
3589 IF (BIG12.GT.BIG) BIG=BIG12
3590 BIG13=ABS(HHH/2.*3.*EQ2(2,J)/8.)
3591 IF (BIG13.GT.BIG) BIG=BIG13
3592 BIG14=ABS(HHH/2.*3.*EQ2(1,J)/8.)

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3593 IF (BIG14.GT.BIG) BIG=BIG14
3594 BIG15=ABS(HHH/2.*EQ2(2,J-1)/8.)
3595 IF (BIG15.GT.BIG) BIG=BIG15
3596 BIG16=ABS(HHH/2.*EQ2(1,J-1)/8.)
3597 IF (BIG16.GT.BIG) BIG=BIG16
3598 BIG17=ABS(HH/2.*3.*OXY(2,J)/(4.*DT))
3599 IF (BIG17.GT.BIG) BIG=BIG17
3600 BIG18=ABS(HH/2.*3.*OXY(1,J)/(4.*DT))
3601 IF (BIG18.GT.BIG) BIG=BIG18
3602 BIG19=ABS(HH/2.*OXY(2,J+1)/(4.*DT))
3603 IF (BIG19.GT.BIG) BIG=BIG19
3604 BIG20=ABS(HH/2.*OXY(1,J+1)/(4.*DT))
3605 IF (BIG20.GT.BIG) BIG=BIG20
3606 BIG21=ABS(HHH/2.*3.*OXY(2,J)/(4.*DT))
3607 IF (BIG21.GT.BIG) BIG=BIG21
3608 BIG22=ABS(HHH/2.*3.*OXY(1,J)/(4.*DT))
3609 IF (BIG22.GT.BIG) BIG=BIG22
3610 BIG23=ABS(HHH/2.*OXY(2,J-1)/(4.*DT))
3611 IF (BIG23.GT.BIG) BIG=BIG23
3612 BIG24=ABS(HHH/2.*OXY(1,J-1)/(4.*DT))
3613 IF (BIG24.GT.BIG) BIG=BIG24
3614 IF (ABS(G(5)).LT.BIG*EBIG) G(5)=0
3615
3616
3617 C For H2O2, reacting species
3618 G(6)=COEFF6HH/2.*(HPR(2,J+1)+HPR(1,J+1)-HPR(2,J)-HPR(1,J))
3619 1 -COEFF6HHH/2.*(HPR(2,J)+HPR(1,J)-HPR(2,J-1)-HPR(1,J-1))
3620 2 +(HH/2.)*(3.*(RHP(2,J)+RHP(1,J))+(RHP(2,J+1)+RHP(1,J+1)))/8.
3621 3 +(HHH/2.)*(3.*(RHP(2,J)+RHP(1,J))+(RHP(2,J-1)+RHP(1,J-1)))/8.
3622 4 -HH/2.*(3.*(HPR(2,J)-HPR(1,J))+(HPR(2,J+1)-HPR(1,J+1)))/(4.*DT)
3623 5 -HHH/2.*(3.*(HPR(2,J)-HPR(1,J))+(HPR(2,J-1)-HPR(1,J-1)))/(4.*DT)
3624
3625 B(6,6)=COEFF6HH/2.+COEFF6HHH/2.+HH/2.*3./(4.*DT)+HHH/2.*3./(4.*DT)
3626 D(6,6)=-COEFF6HH/2.+HH/2./(4.*DT)
3627 A(6,6)=-COEFF6HHH/2.+HHH/2./(4.*DT)
3628 B(6,12)=- (HH/2.)*(3./8.)-(HHH/2.)*(3./8.)
3629 D(6,12)=- (HH/2.)*(1./8.)
3630 A(6,12)=- (HHH/2.)*(1./8.)
3631
3632 BIG=ABS(COEFF6HH/2.*HPR(2,J+1))
3633 BIG2=ABS(COEFF6HH/2.*HPR(1,J+1))
3634 IF (BIG2.GT.BIG) BIG=BIG2
3635 BIG3=ABS(COEFF6HH/2.*HPR(2,J))
3636 IF (BIG3.GT.BIG) BIG=BIG3
3637 BIG4=ABS(COEFF6HH/2.*HPR(1,J))
3638 IF (BIG4.GT.BIG) BIG=BIG4
3639 BIG5=ABS(COEFF6HHH/2.*HPR(2,J))
3640 IF (BIG5.GT.BIG) BIG=BIG5
3641 BIG6=ABS(COEFF6HHH/2.*HPR(1,J))
3642 IF (BIG6.GT.BIG) BIG=BIG6
3643 BIG7=ABS(COEFF6HHH/2.*HPR(2,J-1))
3644 IF (BIG7.GT.BIG) BIG=BIG7
3645 BIG8=ABS(COEFF6HHH/2.*HPR(1,J-1))
3646 IF (BIG8.GT.BIG) BIG=BIG8
3647 BIG9=ABS(HH/2.*3.*RHP(2,J)/8.)
3648 IF (BIG9.GT.BIG) BIG=BIG9
3649 BIG10=ABS(HH/2.*3.*RHP(1,J)/8.)
3650 IF (BIG10.GT.BIG) BIG=BIG10

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3651 BIG11=ABS(HH/2.*RHP(2,J+1)/8.)
3652 IF (BIG11.GT.BIG) BIG=BIG11
3653 BIG12=ABS(HH/2.*RHP(1,J+1)/8.)
3654 IF (BIG12.GT.BIG) BIG=BIG12
3655 BIG13=ABS(HHH/2.*3.*RHP(2,J)/8.)
3656 IF (BIG13.GT.BIG) BIG=BIG13
3657 BIG14=ABS(HHH/2.*3.*RHP(1,J)/8.)
3658 IF (BIG14.GT.BIG) BIG=BIG14
3659 BIG15=ABS(HHH/2.*RHP(2,J-1)/8.)
3660 IF (BIG15.GT.BIG) BIG=BIG15
3661 BIG16=ABS(HHH/2.*RHP(1,J-1)/8.)
3662 IF (BIG16.GT.BIG) BIG=BIG16
3663 BIG17=ABS(HH/2.*3.*HPR(2,J)/(4.*DT))
3664 IF (BIG17.GT.BIG) BIG=BIG17
3665 BIG18=ABS(HH/2.*3.*HPR(1,J)/(4.*DT))
3666 IF (BIG18.GT.BIG) BIG=BIG18
3667 BIG19=ABS(HH/2.*HPR(2,J+1)/(4.*DT))
3668 IF (BIG19.GT.BIG) BIG=BIG19
3669 BIG20=ABS(HH/2.*HPR(1,J+1)/(4.*DT))
3670 IF (BIG20.GT.BIG) BIG=BIG20
3671 BIG21=ABS(HHH/2.*3.*HPR(2,J)/(4.*DT))
3672 IF (BIG21.GT.BIG) BIG=BIG21
3673 BIG22=ABS(HHH/2.*3.*HPR(1,J)/(4.*DT))
3674 IF (BIG22.GT.BIG) BIG=BIG22
3675 BIG23=ABS(HHH/2.*HPR(2,J-1)/(4.*DT))
3676 IF (BIG23.GT.BIG) BIG=BIG23
3677 BIG24=ABS(HHH/2.*HPR(1,J-1)/(4.*DT))
3678 IF (BIG24.GT.BIG) BIG=BIG24
3679 IF (ABS(G(6)).LT.BIG*EBIG) G(6)=0
3680
3681 C For CX-GOx2, enzyme
3682 G(7)=(EQ1(2,J)+EQ1(1,J))/2.-(RGA(2,J)+RGA(1,J))/2.
3683 1 -(GOA(2,J)-GOA(1,J))/DT
3684
3685 B(7,7)=+1./DT
3686 B(7,9)=-1./2.
3687 B(7,10)=1./2.
3688
3689 IF (ABS(EQ1(2,J)).GT.BIG) BIG=ABS(EQ1(2,J))
3690 IF (ABS(EQ1(1,J)).GT.BIG) BIG=ABS(EQ1(1,J))
3691 IF (ABS(RGA(2,J)).GT.BIG) BIG=ABS(RGA(2,J))
3692 IF (ABS(RGA(1,J)).GT.BIG) BIG=ABS(RGA(1,J))
3693 IF (ABS(GOA(2,J)/DT).GT.BIG) BIG=ABS(GOA(2,J)/DT)
3694 IF (ABS(GOA(1,J)/DT).GT.BIG) BIG=ABS(GOA(1,J)/DT)
3695 IF (ABS(G(7)).LT.BIG*EBIG) G(7)=0
3696
3697
3698 C For CX-GOx, enzyme
3699 G(8)=(EQ2(2,J)+EQ2(1,J))/2.-(RHP(2,J)+RHP(1,J))/2.
3700 1 -(GOP(2,J)-GOP(1,J))/DT
3701 B(8,8)=+1./DT
3702 B(8,11)=-1./2.
3703 B(8,12)=1./2.
3704
3705 IF (ABS(EQ2(2,J)).GT.BIG) BIG=ABS(EQ2(2,J))
3706 IF (ABS(EQ2(1,J)).GT.BIG) BIG=ABS(EQ2(1,J))
3707 IF (ABS(RHP(2,J)).GT.BIG) BIG=ABS(RHP(2,J))
3708 IF (ABS(RHP(1,J)).GT.BIG) BIG=ABS(RHP(1,J))

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3709 IF (ABS(GOP(2,J)/DT).GT.BIG) BIG=ABS(GOP(2,J)/DT)
3710 IF (ABS(GOP(1,J)/DT).GT.BIG) BIG=ABS(GOP(1,J)/DT)
3711 IF (ABS(G(8)).LT.BIG*EBIG) G(8)=0
3712
3713
3714 C REACTION1
3715 214 G(9)=-((EQ1(2,J)+EQ1(1,J))/2.
3716 1 +ratef1*((GLU(2,J)+GLU(1,J))*(GOX(2,J)+GOX(1,J))/4.
3717 2 -(GOA(2,J)+GOA(1,J))/2./equilib1)
3718 B(9,1)=-ratef1*(GOX(2,J)+GOX(1,J))/4.
3719 B(9,2)=-ratef1*(GLU(2,J)+GLU(1,J))/4.
3720 B(9,7)=ratef1/2./equilib1
3721 B(9,9)=+1./2.
3722
3723 BIG=ABS(EQ1(2,J)/2.)
3724 BIG2=ABS(EQ1(1,J)/2.)
3725 IF (BIG2.GT.BIG) BIG=BIG2
3726 BIG3=ABS(ratef1*GLU(2,J)*GOX(2,J)/4.)
3727 IF (BIG3.GT.BIG) BIG=BIG3
3728 BIG4=ABS(ratef1*GLU(1,J)*GOX(2,J)/4)
3729 IF (BIG4.GT.BIG) BIG=BIG4
3730 BIG5=ABS(ratef1*GLU(2,J)*GOX(1,J)/4)
3731 IF (BIG5.GT.BIG) BIG=BIG5
3732 BIG6=ABS(ratef1*GLU(1,J)*GOX(1,J)/4)
3733 IF (BIG6.GT.BIG) BIG=BIG6
3734 BIG7=ABS(ratef1*GOA(2,J)/2./equilib1)
3735 IF (BIG7.GT.BIG) BIG=BIG7
3736 BIG8=ABS(ratef1*GOA(1,J)/2./equilib1)
3737 IF (BIG8.GT.BIG) BIG=BIG8
3738 IF (ABS(G(9)).LT.BIG*EBIG) G(9)=0
3739
3740
3741 C REACTION2
3742 215 G(10)=-((RGA(2,J)+RGA(1,J))/2.+ratef2*(GOA(2,J)+GOA(1,J))/2.
3743 B(10,7)=-ratef2/2.
3744 B(10,10)=+1./2.
3745
3746 BIG=ABS(RGA(2,J)/2.)
3747 BIG2=ABS(RGA(1,J)/2.)
3748 IF (BIG2.GT.BIG) BIG=BIG2
3749 BIG3=ABS(ratef2*GOA(2,J)/2.)
3750 IF (BIG3.GT.BIG) BIG=BIG3
3751 BIG4=ABS(ratef2*GOA(1,J)/2.)
3752 IF (BIG4.GT.BIG) BIG=BIG4
3753 IF (ABS(G(10)).LT.BIG*EBIG) G(10)=0
3754
3755 C REACTION3
3756 216 G(11)=-((EQ2(2,J)+EQ2(1,J))/2.
3757 1 +ratef3*((GOR(2,J)+GOR(1,J))*(OXY(2,J)+OXY(1,J))/4.
3758 2 -(GOP(2,J)+GOP(1,J))/2./equilib3)
3759 B(11,4)=-ratef3*(OXY(2,J)+OXY(1,J))/4.
3760 B(11,5)=-ratef3*(GOR(2,J)+GOR(1,J))/4.
3761 B(11,8)=ratef3/2./equilib3
3762 B(11,11)=+1./2.
3763
3764 BIG=ABS(EQ2(2,J)/2.)
3765 BIG2=ABS(EQ2(1,J)/2.)
3766 IF (BIG2.GT.BIG) BIG=BIG2

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3767     BIG3=ABS(ratef3 *GOR(2 , J)*OXY(2 , J) /4.)
3768     IF (BIG3.GT.BIG) BIG=BIG3
3769     BIG4=ABS(ratef3 *GOR(1 , J)*OXY(2 , J) /4)
3770     IF (BIG4.GT.BIG) BIG=BIG4
3771     BIG5=ABS(ratef3 *GOR(2 , J)*OXY(1 , J) /4)
3772     IF (BIG5.GT.BIG) BIG=BIG5
3773     BIG6=ABS(ratef3 *GOR(1 , J)*OXY(1 , J) /4)
3774     IF (BIG6.GT.BIG) BIG=BIG6
3775     BIG7=ABS(ratef3 *GOP(2 , J) /2./EQUILIB3)
3776     IF (BIG7.GT.BIG) BIG=BIG7
3777     BIG8=ABS(ratef3 *GOP(1 , J) /2./EQUILIB3)
3778     IF (BIG8.GT.BIG) BIG=BIG8
3779     IF (ABS(G(11)).LT.BIG*EBIG) G(11)=0
3780
3781 C     REACTION4
3782 217 G(12)=-((RHP(2 , J)+RHP(1 , J)) /2.+ ratef4 *(GOP(2 , J)+GOP(1 , J)) /2.
3783     B(12 ,8)=-ratef4 /2.
3784     B(12 ,12)=+1./2.
3785
3786     BIG=ABS(RHP(2 , J) /2.)
3787     BIG2=ABS(RHP(1 , J) /2.)
3788     IF (BIG2.GT.BIG) BIG=BIG2
3789     BIG3=ABS(ratef4 *GOP(2 , J) /2.)
3790     IF (BIG3.GT.BIG) BIG=BIG3
3791     BIG4=ABS(ratef4 *GOP(1 , J) /2.)
3792     IF (BIG4.GT.BIG) BIG=BIG4
3793     IF (ABS(G(12)).LT.BIG*EBIG) G(12)=0
3794
3795 C     REACTION5
3796 218 G(13)=-((ANM(2 , J)+ANM(1 , J)) /2.+ ratef5 *((GLUA(2 , J)+GLUA(1 , J)) /2.
3797 1   -(GLU(2 , J)+GLU(1 , J)) /2./equilib5)
3798     B(13 ,1)=ratef5 /2./equilib5
3799     B(13 ,14)=-ratef5 /2.
3800     B(13 ,13)=+1./2.
3801
3802     BIG=ABS(ANM(2 , J) /2.)
3803     BIG2=ABS(ANM(1 , J) /2.)
3804     IF (BIG2.GT.BIG) BIG=BIG2
3805     BIG3=ABS(ratef5 *GLUA(2 , J) /2.)
3806     IF (BIG3.GT.BIG) BIG=BIG3
3807     BIG4=ABS(ratef5 *GLUA(1 , J) /2.)
3808     IF (BIG4.GT.BIG) BIG=BIG4
3809     BIG5=ABS(ratef5 *GLU(2 , J) /2./equilib5)
3810     IF (BIG5.GT.BIG) BIG=BIG5
3811     BIG6=ABS(ratef5 *GLU(1 , J) /2./equilib5)
3812     IF (BIG6.GT.BIG) BIG=BIG6
3813     IF (ABS(G(13)).LT.BIG*EBIG) G(13)=0.0
3814
3815 C     For alpha Glucose , being consumed only
3816     G(14)=COEFF9HH/2. *(GLUA(2 , J+1)+GLUA(1 , J+1)-GLUA(2 , J)-GLUA(1 , J))
3817 1   -COEFF9HHH/2. *(GLUA(2 , J)+GLUA(1 , J)-GLUA(2 , J-1)-GLUA(1 , J-1))
3818 2   -(HH/2.) *(3. *(ANM(2 , J)+ANM(1 , J)) +(ANM(2 , J+1)+ANM(1 , J+1))) /8.
3819 3   -(HHH/2.) *(3. *(ANM(2 , J)+ANM(1 , J)) +(ANM(2 , J-1)+ANM(1 , J-1))) /8.
3820 4   -HH/2.
3821 5   *(3. *(GLUA(2 , J)-GLUA(1 , J)) +(GLUA(2 , J+1)-GLUA(1 , J+1))) / (4. *DT)
3822 6   -HHH/2.
3823 7   *(3. *(GLUA(2 , J)-GLUA(1 , J)) +(GLUA(2 , J-1)-GLUA(1 , J-1))) / (4. *DT)
3824

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3825
3826      B(14,14)=COEFF9HH/2.+COEFF9HHH/2.+HH/2.*3./(4.*DT)
3827      1 +HHH/2.*3./(4.*DT)
3828      D(14,14)=-COEFF9HH/2.+HH/2./(4.*DT)
3829      A(14,14)=-COEFF9HHH/2.+HHH/2./(4.*DT)
3830      B(14,13)=+(HH/2.)*(3./8.)+(HHH/2.)*(3./8.)
3831      D(14,13)=+(HH/2.)*(1./8.)
3832      A(14,13)=+(HHH/2.)*(1./8.)
3833
3834      BIG=ABS(COEFF9HH/2.*GLUA(2,J+1))
3835      BIG2=ABS(COEFF9HH/2.*GLUA(1,J+1))
3836      IF (BIG2.GT.BIG) BIG=BIG2
3837      BIG3=ABS(COEFF9HH/2.*GLUA(2,J))
3838      IF (BIG3.GT.BIG) BIG=BIG3
3839      BIG4=ABS(COEFF9HH/2.*GLUA(1,J))
3840      IF (BIG4.GT.BIG) BIG=BIG4
3841      BIG5=ABS(COEFF9HHH/2.*GLUA(2,J))
3842      IF (BIG5.GT.BIG) BIG=BIG5
3843      BIG6=ABS(COEFF9HHH/2.*GLUA(1,J))
3844      IF (BIG6.GT.BIG) BIG=BIG6
3845      BIG7=ABS(COEFF9HHH/2.*GLUA(2,J-1))
3846      IF (BIG7.GT.BIG) BIG=BIG7
3847      BIG8=ABS(COEFF9HHH/2.*GLUA(1,J-1))
3848      IF (BIG8.GT.BIG) BIG=BIG8
3849      BIG9=ABS(HH/2.*3.*GLUA(2,J)/(4.*DT))
3850      IF (BIG9.GT.BIG) BIG=BIG9
3851      BIG10=ABS(HH/2.*3.*GLUA(1,J)/(4.*DT))
3852      IF (BIG10.GT.BIG) BIG=BIG10
3853      BIG11=ABS(HH/2.*GLUA(2,J+1)/(4.*DT))
3854      IF (BIG11.GT.BIG) BIG=BIG11
3855      BIG12=ABS(HH/2.*GLUA(1,J+1)/(4.*DT))
3856      IF (BIG12.GT.BIG) BIG=BIG12
3857      BIG13=ABS(HHH/2.*3.*GLUA(2,J)/(4.*DT))
3858      IF (BIG13.GT.BIG) BIG=BIG13
3859      BIG14=ABS(HHH/2.*3.*GLUA(1,J)/(4.*DT))
3860      IF (BIG14.GT.BIG) BIG=BIG14
3861      BIG15=ABS(HHH/2.*GLUA(2,J-1)/(4.*DT))
3862      IF (BIG15.GT.BIG) BIG=BIG15
3863      BIG16=ABS(HHH/2.*GLUA(1,J-1)/(4.*DT))
3864      IF (BIG16.GT.BIG) BIG=BIG16
3865      BIG17=ABS(HH/2.*3.*ANM(2,J)/8.)
3866      IF (BIG17.GT.BIG) BIG=BIG17
3867      BIG18=ABS(HH/2.*3.*ANM(1,J)/8.)
3868      IF (BIG18.GT.BIG) BIG=BIG18
3869      BIG19=ABS(HH/2.*ANM(2,J+1)/8.)
3870      IF (BIG19.GT.BIG) BIG=BIG19
3871      BIG20=ABS(HH/2.*ANM(1,J+1)/8.)
3872      IF (BIG20.GT.BIG) BIG=BIG20
3873      BIG21=ABS(HHH/2.*3.*ANM(2,J)/8.)
3874      IF (BIG21.GT.BIG) BIG=BIG21
3875      BIG22=ABS(HHH/2.*3.*ANM(1,J)/8.)
3876      IF (BIG22.GT.BIG) BIG=BIG22
3877      BIG23=ABS(HHH/2.*ANM(2,J-1)/8.)
3878      IF (BIG23.GT.BIG) BIG=BIG23
3879      BIG24=ABS(HHH/2.*ANM(1,J-1)/8.)
3880      IF (BIG24.GT.BIG) BIG=BIG24
3881      IF (ABS(G(14)).LT.BIG*EBIG) G(14)=0
3882

```

3883 C Gluconic acid dissociation

3884  
 3885 G(15)=equilib6\*(GLA(2,J)+GLA(1,J))/2.-(GLI(2,J)+GLI(1,J))\*  
 3886 1 (HYD(2,J)+HYD(1,J))/4.  
 3887 B(15,3)=-equilib6/2.  
 3888 B(15,15)=(HYD(2,J)+HYD(1,J))/4.  
 3889 B(15,16)=(GLI(2,J)+GLI(1,J))/4.  
 3890  
 3891 BIG=ABS(equilib6\*GLA(2,J)/2.)  
 3892 BIG2=ABS(equilib6\*GLA(1,J)/2.)  
 3893 IF (BIG2.GT.BIG) BIG=BIG2  
 3894 BIG3=ABS(GLI(2,J)\*HYD(2,J)/4.)  
 3895 IF (BIG3.GT.BIG) BIG=BIG3  
 3896 BIG4=ABS(GLI(2,J)\*HYD(1,J)/4)  
 3897 IF (BIG4.GT.BIG) BIG=BIG4  
 3898 BIG5=ABS(GLI(1,J)\*HYD(2,J)/4)  
 3899 IF (BIG5.GT.BIG) BIG=BIG5  
 3900 BIG6=ABS(GLI(1,J)\*HYD(1,J)/4)  
 3901 IF (BIG6.GT.BIG) BIG=BIG6  
 3902 IF (ABS(G(15)).LT.BIG\*EBIG) G(15)=0  
 3903

3904 C Hydrogen ion, hydroxide ion, gluconate ion, bicarbonate ion flux

3905 G(16)=COEFF11HH/2.\*(HYD(2,J+1)+HYD(1,J+1)-HYD(2,J)-HYD(1,J))  
 3906 1 -COEFF11HHH/2.\*(HYD(2,J)+HYD(1,J)-HYD(2,J-1)-HYD(1,J-1))  
 3907 2 -COEFF15HH/2.\*(OHI(2,J+1)+OHI(1,J+1)-OHI(2,J)-OHI(1,J))  
 3908 3 +COEFF15HHH/2.\*(OHI(2,J)+OHI(1,J)-OHI(2,J-1)-OHI(1,J-1))  
 3909 4 -COEFF10HH/2.\*(GLI(2,J+1)+GLI(1,J+1)-GLI(2,J)-GLI(1,J))  
 3910 5 +COEFF10HHH/2.\*(GLI(2,J)+GLI(1,J)-GLI(2,J-1)-GLI(1,J-1))  
 3911 6 -COEFF14HH/2.\*(CBI(2,J+1)+CBI(1,J+1)-CBI(2,J)-CBI(1,J))  
 3912 7 +COEFF14HHH/2.\*(CBI(2,J)+CBI(1,J)-CBI(2,J-1)-CBI(1,J-1))  
 3913 8 -HH/2.\*(3.\*(HYD(2,J)-HYD(1,J))+(HYD(2,J+1)-HYD(1,J+1)))/(4.\*DT)  
 3914 9 -HHH/2.\*(3.\*(HYD(2,J)-HYD(1,J))+(HYD(2,J-1)-HYD(1,J-1)))/(4.\*DT)  
 3915 1 +HH/2.\*(3.\*(OHI(2,J)-OHI(1,J))+(OHI(2,J+1)-OHI(1,J+1)))/(4.\*DT)  
 3916 2 +HHH/2.\*(3.\*(OHI(2,J)-OHI(1,J))+(OHI(2,J-1)-OHI(1,J-1)))/(4.\*DT)  
 3917 3 +HH/2.\*(3.\*(GLI(2,J)-GLI(1,J))+(GLI(2,J+1)-GLI(1,J+1)))/(4.\*DT)  
 3918 4 +HHH/2.\*(3.\*(GLI(2,J)-GLI(1,J))+(GLI(2,J-1)-GLI(1,J-1)))/(4.\*DT)  
 3919 5 +HH/2.\*(3.\*(CBI(2,J)-CBI(1,J))+(CBI(2,J+1)-CBI(1,J+1)))/(4.\*DT)  
 3920 6 +HHH/2.\*(3.\*(CBI(2,J)-CBI(1,J))+(CBI(2,J-1)-CBI(1,J-1)))/(4.\*DT)  
 3921  
 3922 B(16,16)=COEFF11HH/2.+COEFF11HHH/2.+HH/2.\*3./(4.\*DT)  
 3923 1 +HHH/2.\*3./(4.\*DT)  
 3924 D(16,16)=-COEFF11HH/2.+HH/2./(4.\*DT)  
 3925 A(16,16)=-COEFF11HHH/2.+HHH/2./(4.\*DT)  
 3926  
 3927 B(16,17)=-COEFF15HH/2.-COEFF15HHH/2.-HH/2.\*3./(4.\*DT)  
 3928 1 -HHH/2.\*3./(4.\*DT)  
 3929 D(16,17)=+COEFF15HH/2.-HH/2./(4.\*DT)  
 3930 A(16,17)=+COEFF15HHH/2.-HHH/2./(4.\*DT)  
 3931  
 3932 B(16,15)=-COEFF10HH/2.-COEFF10HHH/2.-HH/2.\*3./(4.\*DT)  
 3933 1 -HHH/2.\*3./(4.\*DT)  
 3934 D(16,15)=+COEFF10HH/2.-HH/2./(4.\*DT)  
 3935 A(16,15)=+COEFF10HHH/2.-HHH/2./(4.\*DT)  
 3936  
 3937 B(16,20)=-COEFF14HH/2.-COEFF14HHH/2.-HH/2.\*3./(4.\*DT)  
 3938 1 -HHH/2.\*3./(4.\*DT)  
 3939 D(16,20)=+COEFF14HH/2.-HH/2./(4.\*DT)  
 3940 A(16,20)=+COEFF14HHH/2.-HHH/2./(4.\*DT)

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3941
3942     BIG=ABS(COEFF11HH/2.*HYD(2,J+1))
3943     BIG2=ABS(COEFF11HH/2.*HYD(1,J+1))
3944     IF (BIG2.GT.BIG) BIG=BIG2
3945     BIG3=ABS(COEFF11HH/2.*HYD(2,J))
3946     IF (BIG3.GT.BIG) BIG=BIG3
3947     BIG4=ABS(COEFF11HH/2.*HYD(1,J))
3948     IF (BIG4.GT.BIG) BIG=BIG4
3949     BIG5=ABS(COEFF11HHH/2.*HYD(2,J))
3950     IF (BIG5.GT.BIG) BIG=BIG5
3951     BIG6=ABS(COEFF11HHH/2.*HYD(1,J))
3952     IF (BIG6.GT.BIG) BIG=BIG6
3953     BIG7=ABS(COEFF11HHH/2.*HYD(2,J-1))
3954     IF (BIG7.GT.BIG) BIG=BIG7
3955     BIG8=ABS(COEFF11HHH/2.*HYD(1,J-1))
3956     IF (BIG8.GT.BIG) BIG=BIG8
3957     BIG9=ABS(HH/2.*3.*HYD(2,J)/(4.*DT))
3958     IF (BIG9.GT.BIG) BIG=BIG9
3959     BIG10=ABS(HH/2.*3.*HYD(1,J)/(4.*DT))
3960     IF (BIG10.GT.BIG) BIG=BIG10
3961     BIG11=ABS(HH/2.*HYD(2,J+1)/(4.*DT))
3962     IF (BIG11.GT.BIG) BIG=BIG11
3963     BIG12=ABS(HH/2.*HYD(1,J+1)/(4.*DT))
3964     IF (BIG12.GT.BIG) BIG=BIG12
3965     BIG13=ABS(HHH/2.*3.*HYD(2,J)/(4.*DT))
3966     IF (BIG13.GT.BIG) BIG=BIG13
3967     BIG14=ABS(HHH/2.*3.*HYD(1,J)/(4.*DT))
3968     IF (BIG14.GT.BIG) BIG=BIG14
3969     BIG15=ABS(HHH/2.*HYD(2,J-1)/(4.*DT))
3970     IF (BIG15.GT.BIG) BIG=BIG15
3971     BIG16=ABS(HHH/2.*HYD(1,J-1)/(4.*DT))
3972     IF (BIG16.GT.BIG) BIG=BIG16
3973     BIG17=ABS(COEFF15HH/2.*OHI(2,J+1))
3974     IF (BIG17.GT.BIG) BIG=BIG17
3975     BIG18=ABS(COEFF15HH/2.*OHI(1,J+1))
3976     IF (BIG18.GT.BIG) BIG=BIG18
3977     BIG19=ABS(COEFF15HH/2.*OHI(2,J))
3978     IF (BIG19.GT.BIG) BIG=BIG19
3979     BIG20=ABS(COEFF15HH/2.*OHI(1,J))
3980     IF (BIG20.GT.BIG) BIG=BIG20
3981     BIG21=ABS(COEFF15HHH/2.*OHI(2,J))
3982     IF (BIG21.GT.BIG) BIG=BIG21
3983     BIG22=ABS(COEFF15HHH/2.*OHI(1,J))
3984     IF (BIG22.GT.BIG) BIG=BIG22
3985     BIG23=ABS(COEFF15HHH/2.*OHI(2,J-1))
3986     IF (BIG23.GT.BIG) BIG=BIG23
3987     BIG24=ABS(COEFF15HHH/2.*OHI(1,J-1))
3988     IF (BIG24.GT.BIG) BIG=BIG24
3989     BIG25=ABS(HH/2.*3.*OHI(2,J)/(4.*DT))
3990     IF (BIG25.GT.BIG) BIG=BIG25
3991     BIG26=ABS(HH/2.*3.*OHI(1,J)/(4.*DT))
3992     IF (BIG26.GT.BIG) BIG=BIG26
3993     BIG27=ABS(HH/2.*OHI(2,J+1)/(4.*DT))
3994     IF (BIG27.GT.BIG) BIG=BIG27
3995     BIG28=ABS(HH/2.*OHI(1,J+1)/(4.*DT))
3996     IF (BIG28.GT.BIG) BIG=BIG28
3997     BIG29=ABS(HHH/2.*3.*OHI(2,J)/(4.*DT))
3998     IF (BIG29.GT.BIG) BIG=BIG29

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3999  BIG30=ABS(HHH/2.*3.*OHI(1,J)/(4.*DT))
4000  IF (BIG30.GT.BIG) BIG=BIG30
4001  BIG31=ABS(HHH/2.*OHI(2,J-1)/(4.*DT))
4002  IF (BIG31.GT.BIG) BIG=BIG31
4003  BIG32=ABS(HHH/2.*OHI(1,J-1)/(4.*DT))
4004  IF (BIG32.GT.BIG) BIG=BIG32
4005  BIG33=ABS(COEFF10HH/2.*GLI(2,J+1))
4006  IF (BIG33.GT.BIG) BIG=BIG33
4007  BIG34=ABS(COEFF10HH/2.*GLI(1,J+1))
4008  IF (BIG34.GT.BIG) BIG=BIG34
4009  BIG35=ABS(COEFF10HH/2.*GLI(2,J))
4010  IF (BIG35.GT.BIG) BIG=BIG35
4011  BIG36=ABS(COEFF10HH/2.*GLI(1,J))
4012  IF (BIG36.GT.BIG) BIG=BIG36
4013  BIG37=ABS(COEFF10HHH/2.*GLI(2,J))
4014  IF (BIG37.GT.BIG) BIG=BIG37
4015  BIG38=ABS(COEFF10HHH/2.*GLI(1,J))
4016  IF (BIG38.GT.BIG) BIG=BIG38
4017  BIG39=ABS(COEFF10HHH/2.*GLI(2,J-1))
4018  IF (BIG39.GT.BIG) BIG=BIG39
4019  BIG40=ABS(COEFF10HHH/2.*GLI(1,J-1))
4020  IF (BIG40.GT.BIG) BIG=BIG40
4021  BIG41=ABS(HH/2.*3.*GLI(2,J)/(4.*DT))
4022  IF (BIG41.GT.BIG) BIG=BIG41
4023  BIG42=ABS(HH/2.*3.*GLI(1,J)/(4.*DT))
4024  IF (BIG42.GT.BIG) BIG=BIG42
4025  BIG43=ABS(HH/2.*GLI(2,J+1)/(4.*DT))
4026  IF (BIG43.GT.BIG) BIG=BIG43
4027  BIG44=ABS(HH/2.*GLI(1,J+1)/(4.*DT))
4028  IF (BIG44.GT.BIG) BIG=BIG44
4029  BIG45=ABS(HHH/2.*3.*GLI(2,J)/(4.*DT))
4030  IF (BIG45.GT.BIG) BIG=BIG45
4031  BIG46=ABS(HHH/2.*3.*GLI(1,J)/(4.*DT))
4032  IF (BIG46.GT.BIG) BIG=BIG46
4033  BIG47=ABS(HHH/2.*GLI(2,J-1)/(4.*DT))
4034  IF (BIG47.GT.BIG) BIG=BIG47
4035  BIG48=ABS(HHH/2.*GLI(1,J-1)/(4.*DT))
4036  IF (BIG48.GT.BIG) BIG=BIG48
4037  BIG49=ABS(COEFF14HH/2.*CBI(2,J+1))
4038  IF (BIG49.GT.BIG) BIG=BIG49
4039  BIG50=ABS(COEFF14HH/2.*CBI(1,J+1))
4040  IF (BIG50.GT.BIG) BIG=BIG50
4041  BIG51=ABS(COEFF14HH/2.*CBI(2,J))
4042  IF (BIG51.GT.BIG) BIG=BIG51
4043  BIG52=ABS(COEFF14HH/2.*CBI(1,J))
4044  IF (BIG52.GT.BIG) BIG=BIG52
4045  BIG53=ABS(COEFF14HHH/2.*CBI(2,J))
4046  IF (BIG53.GT.BIG) BIG=BIG53
4047  BIG54=ABS(COEFF14HHH/2.*CBI(1,J))
4048  IF (BIG54.GT.BIG) BIG=BIG54
4049  BIG55=ABS(COEFF14HHH/2.*CBI(2,J-1))
4050  IF (BIG55.GT.BIG) BIG=BIG55
4051  BIG56=ABS(COEFF14HHH/2.*CBI(1,J-1))
4052  IF (BIG56.GT.BIG) BIG=BIG56
4053  BIG57=ABS(HH/2.*3.*CBI(2,J)/(4.*DT))
4054  IF (BIG57.GT.BIG) BIG=BIG57
4055  BIG58=ABS(HH/2.*3.*CBI(1,J)/(4.*DT))
4056  IF (BIG58.GT.BIG) BIG=BIG58

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4057 BIG59=ABS(HH/2.*CBI(2,J+1)/(4.*DT))
4058 IF (BIG59.GT.BIG) BIG=BIG59
4059 BIG60=ABS(HH/2.*CBI(1,J+1)/(4.*DT))
4060 IF (BIG60.GT.BIG) BIG=BIG60
4061 BIG61=ABS(HHH/2.*3.*CBI(2,J)/(4.*DT))
4062 IF (BIG61.GT.BIG) BIG=BIG61
4063 BIG62=ABS(HHH/2.*3.*CBI(1,J)/(4.*DT))
4064 IF (BIG62.GT.BIG) BIG=BIG62
4065 BIG63=ABS(HHH/2.*CBI(2,J-1)/(4.*DT))
4066 IF (BIG63.GT.BIG) BIG=BIG63
4067 BIG64=ABS(HHH/2.*CBI(1,J-1)/(4.*DT))
4068 IF (BIG64.GT.BIG) BIG=BIG64
4069 IF (ABS(G(16)).LT.BIG*EBIG) G(16)=0
4070
4071 c Water Dissociation
4072 G(17)=equilib9 -(HYD(2,J)+HYD(1,J))*(OHI(2,J)+OHI(1,J))/4.
4073 B(17,17)=(HYD(2,J)+HYD(1,J))/4.
4074 B(17,16)=(OHI(2,J)+OHI(1,J))/4.
4075
4076 BIG=ABS(equilib9)
4077 BIG2=ABS(HYD(2,J)*OHI(2,J)/4.)
4078 IF (BIG2.GT.BIG) BIG=BIG2
4079 BIG3=ABS(HYD(2,J)*OHI(1,J)/4.)
4080 IF (BIG3.GT.BIG) BIG=BIG3
4081 BIG4=ABS(HYD(1,J)*OHI(2,J)/4.)
4082 IF (BIG4.GT.BIG) BIG=BIG4
4083 BIG5=ABS(HYD(1,J)*OHI(1,J)/4.)
4084 IF (BIG5.GT.BIG) BIG=BIG5
4085 IF (ABS(G(17)).LT.BIG*EBIG) G(17)=0
4086
4087 C CO2 Hydration
4088
4089 G(18)=equilib7 *(CO2(2,J)+CO2(1,J))/2. -(CBA(2,J)+CBA(1,J))/2.
4090 B(18,18)=-equilib7/2.
4091 B(18,19)=1./2.
4092
4093 BIG=ABS(equilib7*CO2(2,J)/2.)
4094 BIG2=ABS(equilib7*CO2(1,J)/2.)
4095 IF (BIG2.GT.BIG) BIG=BIG2
4096 BIG3=ABS(CBA(2,J)/2.)
4097 IF (BIG3.GT.BIG) BIG=BIG3
4098 BIG4=ABS(CBA(1,J)/2.)
4099 IF (BIG4.GT.BIG) BIG=BIG4
4100 IF (ABS(G(18)).LT.BIG*EBIG) G(18)=0
4101
4102 C Carbonic acid dissociation
4103
4104 G(19)=equilib8 *(CBA(2,J)+CBA(1,J))/2. -(CBI(2,J)+CBI(1,J))
4105 1 *(HYD(2,J)+HYD(1,J))/4.
4106 B(19,19)=-equilib8/2.
4107 B(19,20)=(HYD(2,J)+HYD(1,J))/4.
4108 B(19,16)=(CBI(2,J)+CBI(1,J))/4.
4109
4110 BIG=ABS(equilib8*CBA(2,J)/2.)
4111 BIG2=ABS(equilib8*CBA(1,J)/2.)
4112 IF (BIG2.GT.BIG) BIG=BIG2
4113 BIG3=ABS(CBI(2,J)*HYD(2,J)/4.)
4114 IF (BIG3.GT.BIG) BIG=BIG3

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4115     BIG4=ABS(CBI(2,J)*HYD(1,J)/4.)
4116     IF (BIG4.GT.BIG) BIG=BIG4
4117     BIG5=ABS(CBI(1,J)*HYD(2,J)/4.)
4118     IF (BIG5.GT.BIG) BIG=BIG5
4119     BIG6=ABS(CBI(1,J)*HYD(1,J)/4.)
4120     IF (BIG6.GT.BIG) BIG=BIG6
4121     IF (ABS(G(19)).LT.BIG*EBIG) G(19)=0
4122
4123 C FLUX OF CO2, CARBONIC ACID, BICARBONATE ION
4124     G(20)=COEFF12HH/2.*(CO2(2,J+1)+CO2(1,J+1)-CO2(2,J)-CO2(1,J))
4125     1   -COEFF12HHH/2.*(CO2(2,J)+CO2(1,J)-CO2(2,J-1)-CO2(1,J-1))
4126     2   +COEFF13HH/2.*(CBA(2,J+1)+CBA(1,J+1)-CBA(2,J)-CBA(1,J))
4127     3   -COEFF13HHH/2.*(CBA(2,J)+CBA(1,J)-CBA(2,J-1)-CBA(1,J-1))
4128     4   +COEFF14HH/2.*(CBI(2,J+1)+CBI(1,J+1)-CBI(2,J)-CBI(1,J))
4129     5   -COEFF14HHH/2.*(CBI(2,J)+CBI(1,J)-CBI(2,J-1)-CBI(1,J-1))
4130     6   -HH/2.*(3.*(CO2(2,J)-CO2(1,J))+(CO2(2,J+1)-CO2(1,J+1)))/(4.*DT)
4131     7   -HHH/2.*(3.*(CO2(2,J)-CO2(1,J))+(CO2(2,J-1)-CO2(1,J-1)))/(4.*DT)
4132     8   -HH/2.*(3.*(CBA(2,J)-CBA(1,J))+(CBA(2,J+1)-CBA(1,J+1)))/(4.*DT)
4133     9   -HHH/2.*(3.*(CBA(2,J)-CBA(1,J))+(CBA(2,J-1)-CBA(1,J-1)))/(4.*DT)
4134     1   -HH/2.*(3.*(CBI(2,J)-CBI(1,J))+(CBI(2,J+1)-CBI(1,J+1)))/(4.*DT)
4135     2   -HHH/2.*(3.*(CBI(2,J)-CBI(1,J))+(CBI(2,J-1)-CBI(1,J-1)))/(4.*DT)
4136
4137     B(20,20)=COEFF14HH/2.+COEFF14HHH/2.+HH/2.*3./(4.*DT)
4138     1   +HHH/2.*3./(4.*DT)
4139     D(20,20)=-COEFF14HH/2.+HH/2./(4.*DT)
4140     A(20,20)=-COEFF14HHH/2.+HHH/2./(4.*DT)
4141     B(20,18)=COEFF12HH/2.+COEFF12HHH/2.+HH/2.*3./(4.*DT)
4142     1   +HHH/2.*3./(4.*DT)
4143     D(20,18)=-COEFF12HH/2.+HH/2./(4.*DT)
4144     A(20,18)=-COEFF12HHH/2.+HHH/2./(4.*DT)
4145     B(20,19)=COEFF13HH/2.+COEFF13HHH/2.+HH/2.*3./(4.*DT)
4146     1   +HHH/2.*3./(4.*DT)
4147     D(20,19)=-COEFF13HH/2.+HH/2./(4.*DT)
4148     A(20,19)=-COEFF13HHH/2.+HHH/2./(4.*DT)
4149
4150     BIG=ABS(COEFF12HH/2.*CO2(2,J+1))
4151     BIG2=ABS(COEFF12HH/2.*CO2(1,J+1))
4152     IF (BIG2.GT.BIG) BIG=BIG2
4153     BIG3=ABS(COEFF12HH/2.*CO2(2,J))
4154     IF (BIG3.GT.BIG) BIG=BIG3
4155     BIG4=ABS(COEFF12HH/2.*CO2(1,J))
4156     IF (BIG4.GT.BIG) BIG=BIG4
4157     BIG5=ABS(COEFF12HHH/2.*CO2(2,J))
4158     IF (BIG5.GT.BIG) BIG=BIG5
4159     BIG6=ABS(COEFF12HHH/2.*CO2(1,J))
4160     IF (BIG6.GT.BIG) BIG=BIG6
4161     BIG7=ABS(COEFF12HHH/2.*CO2(2,J-1))
4162     IF (BIG7.GT.BIG) BIG=BIG7
4163     BIG8=ABS(COEFF12HHH/2.*CO2(1,J-1))
4164     IF (BIG8.GT.BIG) BIG=BIG8
4165     BIG9=ABS(HH/2.*3.*CO2(2,J)/(4.*DT))
4166     IF (BIG9.GT.BIG) BIG=BIG9
4167     BIG10=ABS(HH/2.*3.*CO2(1,J)/(4.*DT))
4168     IF (BIG10.GT.BIG) BIG=BIG10
4169     BIG11=ABS(HH/2.*CO2(2,J+1)/(4.*DT))
4170     IF (BIG11.GT.BIG) BIG=BIG11
4171     BIG12=ABS(HH/2.*CO2(1,J+1)/(4.*DT))
4172     IF (BIG12.GT.BIG) BIG=BIG12

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4173 BIG13=ABS(HHH/2.*3.*CO2(2,J)/(4.*DT))
4174 IF (BIG13.GT.BIG) BIG=BIG13
4175 BIG14=ABS(HHH/2.*3.*CO2(1,J)/(4.*DT))
4176 IF (BIG14.GT.BIG) BIG=BIG14
4177 BIG15=ABS(HHH/2.*CO2(2,J-1)/(4.*DT))
4178 IF (BIG15.GT.BIG) BIG=BIG15
4179 BIG16=ABS(HHH/2.*CO2(1,J-1)/(4.*DT))
4180 IF (BIG16.GT.BIG) BIG=BIG16
4181 BIG17=ABS(COEFF13HH/2.*CBA(2,J+1))
4182 IF (BIG17.GT.BIG) BIG=BIG17
4183 BIG18=ABS(COEFF13HH/2.*CBA(1,J+1))
4184 IF (BIG18.GT.BIG) BIG=BIG18
4185 BIG19=ABS(COEFF13HH/2.*CBA(2,J))
4186 IF (BIG19.GT.BIG) BIG=BIG19
4187 BIG20=ABS(COEFF13HH/2.*CBA(1,J))
4188 IF (BIG20.GT.BIG) BIG=BIG20
4189 BIG21=ABS(COEFF13HHH/2.*CBA(2,J))
4190 IF (BIG21.GT.BIG) BIG=BIG21
4191 BIG22=ABS(COEFF13HHH/2.*CBA(1,J))
4192 IF (BIG22.GT.BIG) BIG=BIG22
4193 BIG23=ABS(COEFF13HHH/2.*CBA(2,J-1))
4194 IF (BIG23.GT.BIG) BIG=BIG23
4195 BIG24=ABS(COEFF13HHH/2.*CBA(1,J-1))
4196 IF (BIG24.GT.BIG) BIG=BIG24
4197 BIG25=ABS(HH/2.*3.*CBA(2,J)/(4.*DT))
4198 IF (BIG25.GT.BIG) BIG=BIG25
4199 BIG26=ABS(HH/2.*3.*CBA(1,J)/(4.*DT))
4200 IF (BIG26.GT.BIG) BIG=BIG26
4201 BIG27=ABS(HH/2.*CBA(2,J+1)/(4.*DT))
4202 IF (BIG27.GT.BIG) BIG=BIG27
4203 BIG28=ABS(HH/2.*CBA(1,J+1)/(4.*DT))
4204 IF (BIG28.GT.BIG) BIG=BIG28
4205 BIG29=ABS(HHH/2.*3.*CBA(2,J)/(4.*DT))
4206 IF (BIG29.GT.BIG) BIG=BIG29
4207 BIG30=ABS(HHH/2.*3.*CBA(1,J)/(4.*DT))
4208 IF (BIG30.GT.BIG) BIG=BIG30
4209 BIG31=ABS(HHH/2.*CBA(2,J-1)/(4.*DT))
4210 IF (BIG31.GT.BIG) BIG=BIG31
4211 BIG32=ABS(HHH/2.*CBA(1,J-1)/(4.*DT))
4212 IF (BIG32.GT.BIG) BIG=BIG32
4213 BIG33=ABS(COEFF14HH/2.*CBI(2,J+1))
4214 IF (BIG33.GT.BIG) BIG=BIG33
4215 BIG34=ABS(COEFF14HH/2.*CBI(1,J+1))
4216 IF (BIG34.GT.BIG) BIG=BIG34
4217 BIG35=ABS(COEFF14HH/2.*CBI(2,J))
4218 IF (BIG35.GT.BIG) BIG=BIG35
4219 BIG36=ABS(COEFF14HH/2.*CBI(1,J))
4220 IF (BIG36.GT.BIG) BIG=BIG36
4221 BIG37=ABS(COEFF14HHH/2.*CBI(2,J))
4222 IF (BIG37.GT.BIG) BIG=BIG37
4223 BIG38=ABS(COEFF14HHH/2.*CBI(1,J))
4224 IF (BIG38.GT.BIG) BIG=BIG38
4225 BIG39=ABS(COEFF14HHH/2.*CBI(2,J-1))
4226 IF (BIG39.GT.BIG) BIG=BIG39
4227 BIG40=ABS(COEFF14HHH/2.*CBI(1,J-1))
4228 IF (BIG40.GT.BIG) BIG=BIG40
4229 BIG41=ABS(HH/2.*3.*CBI(2,J)/(4.*DT))
4230 IF (BIG41.GT.BIG) BIG=BIG41

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4231 BIG42=ABS(HH/2.*3.*CBI(1,J)/(4.*DT))
4232 IF (BIG42.GT.BIG) BIG=BIG42
4233 BIG43=ABS(HH/2.*CBI(2,J+1)/(4.*DT))
4234 IF (BIG43.GT.BIG) BIG=BIG43
4235 BIG44=ABS(HH/2.*CBI(1,J+1)/(4.*DT))
4236 IF (BIG44.GT.BIG) BIG=BIG44
4237 BIG45=ABS(HHH/2.*3.*CBI(2,J)/(4.*DT))
4238 IF (BIG45.GT.BIG) BIG=BIG45
4239 BIG46=ABS(HHH/2.*3.*CBI(1,J)/(4.*DT))
4240 IF (BIG46.GT.BIG) BIG=BIG46
4241 BIG47=ABS(HHH/2.*CBI(2,J-1)/(4.*DT))
4242 IF (BIG47.GT.BIG) BIG=BIG47
4243 BIG48=ABS(HHH/2.*CBI(1,J-1)/(4.*DT))
4244 IF (BIG48.GT.BIG) BIG=BIG48
4245 IF (ABS(G(20)).LT.BIG*EBIG) G(20)=0
4246
4247
4248 C For Acetaminophen, reacting species
4249 G(21)=COEFF16HH/2.*(ACE(2,J+1)+ACE(1,J+1)-ACE(2,J)-ACE(1,J))
4250 1 -COEFF16HHH/2.*(ACE(2,J)+ACE(1,J)-ACE(2,J-1)-ACE(1,J-1))
4251 4 -HH/2.*(3.*(ACE(2,J)-ACE(1,J))+(ACE(2,J+1)-ACE(1,J+1)))/(4.*DT)
4252 5 -HHH/2.*(3.*(ACE(2,J)-ACE(1,J))+(ACE(2,J-1)-ACE(1,J-1)))/(4.*DT)
4253
4254 B(21,21)=COEFF16HH/2.+COEFF16HHH/2.
4255 1 +HH/2.*3./(4.*DT)+HHH/2.*3./(4.*DT)
4256 D(21,21)=-COEFF16HH/2.+HH/2./(4.*DT)
4257 A(21,21)=-COEFF16HHH/2.+HHH/2./(4.*DT)
4258
4259
4260 BIG=ABS(COEFF16HH/2.*ACE(2,J+1))
4261 BIG2=ABS(COEFF16HH/2.*ACE(1,J+1))
4262 IF (BIG2.GT.BIG) BIG=BIG2
4263 BIG3=ABS(COEFF16HH/2.*ACE(2,J))
4264 IF (BIG3.GT.BIG) BIG=BIG3
4265 BIG4=ABS(COEFF16HH/2.*ACE(1,J))
4266 IF (BIG4.GT.BIG) BIG=BIG4
4267 BIG5=ABS(COEFF16HHH/2.*ACE(2,J))
4268 IF (BIG5.GT.BIG) BIG=BIG5
4269 BIG6=ABS(COEFF16HHH/2.*ACE(1,J))
4270 IF (BIG6.GT.BIG) BIG=BIG6
4271 BIG7=ABS(COEFF16HHH/2.*ACE(2,J-1))
4272 IF (BIG7.GT.BIG) BIG=BIG7
4273 BIG8=ABS(COEFF16HHH/2.*ACE(1,J-1))
4274 IF (BIG8.GT.BIG) BIG=BIG8
4275 BIG17=ABS(HH/2.*3.*ACE(2,J)/(4.*DT))
4276 IF (BIG17.GT.BIG) BIG=BIG17
4277 BIG18=ABS(HH/2.*3.*ACE(1,J)/(4.*DT))
4278 IF (BIG18.GT.BIG) BIG=BIG18
4279 BIG19=ABS(HH/2.*ACE(2,J+1)/(4.*DT))
4280 IF (BIG19.GT.BIG) BIG=BIG19
4281 BIG20=ABS(HH/2.*ACE(1,J+1)/(4.*DT))
4282 IF (BIG20.GT.BIG) BIG=BIG20
4283 BIG21=ABS(HHH/2.*3.*ACE(2,J)/(4.*DT))
4284 IF (BIG21.GT.BIG) BIG=BIG21
4285 BIG22=ABS(HHH/2.*3.*ACE(1,J)/(4.*DT))
4286 IF (BIG22.GT.BIG) BIG=BIG22
4287 BIG23=ABS(HHH/2.*ACE(2,J-1)/(4.*DT))
4288 IF (BIG23.GT.BIG) BIG=BIG23

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4289     BIG24=ABS(HHH/2.*ACE(1,J-1)/(4.*DT))
4290     IF (BIG24.GT.BIG) BIG=BIG24
4291     IF (ABS(G(21)).LT.BIG*EBIG) G(21)=0
4292
4293
4294 C     DOUBLE LAYER VOLTAGE DUMMY VARIABLE
4295
4296     G(22)=(VDL(2,J)+VDL(1,J))/2.
4297
4298     B(22,22)=-1./2.
4299
4300     BIG=ABS(VDL(2,J)/2.)
4301     BIG2=ABS(VDL(1,J)/2.)
4302     IF (BIG2.GT.BIG) BIG=BIG2
4303     IF (ABS(G(22)).LT.BIG*EBIG) G(22)=0
4304
4305
4306 C     212 WRITE(12,301) J, (G(K),K=1,N)
4307     RETURN
4308     END
4309
4310 C     INNER GOX REACTION LAYER
4311
4312     SUBROUTINE INNER(J)
4313     IMPLICIT DOUBLE PRECISION (A-H, O-Z)
4314     COMMON/BAB/ A(22,22),B(22,22),C(22,80001),D(22,45),G(22),X(22,22)
4315     1 ,Y(22,22)
4316     COMMON/NSN/ N, NJ
4317     COMMON/GLC/ NTIME,LL
4318     COMMON/VAR/ DIFF(16),H,EBIG,HH,IJ,KJ,TT,VAP,HHH,DT,RE,AKB,BB,CDL
4319     COMMON/VARR/ HHHH,HHHHH,MJ,LJ
4320     COMMON/DIN/ DGOX(16),DGLM(16),DIRM(16),DBULK(16)
4321     COMMON/SPCI/ GLU(2,80001),GOX(2,80001),GLA(2,80001),GOR(2,80001)
4322     COMMON/SPCII/ OXY(2,80001),HPR(2,80001),GOA(2,80001),GOP(2,80001)
4323     COMMON/RXT/ EQ1(2,80001),RGA(2,80001),EQ2(2,80001),RHP(2,80001)
4324     COMMON/SPCIII/ ANM(2,80001),GLUA(2,80001),GLI(2,80001)
4325     COMMON/SPCIV/ HYD(2,80001),OHI(2,80001),CO2(2,80001),CBA(2,80001)
4326     COMMON/SPCV/ CBI(2,80001),ACE(2,80001)
4327     COMMON/VOL/ VDL(2,80001)
4328     COMMON/POR/ POR1,POR2,PORGLU,PARION,PARACE
4329     COMMON/RTE/ ratef1,equilib1,ratef2,ratef3,equilib3,ratef4
4330     COMMON/RTD/ ratef5,equilib5,equilib6,equilib7,equilib8,equilib9
4331     COMMON/BUL/ CBULK(16),PARH2O2,PARO2,PARGLUOSE,JCOUNT
4332
4333
4334     301 FORMAT (5x,'J=' I5, 12E18.9)
4335
4336
4337 C     For Glucose, being consumed only
4338     G(1)=DGOX(1)*(GLU(2,J+1)-2.*GLU(2,J)+GLU(2,J-1)
4339     1 +GLU(1,J+1)-2.*GLU(1,J)+GLU(1,J-1))/(2.*HH**2.)
4340     2 +(ANM(2,J)+ANM(1,J))/2.
4341     3 -(EQ1(2,J)+EQ1(1,J))/2.-(GLU(2,J)-GLU(1,J))/DT
4342
4343     B(1,1)=DGOX(1)/HH**2.+1./DT
4344     D(1,1)=-DGOX(1)/(2.*HH**2.)
4345     A(1,1)=-DGOX(1)/(2.*HH**2.)
4346     B(1,9)=+1./2.

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4347 B(1,13) = -1./2.
4348
4349 BIG=ABS(DGOX(1)*(GLU(2,J+1))/(2.*HH**2.))
4350 BIG2=ABS(DGOX(1)*(GLU(2,J))/(HH**2.))
4351 IF (BIG2.GT.BIG) BIG=BIG2
4352 BIG3=ABS(DGOX(1)*(GLU(2,J-1))/(2.*HH**2.))
4353 IF (BIG3.GT.BIG) BIG=BIG3
4354 BIG4=ABS(DGOX(1)*(GLU(1,J+1))/(2.*HH**2.))
4355 IF (BIG4.GT.BIG) BIG=BIG4
4356 BIG5=ABS(DGOX(1)*(GLU(1,J))/(HH**2.))
4357 IF (BIG5.GT.BIG) BIG=BIG5
4358 BIG6=ABS(DGOX(1)*(GLU(1,J-1))/(2.*HH**2.))
4359 IF (BIG6.GT.BIG) BIG=BIG6
4360 BIG7=ABS(EQ1(2,J)/2.)
4361 IF (BIG7.GT.BIG) BIG=BIG7
4362 BIG8=ABS(EQ1(1,J)/2.)
4363 IF (BIG8.GT.BIG) BIG=BIG8
4364 BIG9=ABS(ANM(2,J)/2.)
4365 IF (BIG9.GT.BIG) BIG=BIG9
4366 BIG10=ABS(ANM(1,J)/2.)
4367 IF (BIG10.GT.BIG) BIG=BIG10
4368 BIG11=ABS(GLU(2,J)/DT)
4369 IF (BIG11.GT.BIG) BIG=BIG11
4370 BIG12=ABS(GLU(1,J)/DT)
4371 IF (BIG12.GT.BIG) BIG=BIG12
4372 IF (ABS(G(1)).LT.BIG*EBIG) G(1)=0
4373
4374 C For GOx, enzyme
4375 G(2)=- (EQ1(2,J)+EQ1(1,J))/2.+(RHP(2,J)+RHP(1,J))/2.
4376 1 -(GOX(2,J)-GOX(1,J))/DT
4377 B(2,2)=+1./DT
4378 B(2,9)=+1./2.
4379 B(2,12)=-1./2.
4380
4381
4382 IF (ABS(EQ1(2,J)).GT.BIG) BIG=ABS(EQ1(2,J))
4383 IF (ABS(EQ1(1,J)).GT.BIG) BIG=ABS(EQ1(1,J))
4384 IF (ABS(RHP(2,J)).GT.BIG) BIG=ABS(RHP(2,J))
4385 IF (ABS(RHP(1,J)).GT.BIG) BIG=ABS(RHP(1,J))
4386 IF (ABS(GOX(2,J)/DT).GT.BIG) BIG=ABS(GOX(2,J)/DT)
4387 IF (ABS(GOX(1,J)/DT).GT.BIG) BIG=ABS(GOX(1,J)/DT)
4388 IF (ABS(G(2)).LT.BIG*EBIG) G(2)=0
4389
4390
4391
4392 C For Gluconic Acid, being produced only
4393 G(3)=DGOX(3)*(GLA(2,J+1)-2.*GLA(2,J)+GLA(2,J-1)
4394 1 +GLA(1,J+1)-2.*GLA(1,J)+GLA(1,J-1))/(2.*HH**2.)
4395 2 +DGOX(10)*(GLI(2,J+1)-2.*GLI(2,J)+GLI(2,J-1)
4396 3 +GLI(1,J+1)-2.*GLI(1,J)+GLI(1,J-1))/(2.*HH**2.)
4397 4 +(RGA(2,J)+RGA(1,J))/2.-(GLA(2,J)-GLA(1,J))/DT
4398 5 -(GLI(2,J)-GLI(1,J))/DT
4399
4400
4401 B(3,3)=DGOX(3)/HH**2.+1./DT
4402 B(3,10)=-1./2.
4403 D(3,3)=-DGOX(3)/(2.*HH**2.)
4404 A(3,3)=-DGOX(3)/(2.*HH**2.)

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4405 B(3,15)=DGOX(10)/HH**2.+1./DT
4406 D(3,15)=-DGOX(10)/(2.*HH**2.)
4407 A(3,15)=-DGOX(10)/(2.*HH**2.)
4408
4409
4410 BIG=ABS(DGOX(3)*GLA(2,J+1)/(2.*HH**2.))
4411 BIG2=ABS(DGOX(3)*GLA(2,J)/(HH**2.))
4412 IF (BIG2.GT.BIG) BIG=BIG2
4413 BIG3=ABS(DGOX(3)*GLA(2,J-1)/(2.*HH**2.))
4414 IF (BIG3.GT.BIG) BIG=BIG3
4415 BIG4=ABS(DGOX(3)*GLA(1,J+1)/(2.*HH**2.))
4416 IF (BIG4.GT.BIG) BIG=BIG4
4417 BIG5=ABS(DGOX(3)*GLA(1,J)/(HH**2.))
4418 IF (BIG5.GT.BIG) BIG=BIG5
4419 BIG6=ABS(DGOX(3)*GLA(1,J-1)/(2.*HH**2.))
4420 IF (BIG6.GT.BIG) BIG=BIG6
4421 BIG7=ABS(DGOX(10)*GLI(2,J+1)/(2.*HH**2.))
4422 IF (BIG7.GT.BIG) BIG=BIG7
4423 BIG8=ABS(DGOX(10)*GLI(2,J)/(HH**2.))
4424 IF (BIG8.GT.BIG) BIG=BIG8
4425 BIG9=ABS(DGOX(10)*GLI(2,J-1)/(2.*HH**2.))
4426 IF (BIG9.GT.BIG) BIG=BIG9
4427 BIG10=ABS(DGOX(10)*GLI(1,J+1)/(2.*HH**2.))
4428 IF (BIG10.GT.BIG) BIG=BIG10
4429 BIG11=ABS(DGOX(10)*GLI(1,J)/(HH**2.))
4430 IF (BIG11.GT.BIG) BIG=BIG11
4431 BIG12=ABS(DGOX(10)*GLI(1,J-1)/(2.*HH**2.))
4432 IF (BIG12.GT.BIG) BIG=BIG12
4433 BIG13=ABS(RGA(2,J)/2.)
4434 IF (BIG13.GT.BIG) BIG=BIG13
4435 BIG14=ABS(RGA(1,J)/2.)
4436 IF (BIG14.GT.BIG) BIG=BIG14
4437 BIG15=ABS(GLA(2,J)/DT)
4438 IF (BIG15.GT.BIG) BIG=BIG15
4439 BIG16=ABS(GLA(1,J)/DT)
4440 IF (BIG16.GT.BIG) BIG=BIG16
4441 BIG17=ABS(GLI(2,J)/DT)
4442 IF (BIG17.GT.BIG) BIG=BIG17
4443 BIG18=ABS(GLI(1,J)/DT)
4444 IF (BIG18.GT.BIG) BIG=BIG18
4445 IF (ABS(G(3)).LT.BIG*EBIG) G(3)=0
4446
4447
4448
4449 C For GOx2, enzyme
4450
4451 G(4)=CBULK(2)+CBULK(4)+CBULK(7)+CBULK(8)-(GOX(2,J)+GOX(1,J))/2.
4452 1 -(GOR(2,J)+GOR(1,J))/2.-(GOA(2,J)+GOA(1,J))/2.
4453 2 -(GOP(2,J)+GOP(1,J))/2.
4454 B(4,4)=+1./2.
4455 B(4,2)=+1./2.
4456 B(4,7)=+1./2.
4457 B(4,8)=+1./2.
4458
4459 BIG=ABS(CBULK(2))
4460 IF (ABS(CBULK(4)).GT.BIG) BIG=ABS(CBULK(4))
4461 IF (ABS(CBULK(7)).GT.BIG) BIG=ABS(CBULK(7))
4462 IF (ABS(CBULK(8)).GT.BIG) BIG=ABS(CBULK(8))

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4463 IF (ABS(GOX(2,J)/2.) .GT. BIG) BIG=ABS(GOX(2,J)/2.)
4464 IF (ABS(GOX(1,J)/2.) .GT. BIG) BIG=ABS(GOX(1,J)/2.)
4465 IF (ABS(GOR(2,J)/2.) .GT. BIG) BIG=ABS(GOR(2,J)/2.)
4466 IF (ABS(GOR(1,J)/2.) .GT. BIG) BIG=ABS(GOR(1,J)/2.)
4467 IF (ABS(GOA(2,J)/2.) .GT. BIG) BIG=ABS(GOA(2,J)/2.)
4468 IF (ABS(GOA(1,J)/2.) .GT. BIG) BIG=ABS(GOA(1,J)/2.)
4469 IF (ABS(GOP(2,J)/2.) .GT. BIG) BIG=ABS(GOP(2,J)/2.)
4470 IF (ABS(GOP(1,J)/2.) .GT. BIG) BIG=ABS(GOP(1,J)/2.)
4471 IF (ABS(G(4)) .LT. BIG*EBIG) G(4)=0
4472
4473
4474 C For O2, being consumed only, Diff(5), OXY,G5,EQ2
4475 G(5)=DGOX(5)*(OXY(2,J+1)-2.*OXY(2,J)+OXY(2,J-1)
4476 1 +OXY(1,J+1)-2.*OXY(1,J)+OXY(1,J-1))/(2.*HH**2.)
4477 2 -(EQ2(2,J)+EQ2(1,J))/2. -(OXY(2,J)-OXY(1,J))/DT
4478
4479
4480 B(5,5)=DGOX(5)/HH**2.+1./DT
4481 B(5,11)=1./2.
4482 D(5,5)=-DGOX(5)/(2.*HH**2.)
4483 A(5,5)=-DGOX(5)/(2.*HH**2.)
4484
4485
4486 BIG=ABS(DGOX(5)*OXY(2,J+1)/(2.*HH**2.))
4487 BIG2=ABS(DGOX(5)*OXY(2,J)/(HH**2.))
4488 IF (BIG2.GT.BIG) BIG=BIG2
4489 BIG3=ABS(DGOX(5)*OXY(2,J-1)/(2.*HH**2.))
4490 IF (BIG3.GT.BIG) BIG=BIG3
4491 BIG4=ABS(DGOX(5)*OXY(1,J+1)/(2.*HH**2.))
4492 IF (BIG4.GT.BIG) BIG=BIG4
4493 BIG5=ABS(DGOX(5)*OXY(1,J)/(HH**2.))
4494 IF (BIG5.GT.BIG) BIG=BIG5
4495 BIG6=ABS(DGOX(5)*OXY(1,J-1)/(2.*HH**2.))
4496 IF (BIG6.GT.BIG) BIG=BIG6
4497 BIG7=ABS(EQ2(2,J)/2.)
4498 IF (BIG7.GT.BIG) BIG=BIG7
4499 BIG8=ABS(EQ2(1,J)/2.)
4500 IF (BIG8.GT.BIG) BIG=BIG8
4501 BIG9=ABS(OXY(2,J)/DT)
4502 IF (BIG9.GT.BIG) BIG=BIG9
4503 BIG10=ABS(OXY(1,J)/DT)
4504 IF (BIG10.GT.BIG) BIG=BIG10
4505 IF (ABS(G(5)) .LT. BIG*EBIG) G(5)=0
4506
4507 C For H2O2, reacting species,DIFF(6),H2O2,RHP,G6
4508 G(6)=DGOX(6)*(HPR(2,J+1)-2.*HPR(2,J)+HPR(2,J-1)
4509 1 +HPR(1,J+1)-2.*HPR(1,J)+HPR(1,J-1))/(2.*HH**2.)
4510 2 +(RHP(2,J)+RHP(1,J))/2. -(HPR(2,J)-HPR(1,J))/DT
4511
4512
4513 B(6,6)=DGOX(6)/HH**2.+1./DT
4514 B(6,12)=-1./2.
4515 D(6,6)=-DGOX(6)/(2.*HH**2.)
4516 A(6,6)=-DGOX(6)/(2.*HH**2.)
4517
4518
4519 BIG=ABS(DGOX(6)*HPR(2,J+1)/(2.*HH**2.))
4520 BIG2=ABS(DGOX(6)*HPR(2,J)/(HH**2.))

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4521 IF (BIG2.GT.BIG) BIG=BIG2
4522 BIG3=ABS(DGOX(6)*HPR(2,J-1)/(2.*HH**2.))
4523 IF (BIG3.GT.BIG) BIG=BIG3
4524 BIG4=ABS(DGOX(6)*HPR(1,J+1)/(2.*HH**2.))
4525 IF (BIG4.GT.BIG) BIG=BIG4
4526 BIG5=ABS(DGOX(6)*HPR(1,J)/(HH**2.))
4527 IF (BIG5.GT.BIG) BIG=BIG5
4528 BIG6=ABS(DGOX(6)*HPR(1,J-1)/(2.*HH**2.))
4529 IF (BIG6.GT.BIG) BIG=BIG6
4530 BIG7=ABS(RHP(2,J)/2.)
4531 IF (BIG7.GT.BIG) BIG=BIG7
4532 BIG8=ABS(RHP(1,J)/2)
4533 IF (BIG8.GT.BIG) BIG=BIG8
4534 BIG9=ABS(HPR(2,J)/DT)
4535 IF (BIG9.GT.BIG) BIG=BIG9
4536 BIG10=ABS(HPR(1,J)/DT)
4537 IF (BIG10.GT.BIG) BIG=BIG10
4538 IF (ABS(G(6)).LT.BIG*EBIG) G(6)=0
4539
4540 C For CX-GOx2, enzyme
4541 G(7)=(EQ1(2,J)+EQ1(1,J))/2.-(RGA(2,J)+RGA(1,J))/2.
4542 1 -(GOA(2,J)-GOA(1,J))/DT
4543
4544 B(7,7)=+1./DT
4545 B(7,9)=-1./2.
4546 B(7,10)=1./2.
4547
4548 IF (ABS(EQ1(2,J)).GT.BIG) BIG=ABS(EQ1(2,J))
4549 IF (ABS(EQ1(1,J)).GT.BIG) BIG=ABS(EQ1(1,J))
4550 IF (ABS(RGA(2,J)).GT.BIG) BIG=ABS(RGA(2,J))
4551 IF (ABS(RGA(1,J)).GT.BIG) BIG=ABS(RGA(1,J))
4552 IF (ABS(GOA(2,J)/DT).GT.BIG) BIG=ABS(GOA(2,J)/DT)
4553 IF (ABS(GOA(1,J)/DT).GT.BIG) BIG=ABS(GOA(1,J)/DT)
4554 IF (ABS(G(7)).LT.BIG*EBIG) G(7)=0
4555
4556 C For CX-GOx, enzyme
4557 G(8)=(EQ2(2,J)+EQ2(1,J))/2.-(RHP(2,J)+RHP(1,J))/2.
4558 1 -(GOP(2,J)-GOP(1,J))/DT
4559 B(8,8)=+1./DT
4560 B(8,11)=-1./2.
4561 B(8,12)=1./2.
4562
4563 IF (ABS(EQ2(2,J)).GT.BIG) BIG=ABS(EQ2(2,J))
4564 IF (ABS(EQ2(1,J)).GT.BIG) BIG=ABS(EQ2(1,J))
4565 IF (ABS(RHP(2,J)).GT.BIG) BIG=ABS(RHP(2,J))
4566 IF (ABS(RHP(1,J)).GT.BIG) BIG=ABS(RHP(1,J))
4567 IF (ABS(GOP(2,J)/DT).GT.BIG) BIG=ABS(GOP(2,J)/DT)
4568 IF (ABS(GOP(1,J)/DT).GT.BIG) BIG=ABS(GOP(1,J)/DT)
4569 IF (ABS(G(8)).LT.BIG*EBIG) G(8)=0
4570
4571
4572 C REACTION1
4573 214 G(9)=-((EQ1(2,J)+EQ1(1,J))/2.
4574 1 +ratef1*((GLU(2,J)+GLU(1,J))*(GOX(2,J)+GOX(1,J))/4.
4575 2 -(GOA(2,J)+GOA(1,J))/2./equilib1)
4576 B(9,1)=-ratef1*(GOX(2,J)+GOX(1,J))/4.
4577 B(9,2)=-ratef1*(GLU(2,J)+GLU(1,J))/4.
4578 B(9,7)=ratef1/2./equilib1

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4579      B(9,9)=+1./2.
4580
4581      BIG=ABS(EQ1(2,J)/2.)
4582      BIG2=ABS(EQ1(1,J)/2.)
4583      IF (BIG2.GT.BIG) BIG=BIG2
4584      BIG3=ABS(ratef1*GLU(2,J)*GOX(2,J)/4.)
4585      IF (BIG3.GT.BIG) BIG=BIG3
4586      BIG4=ABS(ratef1*GLU(1,J)*GOX(2,J)/4)
4587      IF (BIG4.GT.BIG) BIG=BIG4
4588      BIG5=ABS(ratef1*GLU(2,J)*GOX(1,J)/4)
4589      IF (BIG5.GT.BIG) BIG=BIG5
4590      BIG6=ABS(ratef1*GLU(1,J)*GOX(1,J)/4)
4591      IF (BIG6.GT.BIG) BIG=BIG6
4592      BIG7=ABS(ratef1*GOA(2,J)/2./equilib1)
4593      IF (BIG7.GT.BIG) BIG=BIG7
4594      BIG8=ABS(ratef1*GOA(1,J)/2./equilib1)
4595      IF (BIG8.GT.BIG) BIG=BIG8
4596      IF (ABS(G(9)).LT.BIG*EBIG) G(9)=0
4597
4598
4599 C      REACTION2
4600 215 G(10)=-((RGA(2,J)+RGA(1,J))/2.+ratef2*(GOA(2,J)+GOA(1,J))/2.
4601      B(10,7)=-ratef2/2.
4602      B(10,10)=+1./2.
4603
4604      BIG=ABS(RGA(2,J)/2.)
4605      BIG2=ABS(RGA(1,J)/2.)
4606      IF (BIG2.GT.BIG) BIG=BIG2
4607      BIG3=ABS(ratef2*GOA(2,J)/2.)
4608      IF (BIG3.GT.BIG) BIG=BIG3
4609      BIG4=ABS(ratef2*GOA(1,J)/2.)
4610      IF (BIG4.GT.BIG) BIG=BIG4
4611      IF (ABS(G(10)).LT.BIG*EBIG) G(10)=0
4612
4613 C      REACTION3
4614 216 G(11)=-((EQ2(2,J)+EQ2(1,J))/2.
4615      1 +ratef3*((GOR(2,J)+GOR(1,J))*(OXY(2,J)+OXY(1,J))/4.
4616      2 -(GOP(2,J)+GOP(1,J))/2./equilib3)
4617      B(11,4)=-ratef3*(OXY(2,J)+OXY(1,J))/4.
4618      B(11,5)=-ratef3*(GOR(2,J)+GOR(1,J))/4.
4619      B(11,8)=ratef3/2./equilib3
4620      B(11,11)=+1./2.
4621
4622      BIG=ABS(EQ2(2,J)/2.)
4623      BIG2=ABS(EQ2(1,J)/2.)
4624      IF (BIG2.GT.BIG) BIG=BIG2
4625      BIG3=ABS(ratef3*GOR(2,J)*OXY(2,J)/4.)
4626      IF (BIG3.GT.BIG) BIG=BIG3
4627      BIG4=ABS(ratef3*GOR(1,J)*OXY(2,J)/4)
4628      IF (BIG4.GT.BIG) BIG=BIG4
4629      BIG5=ABS(ratef3*GOR(2,J)*OXY(1,J)/4)
4630      IF (BIG5.GT.BIG) BIG=BIG5
4631      BIG6=ABS(ratef3*GOR(1,J)*OXY(1,J)/4)
4632      IF (BIG6.GT.BIG) BIG=BIG6
4633      BIG7=ABS(ratef3*GOP(2,J)/2./EQUILIB3)
4634      IF (BIG7.GT.BIG) BIG=BIG7
4635      BIG8=ABS(ratef3*GOP(1,J)/2./EQUILIB3)
4636      IF (BIG8.GT.BIG) BIG=BIG8

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4637     IF (ABS(G(11)).LT.BIG*EBIG) G(11)=0
4638
4639 C     REACTION4
4640 217 G(12)=-((RHP(2,J)+RHP(1,J))/2.+ratef4*(GOP(2,J)+GOP(1,J))/2.
4641     B(12,8)=-ratef4/2.
4642     B(12,12)=+1./2.
4643
4644     BIG=ABS(RHP(2,J)/2.)
4645     BIG2=ABS(RHP(1,J)/2.)
4646     IF (BIG2.GT.BIG) BIG=BIG2
4647     BIG3=ABS(ratef4*GOP(2,J)/2.)
4648     IF (BIG3.GT.BIG) BIG=BIG3
4649     BIG4=ABS(ratef4*GOP(1,J)/2.)
4650     IF (BIG4.GT.BIG) BIG=BIG4
4651     IF (ABS(G(12)).LT.BIG*EBIG) G(12)=0
4652
4653 C     REACTION5
4654 218 G(13)=-((ANM(2,J)+ANM(1,J))/2.+ratef5*((GLUA(2,J)+GLUA(1,J))/2.
4655 1   -(GLU(2,J)+GLU(1,J))/2./equilib5)
4656     B(13,1)=ratef5/2./equilib5
4657     B(13,14)=-ratef5/2.
4658     B(13,13)=+1./2.
4659
4660     BIG=ABS(ANM(2,J)/2.)
4661     BIG2=ABS(ANM(1,J)/2.)
4662     IF (BIG2.GT.BIG) BIG=BIG2
4663     BIG3=ABS(ratef5*GLUA(2,J)/2.)
4664     IF (BIG3.GT.BIG) BIG=BIG3
4665     BIG4=ABS(ratef5*GLUA(1,J)/2.)
4666     IF (BIG4.GT.BIG) BIG=BIG4
4667     BIG5=ABS(ratef5*GLU(2,J)/2./equilib5)
4668     IF (BIG5.GT.BIG) BIG=BIG5
4669     BIG6=ABS(ratef5*GLU(1,J)/2./equilib5)
4670     IF (BIG6.GT.BIG) BIG=BIG6
4671     IF (ABS(G(13)).LT.BIG*EBIG) G(13)=0.0
4672
4673 C     For alpha Glucose, being consumed only
4674     G(14)=DGOX(9)*(GLUA(2,J+1)-2.*GLUA(2,J)+GLUA(2,J-1)
4675 1     +GLUA(1,J+1)-2.*GLUA(1,J)+GLUA(1,J-1))/(2.*HH**2.)
4676 2     -(ANM(2,J)+ANM(1,J))/2.-(GLUA(2,J)-GLUA(1,J))/DT
4677     B(14,14)=DGOX(9)/HH**2.+1./DT
4678     D(14,14)=-DGOX(9)/(2.*HH**2.)
4679     A(14,14)=-DGOX(9)/(2.*HH**2.)
4680     B(14,13)=1./2.
4681
4682     BIG=ABS(DGOX(9)*(GLUA(2,J+1))/(2.*HH**2.))
4683     BIG2=ABS(DGOX(9)*(GLUA(2,J))/(HH**2.))
4684     IF (BIG2.GT.BIG) BIG=BIG2
4685     BIG3=ABS(DGOX(9)*(GLUA(2,J-1))/(2.*HH**2.))
4686     IF (BIG3.GT.BIG) BIG=BIG3
4687     BIG4=ABS(DGOX(9)*(GLUA(1,J+1))/(2.*HH**2.))
4688     IF (BIG4.GT.BIG) BIG=BIG4
4689     BIG5=ABS(DGOX(9)*(GLUA(1,J))/(HH**2.))
4690     IF (BIG5.GT.BIG) BIG=BIG5
4691     BIG6=ABS(DGOX(9)*(GLUA(1,J-1))/(2.*HH**2.))
4692     IF (BIG6.GT.BIG) BIG=BIG6
4693     BIG7=ABS(ANM(2,J)/2.)
4694     IF (BIG7.GT.BIG) BIG=BIG7

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4695     BIG8=ABS(ANM(1,J)/2.)
4696     IF (BIG8.GT.BIG) BIG=BIG8
4697     BIG9=ABS(GLUA(2,J)/DT)
4698     IF (BIG9.GT.BIG) BIG=BIG9
4699     BIG10=ABS(GLUA(1,J)/DT)
4700     IF (BIG10.GT.BIG) BIG=BIG10
4701     IF (ABS(G(14)).LT.BIG*EBIG) G(14)=0.0
4702
4703 C Gluconic acid dissociation
4704
4705     G(15)=equilib6*(GLA(2,J)+GLA(1,J))/2.-(GLI(2,J)+GLI(1,J))*
4706 1 (HYD(2,J)+HYD(1,J))/4.
4707     B(15,3)=-equilib6/2.
4708     B(15,15)=(HYD(2,J)+HYD(1,J))/4.
4709     B(15,16)=(GLI(2,J)+GLI(1,J))/4.
4710
4711     BIG=ABS(equilib6*GLA(2,J)/2.)
4712     BIG2=ABS(equilib6*GLA(1,J)/2.)
4713     IF (BIG2.GT.BIG) BIG=BIG2
4714     BIG3=ABS(GLI(2,J)*HYD(2,J)/4.)
4715     IF (BIG3.GT.BIG) BIG=BIG3
4716     BIG4=ABS(GLI(2,J)*HYD(1,J)/4)
4717     IF (BIG4.GT.BIG) BIG=BIG4
4718     BIG5=ABS(GLI(1,J)*HYD(2,J)/4)
4719     IF (BIG5.GT.BIG) BIG=BIG5
4720     BIG6=ABS(GLI(1,J)*HYD(1,J)/4)
4721     IF (BIG6.GT.BIG) BIG=BIG6
4722     IF (ABS(G(15)).LT.BIG*EBIG) G(15)=0
4723
4724 C Hydrogen ion, hydroxide ion, gluconate ion, bicarbonate ion flux
4725     G(16)=DGOX(11)*(HYD(2,J+1)-2.*HYD(2,J)+HYD(2,J-1)
4726 1 +HYD(1,J+1)-2.*HYD(1,J)+HYD(1,J-1))/(2.*HH**2.)
4727 2 -DGOX(15)*(OHI(2,J+1)-2.*OHI(2,J)+OHI(2,J-1)
4728 3 +OHI(1,J+1)-2.*OHI(1,J)+OHI(1,J-1))/(2.*HH**2.)
4729 4 -DGOX(10)*(GLI(2,J+1)-2.*GLI(2,J)+GLI(2,J-1)
4730 5 +GLI(1,J+1)-2.*GLI(1,J)+GLI(1,J-1))/(2.*HH**2.)
4731 6 -DGOX(14)*(CBI(2,J+1)-2.*CBI(2,J)+CBI(2,J-1)
4732 7 +CBI(1,J+1)-2.*CBI(1,J)+CBI(1,J-1))/(2.*HH**2.)
4733 8 -(HYD(2,J)-HYD(1,J))/DT+(OHI(2,J)-OHI(1,J))/DT
4734 9 +(GLI(2,J)-GLI(1,J))/DT+(CBI(2,J)-CBI(1,J))/DT
4735
4736     B(16,16)=DGOX(11)/HH**2.+1./DT
4737     D(16,16)=-DGOX(11)/(2.*HH**2.)
4738     A(16,16)=-DGOX(11)/(2.*HH**2.)
4739     B(16,17)=-DGOX(15)/HH**2.-1./DT
4740     D(16,17)=DGOX(15)/(2.*HH**2.)
4741     A(16,17)=DGOX(15)/(2.*HH**2.)
4742     B(16,15)=-DGOX(10)/HH**2.-1./DT
4743     D(16,15)=DGOX(10)/(2.*HH**2.)
4744     A(16,15)=DGOX(10)/(2.*HH**2.)
4745     B(16,20)=-DGOX(14)/HH**2.-1./DT
4746     D(16,20)=DGOX(14)/(2.*HH**2.)
4747     A(16,20)=DGOX(14)/(2.*HH**2.)
4748
4749     BIG=ABS(DGOX(11)*(HYD(2,J+1))/(2.*HH**2.))
4750     BIG2=ABS(DGOX(11)*(HYD(2,J))/(HH**2.))
4751     IF (BIG2.GT.BIG) BIG=BIG2
4752     BIG3=ABS(DGOX(11)*(HYD(2,J-1))/(2.*HH**2.))

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4753 IF (BIG3.GT.BIG) BIG=BIG3
4754 BIG4=ABS(DGOX(11)*(HYD(1,J+1))/(2.*HH**2.))
4755 IF (BIG4.GT.BIG) BIG=BIG4
4756 BIG5=ABS(DGOX(11)*(HYD(1,J))/(HH**2.))
4757 IF (BIG5.GT.BIG) BIG=BIG5
4758 BIG6=ABS(DGOX(11)*(HYD(1,J-1))/(2.*HH**2.))
4759 IF (BIG6.GT.BIG) BIG=BIG6
4760 BIG7=ABS(DGOX(15)*OHI(2,J+1)/(2.*HH**2.))
4761 IF (BIG7.GT.BIG) BIG=BIG7
4762 BIG8=ABS(DGOX(15)*OHI(2,J)/(HH**2.))
4763 IF (BIG8.GT.BIG) BIG=BIG8
4764 BIG9=ABS(DGOX(15)*OHI(2,J-1)/(2.*HH**2.))
4765 IF (BIG9.GT.BIG) BIG=BIG9
4766 BIG10=ABS(DGOX(15)*OHI(1,J+1)/(2.*HH**2.))
4767 IF (BIG10.GT.BIG) BIG=BIG10
4768 BIG11=ABS(DGOX(15)*OHI(1,J)/(HH**2.))
4769 IF (BIG11.GT.BIG) BIG=BIG11
4770 BIG12=ABS(DGOX(15)*OHI(1,J-1)/(2.*HH**2.))
4771 IF (BIG12.GT.BIG) BIG=BIG12
4772 BIG13=ABS(DGOX(10)*GLI(2,J+1)/(2.*HH**2.))
4773 IF (BIG13.GT.BIG) BIG=BIG13
4774 BIG14=ABS(DGOX(10)*GLI(2,J)/(HH**2.))
4775 IF (BIG14.GT.BIG) BIG=BIG14
4776 BIG15=ABS(DGOX(10)*GLI(2,J-1)/(2.*HH**2.))
4777 IF (BIG15.GT.BIG) BIG=BIG15
4778 BIG16=ABS(DGOX(10)*GLI(1,J+1)/(2.*HH**2.))
4779 IF (BIG16.GT.BIG) BIG=BIG16
4780 BIG17=ABS(DGOX(10)*GLI(1,J)/(HH**2.))
4781 IF (BIG17.GT.BIG) BIG=BIG17
4782 BIG18=ABS(DGOX(10)*GLI(1,J-1)/(2.*HH**2.))
4783 IF (BIG18.GT.BIG) BIG=BIG18
4784 BIG19=ABS(DGOX(14)*CBI(2,J+1)/(2.*HH**2.))
4785 IF (BIG19.GT.BIG) BIG=BIG19
4786 BIG20=ABS(DGOX(14)*CBI(2,J)/(HH**2.))
4787 IF (BIG20.GT.BIG) BIG=BIG20
4788 BIG21=ABS(DGOX(14)*CBI(2,J-1)/(2.*HH**2.))
4789 IF (BIG21.GT.BIG) BIG=BIG21
4790 BIG22=ABS(DGOX(14)*CBI(1,J+1)/(2.*HH**2.))
4791 IF (BIG22.GT.BIG) BIG=BIG22
4792 BIG23=ABS(DGOX(14)*CBI(1,J)/(HH**2.))
4793 IF (BIG23.GT.BIG) BIG=BIG23
4794 BIG24=ABS(DGOX(14)*CBI(1,J-1)/(2.*HH**2.))
4795 IF (BIG24.GT.BIG) BIG=BIG24
4796 BIG25=ABS(HYD(2,J)/DT)
4797 IF (BIG25.GT.BIG) BIG=BIG25
4798 BIG26=ABS(HYD(1,J)/DT)
4799 IF (BIG26.GT.BIG) BIG=BIG26
4800 BIG27=ABS(OHI(2,J)/DT)
4801 IF (BIG27.GT.BIG) BIG=BIG27
4802 BIG28=ABS(OHI(1,J)/DT)
4803 IF (BIG28.GT.BIG) BIG=BIG28
4804 BIG29=ABS(GLI(2,J)/DT)
4805 IF (BIG29.GT.BIG) BIG=BIG29
4806 BIG30=ABS(GLI(1,J)/DT)
4807 IF (BIG30.GT.BIG) BIG=BIG30
4808 BIG31=ABS(CBI(2,J)/DT)
4809 IF (BIG31.GT.BIG) BIG=BIG31
4810 BIG32=ABS(CBI(1,J)/DT)

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4811 IF (BIG32.GT.BIG) BIG=BIG32
4812 IF (ABS(G(16)).LT.BIG*EBIG) G(16)=0
4813
4814 c Water Dissociation
4815 G(17)=equilib9 -(HYD(2,J)+HYD(1,J))*(OHI(2,J)+OHI(1,J))/4.
4816 B(17,17)=(HYD(2,J)+HYD(1,J))/4.
4817 B(17,16)=(OHI(2,J)+OHI(1,J))/4.
4818
4819 BIG=ABS(equilib9)
4820 BIG2=ABS(HYD(2,J)*OHI(2,J)/4.)
4821 IF (BIG2.GT.BIG) BIG=BIG2
4822 BIG3=ABS(HYD(2,J)*OHI(1,J)/4.)
4823 IF (BIG3.GT.BIG) BIG=BIG3
4824 BIG4=ABS(HYD(1,J)*OHI(2,J)/4.)
4825 IF (BIG4.GT.BIG) BIG=BIG4
4826 BIG5=ABS(HYD(1,J)*OHI(1,J)/4.)
4827 IF (BIG5.GT.BIG) BIG=BIG5
4828 IF (ABS(G(17)).LT.BIG*EBIG) G(17)=0
4829
4830 C CO2 Hydration
4831
4832 G(18)=equilib7 *(CO2(2,J)+CO2(1,J))/2. -(CBA(2,J)+CBA(1,J))/2.
4833 B(18,18)=-equilib7/2.
4834 B(18,19)=1./2.
4835
4836 BIG=ABS(equilib7*CO2(2,J)/2.)
4837 BIG2=ABS(equilib7*CO2(1,J)/2.)
4838 IF (BIG2.GT.BIG) BIG=BIG2
4839 BIG3=ABS(CBA(2,J)/2.)
4840 IF (BIG3.GT.BIG) BIG=BIG3
4841 BIG4=ABS(CBA(1,J)/2.)
4842 IF (BIG4.GT.BIG) BIG=BIG4
4843 IF (ABS(G(18)).LT.BIG*EBIG) G(18)=0
4844
4845 C Carbonic acid dissociation
4846
4847 G(19)=equilib8 *(CBA(2,J)+CBA(1,J))/2. -(CBI(2,J)+CBI(1,J))
4848 1 *(HYD(2,J)+HYD(1,J))/4.
4849 B(19,19)=-equilib8/2.
4850 B(19,20)=(HYD(2,J)+HYD(1,J))/4.
4851 B(19,16)=(CBI(2,J)+CBI(1,J))/4.
4852
4853 BIG=ABS(equilib8*CBA(2,J)/2.)
4854 BIG2=ABS(equilib8*CBA(1,J)/2.)
4855 IF (BIG2.GT.BIG) BIG=BIG2
4856 BIG3=ABS(CBI(2,J)*HYD(2,J)/4.)
4857 IF (BIG3.GT.BIG) BIG=BIG3
4858 BIG4=ABS(CBI(2,J)*HYD(1,J)/4.)
4859 IF (BIG4.GT.BIG) BIG=BIG4
4860 BIG5=ABS(CBI(1,J)*HYD(2,J)/4.)
4861 IF (BIG5.GT.BIG) BIG=BIG5
4862 BIG6=ABS(CBI(1,J)*HYD(1,J)/4.)
4863 IF (BIG6.GT.BIG) BIG=BIG6
4864 IF (ABS(G(19)).LT.BIG*EBIG) G(19)=0
4865
4866 C FLUX OF CO2, CARBONIC ACID, BICARBONATE ION
4867 G(20)=DGOX(12)*(CO2(2,J+1)-2.*CO2(2,J)+CO2(2,J-1)
4868 1 +CO2(1,J+1)-2.*CO2(1,J)+CO2(1,J-1))/(2.*HH**2.)

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4869 2 +DGOX(13)*(CBA(2,J+1)-2.*CBA(2,J)+CBA(2,J-1)
4870 3 +CBA(1,J+1)-2.*CBA(1,J)+CBA(1,J-1))/(2.*HH**2.)
4871 4 +DGOX(14)*(CBI(2,J+1)-2.*CBI(2,J)+CBI(2,J-1)
4872 5 +CBI(1,J+1)-2.*CBI(1,J)+CBI(1,J-1))/(2.*HH**2.)
4873 8 -(CO2(2,J)-CO2(1,J))/DT-(CBA(2,J)-CBA(1,J))/DT
4874 9 -(CBI(2,J)-CBI(1,J))/DT
4875
4876 B(20,20)=DGOX(14)/HH**2.+1./DT
4877 D(20,20)=-DGOX(14)/(2.*HH**2.)
4878 A(20,20)=-DGOX(14)/(2.*HH**2.)
4879 B(20,18)=DGOX(12)/HH**2.+1./DT
4880 D(20,18)=-DGOX(12)/(2.*HH**2.)
4881 A(20,18)=-DGOX(12)/(2.*HH**2.)
4882 B(20,19)=DGOX(13)/HH**2.+1./DT
4883 D(20,19)=-DGOX(13)/(2.*HH**2.)
4884 A(20,19)=-DGOX(13)/(2.*HH**2.)
4885
4886
4887 BIG=ABS(DGOX(12)*(CO2(2,J+1))/(2.*HH**2.))
4888 BIG2=ABS(DGOX(12)*(CO2(2,J))/(HH**2.))
4889 IF (BIG2.GT.BIG) BIG=BIG2
4890 BIG3=ABS(DGOX(12)*(CO2(2,J-1))/(2.*HH**2.))
4891 IF (BIG3.GT.BIG) BIG=BIG3
4892 BIG4=ABS(DGOX(12)*(CO2(1,J+1))/(2.*HH**2.))
4893 IF (BIG4.GT.BIG) BIG=BIG4
4894 BIG5=ABS(DGOX(12)*(CO2(1,J))/(HH**2.))
4895 IF (BIG5.GT.BIG) BIG=BIG5
4896 BIG6=ABS(DGOX(12)*(CO2(1,J-1))/(2.*HH**2.))
4897 IF (BIG6.GT.BIG) BIG=BIG6
4898 BIG7=ABS(DGOX(13)*CBA(2,J+1)/(2.*HH**2.))
4899 IF (BIG7.GT.BIG) BIG=BIG7
4900 BIG8=ABS(DGOX(13)*CBA(2,J)/(HH**2.))
4901 IF (BIG8.GT.BIG) BIG=BIG8
4902 BIG9=ABS(DGOX(13)*CBA(2,J-1)/(2.*HH**2.))
4903 IF (BIG9.GT.BIG) BIG=BIG9
4904 BIG10=ABS(DGOX(13)*CBA(1,J+1)/(2.*HH**2.))
4905 IF (BIG10.GT.BIG) BIG=BIG10
4906 BIG11=ABS(DGOX(13)*CBA(1,J)/(HH**2.))
4907 IF (BIG11.GT.BIG) BIG=BIG11
4908 BIG12=ABS(DGOX(13)*CBA(1,J-1)/(2.*HH**2.))
4909 IF (BIG12.GT.BIG) BIG=BIG12
4910 BIG13=ABS(DGOX(14)*CBI(2,J+1)/(2.*HH**2.))
4911 IF (BIG13.GT.BIG) BIG=BIG13
4912 BIG14=ABS(DGOX(14)*CBI(2,J)/(HH**2.))
4913 IF (BIG14.GT.BIG) BIG=BIG14
4914 BIG15=ABS(DGOX(14)*CBI(2,J-1)/(2.*HH**2.))
4915 IF (BIG15.GT.BIG) BIG=BIG15
4916 BIG16=ABS(DGOX(14)*CBI(1,J+1)/(2.*HH**2.))
4917 IF (BIG16.GT.BIG) BIG=BIG16
4918 BIG17=ABS(DGOX(14)*CBI(1,J)/(HH**2.))
4919 IF (BIG17.GT.BIG) BIG=BIG17
4920 BIG18=ABS(DGOX(14)*CBI(1,J-1)/(2.*HH**2.))
4921 IF (BIG18.GT.BIG) BIG=BIG18
4922 BIG19=ABS(CO2(2,J)/DT)
4923 IF (BIG19.GT.BIG) BIG=BIG19
4924 BIG20=ABS(CO2(1,J)/DT)
4925 IF (BIG20.GT.BIG) BIG=BIG20
4926 BIG21=ABS(CBA(2,J)/DT)

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4927 IF (BIG21.GT.BIG) BIG=BIG21
4928 BIG22=ABS(CBA(1,J)/DT)
4929 IF (BIG22.GT.BIG) BIG=BIG22
4930 BIG23=ABS(CBI(2,J)/DT)
4931 IF (BIG23.GT.BIG) BIG=BIG23
4932 BIG24=ABS(CBI(1,J)/DT)
4933 IF (BIG24.GT.BIG) BIG=BIG24
4934 IF (ABS(G(20)).LT.BIG*EBIG) G(20)=0
4935
4936
4937 C For Acetaminophen
4938 G(21)=DGOX(16)*(ACE(2,J+1)-2.*ACE(2,J)+ACE(2,J-1)
4939 1 +ACE(1,J+1)-2.*ACE(1,J)+ACE(1,J-1))/(2.*HH**2.)
4940 2 -(ACE(2,J)-ACE(1,J))/DT
4941
4942 B(21,21)=DGOX(16)/HH**2.+1./DT
4943 D(21,21)=-DGOX(16)/(2.*HH**2.)
4944 A(21,21)=-DGOX(16)/(2.*HH**2.)
4945
4946
4947 BIG=ABS(DGOX(16)*(ACE(2,J+1))/(2.*HH**2.))
4948 BIG2=ABS(DGOX(16)*(ACE(2,J))/(HH**2.))
4949 IF (BIG2.GT.BIG) BIG=BIG2
4950 BIG3=ABS(DGOX(16)*(ACE(2,J-1))/(2.*HH**2.))
4951 IF (BIG3.GT.BIG) BIG=BIG3
4952 BIG4=ABS(DGOX(16)*(ACE(1,J+1))/(2.*HH**2.))
4953 IF (BIG4.GT.BIG) BIG=BIG4
4954 BIG5=ABS(DGOX(16)*(ACE(1,J))/(HH**2.))
4955 IF (BIG5.GT.BIG) BIG=BIG5
4956 BIG6=ABS(DGOX(16)*(ACE(1,J-1))/(2.*HH**2.))
4957 IF (BIG6.GT.BIG) BIG=BIG6
4958 BIG7=ABS(ACE(2,J)/DT)
4959 IF (BIG7.GT.BIG) BIG=BIG7
4960 BIG8=ABS(ACE(1,J)/DT)
4961 IF (BIG8.GT.BIG) BIG=BIG8
4962 IF (ABS(G(21)).LT.BIG*EBIG) G(21)=0
4963
4964 C DOUBLE IAYER voLTAGE - DUMMY
4965
4966 G(22)=(VDL(2,J)+VDL(1,J))/2.
4967
4968 B(22,22)=-1./2.
4969
4970 BIG=ABS(VDL(2,J)/2.)
4971 BIG2=ABS(VDL(1,J)/2.)
4972 IF (BIG2.GT.BIG) BIG=BIG2
4973 IF (ABS(G(22)).LT.BIG*EBIG) G(22)=0
4974
4975
4976 RETURN
4977 END
4978
4979
4980
4981
4982 c SAVE G OUT DATA
4983
4984

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4985
4986
4987     SUBROUTINE COUPLER2(J)
4988     IMPLICIT DOUBLE PRECISION (A-H, O-Z)
4989     COMMON/BAB/ A(22,22),B(22,22),C(22,80001),D(22,45),G(22),X(22,22)
4990     1 ,Y(22,22)
4991     COMMON/NSN/ N, NJ
4992     COMMON/GLC/ NTIME,LL
4993     COMMON/VAR/ DIFF(16),H,EBIG,HH,IJ,KJ,TT,VAP,HHH,DT,RE,AKB,BB,CDL
4994     COMMON/VARR/ HHHH,HHHHH,MJ,LJ
4995     COMMON/DIN/ DGOX(16),DGLM(16),DIRM(16),DBULK(16)
4996     COMMON/SPCI/ GLU(2,80001),GOX(2,80001),GLA(2,80001),GOR(2,80001)
4997     COMMON/SPCII/ OXY(2,80001),HPR(2,80001),GOA(2,80001),GOP(2,80001)
4998     COMMON/RXT/ EQ1(2,80001),RGA(2,80001),EQ2(2,80001),RHP(2,80001)
4999     COMMON/SPCIII/ ANM(2,80001),GLUA(2,80001),GLI(2,80001)
5000     COMMON/SPCIV/ HYD(2,80001),OHI(2,80001),CO2(2,80001),CBA(2,80001)
5001     COMMON/SPCV/ CBI(2,80001),ACE(2,80001)
5002     COMMON/VOL/ VDL(2,80001)
5003     COMMON/POR/ POR1,POR2,PORGLU,PARION,PARACE
5004     COMMON/RTE/ ratef1,equilib1,ratef2,ratef3,equilib3,ratef4
5005     COMMON/RTD/ ratef5,equilib5,equilib6,equilib7,equilib8,equilib9
5006     COMMON/BUL/ CBULK(16),PARH2O2,PARO2,PARGLUPOSE,JCOUNT
5007
5008 301 FORMAT (5x,'J=' I5, 12E18.9)
5009
5010
5011     COEFF1H=DGLM(1)/H
5012     COEFF1HH=DGOX(1)/HH
5013     COEFF3H=DGLM(3)/H
5014     COEFF3HH=DGOX(3)/HH
5015     COEFF5H=DGLM(5)/H
5016     COEFF5HH=DGOX(5)/HH
5017     COEFF6H=DGLM(6)/H
5018     COEFF6HH=DGOX(6)/HH
5019     COEFF9H=DGLM(9)/H
5020     COEFF9HH=DGOX(9)/HH
5021     COEFF10H=DGLM(10)/H
5022     COEFF10HH=DGOX(10)/HH
5023     COEFF11H=DGLM(11)/H
5024     COEFF11HH=DGOX(11)/HH
5025     COEFF12H=DGLM(12)/H
5026     COEFF12HH=DGOX(12)/HH
5027     COEFF13H=DGLM(13)/H
5028     COEFF13HH=DGOX(13)/HH
5029     COEFF14H=DGLM(14)/H
5030     COEFF14HH=DGOX(14)/HH
5031     COEFF15H=DGLM(15)/H
5032     COEFF15HH=DGOX(15)/HH
5033     COEFF16H=DGLM(16)/H
5034     COEFF16HH=DGOX(16)/HH
5035
5036 C     For Glucose, being consumed only
5037     G(1)=COEFF1H/2.*(GLU(2,J+1)+GLU(1,J+1)-GLU(2,J)-GLU(1,J))
5038     1 -COEFF1HH/2.*(GLU(2,J)+GLU(1,J)-GLU(2,J-1)-GLU(1,J-1))
5039     2 -(HH/2.)*(3.*(EQ1(2,J)+EQ1(1,J))+(EQ1(2,J-1)+EQ1(1,J-1)))/8.
5040     3 +(H/2.)*(3.*(ANM(2,J)+ANM(1,J))+(ANM(2,J+1)+ANM(1,J+1)))/8.
5041     4 +(HH/2.)*(3.*(ANM(2,J)+ANM(1,J))+(ANM(2,J-1)+ANM(1,J-1)))/8.
5042     5 -H/2.*(3.*(GLU(2,J)-GLU(1,J))+(GLU(2,J+1)-GLU(1,J+1)))/(4.*DT)

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5043 6  -HH/2.*(3.*(GLU(2,J)-GLU(1,J))+(GLU(2,J-1)-GLU(1,J-1)))/(4.*DT)
5044
5045  B(1,1)=COEFF1H/2.+COEFF1HH/2.+H/2.*3./(4.*DT)+HH/2.*3./(4.*DT)
5046  D(1,1)=-COEFF1H/2.+H/2./(4.*DT)
5047  A(1,1)=-COEFF1HH/2.+HH/2./(4.*DT)
5048  B(1,9)=+(HH/2.)*(3./8.)
5049  A(1,9)=+(HH/2.)*(1./8.)
5050  B(1,13)=-(H/2.)*(3./8.)-(HH/2.)*(3./8.)
5051  D(1,13)=-(H/2.)*(1./8.)
5052  A(1,13)=-HH/2.)*(1./8.)
5053
5054
5055  BIG=ABS(COEFF1H/2.*GLU(2,J+1))
5056  BIG2=ABS(COEFF1H/2.*GLU(1,J+1))
5057  IF (BIG2.GT.BIG) BIG=BIG2
5058  BIG3=ABS(COEFF1H/2.*GLU(2,J))
5059  IF (BIG3.GT.BIG) BIG=BIG3
5060  BIG4=ABS(COEFF1H/2.*GLU(1,J))
5061  IF (BIG4.GT.BIG) BIG=BIG4
5062  BIG5=ABS(COEFF1HH/2.*GLU(2,J))
5063  IF (BIG5.GT.BIG) BIG=BIG5
5064  BIG6=ABS(COEFF1HH/2.*GLU(1,J))
5065  IF (BIG6.GT.BIG) BIG=BIG6
5066  BIG7=ABS(COEFF1HH/2.*GLU(2,J-1))
5067  IF (BIG7.GT.BIG) BIG=BIG7
5068  BIG8=ABS(COEFF1HH/2.*GLU(1,J-1))
5069  IF (BIG8.GT.BIG) BIG=BIG8
5070  BIG9=ABS(HH/2.*3.*EQ1(2,J)/8.)
5071  IF (BIG9.GT.BIG) BIG=BIG9
5072  BIG10=ABS(HH/2.*3.*EQ1(1,J)/8.)
5073  IF (BIG10.GT.BIG) BIG=BIG10
5074  BIG11=ABS(HH/2.*EQ1(2,J-1)/8.)
5075  IF (BIG11.GT.BIG) BIG=BIG11
5076  BIG12=ABS(HH/2.*EQ1(1,J-1)/8.)
5077  IF (BIG12.GT.BIG) BIG=BIG12
5078  BIG13=ABS(H/2.*3.*GLU(2,J)/(4.*DT))
5079  IF (BIG13.GT.BIG) BIG=BIG13
5080  BIG14=ABS(H/2.*3.*GLU(1,J)/(4.*DT))
5081  IF (BIG14.GT.BIG) BIG=BIG14
5082  BIG15=ABS(H/2.*GLU(2,J+1)/(4.*DT))
5083  IF (BIG15.GT.BIG) BIG=BIG15
5084  BIG16=ABS(H/2.*GLU(1,J+1)/(4.*DT))
5085  IF (BIG16.GT.BIG) BIG=BIG16
5086  BIG17=ABS(HH/2.*3.*GLU(2,J)/(4.*DT))
5087  IF (BIG17.GT.BIG) BIG=BIG17
5088  BIG18=ABS(HH/2.*3.*GLU(1,J)/(4.*DT))
5089  IF (BIG18.GT.BIG) BIG=BIG18
5090  BIG19=ABS(HH/2.*GLU(2,J-1)/(4.*DT))
5091  IF (BIG19.GT.BIG) BIG=BIG19
5092  BIG20=ABS(HH/2.*GLU(1,J-1)/(4.*DT))
5093  IF (BIG20.GT.BIG) BIG=BIG20
5094  BIG21=ABS(H/2.*3.*ANM(2,J)/8.)
5095  IF (BIG21.GT.BIG) BIG=BIG21
5096  BIG22=ABS(H/2.*3.*ANM(1,J)/8.)
5097  IF (BIG22.GT.BIG) BIG=BIG22
5098  BIG23=ABS(H/2.*ANM(2,J+1)/8.)
5099  IF (BIG23.GT.BIG) BIG=BIG23
5100  BIG24=ABS(H/2.*ANM(1,J+1)/8.)

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5101 IF (BIG24.GT.BIG) BIG=BIG24
5102 BIG25=ABS(HH/2.*3.*ANM(2,J)/8.)
5103 IF (BIG25.GT.BIG) BIG=BIG25
5104 BIG26=ABS(HH/2.*3.*ANM(1,J)/8.)
5105 IF (BIG26.GT.BIG) BIG=BIG26
5106 BIG27=ABS(HH/2.*ANM(2,J-1)/8.)
5107 IF (BIG27.GT.BIG) BIG=BIG27
5108 BIG28=ABS(HH/2.*ANM(1,J-1)/8.)
5109 IF (BIG28.GT.BIG) BIG=BIG28
5110 IF (ABS(G(1)).LT.BIG*EBIG) G(1)=0
5111
5112 C For GOx, enzyme
5113 G(2)=- (EQ1(2,J)+EQ1(1,J))/2.+(RHP(2,J)+RHP(1,J))/2.
5114 1 -(GOX(2,J)-GOX(1,J))/DT
5115 B(2,2)=+1./DT
5116 B(2,9)=+1./2.
5117 B(2,12)=-1./2.
5118
5119
5120 IF (ABS(EQ1(2,J)).GT.BIG) BIG=ABS(EQ1(2,J))
5121 IF (ABS(EQ1(1,J)).GT.BIG) BIG=ABS(EQ1(1,J))
5122 IF (ABS(RHP(2,J)).GT.BIG) BIG=ABS(RHP(2,J))
5123 IF (ABS(RHP(1,J)).GT.BIG) BIG=ABS(RHP(1,J))
5124 IF (ABS(GOX(2,J)/DT).GT.BIG) BIG=ABS(GOX(2,J)/DT)
5125 IF (ABS(GOX(1,J)/DT).GT.BIG) BIG=ABS(GOX(1,J)/DT)
5126 IF (ABS(G(2)).LT.BIG*EBIG) G(2)=0
5127
5128 C For Gluconic Acid, being produced only
5129 G(3)=COEFF3H/2.*(GLA(2,J+1)+GLA(1,J+1)-GLA(2,J)-GLA(1,J))
5130 1 -COEFF3HH/2.*(GLA(2,J)+GLA(1,J)-GLA(2,J-1)-GLA(1,J-1))
5131 2 +COEFF10H/2.*(GLI(2,J+1)+GLI(1,J+1)-GLI(2,J)-GLI(1,J))
5132 3 -COEFF10HH/2.*(GLI(2,J)+GLI(1,J)-GLI(2,J-1)-GLI(1,J-1))
5133 4 +(HH/2.)*(3.*(RGA(2,J)+RGA(1,J))+RGA(2,J-1)+RGA(1,J-1))/8.
5134 5 -H/2.*(3.*(GLA(2,J)-GLA(1,J))+GLA(2,J+1)-GLA(1,J+1))/(4.*DT)
5135 6 -HH/2.*(3.*(GLA(2,J)-GLA(1,J))+GLA(2,J-1)-GLA(1,J-1))/(4.*DT)
5136 7 -H/2.*(3.*(GLI(2,J)-GLI(1,J))+GLI(2,J+1)-GLI(1,J+1))/(4.*DT)
5137 8 -HH/2.*(3.*(GLI(2,J)-GLI(1,J))+GLI(2,J-1)-GLI(1,J-1))/(4.*DT)
5138
5139 B(3,3)=COEFF3H/2.+COEFF3HH/2.+H/2.*3./(4.*DT)+HH/2.*3./(4.*DT)
5140 D(3,3)=-COEFF3H/2.+H/2./(4.*DT)
5141 A(3,3)=-COEFF3HH/2.+HH/2./(4.*DT)
5142 B(3,15)=COEFF10H/2.+COEFF10HH/2.+H/2.*3./(4.*DT)+HH/2.*3./(4.*DT)
5143 D(3,15)=-COEFF10H/2.+H/2./(4.*DT)
5144 A(3,15)=-COEFF10HH/2.+HH/2./(4.*DT)
5145 B(3,10)=- (HH/2.)*(3./8.)
5146 A(3,10)=- (HH/2.)*(1./8.)
5147
5148
5149 BIG=ABS(COEFF3H/2.*GLA(2,J+1))
5150 BIG2=ABS(COEFF3H/2.*GLA(1,J+1))
5151 IF (BIG2.GT.BIG) BIG=BIG2
5152 BIG3=ABS(COEFF3H/2.*GLA(2,J))
5153 IF (BIG3.GT.BIG) BIG=BIG3
5154 BIG4=ABS(COEFF3H/2.*GLA(1,J))
5155 IF (BIG4.GT.BIG) BIG=BIG4
5156 BIG5=ABS(COEFF3HH/2.*GLA(2,J))
5157 IF (BIG5.GT.BIG) BIG=BIG5
5158 BIG6=ABS(COEFF3HH/2.*GLA(1,J))

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5159 IF (BIG6.GT.BIG) BIG=BIG6
5160 BIG7=ABS(COEFF3HH/2.*GLA(2,J-1))
5161 IF (BIG7.GT.BIG) BIG=BIG7
5162 BIG8=ABS(COEFF3HH/2.*GLA(1,J-1))
5163 IF (BIG8.GT.BIG) BIG=BIG8
5164 BIG9=ABS(HH/2.*3.*RGA(2,J)/8.)
5165 IF (BIG9.GT.BIG) BIG=BIG9
5166 BIG10=ABS(HH/2.*3.*RGA(1,J)/8.)
5167 IF (BIG10.GT.BIG) BIG=BIG10
5168 BIG11=ABS(HH/2.*RGA(2,J-1)/8.)
5169 IF (BIG11.GT.BIG) BIG=BIG11
5170 BIG12=ABS(HH/2.*RGA(1,J-1)/8.)
5171 IF (BIG12.GT.BIG) BIG=BIG12
5172 BIG13=ABS(H/2.*3.*GLA(2,J)/(4.*DT))
5173 IF (BIG13.GT.BIG) BIG=BIG13
5174 BIG14=ABS(H/2.*3.*GLA(1,J)/(4.*DT))
5175 IF (BIG14.GT.BIG) BIG=BIG14
5176 BIG15=ABS(H/2.*GLA(2,J+1)/(4.*DT))
5177 IF (BIG15.GT.BIG) BIG=BIG15
5178 BIG16=ABS(H/2.*GLA(1,J+1)/(4.*DT))
5179 IF (BIG16.GT.BIG) BIG=BIG16
5180 BIG17=ABS(HH/2.*3.*GLA(2,J)/(4.*DT))
5181 IF (BIG17.GT.BIG) BIG=BIG17
5182 BIG18=ABS(HH/2.*3.*GLA(1,J)/(4.*DT))
5183 IF (BIG18.GT.BIG) BIG=BIG18
5184 BIG19=ABS(HH/2.*GLA(2,J-1)/(4.*DT))
5185 IF (BIG19.GT.BIG) BIG=BIG19
5186 BIG20=ABS(HH/2.*GLA(1,J-1)/(4.*DT))
5187 IF (BIG20.GT.BIG) BIG=BIG20
5188 BIG21=ABS(COEFF10H/2.*GLI(2,J+1))
5189 IF (BIG21.GT.BIG) BIG=BIG21
5190 BIG22=ABS(COEFF10H/2.*GLI(1,J+1))
5191 IF (BIG22.GT.BIG) BIG=BIG22
5192 BIG23=ABS(COEFF10H/2.*GLI(2,J))
5193 IF (BIG23.GT.BIG) BIG=BIG23
5194 BIG24=ABS(COEFF10H/2.*GLI(1,J))
5195 IF (BIG24.GT.BIG) BIG=BIG24
5196 BIG25=ABS(COEFF10HH/2.*GLI(2,J))
5197 IF (BIG25.GT.BIG) BIG=BIG25
5198 BIG26=ABS(COEFF10HH/2.*GLI(1,J))
5199 IF (BIG26.GT.BIG) BIG=BIG26
5200 BIG27=ABS(COEFF10HH/2.*GLI(2,J-1))
5201 IF (BIG27.GT.BIG) BIG=BIG27
5202 BIG28=ABS(COEFF10HH/2.*GLI(1,J-1))
5203 IF (BIG28.GT.BIG) BIG=BIG28
5204 BIG29=ABS(H/2.*3.*GLI(2,J)/(4.*DT))
5205 IF (BIG29.GT.BIG) BIG=BIG29
5206 BIG30=ABS(H/2.*3.*GLI(1,J)/(4.*DT))
5207 IF (BIG30.GT.BIG) BIG=BIG30
5208 BIG31=ABS(H/2.*GLI(2,J+1)/(4.*DT))
5209 IF (BIG31.GT.BIG) BIG=BIG31
5210 BIG32=ABS(H/2.*GLI(1,J+1)/(4.*DT))
5211 IF (BIG32.GT.BIG) BIG=BIG32
5212 BIG33=ABS(HH/2.*3.*GLI(2,J)/(4.*DT))
5213 IF (BIG33.GT.BIG) BIG=BIG33
5214 BIG34=ABS(HH/2.*3.*GLI(1,J)/(4.*DT))
5215 IF (BIG34.GT.BIG) BIG=BIG34
5216 BIG35=ABS(HH/2.*GLI(2,J-1)/(4.*DT))

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5217 IF (BIG35.GT.BIG) BIG=BIG35
5218 BIG36=ABS(HH/2.*GLI(1,J-1)/(4.*DT))
5219 IF (BIG36.GT.BIG) BIG=BIG36
5220 IF (ABS(G(3)).LT.BIG*EBIG) G(3)=0
5221
5222 C For GOx2, enzyme
5223 G(4)=CBULK(2)+CBULK(4)+CBULK(7)+CBULK(8)-(GOX(2,J)+GOX(1,J))/2.
5224 1 -(GOR(2,J)+GOR(1,J))/2.-(GOA(2,J)+GOA(1,J))/2.
5225 2 -(GOP(2,J)+GOP(1,J))/2.
5226 B(4,4)=+1./2.
5227 B(4,2)=+1./2.
5228 B(4,7)=+1./2.
5229 B(4,8)=+1./2.
5230
5231 BIG=ABS(CBULK(2))
5232 IF (ABS(CBULK(4)).GT.BIG) BIG=ABS(CBULK(4))
5233 IF (ABS(CBULK(7)).GT.BIG) BIG=ABS(CBULK(7))
5234 IF (ABS(CBULK(8)).GT.BIG) BIG=ABS(CBULK(8))
5235 IF (ABS(GOX(2,J)/2.).GT.BIG) BIG=ABS(GOX(2,J)/2.)
5236 IF (ABS(GOX(1,J)/2.).GT.BIG) BIG=ABS(GOX(1,J)/2.)
5237 IF (ABS(GOR(2,J)/2.).GT.BIG) BIG=ABS(GOR(2,J)/2.)
5238 IF (ABS(GOR(1,J)/2.).GT.BIG) BIG=ABS(GOR(1,J)/2.)
5239 IF (ABS(GOA(2,J)/2.).GT.BIG) BIG=ABS(GOA(2,J)/2.)
5240 IF (ABS(GOA(1,J)/2.).GT.BIG) BIG=ABS(GOA(1,J)/2.)
5241 IF (ABS(GOP(2,J)/2.).GT.BIG) BIG=ABS(GOP(2,J)/2.)
5242 IF (ABS(GOP(1,J)/2.).GT.BIG) BIG=ABS(GOP(1,J)/2.)
5243 IF (ABS(G(4)).LT.BIG*EBIG) G(4)=0
5244
5245 C For O2, being consumed only G(5), COEFF5, -EQ2 (11)
5246 G(5)=COEFF5H/2.*(OXY(2,J+1)+OXY(1,J+1)-OXY(2,J)-OXY(1,J))
5247 1 -COEFF5HH/2.*(OXY(2,J)+OXY(1,J)-OXY(2,J-1)-OXY(1,J-1))
5248 2 -(HH/2.)*(3.*(EQ2(2,J)+EQ2(1,J))+(EQ2(2,J-1)+EQ2(1,J-1)))/8.
5249 3 -H/2.*(3.*(OXY(2,J)-OXY(1,J))+(OXY(2,J+1)-OXY(1,J+1)))/(4.*DT)
5250 4 -HH/2.*(3.*(OXY(2,J)-OXY(1,J))+(OXY(2,J-1)-OXY(1,J-1)))/(4.*DT)
5251
5252 B(5,5)=COEFF5H/2.+COEFF5HH/2.+H/2.*3./(4.*DT)+HH/2.*3./(4.*DT)
5253 D(5,5)=-COEFF5H/2.+H/2./(4.*DT)
5254 A(5,5)=-COEFF5HH/2.+HH/2./(4.*DT)
5255 B(5,11)=+(HH/2.)*(3./8.)
5256 A(5,11)=+(HH/2.)*(1./8.)
5257
5258
5259 BIG=ABS(COEFF5H/2.*OXY(2,J+1))
5260 BIG2=ABS(COEFF5H/2.*OXY(1,J+1))
5261 IF (BIG2.GT.BIG) BIG=BIG2
5262 BIG3=ABS(COEFF5H/2.*OXY(2,J))
5263 IF (BIG3.GT.BIG) BIG=BIG3
5264 BIG4=ABS(COEFF5H/2.*OXY(1,J))
5265 IF (BIG4.GT.BIG) BIG=BIG4
5266 BIG5=ABS(COEFF5HH/2.*OXY(2,J))
5267 IF (BIG5.GT.BIG) BIG=BIG5
5268 BIG6=ABS(COEFF5HH/2.*OXY(1,J))
5269 IF (BIG6.GT.BIG) BIG=BIG6
5270 BIG7=ABS(COEFF5HH/2.*OXY(2,J-1))
5271 IF (BIG7.GT.BIG) BIG=BIG7
5272 BIG8=ABS(COEFF5HH/2.*OXY(1,J-1))
5273 IF (BIG8.GT.BIG) BIG=BIG8
5274 BIG9=ABS(HH/2.*3.*EQ2(2,J)/8.)

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5275 IF (BIG9.GT.BIG) BIG=BIG9
5276 BIG10=ABS(HH/2.*3.*EQ2(1,J)/8.)
5277 IF (BIG10.GT.BIG) BIG=BIG10
5278 BIG11=ABS(HH/2.*EQ2(2,J-1)/8.)
5279 IF (BIG11.GT.BIG) BIG=BIG11
5280 BIG12=ABS(HH/2.*EQ2(1,J-1)/8.)
5281 IF (BIG12.GT.BIG) BIG=BIG12
5282 BIG13=ABS(H/2.*3.*OXY(2,J)/(4.*DT))
5283 IF (BIG13.GT.BIG) BIG=BIG13
5284 BIG14=ABS(H/2.*3.*OXY(1,J)/(4.*DT))
5285 IF (BIG14.GT.BIG) BIG=BIG14
5286 BIG15=ABS(H/2.*OXY(2,J+1)/(4.*DT))
5287 IF (BIG15.GT.BIG) BIG=BIG15
5288 BIG16=ABS(H/2.*OXY(1,J+1)/(4.*DT))
5289 IF (BIG16.GT.BIG) BIG=BIG16
5290 BIG17=ABS(HH/2.*3.*OXY(2,J)/(4.*DT))
5291 IF (BIG17.GT.BIG) BIG=BIG17
5292 BIG18=ABS(HH/2.*3.*OXY(1,J)/(4.*DT))
5293 IF (BIG18.GT.BIG) BIG=BIG18
5294 BIG19=ABS(HH/2.*OXY(2,J-1)/(4.*DT))
5295 IF (BIG19.GT.BIG) BIG=BIG19
5296 BIG20=ABS(HH/2.*OXY(1,J-1)/(4.*DT))
5297 IF (BIG20.GT.BIG) BIG=BIG20
5298 IF (ABS(G(5)).LT.BIG*EBIG) G(5)=0
5299
5300 C For H2O2, reacting species COEFF6, G(6), +RHP (12), HPR
5301 G(6)=COEFF6H/2.*(HPR(2,J+1)+HPR(1,J+1)-HPR(2,J)-HPR(1,J))
5302 1 -COEFF6HH/2.*(HPR(2,J)+HPR(1,J)-HPR(2,J-1)-HPR(1,J-1))
5303 2 +(HH/2.)*(3.*(RHP(2,J)+RHP(1,J))+(RHP(2,J-1)+RHP(1,J-1)))/8.
5304 3 -H/2.*(3.*(HPR(2,J)-HPR(1,J))+(HPR(2,J+1)-HPR(1,J+1)))/(4.*DT)
5305 4 -HH/2.*(3.*(HPR(2,J)-HPR(1,J))+(HPR(2,J-1)-HPR(1,J-1)))/(4.*DT)
5306
5307 B(6,6)=COEFF6H/2.+COEFF6HH/2.+H/2.*3./(4.*DT)+HH/2.*3./(4.*DT)
5308 D(6,6)=-COEFF6H/2.+H/2./(4.*DT)
5309 A(6,6)=-COEFF6HH/2.+HH/2./(4.*DT)
5310 B(6,12)=-HH/2.)*(3./8.)
5311 A(6,12)=-HH/2.)*(1./8.)
5312
5313
5314 BIG=ABS(COEFF6H/2.*HPR(2,J+1))
5315 BIG2=ABS(COEFF6H/2.*HPR(1,J+1))
5316 IF (BIG2.GT.BIG) BIG=BIG2
5317 BIG3=ABS(COEFF6H/2.*HPR(2,J))
5318 IF (BIG3.GT.BIG) BIG=BIG3
5319 BIG4=ABS(COEFF6H/2.*HPR(1,J))
5320 IF (BIG4.GT.BIG) BIG=BIG4
5321 BIG5=ABS(COEFF6HH/2.*HPR(2,J))
5322 IF (BIG5.GT.BIG) BIG=BIG5
5323 BIG6=ABS(COEFF6HH/2.*HPR(1,J))
5324 IF (BIG6.GT.BIG) BIG=BIG6
5325 BIG7=ABS(COEFF6HH/2.*HPR(2,J-1))
5326 IF (BIG7.GT.BIG) BIG=BIG7
5327 BIG8=ABS(COEFF6HH/2.*HPR(1,J-1))
5328 IF (BIG8.GT.BIG) BIG=BIG8
5329 BIG9=ABS(HH/2.*3.*RHP(2,J)/8.)
5330 IF (BIG9.GT.BIG) BIG=BIG9
5331 BIG10=ABS(HH/2.*3.*RHP(1,J)/8.)
5332 IF (BIG10.GT.BIG) BIG=BIG10

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5333 BIG11=ABS(HH/2.*RHP(2,J-1)/8.)
5334 IF (BIG11.GT.BIG) BIG=BIG11
5335 BIG12=ABS(HH/2.*RHP(1,J-1)/8.)
5336 IF (BIG12.GT.BIG) BIG=BIG12
5337 BIG13=ABS(H/2.*3.*HPR(2,J)/(4.*DT))
5338 IF (BIG13.GT.BIG) BIG=BIG13
5339 BIG14=ABS(H/2.*3.*HPR(1,J)/(4.*DT))
5340 IF (BIG14.GT.BIG) BIG=BIG14
5341 BIG15=ABS(H/2.*HPR(2,J+1)/(4.*DT))
5342 IF (BIG15.GT.BIG) BIG=BIG15
5343 BIG16=ABS(H/2.*HPR(1,J+1)/(4.*DT))
5344 IF (BIG16.GT.BIG) BIG=BIG16
5345 BIG17=ABS(HH/2.*3.*HPR(2,J)/(4.*DT))
5346 IF (BIG17.GT.BIG) BIG=BIG17
5347 BIG18=ABS(HH/2.*3.*HPR(1,J)/(4.*DT))
5348 IF (BIG18.GT.BIG) BIG=BIG18
5349 BIG19=ABS(HH/2.*HPR(2,J-1)/(4.*DT))
5350 IF (BIG19.GT.BIG) BIG=BIG19
5351 BIG20=ABS(HH/2.*HPR(1,J-1)/(4.*DT))
5352 IF (BIG20.GT.BIG) BIG=BIG20
5353 IF (ABS(G(6)).LT.BIG*EBIG) G(6)=0
5354
5355 C For CX-GOx2, enzyme
5356 G(7)=(EQ1(2,J)+EQ1(1,J))/2.-(RGA(2,J)+RGA(1,J))/2.
5357 1 -(GOA(2,J)-GOA(1,J))/DT
5358
5359 B(7,7)=+1./DT
5360 B(7,9)=-1./2.
5361 B(7,10)=1./2.
5362
5363 IF (ABS(EQ1(2,J)).GT.BIG) BIG=ABS(EQ1(2,J))
5364 IF (ABS(EQ1(1,J)).GT.BIG) BIG=ABS(EQ1(1,J))
5365 IF (ABS(RGA(2,J)).GT.BIG) BIG=ABS(RGA(2,J))
5366 IF (ABS(RGA(1,J)).GT.BIG) BIG=ABS(RGA(1,J))
5367 IF (ABS(GOA(2,J)/DT).GT.BIG) BIG=ABS(GOA(2,J)/DT)
5368 IF (ABS(GOA(1,J)/DT).GT.BIG) BIG=ABS(GOA(1,J)/DT)
5369 IF (ABS(G(7)).LT.BIG*EBIG) G(7)=0
5370
5371 C For CX-GOx, enzyme
5372 G(8)=(EQ2(2,J)+EQ2(1,J))/2.-(RHP(2,J)+RHP(1,J))/2.
5373 1 -(GOP(2,J)-GOP(1,J))/DT
5374 B(8,8)=+1./DT
5375 B(8,11)=-1./2.
5376 B(8,12)=1./2.
5377
5378 IF (ABS(EQ2(2,J)).GT.BIG) BIG=ABS(EQ2(2,J))
5379 IF (ABS(EQ2(1,J)).GT.BIG) BIG=ABS(EQ2(1,J))
5380 IF (ABS(RHP(2,J)).GT.BIG) BIG=ABS(RHP(2,J))
5381 IF (ABS(RHP(1,J)).GT.BIG) BIG=ABS(RHP(1,J))
5382 IF (ABS(GOP(2,J)/DT).GT.BIG) BIG=ABS(GOP(2,J)/DT)
5383 IF (ABS(GOP(1,J)/DT).GT.BIG) BIG=ABS(GOP(1,J)/DT)
5384 IF (ABS(G(8)).LT.BIG*EBIG) G(8)=0
5385
5386
5387 C REACTION1
5388 214 G(9)=-((EQ1(2,J)+EQ1(1,J))/2.
5389 1 +ratef1*((GLU(2,J)+GLU(1,J))*(GOX(2,J)+GOX(1,J))/4.
5390 2 -(GOA(2,J)+GOA(1,J))/2./equilib1)

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5391 B(9,1)=-ratef1*(GOX(2,J)+GOX(1,J))/4.
5392 B(9,2)=-ratef1*(GLU(2,J)+GLU(1,J))/4.
5393 B(9,7)=ratef1/2./equilib1
5394 B(9,9)=+1./2.
5395
5396 BIG=ABS(EQ1(2,J)/2.)
5397 BIG2=ABS(EQ1(1,J)/2.)
5398 IF (BIG2.GT.BIG) BIG=BIG2
5399 BIG3=ABS(ratef1*GLU(2,J)*GOX(2,J)/4.)
5400 IF (BIG3.GT.BIG) BIG=BIG3
5401 BIG4=ABS(ratef1*GLU(1,J)*GOX(2,J)/4)
5402 IF (BIG4.GT.BIG) BIG=BIG4
5403 BIG5=ABS(ratef1*GLU(2,J)*GOX(1,J)/4)
5404 IF (BIG5.GT.BIG) BIG=BIG5
5405 BIG6=ABS(ratef1*GLU(1,J)*GOX(1,J)/4)
5406 IF (BIG6.GT.BIG) BIG=BIG6
5407 BIG7=ABS(ratef1*GOA(2,J)/2./equilib1)
5408 IF (BIG7.GT.BIG) BIG=BIG7
5409 BIG8=ABS(ratef1*GOA(1,J)/2./equilib1)
5410 IF (BIG8.GT.BIG) BIG=BIG8
5411 IF (ABS(G(9)).LT.BIG*EBIG) G(9)=0
5412
5413 C REACTION2
5414 215 G(10)=- (RGA(2,J)+RGA(1,J))/2.+ratef2*(GOA(2,J)+GOA(1,J))/2.
5415 B(10,7)=-ratef2/2.
5416 B(10,10)=+1./2.
5417
5418 BIG=ABS(RGA(2,J)/2.)
5419 BIG2=ABS(RGA(1,J)/2.)
5420 IF (BIG2.GT.BIG) BIG=BIG2
5421 BIG3=ABS(ratef2*GOA(2,J)/2.)
5422 IF (BIG3.GT.BIG) BIG=BIG3
5423 BIG4=ABS(ratef2*GOA(1,J)/2.)
5424 IF (BIG4.GT.BIG) BIG=BIG4
5425 IF (ABS(G(10)).LT.BIG*EBIG) G(10)=0
5426
5427 C REACTION3
5428 216 G(11)=- (EQ2(2,J)+EQ2(1,J))/2.
5429 1 +ratef3*((GOR(2,J)+GOR(1,J))*(OXY(2,J)+OXY(1,J))/4.
5430 2 -(GOP(2,J)+GOP(1,J))/2./equilib3)
5431 B(11,4)=-ratef3*(OXY(2,J)+OXY(1,J))/4.
5432 B(11,5)=-ratef3*(GOR(2,J)+GOR(1,J))/4.
5433 B(11,8)=ratef3/2./equilib3
5434 B(11,11)=+1./2.
5435
5436 BIG=ABS(EQ2(2,J)/2.)
5437 BIG2=ABS(EQ2(1,J)/2.)
5438 IF (BIG2.GT.BIG) BIG=BIG2
5439 BIG3=ABS(ratef3*GOR(2,J)*OXY(2,J)/4.)
5440 IF (BIG3.GT.BIG) BIG=BIG3
5441 BIG4=ABS(ratef3*GOR(1,J)*OXY(2,J)/4)
5442 IF (BIG4.GT.BIG) BIG=BIG4
5443 BIG5=ABS(ratef3*GOR(2,J)*OXY(1,J)/4)
5444 IF (BIG5.GT.BIG) BIG=BIG5
5445 BIG6=ABS(ratef3*GOR(1,J)*OXY(1,J)/4)
5446 IF (BIG6.GT.BIG) BIG=BIG6
5447 BIG7=ABS(ratef3*GOP(2,J)/2./EQUILIB3)
5448 IF (BIG7.GT.BIG) BIG=BIG7

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5449     BIG8=ABS(ratef3 *GOP(1 , J) /2 ./ EQUILIB3)
5450     IF (BIG8.GT. BIG) BIG=BIG8
5451     IF (ABS(G(11)).LT. BIG*EBIG) G(11)=0
5452
5453 C     REACTION4
5454 217 G(12)=- (RHP(2 , J)+RHP(1 , J) )/2. + ratef4 *(GOP(2 , J)+GOP(1 , J) )/2.
5455     B(12 ,8)=-ratef4 /2.
5456     B(12 ,12)=+1./2.
5457
5458     BIG=ABS(RHP(2 , J) /2.)
5459     BIG2=ABS(RHP(1 , J) /2.)
5460     IF (BIG2.GT. BIG) BIG=BIG2
5461     BIG3=ABS(ratef4 *GOP(2 , J) /2.)
5462     IF (BIG3.GT. BIG) BIG=BIG3
5463     BIG4=ABS(ratef4 *GOP(1 , J) /2.)
5464     IF (BIG4.GT. BIG) BIG=BIG4
5465     IF (ABS(G(12)).LT. BIG*EBIG) G(12)=0
5466
5467 C     REACTION5
5468 218 G(13)=- (ANM(2 , J)+ANM(1 , J) )/2. + ratef5 *((GLUA(2 , J)+GLUA(1 , J) )/2.
5469 1   -(GLU(2 , J)+GLU(1 , J) )/2. / equilib5)
5470     B(13 ,1)=ratef5 /2. / equilib5
5471     B(13 ,14)=-ratef5 /2.
5472     B(13 ,13)=+1./2.
5473
5474     BIG=ABS(ANM(2 , J) /2.)
5475     BIG2=ABS(ANM(1 , J) /2.)
5476     IF (BIG2.GT. BIG) BIG=BIG2
5477     BIG3=ABS(ratef5 *GLUA(2 , J) /2.)
5478     IF (BIG3.GT. BIG) BIG=BIG3
5479     BIG4=ABS(ratef5 *GLUA(1 , J) /2.)
5480     IF (BIG4.GT. BIG) BIG=BIG4
5481     BIG5=ABS(ratef5 *GLU(2 , J) /2. / equilib5)
5482     IF (BIG5.GT. BIG) BIG=BIG5
5483     BIG6=ABS(ratef5 *GLU(1 , J) /2. / equilib5)
5484     IF (BIG6.GT. BIG) BIG=BIG6
5485     IF (ABS(G(13)).LT. BIG*EBIG) G(13)=0.0
5486
5487 C     For alpha Glucose , being consumed only
5488     G(14)=COEFF9H/2. *(GLUA(2 , J+1)+GLUA(1 , J+1)-GLUA(2 , J)-GLUA(1 , J) )
5489 1   -COEFF9HH/2. *(GLUA(2 , J)+GLUA(1 , J)-GLUA(2 , J-1)-GLUA(1 , J-1) )
5490 2   -(H/2.) *(3. *(ANM(2 , J)+ANM(1 , J) )+(ANM(2 , J+1)+ANM(1 , J+1) ) )/8.
5491 3   -(HH/2.) *(3. *(ANM(2 , J)+ANM(1 , J) )+(ANM(2 , J-1)+ANM(1 , J-1) ) )/8.
5492 4   -H/2.
5493 5   *(3. *(GLUA(2 , J)-GLUA(1 , J) )+(GLUA(2 , J+1)-GLUA(1 , J+1) ) )/(4. *DT)
5494 6   -HH/2.
5495 7   *(3. *(GLUA(2 , J)-GLUA(1 , J) )+(GLUA(2 , J-1)-GLUA(1 , J-1) ) )/(4. *DT)
5496
5497
5498     B(14 ,14)=COEFF9H/2. +COEFF9HH/2. +H/2. *3. /(4. *DT)
5499 1   +HH/2. *3. /(4. *DT)
5500     D(14 ,14)=-COEFF9H/2. +H/2. /(4. *DT)
5501     A(14 ,14)=-COEFF9HH/2. +HH/2. /(4. *DT)
5502     B(14 ,13)=+(H/2.) *(3./8.) +(HH/2.) *(3./8.)
5503     D(14 ,13)=+(H/2.) *(1./8.)
5504     A(14 ,13)=+(HH/2.) *(1./8.)
5505
5506     BIG=ABS(COEFF9H/2. *GLUA(2 , J+1) )

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5507 BIG2=ABS(COEFF9H/2.*GLUA(1,J+1))
5508 IF (BIG2.GT.BIG) BIG=BIG2
5509 BIG3=ABS(COEFF9H/2.*GLUA(2,J))
5510 IF (BIG3.GT.BIG) BIG=BIG3
5511 BIG4=ABS(COEFF9H/2.*GLUA(1,J))
5512 IF (BIG4.GT.BIG) BIG=BIG4
5513 BIG5=ABS(COEFF9HH/2.*GLUA(2,J))
5514 IF (BIG5.GT.BIG) BIG=BIG5
5515 BIG6=ABS(COEFF9HH/2.*GLUA(1,J))
5516 IF (BIG6.GT.BIG) BIG=BIG6
5517 BIG7=ABS(COEFF9HH/2.*GLUA(2,J-1))
5518 IF (BIG7.GT.BIG) BIG=BIG7
5519 BIG8=ABS(COEFF9HH/2.*GLUA(1,J-1))
5520 IF (BIG8.GT.BIG) BIG=BIG8
5521 BIG9=ABS(H/2.*3.*GLUA(2,J)/(4.*DT))
5522 IF (BIG9.GT.BIG) BIG=BIG9
5523 BIG10=ABS(H/2.*3.*GLUA(1,J)/(4.*DT))
5524 IF (BIG10.GT.BIG) BIG=BIG10
5525 BIG11=ABS(H/2.*GLUA(2,J+1)/(4.*DT))
5526 IF (BIG11.GT.BIG) BIG=BIG11
5527 BIG12=ABS(H/2.*GLUA(1,J+1)/(4.*DT))
5528 IF (BIG12.GT.BIG) BIG=BIG12
5529 BIG13=ABS(HH/2.*3.*GLUA(2,J)/(4.*DT))
5530 IF (BIG13.GT.BIG) BIG=BIG13
5531 BIG14=ABS(HH/2.*3.*GLUA(1,J)/(4.*DT))
5532 IF (BIG14.GT.BIG) BIG=BIG14
5533 BIG15=ABS(HH/2.*GLUA(2,J-1)/(4.*DT))
5534 IF (BIG15.GT.BIG) BIG=BIG15
5535 BIG16=ABS(HH/2.*GLUA(1,J-1)/(4.*DT))
5536 IF (BIG16.GT.BIG) BIG=BIG16
5537 BIG17=ABS(H/2.*3.*ANM(2,J)/8.)
5538 IF (BIG17.GT.BIG) BIG=BIG17
5539 BIG18=ABS(H/2.*3.*ANM(1,J)/8.)
5540 IF (BIG18.GT.BIG) BIG=BIG18
5541 BIG19=ABS(H/2.*ANM(2,J+1)/8.)
5542 IF (BIG19.GT.BIG) BIG=BIG19
5543 BIG20=ABS(H/2.*ANM(1,J+1)/8.)
5544 IF (BIG20.GT.BIG) BIG=BIG20
5545 BIG21=ABS(HH/2.*3.*ANM(2,J)/8.)
5546 IF (BIG21.GT.BIG) BIG=BIG21
5547 BIG22=ABS(HH/2.*3.*ANM(1,J)/8.)
5548 IF (BIG22.GT.BIG) BIG=BIG22
5549 BIG23=ABS(HH/2.*ANM(2,J-1)/8.)
5550 IF (BIG23.GT.BIG) BIG=BIG23
5551 BIG24=ABS(HH/2.*ANM(1,J-1)/8.)
5552 IF (BIG24.GT.BIG) BIG=BIG24
5553 IF (ABS(G(14)).LT.BIG*EBIG) G(14)=0
5554
5555 C Gluconic acid dissociation
5556
5557 G(15)=equilib6*(GLA(2,J)+GLA(1,J))/2.-(GLI(2,J)+GLI(1,J))*
5558 1 (HYD(2,J)+HYD(1,J))/4.
5559 B(15,3)=-equilib6/2.
5560 B(15,15)=(HYD(2,J)+HYD(1,J))/4.
5561 B(15,16)=(GLI(2,J)+GLI(1,J))/4.
5562
5563 BIG=ABS(equilib6*GLA(2,J)/2.)
5564 BIG2=ABS(equilib6*GLA(1,J)/2.)

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5565 IF (BIG2.GT.BIG) BIG=BIG2
5566 BIG3=ABS(GLI(2,J)*HYD(2,J)/4.)
5567 IF (BIG3.GT.BIG) BIG=BIG3
5568 BIG4=ABS(GLI(2,J)*HYD(1,J)/4)
5569 IF (BIG4.GT.BIG) BIG=BIG4
5570 BIG5=ABS(GLI(1,J)*HYD(2,J)/4)
5571 IF (BIG5.GT.BIG) BIG=BIG5
5572 BIG6=ABS(GLI(1,J)*HYD(1,J)/4)
5573 IF (BIG6.GT.BIG) BIG=BIG6
5574 IF (ABS(G(15)).LT.BIG*EBIG) G(15)=0
5575
5576 C Hydrogen ion, hydroxide ion, gluconate ion, bicarbonate ion flux
5577
5578 G(16)=COEFF11H/2.*(HYD(2,J+1)+HYD(1,J+1)-HYD(2,J)-HYD(1,J))
5579 1 -COEFF11HH/2.*(HYD(2,J)+HYD(1,J)-HYD(2,J-1)-HYD(1,J-1))
5580 2 -COEFF15H/2.*(OHI(2,J+1)+OHI(1,J+1)-OHI(2,J)-OHI(1,J))
5581 3 +COEFF15HH/2.*(OHI(2,J)+OHI(1,J)-OHI(2,J-1)-OHI(1,J-1))
5582 4 -COEFF10H/2.*(GLI(2,J+1)+GLI(1,J+1)-GLI(2,J)-GLI(1,J))
5583 5 +COEFF10HH/2.*(GLI(2,J)+GLI(1,J)-GLI(2,J-1)-GLI(1,J-1))
5584 6 -COEFF14H/2.*(CBI(2,J+1)+CBI(1,J+1)-CBI(2,J)-CBI(1,J))
5585 7 +COEFF14HH/2.*(CBI(2,J)+CBI(1,J)-CBI(2,J-1)-CBI(1,J-1))
5586 8 -H/2.*(3.*(HYD(2,J)-HYD(1,J))+(HYD(2,J+1)-HYD(1,J+1)))/(4.*DT)
5587 9 -HH/2.*(3.*(HYD(2,J)-HYD(1,J))+(HYD(2,J-1)-HYD(1,J-1)))/(4.*DT)
5588 1 +H/2.*(3.*(OHI(2,J)-OHI(1,J))+(OHI(2,J+1)-OHI(1,J+1)))/(4.*DT)
5589 2 +HH/2.*(3.*(OHI(2,J)-OHI(1,J))+(OHI(2,J-1)-OHI(1,J-1)))/(4.*DT)
5590 3 +H/2.*(3.*(GLI(2,J)-GLI(1,J))+(GLI(2,J+1)-GLI(1,J+1)))/(4.*DT)
5591 4 +HH/2.*(3.*(GLI(2,J)-GLI(1,J))+(GLI(2,J-1)-GLI(1,J-1)))/(4.*DT)
5592 5 +H/2.*(3.*(CBI(2,J)-CBI(1,J))+(CBI(2,J+1)-CBI(1,J+1)))/(4.*DT)
5593 6 +HH/2.*(3.*(CBI(2,J)-CBI(1,J))+(CBI(2,J-1)-CBI(1,J-1)))/(4.*DT)
5594
5595 B(16,16)=COEFF11H/2.+COEFF11HH/2.+H/2.*3./(4.*DT)
5596 1 +HH/2.*3./(4.*DT)
5597 D(16,16)=-COEFF11H/2.+H/2./(4.*DT)
5598 A(16,16)=-COEFF11HH/2.+HH/2./(4.*DT)
5599
5600 B(16,17)=-COEFF15H/2.-COEFF15HH/2.-H/2.*3./(4.*DT)
5601 1 -HH/2.*3./(4.*DT)
5602 D(16,17)=+COEFF15H/2.-H/2./(4.*DT)
5603 A(16,17)=+COEFF15HH/2.-HH/2./(4.*DT)
5604
5605 B(16,15)=-COEFF10H/2.-COEFF10HH/2.-H/2.*3./(4.*DT)
5606 1 -HH/2.*3./(4.*DT)
5607 D(16,15)=+COEFF10H/2.-H/2./(4.*DT)
5608 A(16,15)=+COEFF10HH/2.-HH/2./(4.*DT)
5609
5610 B(16,20)=-COEFF14H/2.-COEFF14HH/2.-H/2.*3./(4.*DT)
5611 1 -HH/2.*3./(4.*DT)
5612 D(16,20)=+COEFF14H/2.-H/2./(4.*DT)
5613 A(16,20)=+COEFF14HH/2.-HH/2./(4.*DT)
5614
5615 BIG=ABS(COEFF11H/2.*HYD(2,J+1))
5616 BIG2=ABS(COEFF11H/2.*HYD(1,J+1))
5617 IF (BIG2.GT.BIG) BIG=BIG2
5618 BIG3=ABS(COEFF11H/2.*HYD(2,J))
5619 IF (BIG3.GT.BIG) BIG=BIG3
5620 BIG4=ABS(COEFF11H/2.*HYD(1,J))
5621 IF (BIG4.GT.BIG) BIG=BIG4
5622 BIG5=ABS(COEFF11HH/2.*HYD(2,J))

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5623 IF (BIG5.GT.BIG) BIG=BIG5
5624 BIG6=ABS(COEFF11HH/2.*HYD(1,J))
5625 IF (BIG6.GT.BIG) BIG=BIG6
5626 BIG7=ABS(COEFF11HH/2.*HYD(2,J-1))
5627 IF (BIG7.GT.BIG) BIG=BIG7
5628 BIG8=ABS(COEFF11HH/2.*HYD(1,J-1))
5629 IF (BIG8.GT.BIG) BIG=BIG8
5630 BIG9=ABS(H/2.*3.*HYD(2,J)/(4.*DT))
5631 IF (BIG9.GT.BIG) BIG=BIG9
5632 BIG10=ABS(H/2.*3.*HYD(1,J)/(4.*DT))
5633 IF (BIG10.GT.BIG) BIG=BIG10
5634 BIG11=ABS(H/2.*HYD(2,J+1)/(4.*DT))
5635 IF (BIG11.GT.BIG) BIG=BIG11
5636 BIG12=ABS(H/2.*HYD(1,J+1)/(4.*DT))
5637 IF (BIG12.GT.BIG) BIG=BIG12
5638 BIG13=ABS(HH/2.*3.*HYD(2,J)/(4.*DT))
5639 IF (BIG13.GT.BIG) BIG=BIG13
5640 BIG14=ABS(HH/2.*3.*HYD(1,J)/(4.*DT))
5641 IF (BIG14.GT.BIG) BIG=BIG14
5642 BIG15=ABS(HH/2.*HYD(2,J-1)/(4.*DT))
5643 IF (BIG15.GT.BIG) BIG=BIG15
5644 BIG16=ABS(HH/2.*HYD(1,J-1)/(4.*DT))
5645 IF (BIG16.GT.BIG) BIG=BIG16
5646 BIG17=ABS(COEFF15H/2.*OHI(2,J+1))
5647 IF (BIG17.GT.BIG) BIG=BIG17
5648 BIG18=ABS(COEFF15H/2.*OHI(1,J+1))
5649 IF (BIG18.GT.BIG) BIG=BIG18
5650 BIG19=ABS(COEFF15H/2.*OHI(2,J))
5651 IF (BIG19.GT.BIG) BIG=BIG19
5652 BIG20=ABS(COEFF15H/2.*OHI(1,J))
5653 IF (BIG20.GT.BIG) BIG=BIG20
5654 BIG21=ABS(COEFF15HH/2.*OHI(2,J))
5655 IF (BIG21.GT.BIG) BIG=BIG21
5656 BIG22=ABS(COEFF15HH/2.*OHI(1,J))
5657 IF (BIG22.GT.BIG) BIG=BIG22
5658 BIG23=ABS(COEFF15HH/2.*OHI(2,J-1))
5659 IF (BIG23.GT.BIG) BIG=BIG23
5660 BIG24=ABS(COEFF15HH/2.*OHI(1,J-1))
5661 IF (BIG24.GT.BIG) BIG=BIG24
5662 BIG25=ABS(H/2.*3.*OHI(2,J)/(4.*DT))
5663 IF (BIG25.GT.BIG) BIG=BIG25
5664 BIG26=ABS(H/2.*3.*OHI(1,J)/(4.*DT))
5665 IF (BIG26.GT.BIG) BIG=BIG26
5666 BIG27=ABS(H/2.*OHI(2,J+1)/(4.*DT))
5667 IF (BIG27.GT.BIG) BIG=BIG27
5668 BIG28=ABS(H/2.*OHI(1,J+1)/(4.*DT))
5669 IF (BIG28.GT.BIG) BIG=BIG28
5670 BIG29=ABS(HH/2.*3.*OHI(2,J)/(4.*DT))
5671 IF (BIG29.GT.BIG) BIG=BIG29
5672 BIG30=ABS(HH/2.*3.*OHI(1,J)/(4.*DT))
5673 IF (BIG30.GT.BIG) BIG=BIG30
5674 BIG31=ABS(HH/2.*OHI(2,J-1)/(4.*DT))
5675 IF (BIG31.GT.BIG) BIG=BIG31
5676 BIG32=ABS(HH/2.*OHI(1,J-1)/(4.*DT))
5677 IF (BIG32.GT.BIG) BIG=BIG32
5678 BIG33=ABS(COEFF10H/2.*GLI(2,J+1))
5679 IF (BIG33.GT.BIG) BIG=BIG33
5680 BIG34=ABS(COEFF10H/2.*GLI(1,J+1))

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5681 IF (BIG34.GT.BIG) BIG=BIG34
5682 BIG35=ABS(COEFF10H/2.*GLI(2,J))
5683 IF (BIG35.GT.BIG) BIG=BIG35
5684 BIG36=ABS(COEFF10H/2.*GLI(1,J))
5685 IF (BIG36.GT.BIG) BIG=BIG36
5686 BIG37=ABS(COEFF10HH/2.*GLI(2,J))
5687 IF (BIG37.GT.BIG) BIG=BIG37
5688 BIG38=ABS(COEFF10HH/2.*GLI(1,J))
5689 IF (BIG38.GT.BIG) BIG=BIG38
5690 BIG39=ABS(COEFF10HH/2.*GLI(2,J-1))
5691 IF (BIG39.GT.BIG) BIG=BIG39
5692 BIG40=ABS(COEFF10HH/2.*GLI(1,J-1))
5693 IF (BIG40.GT.BIG) BIG=BIG40
5694 BIG41=ABS(H/2.*3.*GLI(2,J)/(4.*DT))
5695 IF (BIG41.GT.BIG) BIG=BIG41
5696 BIG42=ABS(H/2.*3.*GLI(1,J)/(4.*DT))
5697 IF (BIG42.GT.BIG) BIG=BIG42
5698 BIG43=ABS(H/2.*GLI(2,J+1)/(4.*DT))
5699 IF (BIG43.GT.BIG) BIG=BIG43
5700 BIG44=ABS(H/2.*GLI(1,J+1)/(4.*DT))
5701 IF (BIG44.GT.BIG) BIG=BIG44
5702 BIG45=ABS(HH/2.*3.*GLI(2,J)/(4.*DT))
5703 IF (BIG45.GT.BIG) BIG=BIG45
5704 BIG46=ABS(HH/2.*3.*GLI(1,J)/(4.*DT))
5705 IF (BIG46.GT.BIG) BIG=BIG46
5706 BIG47=ABS(HH/2.*GLI(2,J-1)/(4.*DT))
5707 IF (BIG47.GT.BIG) BIG=BIG47
5708 BIG48=ABS(HH/2.*GLI(1,J-1)/(4.*DT))
5709 IF (BIG48.GT.BIG) BIG=BIG48
5710 BIG49=ABS(COEFF14H/2.*CBI(2,J+1))
5711 IF (BIG49.GT.BIG) BIG=BIG49
5712 BIG50=ABS(COEFF14H/2.*CBI(1,J+1))
5713 IF (BIG50.GT.BIG) BIG=BIG50
5714 BIG51=ABS(COEFF14H/2.*CBI(2,J))
5715 IF (BIG51.GT.BIG) BIG=BIG51
5716 BIG52=ABS(COEFF14H/2.*CBI(1,J))
5717 IF (BIG52.GT.BIG) BIG=BIG52
5718 BIG53=ABS(COEFF14HH/2.*CBI(2,J))
5719 IF (BIG53.GT.BIG) BIG=BIG53
5720 BIG54=ABS(COEFF14HH/2.*CBI(1,J))
5721 IF (BIG54.GT.BIG) BIG=BIG54
5722 BIG55=ABS(COEFF14HH/2.*CBI(2,J-1))
5723 IF (BIG55.GT.BIG) BIG=BIG55
5724 BIG56=ABS(COEFF14HH/2.*CBI(1,J-1))
5725 IF (BIG56.GT.BIG) BIG=BIG56
5726 BIG57=ABS(H/2.*3.*CBI(2,J)/(4.*DT))
5727 IF (BIG57.GT.BIG) BIG=BIG57
5728 BIG58=ABS(H/2.*3.*CBI(1,J)/(4.*DT))
5729 IF (BIG58.GT.BIG) BIG=BIG58
5730 BIG59=ABS(H/2.*CBI(2,J+1)/(4.*DT))
5731 IF (BIG59.GT.BIG) BIG=BIG59
5732 BIG60=ABS(H/2.*CBI(1,J+1)/(4.*DT))
5733 IF (BIG60.GT.BIG) BIG=BIG60
5734 BIG61=ABS(HH/2.*3.*CBI(2,J)/(4.*DT))
5735 IF (BIG61.GT.BIG) BIG=BIG61
5736 BIG62=ABS(HH/2.*3.*CBI(1,J)/(4.*DT))
5737 IF (BIG62.GT.BIG) BIG=BIG62
5738 BIG63=ABS(HH/2.*CBI(2,J-1)/(4.*DT))

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5739 IF (BIG63.GT.BIG) BIG=BIG63
5740 BIG64=ABS(HH/2.*CBI(1,J-1)/(4.*DT))
5741 IF (BIG64.GT.BIG) BIG=BIG64
5742 IF (ABS(G(16)).LT.BIG*EBIG) G(16)=0
5743
5744 c Water Dissociation
5745 G(17)=equilib9-(HYD(2,J)+HYD(1,J))*(OHI(2,J)+OHI(1,J))/4.
5746 B(17,17)=(HYD(2,J)+HYD(1,J))/4.
5747 B(17,16)=(OHI(2,J)+OHI(1,J))/4.
5748
5749 BIG=ABS(equilib9)
5750 BIG2=ABS(HYD(2,J)*OHI(2,J)/4.)
5751 IF (BIG2.GT.BIG) BIG=BIG2
5752 BIG3=ABS(HYD(2,J)*OHI(1,J)/4.)
5753 IF (BIG3.GT.BIG) BIG=BIG3
5754 BIG4=ABS(HYD(1,J)*OHI(2,J)/4.)
5755 IF (BIG4.GT.BIG) BIG=BIG4
5756 BIG5=ABS(HYD(1,J)*OHI(1,J)/4.)
5757 IF (BIG5.GT.BIG) BIG=BIG5
5758 IF (ABS(G(17)).LT.BIG*EBIG) G(17)=0
5759
5760 C CO2 Hydration
5761
5762 G(18)=equilib7*(CO2(2,J)+CO2(1,J))/2.-(CBA(2,J)+CBA(1,J))/2.
5763 B(18,18)=-equilib7/2.
5764 B(18,19)=1./2.
5765
5766 BIG=ABS(equilib7*CO2(2,J)/2.)
5767 BIG2=ABS(equilib7*CO2(1,J)/2.)
5768 IF (BIG2.GT.BIG) BIG=BIG2
5769 BIG3=ABS(CBA(2,J)/2.)
5770 IF (BIG3.GT.BIG) BIG=BIG3
5771 BIG4=ABS(CBA(1,J)/2.)
5772 IF (BIG4.GT.BIG) BIG=BIG4
5773 IF (ABS(G(18)).LT.BIG*EBIG) G(18)=0
5774
5775 C Carbonic acid dissociation
5776
5777 G(19)=equilib8*(CBA(2,J)+CBA(1,J))/2.-(CBI(2,J)+CBI(1,J))
5778 1*(HYD(2,J)+HYD(1,J))/4.
5779 B(19,19)=-equilib8/2.
5780 B(19,20)=(HYD(2,J)+HYD(1,J))/4.
5781 B(19,16)=(CBI(2,J)+CBI(1,J))/4.
5782
5783 BIG=ABS(equilib8*CBA(2,J)/2.)
5784 BIG2=ABS(equilib8*CBA(1,J)/2.)
5785 IF (BIG2.GT.BIG) BIG=BIG2
5786 BIG3=ABS(CBI(2,J)*HYD(2,J)/4.)
5787 IF (BIG3.GT.BIG) BIG=BIG3
5788 BIG4=ABS(CBI(2,J)*HYD(1,J)/4.)
5789 IF (BIG4.GT.BIG) BIG=BIG4
5790 BIG5=ABS(CBI(1,J)*HYD(2,J)/4.)
5791 IF (BIG5.GT.BIG) BIG=BIG5
5792 BIG6=ABS(CBI(1,J)*HYD(1,J)/4.)
5793 IF (BIG6.GT.BIG) BIG=BIG6
5794 IF (ABS(G(19)).LT.BIG*EBIG) G(19)=0
5795
5796 C FLUX OF CO2, CARBONIC ACID, BICARBONATE ION

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5797 G(20)=COEFF12H/2.*(CO2(2,J+1)+CO2(1,J+1)-CO2(2,J)-CO2(1,J))
5798 1 -COEFF12HH/2.*(CO2(2,J)+CO2(1,J)-CO2(2,J-1)-CO2(1,J-1))
5799 2 +COEFF13H/2.*(CBA(2,J+1)+CBA(1,J+1)-CBA(2,J)-CBA(1,J))
5800 3 -COEFF13HH/2.*(CBA(2,J)+CBA(1,J)-CBA(2,J-1)-CBA(1,J-1))
5801 4 +COEFF14H/2.*(CBI(2,J+1)+CBI(1,J+1)-CBI(2,J)-CBI(1,J))
5802 5 -COEFF14HH/2.*(CBI(2,J)+CBI(1,J)-CBI(2,J-1)-CBI(1,J-1))
5803 6 -H/2.*(3.*(CO2(2,J)-CO2(1,J))+(CO2(2,J+1)-CO2(1,J+1)))/(4.*DT)
5804 7 -HH/2.*(3.*(CO2(2,J)-CO2(1,J))+(CO2(2,J-1)-CO2(1,J-1)))/(4.*DT)
5805 8 -H/2.*(3.*(CBA(2,J)-CBA(1,J))+(CBA(2,J+1)-CBA(1,J+1)))/(4.*DT)
5806 9 -HH/2.*(3.*(CBA(2,J)-CBA(1,J))+(CBA(2,J-1)-CBA(1,J-1)))/(4.*DT)
5807 1 -H/2.*(3.*(CBI(2,J)-CBI(1,J))+(CBI(2,J+1)-CBI(1,J+1)))/(4.*DT)
5808 2 -HH/2.*(3.*(CBI(2,J)-CBI(1,J))+(CBI(2,J-1)-CBI(1,J-1)))/(4.*DT)
5809
5810 B(20,20)=COEFF14H/2.+COEFF14HH/2.+H/2.*3./(4.*DT)
5811 1 +HH/2.*3./(4.*DT)
5812 D(20,20)=-COEFF14H/2.+H/2./(4.*DT)
5813 A(20,20)=-COEFF14HH/2.+HH/2./(4.*DT)
5814 B(20,18)=COEFF12H/2.+COEFF12HH/2.+H/2.*3./(4.*DT)
5815 1 +HH/2.*3./(4.*DT)
5816 D(20,18)=-COEFF12H/2.+H/2./(4.*DT)
5817 A(20,18)=-COEFF12HH/2.+HH/2./(4.*DT)
5818 B(20,19)=COEFF13H/2.+COEFF13HH/2.+H/2.*3./(4.*DT)
5819 1 +HH/2.*3./(4.*DT)
5820 D(20,19)=-COEFF13H/2.+H/2./(4.*DT)
5821 A(20,19)=-COEFF13HH/2.+HH/2./(4.*DT)
5822
5823 BIG=ABS(COEFF12H/2.*CO2(2,J+1))
5824 BIG2=ABS(COEFF12H/2.*CO2(1,J+1))
5825 IF (BIG2.GT.BIG) BIG=BIG2
5826 BIG3=ABS(COEFF12H/2.*CO2(2,J))
5827 IF (BIG3.GT.BIG) BIG=BIG3
5828 BIG4=ABS(COEFF12H/2.*CO2(1,J))
5829 IF (BIG4.GT.BIG) BIG=BIG4
5830 BIG5=ABS(COEFF12HH/2.*CO2(2,J))
5831 IF (BIG5.GT.BIG) BIG=BIG5
5832 BIG6=ABS(COEFF12HH/2.*CO2(1,J))
5833 IF (BIG6.GT.BIG) BIG=BIG6
5834 BIG7=ABS(COEFF12HH/2.*CO2(2,J-1))
5835 IF (BIG7.GT.BIG) BIG=BIG7
5836 BIG8=ABS(COEFF12HH/2.*CO2(1,J-1))
5837 IF (BIG8.GT.BIG) BIG=BIG8
5838 BIG9=ABS(H/2.*3.*CO2(2,J)/(4.*DT))
5839 IF (BIG9.GT.BIG) BIG=BIG9
5840 BIG10=ABS(H/2.*3.*CO2(1,J)/(4.*DT))
5841 IF (BIG10.GT.BIG) BIG=BIG10
5842 BIG11=ABS(H/2.*CO2(2,J+1)/(4.*DT))
5843 IF (BIG11.GT.BIG) BIG=BIG11
5844 BIG12=ABS(H/2.*CO2(1,J+1)/(4.*DT))
5845 IF (BIG12.GT.BIG) BIG=BIG12
5846 BIG13=ABS(HH/2.*3.*CO2(2,J)/(4.*DT))
5847 IF (BIG13.GT.BIG) BIG=BIG13
5848 BIG14=ABS(HH/2.*3.*CO2(1,J)/(4.*DT))
5849 IF (BIG14.GT.BIG) BIG=BIG14
5850 BIG15=ABS(HH/2.*CO2(2,J-1)/(4.*DT))
5851 IF (BIG15.GT.BIG) BIG=BIG15
5852 BIG16=ABS(HH/2.*CO2(1,J-1)/(4.*DT))
5853 IF (BIG16.GT.BIG) BIG=BIG16
5854 BIG17=ABS(COEFF13H/2.*CBA(2,J+1))

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5855 IF (BIG17.GT.BIG) BIG=BIG17
5856 BIG18=ABS(COEFF13H/2.*CBA(1,J+1))
5857 IF (BIG18.GT.BIG) BIG=BIG18
5858 BIG19=ABS(COEFF13H/2.*CBA(2,J))
5859 IF (BIG19.GT.BIG) BIG=BIG19
5860 BIG20=ABS(COEFF13H/2.*CBA(1,J))
5861 IF (BIG20.GT.BIG) BIG=BIG20
5862 BIG21=ABS(COEFF13HH/2.*CBA(2,J))
5863 IF (BIG21.GT.BIG) BIG=BIG21
5864 BIG22=ABS(COEFF13HH/2.*CBA(1,J))
5865 IF (BIG22.GT.BIG) BIG=BIG22
5866 BIG23=ABS(COEFF13HH/2.*CBA(2,J-1))
5867 IF (BIG23.GT.BIG) BIG=BIG23
5868 BIG24=ABS(COEFF13HH/2.*CBA(1,J-1))
5869 IF (BIG24.GT.BIG) BIG=BIG24
5870 BIG25=ABS(H/2.*3.*CBA(2,J)/(4.*DT))
5871 IF (BIG25.GT.BIG) BIG=BIG25
5872 BIG26=ABS(H/2.*3.*CBA(1,J)/(4.*DT))
5873 IF (BIG26.GT.BIG) BIG=BIG26
5874 BIG27=ABS(H/2.*CBA(2,J+1)/(4.*DT))
5875 IF (BIG27.GT.BIG) BIG=BIG27
5876 BIG28=ABS(H/2.*CBA(1,J+1)/(4.*DT))
5877 IF (BIG28.GT.BIG) BIG=BIG28
5878 BIG29=ABS(HH/2.*3.*CBA(2,J)/(4.*DT))
5879 IF (BIG29.GT.BIG) BIG=BIG29
5880 BIG30=ABS(HH/2.*3.*CBA(1,J)/(4.*DT))
5881 IF (BIG30.GT.BIG) BIG=BIG30
5882 BIG31=ABS(HH/2.*CBA(2,J-1)/(4.*DT))
5883 IF (BIG31.GT.BIG) BIG=BIG31
5884 BIG32=ABS(HH/2.*CBA(1,J-1)/(4.*DT))
5885 IF (BIG32.GT.BIG) BIG=BIG32
5886 BIG33=ABS(COEFF14H/2.*CBI(2,J+1))
5887 IF (BIG33.GT.BIG) BIG=BIG33
5888 BIG34=ABS(COEFF14H/2.*CBI(1,J+1))
5889 IF (BIG34.GT.BIG) BIG=BIG34
5890 BIG35=ABS(COEFF14H/2.*CBI(2,J))
5891 IF (BIG35.GT.BIG) BIG=BIG35
5892 BIG36=ABS(COEFF14H/2.*CBI(1,J))
5893 IF (BIG36.GT.BIG) BIG=BIG36
5894 BIG37=ABS(COEFF14HH/2.*CBI(2,J))
5895 IF (BIG37.GT.BIG) BIG=BIG37
5896 BIG38=ABS(COEFF14HH/2.*CBI(1,J))
5897 IF (BIG38.GT.BIG) BIG=BIG38
5898 BIG39=ABS(COEFF14HH/2.*CBI(2,J-1))
5899 IF (BIG39.GT.BIG) BIG=BIG39
5900 BIG40=ABS(COEFF14HH/2.*CBI(1,J-1))
5901 IF (BIG40.GT.BIG) BIG=BIG40
5902 BIG41=ABS(H/2.*3.*CBI(2,J)/(4.*DT))
5903 IF (BIG41.GT.BIG) BIG=BIG41
5904 BIG42=ABS(H/2.*3.*CBI(1,J)/(4.*DT))
5905 IF (BIG42.GT.BIG) BIG=BIG42
5906 BIG43=ABS(H/2.*CBI(2,J+1)/(4.*DT))
5907 IF (BIG43.GT.BIG) BIG=BIG43
5908 BIG44=ABS(H/2.*CBI(1,J+1)/(4.*DT))
5909 IF (BIG44.GT.BIG) BIG=BIG44
5910 BIG45=ABS(HH/2.*3.*CBI(2,J)/(4.*DT))
5911 IF (BIG45.GT.BIG) BIG=BIG45
5912 BIG46=ABS(HH/2.*3.*CBI(1,J)/(4.*DT))

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5913 IF (BIG46.GT.BIG) BIG=BIG46
5914 BIG47=ABS(HH/2.*CBI(2,J-1)/(4.*DT))
5915 IF (BIG47.GT.BIG) BIG=BIG47
5916 BIG48=ABS(HH/2.*CBI(1,J-1)/(4.*DT))
5917 IF (BIG48.GT.BIG) BIG=BIG48
5918 IF (ABS(G(20)).LT.BIG*EBIG) G(20)=0
5919
5920
5921 C For H2O2, reacting species
5922 G(21)=COEFF16H/2.*(ACE(2,J+1)+ACE(1,J+1)-ACE(2,J)-ACE(1,J))
5923 1 -COEFF16HH/2.*(ACE(2,J)+ACE(1,J)-ACE(2,J-1)-ACE(1,J-1))
5924 4 -H/2.*(3.*(ACE(2,J)-ACE(1,J))+ACE(2,J+1)-ACE(1,J+1))/(4.*DT)
5925 5 -HH/2.*(3.*(ACE(2,J)-ACE(1,J))+ACE(2,J-1)-ACE(1,J-1))/(4.*DT)
5926
5927 B(21,21)=COEFF16H/2.+COEFF16HH/2.
5928 1 +H/2.*3./(4.*DT)+HH/2.*3./(4.*DT)
5929 D(21,21)=-COEFF16H/2.+H/2./(4.*DT)
5930 A(21,21)=-COEFF16HH/2.+HH/2./(4.*DT)
5931
5932
5933 BIG=ABS(COEFF16H/2.*ACE(2,J+1))
5934 BIG2=ABS(COEFF16H/2.*ACE(1,J+1))
5935 IF (BIG2.GT.BIG) BIG=BIG2
5936 BIG3=ABS(COEFF16H/2.*ACE(2,J))
5937 IF (BIG3.GT.BIG) BIG=BIG3
5938 BIG4=ABS(COEFF16H/2.*ACE(1,J))
5939 IF (BIG4.GT.BIG) BIG=BIG4
5940 BIG5=ABS(COEFF16HH/2.*ACE(2,J))
5941 IF (BIG5.GT.BIG) BIG=BIG5
5942 BIG6=ABS(COEFF16HH/2.*ACE(1,J))
5943 IF (BIG6.GT.BIG) BIG=BIG6
5944 BIG7=ABS(COEFF16HH/2.*ACE(2,J-1))
5945 IF (BIG7.GT.BIG) BIG=BIG7
5946 BIG8=ABS(COEFF16HH/2.*ACE(1,J-1))
5947 IF (BIG8.GT.BIG) BIG=BIG8
5948 BIG17=ABS(H/2.*3.*ACE(2,J)/(4.*DT))
5949 IF (BIG17.GT.BIG) BIG=BIG17
5950 BIG18=ABS(H/2.*3.*ACE(1,J)/(4.*DT))
5951 IF (BIG18.GT.BIG) BIG=BIG18
5952 BIG19=ABS(H/2.*ACE(2,J+1)/(4.*DT))
5953 IF (BIG19.GT.BIG) BIG=BIG19
5954 BIG20=ABS(H/2.*ACE(1,J+1)/(4.*DT))
5955 IF (BIG20.GT.BIG) BIG=BIG20
5956 BIG21=ABS(HH/2.*3.*ACE(2,J)/(4.*DT))
5957 IF (BIG21.GT.BIG) BIG=BIG21
5958 BIG22=ABS(HH/2.*3.*ACE(1,J)/(4.*DT))
5959 IF (BIG22.GT.BIG) BIG=BIG22
5960 BIG23=ABS(HH/2.*ACE(2,J-1)/(4.*DT))
5961 IF (BIG23.GT.BIG) BIG=BIG23
5962 BIG24=ABS(HH/2.*ACE(1,J-1)/(4.*DT))
5963 IF (BIG24.GT.BIG) BIG=BIG24
5964 IF (ABS(G(21)).LT.BIG*EBIG) G(21)=0
5965
5966 C DOUBLE LAYER voLTAGE - DUMMY
5967 G(22)=(VDL(2,J)+VDL(1,J))/2.
5968
5969 B(22,22)=-1./2.
5970

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5971     BIG=ABS(VDL(2,J)/2.)
5972     BIG2=ABS(VDL(1,J)/2.)
5973     IF (BIG2.GT.BIG) BIG=BIG2
5974     IF (ABS(G(22)).LT.BIG*EBIG) G(22)=0
5975
5976 C   212 WRITE(12,301) J, (G(K),K=1,N)
5977     RETURN
5978     END
5979
5980     SUBROUTINE OUTER(J)
5981     IMPLICIT DOUBLE PRECISION (A-H, O-Z)
5982     COMMON/BAB/ A(22,22),B(22,22),C(22,80001),D(22,45),G(22),X(22,22)
5983     1   ,Y(22,22)
5984     COMMON/NSN/ N, NJ
5985     COMMON/GLC/ NTIME,LL
5986     COMMON/VAR/ DIFF(16),H,EBIG,HH,IJ,KJ,TT,VAP,HHH,DT,RE,AKB,BB,CDL
5987     COMMON/VARR/ HHHH,HHHHH,MJ,LJ
5988     COMMON/DIN/ DGOX(16),DGLM(16),DIRM(16),DBULK(16)
5989     COMMON/SPCI/ GLU(2,80001),GOX(2,80001),GLA(2,80001),GOR(2,80001)
5990     COMMON/SPCII/ OXY(2,80001),HPR(2,80001),GOA(2,80001),GOP(2,80001)
5991     COMMON/RXT/ EQ1(2,80001),RGA(2,80001),EQ2(2,80001),RHP(2,80001)
5992     COMMON/SPCIII/ ANM(2,80001),GLUA(2,80001),GLI(2,80001)
5993     COMMON/SPCIV/ HYD(2,80001),OHI(2,80001),CO2(2,80001),CBA(2,80001)
5994     COMMON/SPCV/ CBI(2,80001),ACE(2,80001)
5995     COMMON/VOL/ VDL(2,80001)
5996     COMMON/POR/ POR1,POR2,PORGLU,PARION,PARACE
5997     COMMON/RTE/ ratef1,equilib1,ratef2,ratef3,equilib3,ratef4
5998     COMMON/RTD/ ratef5,equilib5,equilib6,equilib7,equilib8,equilib9
5999     COMMON/BUL/ CBULK(16),PARH2O2,PARO2,PARGLUCESE,JCOUNT
6000
6001     301 FORMAT (5x,'J=' I5, 12E18.9)
6002
6003 C   For Glucose, being consumed only
6004     G(1)=DGLM(1)*(GLU(2,J+1)-2.*GLU(2,J)+GLU(2,J-1)
6005     1   +GLU(1,J+1)-2.*GLU(1,J)+GLU(1,J-1))/(2.*H**2.)
6006     2   +(ANM(2,J)+ANM(1,J))/2.-(GLU(2,J)-GLU(1,J))/DT
6007
6008     B(1,1)=DGLM(1)/H**2.+1./DT
6009     D(1,1)=-DGLM(1)/(2.*H**2.)
6010     A(1,1)=-DGLM(1)/(2.*H**2.)
6011     B(1,13)=-1./2.
6012
6013
6014     BIG=ABS(DGLM(1)*(GLU(2,J+1))/(2.*H**2.))
6015     BIG2=ABS(DGLM(1)*(GLU(2,J))/(H**2.))
6016     IF (BIG2.GT.BIG) BIG=BIG2
6017     BIG3=ABS(DGLM(1)*(GLU(2,J-1))/(2.*H**2.))
6018     IF (BIG3.GT.BIG) BIG=BIG3
6019     BIG4=ABS(DGLM(1)*(GLU(1,J+1))/(2.*H**2.))
6020     IF (BIG4.GT.BIG) BIG=BIG4
6021     BIG5=ABS(DGLM(1)*(GLU(1,J))/(H**2.))
6022     IF (BIG5.GT.BIG) BIG=BIG5
6023     BIG6=ABS(DGLM(1)*(GLU(1,J-1))/(2.*H**2.))
6024     IF (BIG6.GT.BIG) BIG=BIG6
6025     BIG7=ABS(GLU(2,J)/DT)
6026     IF (BIG7.GT.BIG) BIG=BIG7
6027     BIG8=ABS(GLU(1,J)/DT)
6028     IF (BIG8.GT.BIG) BIG=BIG8

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6029 BIG9=ABS(ANM(2 , J) / 2 .)
6030 IF (BIG9.GT.BIG) BIG=BIG9
6031 BIG10=ABS(ANM(1 , J) / 2 .)
6032 IF (BIG10.GT.BIG) BIG=BIG10
6033 IF (ABS(G(1)) .LT. BIG*EBIG) G(1)=0
6034
6035
6036
6037 C For GOx, enzyme
6038 G(2)=(GOX(2 , J)+GOX(1 , J)) / 2 .
6039 B(2 , 2) = - 1 . / 2 .
6040
6041 C For Gluconic Acid, being produced only
6042 G(3)=DGLM(3) *(GLA(2 , J+1) - 2.*GLA(2 , J)+GLA(2 , J-1)
6043 1 +GLA(1 , J+1) - 2.*GLA(1 , J)+GLA(1 , J-1)) / (2 . *H**2 .)
6044 2 +DGLM(10) *(GLI(2 , J+1) - 2.*GLI(2 , J)+GLI(2 , J-1)
6045 3 +GLI(1 , J+1) - 2.*GLI(1 , J)+GLI(1 , J-1)) / (2 . *H**2 .)
6046 2 -(GLA(2 , J)-GLA(1 , J)) / DT-(GLI(2 , J)-GLI(1 , J)) / DT
6047
6048 B(3 , 3)=DGLM(3) / H**2 . + 1 . / DT
6049 D(3 , 3)=-DGLM(3) / (2 . *H**2 .)
6050 A(3 , 3)=-DGLM(3) / (2 . *H**2 .)
6051 B(3 , 15)=DGLM(10) / H**2 . + 1 . / DT
6052 D(3 , 15)=-DGLM(10) / (2 . *H**2 .)
6053 A(3 , 15)=-DGLM(10) / (2 . *H**2 .)
6054
6055
6056 BIG=ABS(DGLM(3) *(GLA(2 , J+1)) / (2 . *H**2 .))
6057 BIG2=ABS(DGLM(3) *(GLA(2 , J)) / (H**2 .))
6058 IF (BIG2.GT.BIG) BIG=BIG2
6059 BIG3=ABS(DGLM(3) *(GLA(2 , J-1)) / (2 . *H**2 .))
6060 IF (BIG3.GT.BIG) BIG=BIG3
6061 BIG4=ABS(DGLM(3) *(GLA(1 , J+1)) / (2 . *H**2 .))
6062 IF (BIG4.GT.BIG) BIG=BIG4
6063 BIG5=ABS(DGLM(3) *(GLA(1 , J)) / (H**2 .))
6064 IF (BIG5.GT.BIG) BIG=BIG5
6065 BIG6=ABS(DGLM(3) *(GLA(1 , J-1)) / (2 . *H**2 .))
6066 IF (BIG6.GT.BIG) BIG=BIG6
6067 BIG7=ABS(GLA(2 , J) / DT)
6068 IF (BIG7.GT.BIG) BIG=BIG7
6069 BIG8=ABS(GLA(1 , J) / DT)
6070 IF (BIG8.GT.BIG) BIG=BIG8
6071 BIG9=ABS(DGLM(10) *(GLI(2 , J+1)) / (2 . *H**2 .))
6072 IF (BIG9.GT.BIG) BIG=BIG9
6073 BIG10=ABS(DGLM(10) *(GLI(2 , J)) / (H**2 .))
6074 IF (BIG10.GT.BIG) BIG=BIG10
6075 BIG11=ABS(DGLM(10) *(GLI(2 , J-1)) / (2 . *H**2 .))
6076 IF (BIG11.GT.BIG) BIG=BIG11
6077 BIG12=ABS(DGLM(10) *(GLI(1 , J+1)) / (2 . *H**2 .))
6078 IF (BIG12.GT.BIG) BIG=BIG12
6079 BIG13=ABS(DGLM(10) *(GLI(1 , J)) / (H**2 .))
6080 IF (BIG13.GT.BIG) BIG=BIG13
6081 BIG14=ABS(DGLM(10) *(GLI(1 , J-1)) / (2 . *H**2 .))
6082 IF (BIG14.GT.BIG) BIG=BIG14
6083 BIG15=ABS(GLI(2 , J) / DT)
6084 IF (BIG15.GT.BIG) BIG=BIG15
6085 BIG16=ABS(GLI(1 , J) / DT)
6086 IF (BIG16.GT.BIG) BIG=BIG16

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6087     IF (ABS(G(3)) .LT. BIG*EBIG) G(3)=0
6088
6089 C     For GOx2, enzyme
6090     G(4)=(GOR(2,J)+GOR(1,J))/2.
6091     B(4,4)=-1./2.
6092
6093 C     For O2, being consumed only
6094     G(5)=DGLM(5)*(OXY(2,J+1)-2.*OXY(2,J)+OXY(2,J-1)
6095 1      +OXY(1,J+1)-2.*OXY(1,J)+OXY(1,J-1))/(2.*H**2.)
6096 2      -(OXY(2,J)-OXY(1,J))/DT
6097
6098     B(5,5)=DGLM(5)/H**2.+1./DT
6099     D(5,5)=-DGLM(5)/(2.*H**2.)
6100     A(5,5)=-DGLM(5)/(2.*H**2.)
6101
6102
6103     BIG=ABS(DGLM(5)*(OXY(2,J+1))/(2.*H**2.))
6104     BIG2=ABS(DGLM(5)*(OXY(2,J))/(H**2.))
6105     IF (BIG2.GT.BIG) BIG=BIG2
6106     BIG3=ABS(DGLM(5)*(OXY(2,J-1))/(2.*H**2.))
6107     IF (BIG3.GT.BIG) BIG=BIG3
6108     BIG4=ABS(DGLM(5)*(OXY(1,J+1))/(2.*H**2.))
6109     IF (BIG4.GT.BIG) BIG=BIG4
6110     BIG5=ABS(DGLM(5)*(OXY(1,J))/(H**2.))
6111     IF (BIG5.GT.BIG) BIG=BIG5
6112     BIG6=ABS(DGLM(5)*(OXY(1,J-1))/(2.*H**2.))
6113     IF (BIG6.GT.BIG) BIG=BIG6
6114     BIG7=ABS(OXY(2,J)/DT)
6115     IF (BIG7.GT.BIG) BIG=BIG7
6116     BIG8=ABS(OXY(1,J)/DT)
6117     IF (BIG8.GT.BIG) BIG=BIG8
6118     IF (ABS(G(5)) .LT. BIG*EBIG) G(5)=0
6119
6120 C     For H2O2, reacting species
6121     G(6)=DGLM(6)*(HPR(2,J+1)-2.*HPR(2,J)+HPR(2,J-1)
6122 1      +HPR(1,J+1)-2.*HPR(1,J)+HPR(1,J-1))/(2.*H**2.)
6123 2      -(HPR(2,J)-HPR(1,J))/DT
6124
6125     B(6,6)=DGLM(6)/H**2.+1./DT
6126     D(6,6)=-DGLM(6)/(2.*H**2.)
6127     A(6,6)=-DGLM(6)/(2.*H**2.)
6128
6129
6130     BIG=ABS(DGLM(6)*(HPR(2,J+1))/(2.*H**2.))
6131     BIG2=ABS(DGLM(6)*(HPR(2,J))/(H**2.))
6132     IF (BIG2.GT.BIG) BIG=BIG2
6133     BIG3=ABS(DGLM(6)*(HPR(2,J-1))/(2.*H**2.))
6134     IF (BIG3.GT.BIG) BIG=BIG3
6135     BIG4=ABS(DGLM(6)*(HPR(1,J+1))/(2.*H**2.))
6136     IF (BIG4.GT.BIG) BIG=BIG4
6137     BIG5=ABS(DGLM(6)*(HPR(1,J))/(H**2.))
6138     IF (BIG5.GT.BIG) BIG=BIG5
6139     BIG6=ABS(DGLM(6)*(HPR(1,J-1))/(2.*H**2.))
6140     IF (BIG6.GT.BIG) BIG=BIG6
6141     BIG7=ABS(HPR(2,J)/DT)
6142     IF (BIG7.GT.BIG) BIG=BIG7
6143     BIG8=ABS(HPR(1,J)/DT)
6144     IF (BIG8.GT.BIG) BIG=BIG8

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6145     IF (ABS(G(6)).LT.BIG*EBIG) G(6)=0
6146
6147 C     For CX-GOx2, enzyme complex
6148     G(7)=(GOA(2,J)+GOA(1,J))/2.
6149     B(7,7)=-1./2.
6150
6151 C     For CX-GOx, enzyme complex
6152     G(8)=(GOP(2,J)+GOP(1,J))/2.
6153     B(8,8)=-1./2.
6154
6155 C     For Reaction 1 Enzymatic Catalysis
6156     G(9)=(EQ1(2,J)+EQ1(1,J))/2.
6157     B(9,9)=-1./2.
6158
6159 C     For Reaction 2
6160     G(10)=(RGA(2,J)+RGA(1,J))/2.
6161     B(10,10)=-1./2.
6162
6163 C     For Reaction 3 Meditation/regeneration
6164     G(11)=(EQ2(2,J)+EQ2(1,J))/2.
6165     B(11,11)=-1./2.
6166
6167 C     For Reaction 4
6168     G(12)=(RHP(2,J)+RHP(1,J))/2.
6169     B(12,12)=-1./2.
6170
6171 C     REACTIONS
6172 218 G(13)=-((ANM(2,J)+ANM(1,J))/2.+ratef5*((GLUA(2,J)+GLUA(1,J))/2.
6173 1   -(GLU(2,J)+GLU(1,J))/2./equilib5)
6174     B(13,1)=ratef5/2./equilib5
6175     B(13,14)=-ratef5/2.
6176     B(13,13)=+1./2.
6177
6178     BIG=ABS(ANM(2,J)/2.)
6179     BIG2=ABS(ANM(1,J)/2.)
6180     IF (BIG2.GT.BIG) BIG=BIG2
6181     BIG3=ABS(ratef5*GLUA(2,J)/2.)
6182     IF (BIG3.GT.BIG) BIG=BIG3
6183     BIG4=ABS(ratef5*GLUA(1,J)/2.)
6184     IF (BIG4.GT.BIG) BIG=BIG4
6185     BIG5=ABS(ratef5*GLU(2,J)/2./equilib5)
6186     IF (BIG5.GT.BIG) BIG=BIG5
6187     BIG6=ABS(ratef5*GLU(1,J)/2./equilib5)
6188     IF (BIG6.GT.BIG) BIG=BIG6
6189     IF (ABS(G(13)).LT.BIG*EBIG) G(13)=0.0
6190
6191 C     For alpha Glucose, being consumed only
6192     G(14)=DGLM(9)*(GLUA(2,J+1)-2.*GLUA(2,J)+GLUA(2,J-1)
6193 1   +GLUA(1,J+1)-2.*GLUA(1,J)+GLUA(1,J-1))/(2.*H**2.)
6194 2   -(ANM(2,J)+ANM(1,J))/2.-(GLUA(2,J)-GLUA(1,J))/DT
6195     B(14,14)=DGLM(9)/H**2.+1./DT
6196     D(14,14)=-DGLM(9)/(2.*H**2.)
6197     A(14,14)=-DGLM(9)/(2.*H**2.)
6198     B(14,13)=1./2.
6199
6200     BIG=ABS(DGLM(9)*(GLUA(2,J+1))/(2.*H**2.))
6201     BIG2=ABS(DGLM(9)*(GLUA(2,J))/(H**2.))
6202     IF (BIG2.GT.BIG) BIG=BIG2

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6203 BIG3=ABS(DGLM(9)*(GLUA(2,J-1))/(2.*H**2.))
6204 IF (BIG3.GT.BIG) BIG=BIG3
6205 BIG4=ABS(DGLM(9)*(GLUA(1,J+1))/(2.*H**2.))
6206 IF (BIG4.GT.BIG) BIG=BIG4
6207 BIG5=ABS(DGLM(9)*(GLUA(1,J))/(H**2.))
6208 IF (BIG5.GT.BIG) BIG=BIG5
6209 BIG6=ABS(DGLM(9)*(GLUA(1,J-1))/(2.*H**2.))
6210 IF (BIG6.GT.BIG) BIG=BIG6
6211 BIG7=ABS(ANM(2,J)/2.)
6212 IF (BIG7.GT.BIG) BIG=BIG7
6213 BIG8=ABS(ANM(1,J)/2.)
6214 IF (BIG8.GT.BIG) BIG=BIG8
6215 BIG9=ABS(GLUA(2,J)/DT)
6216 IF (BIG9.GT.BIG) BIG=BIG9
6217 BIG10=ABS(GLUA(1,J)/DT)
6218 IF (BIG10.GT.BIG) BIG=BIG10
6219 IF (ABS(G(14)).LT.BIG*EBIG) G(14)=0.0
6220
6221 C Gluconic acid dissociation
6222
6223 G(15)=equilib6*(GLA(2,J)+GLA(1,J))/2.-(GLI(2,J)+GLI(1,J))*
6224 1 (HYD(2,J)+HYD(1,J))/4.
6225 B(15,3)=-equilib6/2.
6226 B(15,15)=(HYD(2,J)+HYD(1,J))/4.
6227 B(15,16)=(GLI(2,J)+GLI(1,J))/4.
6228
6229 BIG=ABS(equilib6*GLA(2,J)/2.)
6230 BIG2=ABS(equilib6*GLA(1,J)/2.)
6231 IF (BIG2.GT.BIG) BIG=BIG2
6232 BIG3=ABS(GLI(2,J)*HYD(2,J)/4.)
6233 IF (BIG3.GT.BIG) BIG=BIG3
6234 BIG4=ABS(GLI(2,J)*HYD(1,J)/4)
6235 IF (BIG4.GT.BIG) BIG=BIG4
6236 BIG5=ABS(GLI(1,J)*HYD(2,J)/4)
6237 IF (BIG5.GT.BIG) BIG=BIG5
6238 BIG6=ABS(GLI(1,J)*HYD(1,J)/4)
6239 IF (BIG6.GT.BIG) BIG=BIG6
6240 IF (ABS(G(15)).LT.BIG*EBIG) G(15)=0
6241
6242 C Hydrogen ion, hydroxide ion, gluconate ion, bicarbonate ion flux
6243 G(16)=DGLM(11)*(HYD(2,J+1)-2.*HYD(2,J)+HYD(2,J-1)
6244 1 +HYD(1,J+1)-2.*HYD(1,J)+HYD(1,J-1))/(2.*H**2.)
6245 2 -DGLM(15)*(OHI(2,J+1)-2.*OHI(2,J)+OHI(2,J-1)
6246 3 +OHI(1,J+1)-2.*OHI(1,J)+OHI(1,J-1))/(2.*H**2.)
6247 4 -DGLM(10)*(GLI(2,J+1)-2.*GLI(2,J)+GLI(2,J-1)
6248 5 +GLI(1,J+1)-2.*GLI(1,J)+GLI(1,J-1))/(2.*H**2.)
6249 6 -DGLM(14)*(CBI(2,J+1)-2.*CBI(2,J)+CBI(2,J-1)
6250 7 +CBI(1,J+1)-2.*CBI(1,J)+CBI(1,J-1))/(2.*H**2.)
6251 8 -(HYD(2,J)-HYD(1,J))/DT+(OHI(2,J)-OHI(1,J))/DT
6252 9 +(GLI(2,J)-GLI(1,J))/DT+(CBI(2,J)-CBI(1,J))/DT
6253
6254 B(16,16)=DGLM(11)/H**2.+1./DT
6255 D(16,16)=-DGLM(11)/(2.*H**2.)
6256 A(16,16)=-DGLM(11)/(2.*H**2.)
6257 B(16,17)=-DGLM(15)/H**2.-1./DT
6258 D(16,17)=DGLM(15)/(2.*H**2.)
6259 A(16,17)=DGLM(15)/(2.*H**2.)
6260 B(16,15)=-DGLM(10)/H**2.-1./DT

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6261 D(16,15)=DGLM(10)/(2.*H**2.)
6262 A(16,15)=DGLM(10)/(2.*H**2.)
6263 B(16,20)=-DGLM(14)/H**2.-1./DT
6264 D(16,20)=DGLM(14)/(2.*H**2.)
6265 A(16,20)=DGLM(14)/(2.*H**2.)
6266
6267 BIG=ABS(DGLM(11)*(HYD(2,J+1))/(2.*H**2.))
6268 BIG2=ABS(DGLM(11)*(HYD(2,J))/(H**2.))
6269 IF (BIG2.GT.BIG) BIG=BIG2
6270 BIG3=ABS(DGLM(11)*(HYD(2,J-1))/(2.*H**2.))
6271 IF (BIG3.GT.BIG) BIG=BIG3
6272 BIG4=ABS(DGLM(11)*(HYD(1,J+1))/(2.*H**2.))
6273 IF (BIG4.GT.BIG) BIG=BIG4
6274 BIG5=ABS(DGLM(11)*(HYD(1,J))/(H**2.))
6275 IF (BIG5.GT.BIG) BIG=BIG5
6276 BIG6=ABS(DGLM(11)*(HYD(1,J-1))/(2.*H**2.))
6277 IF (BIG6.GT.BIG) BIG=BIG6
6278 BIG7=ABS(DGLM(15)*OHI(2,J+1)/(2.*H**2.))
6279 IF (BIG7.GT.BIG) BIG=BIG7
6280 BIG8=ABS(DGLM(15)*OHI(2,J)/(H**2.))
6281 IF (BIG8.GT.BIG) BIG=BIG8
6282 BIG9=ABS(DGLM(15)*OHI(2,J-1)/(2.*H**2.))
6283 IF (BIG9.GT.BIG) BIG=BIG9
6284 BIG10=ABS(DGLM(15)*OHI(1,J+1)/(2.*H**2.))
6285 IF (BIG10.GT.BIG) BIG=BIG10
6286 BIG11=ABS(DGLM(15)*OHI(1,J)/(H**2.))
6287 IF (BIG11.GT.BIG) BIG=BIG11
6288 BIG12=ABS(DGLM(15)*OHI(1,J-1)/(2.*H**2.))
6289 IF (BIG12.GT.BIG) BIG=BIG12
6290 BIG13=ABS(DGLM(10)*GLI(2,J+1)/(2.*H**2.))
6291 IF (BIG13.GT.BIG) BIG=BIG13
6292 BIG14=ABS(DGLM(10)*GLI(2,J)/(H**2.))
6293 IF (BIG14.GT.BIG) BIG=BIG14
6294 BIG15=ABS(DGLM(10)*GLI(2,J-1)/(2.*H**2.))
6295 IF (BIG15.GT.BIG) BIG=BIG15
6296 BIG16=ABS(DGLM(10)*GLI(1,J+1)/(2.*H**2.))
6297 IF (BIG16.GT.BIG) BIG=BIG16
6298 BIG17=ABS(DGLM(10)*GLI(1,J)/(H**2.))
6299 IF (BIG17.GT.BIG) BIG=BIG17
6300 BIG18=ABS(DGLM(10)*GLI(1,J-1)/(2.*H**2.))
6301 IF (BIG18.GT.BIG) BIG=BIG18
6302 BIG19=ABS(DGLM(14)*CBI(2,J+1)/(2.*H**2.))
6303 IF (BIG19.GT.BIG) BIG=BIG19
6304 BIG20=ABS(DGLM(14)*CBI(2,J)/(H**2.))
6305 IF (BIG20.GT.BIG) BIG=BIG20
6306 BIG21=ABS(DGLM(14)*CBI(2,J-1)/(2.*H**2.))
6307 IF (BIG21.GT.BIG) BIG=BIG21
6308 BIG22=ABS(DGLM(14)*CBI(1,J+1)/(2.*H**2.))
6309 IF (BIG22.GT.BIG) BIG=BIG22
6310 BIG23=ABS(DGLM(14)*CBI(1,J)/(H**2.))
6311 IF (BIG23.GT.BIG) BIG=BIG23
6312 BIG24=ABS(DGLM(14)*CBI(1,J-1)/(2.*H**2.))
6313 IF (BIG24.GT.BIG) BIG=BIG24
6314 BIG25=ABS(HYD(2,J)/DT)
6315 IF (BIG25.GT.BIG) BIG=BIG25
6316 BIG26=ABS(HYD(1,J)/DT)
6317 IF (BIG26.GT.BIG) BIG=BIG26
6318 BIG27=ABS(OHI(2,J)/DT)

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6319 IF (BIG27.GT.BIG) BIG=BIG27
6320 BIG28=ABS(OHI(1,J)/DT)
6321 IF (BIG28.GT.BIG) BIG=BIG28
6322 BIG29=ABS(GLI(2,J)/DT)
6323 IF (BIG29.GT.BIG) BIG=BIG29
6324 BIG30=ABS(GLI(1,J)/DT)
6325 IF (BIG30.GT.BIG) BIG=BIG30
6326 BIG31=ABS(CBI(2,J)/DT)
6327 IF (BIG31.GT.BIG) BIG=BIG31
6328 BIG32=ABS(CBI(1,J)/DT)
6329 IF (BIG32.GT.BIG) BIG=BIG32
6330 IF (ABS(G(16)).LT.BIG*EBIG) G(16)=0
6331
6332 c Water Dissociation
6333 G(17)=equilib9 -(HYD(2,J)+HYD(1,J))*(OHI(2,J)+OHI(1,J))/4.
6334 B(17,17)=(HYD(2,J)+HYD(1,J))/4.
6335 B(17,16)=(OHI(2,J)+OHI(1,J))/4.
6336
6337 BIG=ABS(equilib9)
6338 BIG2=ABS(HYD(2,J)*OHI(2,J)/4.)
6339 IF (BIG2.GT.BIG) BIG=BIG2
6340 BIG3=ABS(HYD(2,J)*OHI(1,J)/4.)
6341 IF (BIG3.GT.BIG) BIG=BIG3
6342 BIG4=ABS(HYD(1,J)*OHI(2,J)/4.)
6343 IF (BIG4.GT.BIG) BIG=BIG4
6344 BIG5=ABS(HYD(1,J)*OHI(1,J)/4.)
6345 IF (BIG5.GT.BIG) BIG=BIG5
6346 IF (ABS(G(17)).LT.BIG*EBIG) G(17)=0
6347
6348 C CO2 Hydration
6349
6350 G(18)=equilib7 *(CO2(2,J)+CO2(1,J))/2. -(CBA(2,J)+CBA(1,J))/2.
6351 B(18,18)=-equilib7/2.
6352 B(18,19)=1./2.
6353
6354 BIG=ABS(equilib7*CO2(2,J)/2.)
6355 BIG2=ABS(equilib7*CO2(1,J)/2.)
6356 IF (BIG2.GT.BIG) BIG=BIG2
6357 BIG3=ABS(CBA(2,J)/2.)
6358 IF (BIG3.GT.BIG) BIG=BIG3
6359 BIG4=ABS(CBA(1,J)/2.)
6360 IF (BIG4.GT.BIG) BIG=BIG4
6361 IF (ABS(G(18)).LT.BIG*EBIG) G(18)=0
6362
6363 C Carbonic acid dissociation
6364
6365 G(19)=equilib8 *(CBA(2,J)+CBA(1,J))/2. -(CBI(2,J)+CBI(1,J))
6366 1 *(HYD(2,J)+HYD(1,J))/4.
6367 B(19,19)=-equilib8/2.
6368 B(19,20)=(HYD(2,J)+HYD(1,J))/4.
6369 B(19,16)=(CBI(2,J)+CBI(1,J))/4.
6370
6371 BIG=ABS(equilib8*CBA(2,J)/2.)
6372 BIG2=ABS(equilib8*CBA(1,J)/2.)
6373 IF (BIG2.GT.BIG) BIG=BIG2
6374 BIG3=ABS(CBI(2,J)*HYD(2,J)/4.)
6375 IF (BIG3.GT.BIG) BIG=BIG3
6376 BIG4=ABS(CBI(2,J)*HYD(1,J)/4.)

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6377 IF (BIG4.GT.BIG) BIG=BIG4
6378 BIG5=ABS(CBI(1,J)*HYD(2,J)/4.)
6379 IF (BIG5.GT.BIG) BIG=BIG5
6380 BIG6=ABS(CBI(1,J)*HYD(1,J)/4.)
6381 IF (BIG6.GT.BIG) BIG=BIG6
6382 IF (ABS(G(19)).LT.BIG*EBIG) G(19)=0
6383
6384 C FLUX OF CO2, CARBONIC ACID, BICARBONATE ION
6385 G(20)=DGLM(12)*(CO2(2,J+1)-2.*CO2(2,J)+CO2(2,J-1)
6386 1 +CO2(1,J+1)-2.*CO2(1,J)+CO2(1,J-1))/(2.*H**2.)
6387 2 +DGLM(13)*(CBA(2,J+1)-2.*CBA(2,J)+CBA(2,J-1)
6388 3 +CBA(1,J+1)-2.*CBA(1,J)+CBA(1,J-1))/(2.*H**2.)
6389 4 +DGLM(14)*(CBI(2,J+1)-2.*CBI(2,J)+CBI(2,J-1)
6390 5 +CBI(1,J+1)-2.*CBI(1,J)+CBI(1,J-1))/(2.*H**2.)
6391 8 -(CO2(2,J)-CO2(1,J))/DT-(CBA(2,J)-CBA(1,J))/DT
6392 9 -(CBI(2,J)-CBI(1,J))/DT
6393
6394 B(20,20)=DGLM(14)/H**2.+1./DT
6395 D(20,20)=-DGLM(14)/(2.*H**2.)
6396 A(20,20)=-DGLM(14)/(2.*H**2.)
6397 B(20,18)=DGLM(12)/H**2.+1./DT
6398 D(20,18)=-DGLM(12)/(2.*H**2.)
6399 A(20,18)=-DGLM(12)/(2.*H**2.)
6400 B(20,19)=DGLM(13)/H**2.+1./DT
6401 D(20,19)=-DGLM(13)/(2.*H**2.)
6402 A(20,19)=-DGLM(13)/(2.*H**2.)
6403
6404
6405 BIG=ABS(DGLM(12)*(CO2(2,J+1))/(2.*H**2.))
6406 BIG2=ABS(DGLM(12)*(CO2(2,J))/(H**2.))
6407 IF (BIG2.GT.BIG) BIG=BIG2
6408 BIG3=ABS(DGLM(12)*(CO2(2,J-1))/(2.*H**2.))
6409 IF (BIG3.GT.BIG) BIG=BIG3
6410 BIG4=ABS(DGLM(12)*(CO2(1,J+1))/(2.*H**2.))
6411 IF (BIG4.GT.BIG) BIG=BIG4
6412 BIG5=ABS(DGLM(12)*(CO2(1,J))/(H**2.))
6413 IF (BIG5.GT.BIG) BIG=BIG5
6414 BIG6=ABS(DGLM(12)*(CO2(1,J-1))/(2.*H**2.))
6415 IF (BIG6.GT.BIG) BIG=BIG6
6416 BIG7=ABS(DGLM(13)*CBA(2,J+1)/(2.*H**2.))
6417 IF (BIG7.GT.BIG) BIG=BIG7
6418 BIG8=ABS(DGLM(13)*CBA(2,J)/(H**2.))
6419 IF (BIG8.GT.BIG) BIG=BIG8
6420 BIG9=ABS(DGLM(13)*CBA(2,J-1)/(2.*H**2.))
6421 IF (BIG9.GT.BIG) BIG=BIG9
6422 BIG10=ABS(DGLM(13)*CBA(1,J+1)/(2.*H**2.))
6423 IF (BIG10.GT.BIG) BIG=BIG10
6424 BIG11=ABS(DGLM(13)*CBA(1,J)/(H**2.))
6425 IF (BIG11.GT.BIG) BIG=BIG11
6426 BIG12=ABS(DGLM(13)*CBA(1,J-1)/(2.*H**2.))
6427 IF (BIG12.GT.BIG) BIG=BIG12
6428 BIG13=ABS(DGLM(14)*CBI(2,J+1)/(2.*H**2.))
6429 IF (BIG13.GT.BIG) BIG=BIG13
6430 BIG14=ABS(DGLM(14)*CBI(2,J)/(H**2.))
6431 IF (BIG14.GT.BIG) BIG=BIG14
6432 BIG15=ABS(DGLM(14)*CBI(2,J-1)/(2.*H**2.))
6433 IF (BIG15.GT.BIG) BIG=BIG15
6434 BIG16=ABS(DGLM(14)*CBI(1,J+1)/(2.*H**2.))

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6435 IF (BIG16.GT.BIG) BIG=BIG16
6436 BIG17=ABS(DGLM(14)*CBI(1,J)/(H**2.))
6437 IF (BIG17.GT.BIG) BIG=BIG17
6438 BIG18=ABS(DGLM(14)*CBI(1,J-1)/(2.*H**2.))
6439 IF (BIG18.GT.BIG) BIG=BIG18
6440 BIG19=ABS(CO2(2,J)/DT)
6441 IF (BIG19.GT.BIG) BIG=BIG19
6442 BIG20=ABS(CO2(1,J)/DT)
6443 IF (BIG20.GT.BIG) BIG=BIG20
6444 BIG21=ABS(CBA(2,J)/DT)
6445 IF (BIG21.GT.BIG) BIG=BIG21
6446 BIG22=ABS(CBA(1,J)/DT)
6447 IF (BIG22.GT.BIG) BIG=BIG22
6448 BIG23=ABS(CBI(2,J)/DT)
6449 IF (BIG23.GT.BIG) BIG=BIG23
6450 BIG24=ABS(CBI(1,J)/DT)
6451 IF (BIG24.GT.BIG) BIG=BIG24
6452 IF (ABS(G(20)).LT.BIG*EBIG) G(20)=0
6453
6454 c For Acetaminophen
6455 G(21)=DGLM(16)*(ACE(2,J+1)-2.*ACE(2,J)+ACE(2,J-1)
6456 1 +ACE(1,J+1)-2.*ACE(1,J)+ACE(1,J-1))/(2.*H**2.)
6457 2 -(ACE(2,J)-ACE(1,J))/DT
6458
6459 B(21,21)=DGLM(16)/H**2.+1./DT
6460 D(21,21)=-DGLM(16)/(2.*H**2.)
6461 A(21,21)=-DGLM(16)/(2.*H**2.)
6462
6463
6464 BIG=ABS(DGLM(16)*(ACE(2,J+1))/(2.*H**2.))
6465 BIG2=ABS(DGLM(16)*(ACE(2,J))/(H**2.))
6466 IF (BIG2.GT.BIG) BIG=BIG2
6467 BIG3=ABS(DGLM(16)*(ACE(2,J-1))/(2.*H**2.))
6468 IF (BIG3.GT.BIG) BIG=BIG3
6469 BIG4=ABS(DGLM(16)*(ACE(1,J+1))/(2.*H**2.))
6470 IF (BIG4.GT.BIG) BIG=BIG4
6471 BIG5=ABS(DGLM(16)*(ACE(1,J))/(H**2.))
6472 IF (BIG5.GT.BIG) BIG=BIG5
6473 BIG6=ABS(DGLM(16)*(ACE(1,J-1))/(2.*H**2.))
6474 IF (BIG6.GT.BIG) BIG=BIG6
6475 BIG7=ABS(ACE(2,J)/DT)
6476 IF (BIG7.GT.BIG) BIG=BIG7
6477 BIG8=ABS(ACE(1,J)/DT)
6478 IF (BIG8.GT.BIG) BIG=BIG8
6479 IF (ABS(G(21)).LT.BIG*EBIG) G(21)=0
6480
6481 c INTERFACE VOLTAGE - DUMMY
6482 G(22)=(VDL(2,J)+VDL(1,J))/2.
6483
6484 B(22,22)=-1./2.
6485
6486 BIG=ABS(VDL(2,J)/2.)
6487 BIG2=ABS(VDL(1,J)/2.)
6488 IF (BIG2.GT.BIG) BIG=BIG2
6489 IF (ABS(G(22)).LT.BIG*EBIG) G(22)=0
6490
6491 RETURN
6492 END

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6493
6494 SUBROUTINE FORCEC(J)
6495 IMPLICIT DOUBLE PRECISION (A-H, O-Z)
6496 COMMON/BAB/ A(22,22),B(22,22),C(22,80001),D(22,45),G(22),X(22,22)
6497 1 ,Y(22,22)
6498 COMMON/NSN/ N, NJ
6499 COMMON/GLC/ NTIME,LL
6500 COMMON/VAR/ DIFF(16),H,EBIG,HH,IJ,KJ,TT,VAP,HHH,DT,RE,AKB,BB,CDL
6501 COMMON/VARR/ HHHH,HHHHH,MJ,LJ
6502 COMMON/DIN/ DGOX(16),DGLM(16),DIRM(16),DBULK(16)
6503 COMMON/SPCI/ GLU(2,80001),GOX(2,80001),GLA(2,80001),GOR(2,80001)
6504 COMMON/SPCII/ OXY(2,80001),HPR(2,80001),GOA(2,80001),GOP(2,80001)
6505 COMMON/RXT/ EQ1(2,80001),RGA(2,80001),EQ2(2,80001),RHP(2,80001)
6506 COMMON/SPCIII/ ANM(2,80001),GLUA(2,80001),GLI(2,80001)
6507 COMMON/SPCIV/ HYD(2,80001),OHI(2,80001),CO2(2,80001),CBA(2,80001)
6508 COMMON/SPCV/ CBI(2,80001),ACE(2,80001)
6509 COMMON/VOL/ VDL(2,80001)
6510 COMMON/POR/ POR1,POR2,PORGLU,PARION,PARACE
6511 COMMON/RTE/ ratef1,equilib1,ratef2,ratef3,equilib3,ratef4
6512 COMMON/RTD/ ratef5,equilib5,equilib6,equilib7,equilib8,equilib9
6513 COMMON/BUL/ CBULK(16),PARH2O2,PARO2,PARGLUPOSE,JCOUNT
6514
6515 301 FORMAT (5x,'J=' I5, 12E18.9)
6516
6517 C For Glucose, being consumed only
6518 G(1)=DGLM(1)*(PARGLUPOSE*GLU(2,J+1)-2.*GLU(2,J)+GLU(2,J-1)
6519 1 +PARGLUPOSE*GLU(1,J+1)-2.*GLU(1,J)+GLU(1,J-1))/(2.*H**2.)
6520 2 +(ANM(2,J)+ANM(1,J))/2.-(GLU(2,J)-GLU(1,J))/DT
6521
6522 B(1,1)=DGLM(1)/H**2.+1./DT
6523 D(1,1)=-PARGLUPOSE*DGLM(1)/(2.*H**2.)
6524 A(1,1)=-DGLM(1)/(2.*H**2.)
6525 B(1,13)=-1./2.
6526
6527
6528 BIG=ABS(DGLM(1)*(GLU(2,J+1))/(2.*H**2.)*PARGLUPOSE)
6529 BIG2=ABS(DGLM(1)*(GLU(2,J))/(H**2.))
6530 IF (BIG2.GT.BIG) BIG=BIG2
6531 BIG3=ABS(DGLM(1)*(GLU(2,J-1))/(2.*H**2.))
6532 IF (BIG3.GT.BIG) BIG=BIG3
6533 BIG4=ABS(DGLM(1)*(GLU(1,J+1))/(2.*H**2.)*PARGLUPOSE)
6534 IF (BIG4.GT.BIG) BIG=BIG4
6535 BIG5=ABS(DGLM(1)*(GLU(1,J))/(H**2.))
6536 IF (BIG5.GT.BIG) BIG=BIG5
6537 BIG6=ABS(DGLM(1)*(GLU(1,J-1))/(2.*H**2.))
6538 IF (BIG6.GT.BIG) BIG=BIG6
6539 BIG7=ABS(GLU(2,J)/DT)
6540 IF (BIG7.GT.BIG) BIG=BIG7
6541 BIG8=ABS(GLU(1,J)/DT)
6542 IF (BIG8.GT.BIG) BIG=BIG8
6543 BIG9=ABS(ANM(2,J)/2.)
6544 IF (BIG9.GT.BIG) BIG=BIG9
6545 BIG10=ABS(ANM(1,J)/2.)
6546 IF (BIG10.GT.BIG) BIG=BIG10
6547 IF (ABS(G(1)).LT.BIG*EBIG) G(1)=0
6548
6549 C For GOx, enzyme
6550 G(2)=(GOX(2,J)+GOX(1,J))/2.

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6551      B(2,2) = -1./2.
6552
6553 C      For Gluconic Acid, being produced only
6554      G(3)=DGLM(3)*(PARGLUCOSE*GLA(2,J+1)-2.*GLA(2,J)+GLA(2,J-1)
6555      1      +PARGLUCOSE*GLA(1,J+1)-2.*GLA(1,J)+GLA(1,J-1))/(2.*H**2.)
6556      2      +DGLM(10)*(PARGLUCOSE*GLI(2,J+1)-2.*GLI(2,J)+GLI(2,J-1)
6557      3      +PARGLUCOSE*GLI(1,J+1)-2.*GLI(1,J)+GLI(1,J-1))/(2.*H**2.)
6558      2      -(GLA(2,J)-GLA(1,J))/DT-(GLI(2,J)-GLI(1,J))/DT
6559
6560      B(3,3)=DGLM(3)/H**2.+1./DT
6561      D(3,3)=-DGLM(3)/(2.*H**2.)*PARGLUCOSE
6562      A(3,3)=-DGLM(3)/(2.*H**2.)
6563      B(3,15)=DGLM(10)/H**2.+1./DT
6564      D(3,15)=-DGLM(10)/(2.*H**2.)*PARGLUCOSE
6565      A(3,15)=-DGLM(10)/(2.*H**2.)
6566
6567
6568      BIG=ABS(DGLM(3)*(GLA(2,J+1))/(2.*H**2.)*PARGLUCOSE)
6569      BIG2=ABS(DGLM(3)*(GLA(2,J))/(H**2.))
6570      IF (BIG2.GT.BIG) BIG=BIG2
6571      BIG3=ABS(DGLM(3)*(GLA(2,J-1))/(2.*H**2.))
6572      IF (BIG3.GT.BIG) BIG=BIG3
6573      BIG4=ABS(DGLM(3)*(GLA(1,J+1))/(2.*H**2.)*PARGLUCOSE)
6574      IF (BIG4.GT.BIG) BIG=BIG4
6575      BIG5=ABS(DGLM(3)*(GLA(1,J))/(H**2.))
6576      IF (BIG5.GT.BIG) BIG=BIG5
6577      BIG6=ABS(DGLM(3)*(GLA(1,J-1))/(2.*H**2.))
6578      IF (BIG6.GT.BIG) BIG=BIG6
6579      BIG7=ABS(GLA(2,J)/DT)
6580      IF (BIG7.GT.BIG) BIG=BIG7
6581      BIG8=ABS(GLA(1,J)/DT)
6582      IF (BIG8.GT.BIG) BIG=BIG8
6583      BIG9=ABS(DGLM(10)*(GLI(2,J+1))/(2.*H**2.)*PARGLUCOSE)
6584      IF (BIG9.GT.BIG) BIG=BIG9
6585      BIG10=ABS(DGLM(10)*(GLI(2,J))/(H**2.))
6586      IF (BIG10.GT.BIG) BIG=BIG10
6587      BIG11=ABS(DGLM(10)*(GLI(2,J-1))/(2.*H**2.))
6588      IF (BIG11.GT.BIG) BIG=BIG11
6589      BIG12=ABS(DGLM(10)*(GLI(1,J+1))/(2.*H**2.)*PARGLUCOSE)
6590      IF (BIG12.GT.BIG) BIG=BIG12
6591      BIG13=ABS(DGLM(10)*(GLI(1,J))/(H**2.))
6592      IF (BIG13.GT.BIG) BIG=BIG13
6593      BIG14=ABS(DGLM(10)*(GLI(1,J-1))/(2.*H**2.))
6594      IF (BIG14.GT.BIG) BIG=BIG14
6595      BIG15=ABS(GLI(2,J)/DT)
6596      IF (BIG15.GT.BIG) BIG=BIG15
6597      BIG16=ABS(GLI(1,J)/DT)
6598      IF (BIG16.GT.BIG) BIG=BIG16
6599      IF (ABS(G(3)).LT.BIG*EBIG) G(3)=0
6600
6601 C      For GOx2, enzyme
6602      G(4)=(GOR(2,J)+GOR(1,J))/2.
6603      B(4,4) = -1./2.
6604
6605 C      For O2, being consumed only
6606      G(5)=DGLM(5)*(PARO2*OXY(2,J+1)-2.*OXY(2,J)+OXY(2,J-1)
6607      1      +PARO2*OXY(1,J+1)-2.*OXY(1,J)+OXY(1,J-1))/(2.*H**2.)
6608      2      -(OXY(2,J)-OXY(1,J))/DT

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6609
6610 B(5,5)=DGLM(5)/H**2.+1./DT
6611 D(5,5)=-DGLM(5)/(2.*H**2.)*PARO2
6612 A(5,5)=-DGLM(5)/(2.*H**2.)
6613
6614
6615 BIG=ABS(DGLM(5)*(OXY(2,J+1))/(2.*H**2.)*PARO2)
6616 BIG2=ABS(DGLM(5)*(OXY(2,J))/(H**2.))
6617 IF (BIG2.GT.BIG) BIG=BIG2
6618 BIG3=ABS(DGLM(5)*(OXY(2,J-1))/(2.*H**2.))
6619 IF (BIG3.GT.BIG) BIG=BIG3
6620 BIG4=ABS(DGLM(5)*(OXY(1,J+1))/(2.*H**2.)*PARO2)
6621 IF (BIG4.GT.BIG) BIG=BIG4
6622 BIG5=ABS(DGLM(5)*(OXY(1,J))/(H**2.))
6623 IF (BIG5.GT.BIG) BIG=BIG5
6624 BIG6=ABS(DGLM(5)*(OXY(1,J-1))/(2.*H**2.))
6625 IF (BIG6.GT.BIG) BIG=BIG6
6626 BIG7=ABS(OXY(2,J)/DT)
6627 IF (BIG7.GT.BIG) BIG=BIG7
6628 BIG8=ABS(OXY(1,J)/DT)
6629 IF (BIG8.GT.BIG) BIG=BIG8
6630 IF (ABS(G(5)).LT.BIG*EBIG) G(5)=0
6631
6632 C For H2O2, reacting species
6633 G(6)=DGLM(6)*(PARH2O2*HPR(2,J+1)-2.*HPR(2,J)+HPR(2,J-1)
6634 1 +PARH2O2*HPR(1,J+1)-2.*HPR(1,J)+HPR(1,J-1))/(2.*H**2.)
6635 2 -(HPR(2,J)-HPR(1,J))/DT
6636
6637 B(6,6)=DGLM(6)/H**2.+1./DT
6638 D(6,6)=-DGLM(6)/(2.*H**2.)*PARH2O2
6639 A(6,6)=-DGLM(6)/(2.*H**2.)
6640
6641
6642 BIG=ABS(DGLM(6)*(HPR(2,J+1))/(2.*H**2.)*PARH2O2)
6643 BIG2=ABS(DGLM(6)*(HPR(2,J))/(H**2.))
6644 IF (BIG2.GT.BIG) BIG=BIG2
6645 BIG3=ABS(DGLM(6)*(HPR(2,J-1))/(2.*H**2.))
6646 IF (BIG3.GT.BIG) BIG=BIG3
6647 BIG4=ABS(DGLM(6)*(HPR(1,J+1))/(2.*H**2.)*PARH2O2)
6648 IF (BIG4.GT.BIG) BIG=BIG4
6649 BIG5=ABS(DGLM(6)*(HPR(1,J))/(H**2.))
6650 IF (BIG5.GT.BIG) BIG=BIG5
6651 BIG6=ABS(DGLM(6)*(HPR(1,J-1))/(2.*H**2.))
6652 IF (BIG6.GT.BIG) BIG=BIG6
6653 BIG7=ABS(HPR(2,J)/DT)
6654 IF (BIG7.GT.BIG) BIG=BIG7
6655 BIG8=ABS(HPR(1,J)/DT)
6656 IF (BIG8.GT.BIG) BIG=BIG8
6657 IF (ABS(G(6)).LT.BIG*EBIG) G(6)=0
6658
6659 C For CX-GOx2, enzyme complex
6660 G(7)=(GOA(2,J)+GOA(1,J))/2.
6661 B(7,7)=-1./2.
6662
6663 C For CX-GOx, enzyme complex
6664 G(8)=(GOP(2,J)+GOP(1,J))/2.
6665 B(8,8)=-1./2.
6666

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6667 C   For Reaction 1 Enzymatic Catalysis
6668     G(9)=(EQ1(2,J)+EQ1(1,J))/2.
6669     B(9,9)=-1./2.
6670
6671 C   For Reaction 2
6672     G(10)=(RGA(2,J)+RGA(1,J))/2.
6673     B(10,10)=-1./2.
6674
6675 C   For Reaction 3 Meditation/regeneration
6676     G(11)=(EQ2(2,J)+EQ2(1,J))/2.
6677     B(11,11)=-1./2.
6678
6679 C   For Reaction 4
6680     G(12)=(RHP(2,J)+RHP(1,J))/2.
6681     B(12,12)=-1./2.
6682
6683 C   REACTIONS
6684 218 G(13)=-((ANM(2,J)+ANM(1,J))/2.+ratef5*((GLUA(2,J)+GLUA(1,J))/2.
6685 1   -(GLU(2,J)+GLU(1,J))/2./equilib5)
6686     B(13,1)=ratef5/2./equilib5
6687     B(13,14)=-ratef5/2.
6688     B(13,13)=+1./2.
6689
6690     BIG=ABS(ANM(2,J)/2.)
6691     BIG2=ABS(ANM(1,J)/2.)
6692     IF (BIG2.GT.BIG) BIG=BIG2
6693     BIG3=ABS(ratef5*GLUA(2,J)/2.)
6694     IF (BIG3.GT.BIG) BIG=BIG3
6695     BIG4=ABS(ratef5*GLUA(1,J)/2.)
6696     IF (BIG4.GT.BIG) BIG=BIG4
6697     BIG5=ABS(ratef5*GLU(2,J)/2./equilib5)
6698     IF (BIG5.GT.BIG) BIG=BIG5
6699     BIG6=ABS(ratef5*GLU(1,J)/2./equilib5)
6700     IF (BIG6.GT.BIG) BIG=BIG6
6701     IF (ABS(G(13)).LT.BIG*EBIG) G(13)=0.0
6702
6703 C   For alpha Glucose, being consumed only
6704     G(14)=DGLM(9)*(PARGLUCOSE*GLUA(2,J+1)-2.*GLUA(2,J)+GLUA(2,J-1)
6705 1     +PARGLUCOSE*GLUA(1,J+1)-2.*GLUA(1,J)+GLUA(1,J-1))/(2.*H**2.)
6706 2     -(ANM(2,J)+ANM(1,J))/2.-(GLUA(2,J)-GLUA(1,J))/DT
6707     B(14,14)=DGLM(9)/H**2.+1./DT
6708     D(14,14)=-DGLM(9)/(2.*H**2.)*PARGLUCOSE
6709     A(14,14)=-DGLM(9)/(2.*H**2.)
6710     B(14,13)=1./2.
6711
6712     BIG=ABS(DGLM(9)*(GLUA(2,J+1))/(2.*H**2.)*PARGLUCOSE)
6713     BIG2=ABS(DGLM(9)*(GLUA(2,J))/(H**2.))
6714     IF (BIG2.GT.BIG) BIG=BIG2
6715     BIG3=ABS(DGLM(9)*(GLUA(2,J-1))/(2.*H**2.))
6716     IF (BIG3.GT.BIG) BIG=BIG3
6717     BIG4=ABS(DGLM(9)*(GLUA(1,J+1))/(2.*H**2.)*PARGLUCOSE)
6718     IF (BIG4.GT.BIG) BIG=BIG4
6719     BIG5=ABS(DGLM(9)*(GLUA(1,J))/(H**2.))
6720     IF (BIG5.GT.BIG) BIG=BIG5
6721     BIG6=ABS(DGLM(9)*(GLUA(1,J-1))/(2.*H**2.))
6722     IF (BIG6.GT.BIG) BIG=BIG6
6723     BIG7=ABS(ANM(2,J)/2.)
6724     IF (BIG7.GT.BIG) BIG=BIG7

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6725     BIG8=ABS(ANM(1,J)/2.)
6726     IF (BIG8.GT.BIG) BIG=BIG8
6727     BIG9=ABS(GLUA(2,J)/DT)
6728     IF (BIG9.GT.BIG) BIG=BIG9
6729     BIG10=ABS(GLUA(1,J)/DT)
6730     IF (BIG10.GT.BIG) BIG=BIG10
6731     IF (ABS(G(14)).LT.BIG*EBIG) G(14)=0.0
6732
6733 C Gluconic acid dissociation
6734
6735     G(15)=equilib6*(GLA(2,J)+GLA(1,J))/2.-(GLI(2,J)+GLI(1,J))*
6736 1 (HYD(2,J)+HYD(1,J))/4.
6737     B(15,3)=-equilib6/2.
6738     B(15,15)=(HYD(2,J)+HYD(1,J))/4.
6739     B(15,16)=(GLI(2,J)+GLI(1,J))/4.
6740
6741     BIG=ABS(equilib6*GLA(2,J)/2.)
6742     BIG2=ABS(equilib6*GLA(1,J)/2.)
6743     IF (BIG2.GT.BIG) BIG=BIG2
6744     BIG3=ABS(GLI(2,J)*HYD(2,J)/4.)
6745     IF (BIG3.GT.BIG) BIG=BIG3
6746     BIG4=ABS(GLI(2,J)*HYD(1,J)/4)
6747     IF (BIG4.GT.BIG) BIG=BIG4
6748     BIG5=ABS(GLI(1,J)*HYD(2,J)/4)
6749     IF (BIG5.GT.BIG) BIG=BIG5
6750     BIG6=ABS(GLI(1,J)*HYD(1,J)/4)
6751     IF (BIG6.GT.BIG) BIG=BIG6
6752     IF (ABS(G(15)).LT.BIG*EBIG) G(15)=0
6753 C Hydrogen ion, hydroxide ion, gluconate ion, bicarbonate ion flux
6754     G(16)=DGLM(11)*(PARION*HYD(2,J+1)-2.*HYD(2,J)+HYD(2,J-1)
6755 1 +PARION*HYD(1,J+1)-2.*HYD(1,J)+HYD(1,J-1))/(2.*H**2.)
6756 2 -DGLM(15)*(PARION*OHI(2,J+1)-2.*OHI(2,J)+OHI(2,J-1)
6757 3 +PARION*OHI(1,J+1)-2.*OHI(1,J)+OHI(1,J-1))/(2.*H**2.)
6758 4 -DGLM(10)*(PARGLUCOSE*GLI(2,J+1)-2.*GLI(2,J)+GLI(2,J-1)
6759 5 +PARGLUCOSE*GLI(1,J+1)-2.*GLI(1,J)+GLI(1,J-1))/(2.*H**2.)
6760 6 -DGLM(14)*(PARION*CBI(2,J+1)-2.*CBI(2,J)+CBI(2,J-1)
6761 7 +PARION*CBI(1,J+1)-2.*CBI(1,J)+CBI(1,J-1))/(2.*H**2.)
6762 8 -(HYD(2,J)-HYD(1,J))/DT+(OHI(2,J)-OHI(1,J))/DT
6763 9 +(GLI(2,J)-GLI(1,J))/DT+(CBI(2,J)-CBI(1,J))/DT
6764
6765     B(16,16)=DGLM(11)/H**2.+1./DT
6766     D(16,16)=-DGLM(11)/(2.*H**2.)*PARION
6767     A(16,16)=-DGLM(11)/(2.*H**2.)
6768     B(16,17)=-DGLM(15)/H**2.-1./DT
6769     D(16,17)=DGLM(15)/(2.*H**2.)*PARION
6770     A(16,17)=DGLM(15)/(2.*H**2.)
6771     B(16,15)=-DGLM(10)/H**2.-1./DT
6772     D(16,15)=DGLM(10)/(2.*H**2.)*PARGLUCOSE
6773     A(16,15)=DGLM(10)/(2.*H**2.)
6774     B(16,20)=-DGLM(14)/H**2.-1./DT
6775     D(16,20)=DGLM(14)/(2.*H**2.)*PARION
6776     A(16,20)=DGLM(14)/(2.*H**2.)
6777
6778     BIG=ABS(DGLM(11)*(HYD(2,J+1))/(2.*H**2.)*PARION)
6779     BIG2=ABS(DGLM(11)*(HYD(2,J))/(H**2.))
6780     IF (BIG2.GT.BIG) BIG=BIG2
6781     BIG3=ABS(DGLM(11)*(HYD(2,J-1))/(2.*H**2.))
6782     IF (BIG3.GT.BIG) BIG=BIG3

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6783 BIG4=ABS(DGLM(11)*(HYD(1,J+1))/(2.*H**2.)*PARION)
6784 IF (BIG4.GT.BIG) BIG=BIG4
6785 BIG5=ABS(DGLM(11)*(HYD(1,J))/(H**2.))
6786 IF (BIG5.GT.BIG) BIG=BIG5
6787 BIG6=ABS(DGLM(11)*(HYD(1,J-1))/(2.*H**2.))
6788 IF (BIG6.GT.BIG) BIG=BIG6
6789 BIG7=ABS(DGLM(15)*OHI(2,J+1)/(2.*H**2.)*PARION)
6790 IF (BIG7.GT.BIG) BIG=BIG7
6791 BIG8=ABS(DGLM(15)*OHI(2,J)/(H**2.))
6792 IF (BIG8.GT.BIG) BIG=BIG8
6793 BIG9=ABS(DGLM(15)*OHI(2,J-1)/(2.*H**2.))
6794 IF (BIG9.GT.BIG) BIG=BIG9
6795 BIG10=ABS(DGLM(15)*OHI(1,J+1)/(2.*H**2.)*PARION)
6796 IF (BIG10.GT.BIG) BIG=BIG10
6797 BIG11=ABS(DGLM(15)*OHI(1,J)/(H**2.))
6798 IF (BIG11.GT.BIG) BIG=BIG11
6799 BIG12=ABS(DGLM(15)*OHI(1,J-1)/(2.*H**2.))
6800 IF (BIG12.GT.BIG) BIG=BIG12
6801 BIG13=ABS(DGLM(10)*GLI(2,J+1)/(2.*H**2.)*PARGLUCOSE)
6802 IF (BIG13.GT.BIG) BIG=BIG13
6803 BIG14=ABS(DGLM(10)*GLI(2,J)/(H**2.))
6804 IF (BIG14.GT.BIG) BIG=BIG14
6805 BIG15=ABS(DGLM(10)*GLI(2,J-1)/(2.*H**2.))
6806 IF (BIG15.GT.BIG) BIG=BIG15
6807 BIG16=ABS(DGLM(10)*GLI(1,J+1)/(2.*H**2.)*PARGLUCOSE)
6808 IF (BIG16.GT.BIG) BIG=BIG16
6809 BIG17=ABS(DGLM(10)*GLI(1,J)/(H**2.))
6810 IF (BIG17.GT.BIG) BIG=BIG17
6811 BIG18=ABS(DGLM(10)*GLI(1,J-1)/(2.*H**2.))
6812 IF (BIG18.GT.BIG) BIG=BIG18
6813 BIG19=ABS(DGLM(14)*CBI(2,J+1)/(2.*H**2.)*PARION)
6814 IF (BIG19.GT.BIG) BIG=BIG19
6815 BIG20=ABS(DGLM(14)*CBI(2,J)/(H**2.))
6816 IF (BIG20.GT.BIG) BIG=BIG20
6817 BIG21=ABS(DGLM(14)*CBI(2,J-1)/(2.*H**2.))
6818 IF (BIG21.GT.BIG) BIG=BIG21
6819 BIG22=ABS(DGLM(14)*CBI(1,J+1)/(2.*H**2.)*PARION)
6820 IF (BIG22.GT.BIG) BIG=BIG22
6821 BIG23=ABS(DGLM(14)*CBI(1,J)/(H**2.))
6822 IF (BIG23.GT.BIG) BIG=BIG23
6823 BIG24=ABS(DGLM(14)*CBI(1,J-1)/(2.*H**2.))
6824 IF (BIG24.GT.BIG) BIG=BIG24
6825 BIG25=ABS(HYD(2,J)/DT)
6826 IF (BIG25.GT.BIG) BIG=BIG25
6827 BIG26=ABS(HYD(1,J)/DT)
6828 IF (BIG26.GT.BIG) BIG=BIG26
6829 BIG27=ABS(OHI(2,J)/DT)
6830 IF (BIG27.GT.BIG) BIG=BIG27
6831 BIG28=ABS(OHI(1,J)/DT)
6832 IF (BIG28.GT.BIG) BIG=BIG28
6833 BIG29=ABS(GLI(2,J)/DT)
6834 IF (BIG29.GT.BIG) BIG=BIG29
6835 BIG30=ABS(GLI(1,J)/DT)
6836 IF (BIG30.GT.BIG) BIG=BIG30
6837 BIG31=ABS(CBI(2,J)/DT)
6838 IF (BIG31.GT.BIG) BIG=BIG31
6839 BIG32=ABS(CBI(1,J)/DT)
6840 IF (BIG32.GT.BIG) BIG=BIG32

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6841     IF (ABS(G(16)).LT.BIG*EBIG) G(16)=0
6842
6843 c Water Dissociation
6844     G(17)=equilib9 -(HYD(2,J)+HYD(1,J))*(OHI(2,J)+OHI(1,J))/4.
6845     B(17,17)=(HYD(2,J)+HYD(1,J))/4.
6846     B(17,16)=(OHI(2,J)+OHI(1,J))/4.
6847
6848     BIG=ABS(equilib9)
6849     BIG2=ABS(HYD(2,J)*OHI(2,J)/4.)
6850     IF (BIG2.GT.BIG) BIG=BIG2
6851     BIG3=ABS(HYD(2,J)*OHI(1,J)/4.)
6852     IF (BIG3.GT.BIG) BIG=BIG3
6853     BIG4=ABS(HYD(1,J)*OHI(2,J)/4.)
6854     IF (BIG4.GT.BIG) BIG=BIG4
6855     BIG5=ABS(HYD(1,J)*OHI(1,J)/4.)
6856     IF (BIG5.GT.BIG) BIG=BIG5
6857     IF (ABS(G(17)).LT.BIG*EBIG) G(17)=0
6858
6859 C CO2 Hydration
6860
6861     G(18)=equilib7 *(CO2(2,J)+CO2(1,J))/2. -(CBA(2,J)+CBA(1,J))/2.
6862     B(18,18)=-equilib7/2.
6863     B(18,19)=1./2.
6864
6865     BIG=ABS(equilib7*CO2(2,J)/2.)
6866     BIG2=ABS(equilib7*CO2(1,J)/2.)
6867     IF (BIG2.GT.BIG) BIG=BIG2
6868     BIG3=ABS(CBA(2,J)/2.)
6869     IF (BIG3.GT.BIG) BIG=BIG3
6870     BIG4=ABS(CBA(1,J)/2.)
6871     IF (BIG4.GT.BIG) BIG=BIG4
6872     IF (ABS(G(18)).LT.BIG*EBIG) G(18)=0
6873
6874 C Carbonic acid dissociation
6875
6876     G(19)=equilib8 *(CBA(2,J)+CBA(1,J))/2. -(CBI(2,J)+CBI(1,J))
6877 1 *(HYD(2,J)+HYD(1,J))/4.
6878     B(19,19)=-equilib8/2.
6879     B(19,20)=(HYD(2,J)+HYD(1,J))/4.
6880     B(19,16)=(CBI(2,J)+CBI(1,J))/4.
6881
6882     BIG=ABS(equilib8*CBA(2,J)/2.)
6883     BIG2=ABS(equilib8*CBA(1,J)/2.)
6884     IF (BIG2.GT.BIG) BIG=BIG2
6885     BIG3=ABS(CBI(2,J)*HYD(2,J)/4.)
6886     IF (BIG3.GT.BIG) BIG=BIG3
6887     BIG4=ABS(CBI(2,J)*HYD(1,J)/4.)
6888     IF (BIG4.GT.BIG) BIG=BIG4
6889     BIG5=ABS(CBI(1,J)*HYD(2,J)/4.)
6890     IF (BIG5.GT.BIG) BIG=BIG5
6891     BIG6=ABS(CBI(1,J)*HYD(1,J)/4.)
6892     IF (BIG6.GT.BIG) BIG=BIG6
6893     IF (ABS(G(19)).LT.BIG*EBIG) G(19)=0
6894
6895 C FLUX OF CO2, CARBONIC ACID, BICARBONATE ION
6896     G(20)=DGLM(12)*(PARION*CO2(2,J+1)-2.*CO2(2,J)+CO2(2,J-1)
6897 1 +PARION*CO2(1,J+1)-2.*CO2(1,J)+CO2(1,J-1))/(2.*H**2.)
6898 2 +DGLM(13)*(PARION*CBA(2,J+1)-2.*CBA(2,J)+CBA(2,J-1)

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6899      3      +PARION*CBA(1,J+1)-2.*CBA(1,J)+CBA(1,J-1))/(2.*H**2.)
6900      4      +DGLM(14)*(PARION*CBI(2,J+1)-2.*CBI(2,J)+CBI(2,J-1)
6901      5      +PARION*CBI(1,J+1)-2.*CBI(1,J)+CBI(1,J-1))/(2.*H**2.)
6902      8      -(CO2(2,J)-CO2(1,J))/DT-(CBA(2,J)-CBA(1,J))/DT
6903      9      -(CBI(2,J)-CBI(1,J))/DT
6904
6905      B(20,20)=DGLM(14)/H**2.+1./DT
6906      D(20,20)=-DGLM(14)/(2.*H**2.)*PARION
6907      A(20,20)=-DGLM(14)/(2.*H**2.)
6908      B(20,18)=DGLM(12)/H**2.+1./DT
6909      D(20,18)=-DGLM(12)/(2.*H**2.)*PARION
6910      A(20,18)=-DGLM(12)/(2.*H**2.)
6911      B(20,19)=DGLM(13)/H**2.+1./DT
6912      D(20,19)=-DGLM(13)/(2.*H**2.)*PARION
6913      A(20,19)=-DGLM(13)/(2.*H**2.)
6914
6915
6916      BIG=ABS(DGLM(12)*(CO2(2,J+1))/(2.*H**2.)*PARION)
6917      BIG2=ABS(DGLM(12)*(CO2(2,J))/(H**2.))
6918      IF (BIG2.GT.BIG) BIG=BIG2
6919      BIG3=ABS(DGLM(12)*(CO2(2,J-1))/(2.*H**2.))
6920      IF (BIG3.GT.BIG) BIG=BIG3
6921      BIG4=ABS(DGLM(12)*(CO2(1,J+1))/(2.*H**2.)*PARION)
6922      IF (BIG4.GT.BIG) BIG=BIG4
6923      BIG5=ABS(DGLM(12)*(CO2(1,J))/(H**2.))
6924      IF (BIG5.GT.BIG) BIG=BIG5
6925      BIG6=ABS(DGLM(12)*(CO2(1,J-1))/(2.*H**2.))
6926      IF (BIG6.GT.BIG) BIG=BIG6
6927      BIG7=ABS(DGLM(13)*CBA(2,J+1)/(2.*H**2.)*PARION)
6928      IF (BIG7.GT.BIG) BIG=BIG7
6929      BIG8=ABS(DGLM(13)*CBA(2,J)/(H**2.))
6930      IF (BIG8.GT.BIG) BIG=BIG8
6931      BIG9=ABS(DGLM(13)*CBA(2,J-1)/(2.*H**2.))
6932      IF (BIG9.GT.BIG) BIG=BIG9
6933      BIG10=ABS(DGLM(13)*CBA(1,J+1)/(2.*H**2.)*PARION)
6934      IF (BIG10.GT.BIG) BIG=BIG10
6935      BIG11=ABS(DGLM(13)*CBA(1,J)/(H**2.))
6936      IF (BIG11.GT.BIG) BIG=BIG11
6937      BIG12=ABS(DGLM(13)*CBA(1,J-1)/(2.*H**2.))
6938      IF (BIG12.GT.BIG) BIG=BIG12
6939      BIG13=ABS(DGLM(14)*CBI(2,J+1)/(2.*H**2.)*PARION)
6940      IF (BIG13.GT.BIG) BIG=BIG13
6941      BIG14=ABS(DGLM(14)*CBI(2,J)/(H**2.))
6942      IF (BIG14.GT.BIG) BIG=BIG14
6943      BIG15=ABS(DGLM(14)*CBI(2,J-1)/(2.*H**2.))
6944      IF (BIG15.GT.BIG) BIG=BIG15
6945      BIG16=ABS(DGLM(14)*CBI(1,J+1)/(2.*H**2.)*PARION)
6946      IF (BIG16.GT.BIG) BIG=BIG16
6947      BIG17=ABS(DGLM(14)*CBI(1,J)/(H**2.))
6948      IF (BIG17.GT.BIG) BIG=BIG17
6949      BIG18=ABS(DGLM(14)*CBI(1,J-1)/(2.*H**2.))
6950      IF (BIG18.GT.BIG) BIG=BIG18
6951      BIG19=ABS(CO2(2,J)/DT)
6952      IF (BIG19.GT.BIG) BIG=BIG19
6953      BIG20=ABS(CO2(1,J)/DT)
6954      IF (BIG20.GT.BIG) BIG=BIG20
6955      BIG21=ABS(CBA(2,J)/DT)
6956      IF (BIG21.GT.BIG) BIG=BIG21

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6957     BIG22=ABS(CBA(1,J)/DT)
6958     IF (BIG22.GT.BIG) BIG=BIG22
6959     BIG23=ABS(CBI(2,J)/DT)
6960     IF (BIG23.GT.BIG) BIG=BIG23
6961     BIG24=ABS(CBI(1,J)/DT)
6962     IF (BIG24.GT.BIG) BIG=BIG24
6963     IF (ABS(G(20)).LT.BIG*EBIG) G(20)=0
6964
6965 c     For Acetaminophen
6966     G(21)=DGLM(16)*(PARACE*ACE(2,J+1)-2.*ACE(2,J)+ACE(2,J-1)
6967 1      +PARACE*ACE(1,J+1)-2.*ACE(1,J)+ACE(1,J-1))/(2.*H**2.)
6968 2      -(ACE(2,J)-ACE(1,J))/DT
6969
6970     B(21,21)=DGLM(16)/H**2.+1./DT
6971     D(21,21)=-DGLM(16)/(2.*H**2.)*PARACE
6972     A(21,21)=-DGLM(16)/(2.*H**2.)
6973
6974
6975     BIG=ABS(DGLM(16)*(ACE(2,J+1))/(2.*H**2.)*PARACE)
6976     BIG2=ABS(DGLM(16)*(ACE(2,J))/(H**2.))
6977     IF (BIG2.GT.BIG) BIG=BIG2
6978     BIG3=ABS(DGLM(16)*(ACE(2,J-1))/(2.*H**2.))
6979     IF (BIG3.GT.BIG) BIG=BIG3
6980     BIG4=ABS(DGLM(16)*(ACE(1,J+1))/(2.*H**2.)*PARACE)
6981     IF (BIG4.GT.BIG) BIG=BIG4
6982     BIG5=ABS(DGLM(16)*(ACE(1,J))/(H**2.))
6983     IF (BIG5.GT.BIG) BIG=BIG5
6984     BIG6=ABS(DGLM(16)*(ACE(1,J-1))/(2.*H**2.))
6985     IF (BIG6.GT.BIG) BIG=BIG6
6986     BIG7=ABS(ACE(2,J)/DT)
6987     IF (BIG7.GT.BIG) BIG=BIG7
6988     BIG8=ABS(ACE(1,J)/DT)
6989     IF (BIG8.GT.BIG) BIG=BIG8
6990     IF (ABS(G(21)).LT.BIG*EBIG) G(21)=0
6991
6992 c     INTERFACE VOLTAGE - DUMMY
6993     G(22)=(VDL(2,J)+VDL(1,J))/2.
6994
6995     B(22,22)=-1./2.
6996
6997     BIG=ABS(VDL(2,J)/2.)
6998     BIG2=ABS(VDL(1,J)/2.)
6999     IF (BIG2.GT.BIG) BIG=BIG2
7000     IF (ABS(G(22)).LT.BIG*EBIG) G(22)=0
7001
7002     RETURN
7003     END
7004
7005     SUBROUTINE COUPLER3(J)
7006     IMPLICIT DOUBLE PRECISION (A-H, O-Z)
7007     COMMON/BAB/ A(22,22),B(22,22),C(22,80001),D(22,45),G(22),X(22,22)
7008 1     ,Y(22,22)
7009     COMMON/NSN/ N, NJ
7010     COMMON/GLC/ NTIME,LL
7011     COMMON/VAR/ DIFF(16),H,EBIG,HH,IJ,KJ,TT,VAP,HHH,DT,RE,AKB,BB,CDL
7012     COMMON/VARR/ HHHH,HHHHH,MJ,LJ
7013     COMMON/DIN/ DGOX(16),DGLM(16),DIRM(16),DBULK(16)
7014     COMMON/SPCI/ GLU(2,80001),GOX(2,80001),GLA(2,80001),GOR(2,80001)

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7015 COMMON/SPCII/ OXY(2,80001),HPR(2,80001),GOA(2,80001),GOP(2,80001)
7016 COMMON/RXT/ EQ1(2,80001),RGA(2,80001),EQ2(2,80001),RHP(2,80001)
7017 COMMON/SPCIII/ ANM(2,80001),GLUA(2,80001),GLI(2,80001)
7018 COMMON/SPCIV/ HYD(2,80001),OHI(2,80001),CO2(2,80001),CBA(2,80001)
7019 COMMON/SPCV/ CBI(2,80001),ACE(2,80001)
7020 COMMON/VOL/ VDL(2,80001)
7021 COMMON/POR/ POR1,POR2,PORGLU,PARION,PARACE
7022 COMMON/RTE/ ratef1,equilib1,ratef2,ratef3,equilib3,ratef4
7023 COMMON/RTD/ ratef5,equilib5,equilib6,equilib7,equilib8,equilib9
7024 COMMON/BUL/ CBULK(16),PARH2O2,PARO2,PARGLUCESE,JCOUNT
7025
7026 301 FORMAT (5x,'J=' I5, 12E18.9)
7027
7028 COEFF1HHHHH=DBULK(1)/HHHHH
7029 COEFF1H=DGLM(1)/H
7030 COEFF3HHHHH=DBULK(3)/HHHHH
7031 COEFF3H=DGLM(3)/H
7032 COEFF5HHHHH=DBULK(5)/HHHHH
7033 COEFF5H=DGLM(5)/H
7034 COEFF6HHHHH=DBULK(6)/HHHHH
7035 COEFF6H=DGLM(6)/H
7036 COEFF9HHHHH=DBULK(9)/HHHHH
7037 COEFF9H=DGLM(9)/H
7038 COEFF10HHHHH=DBULK(10)/HHHHH
7039 COEFF10H=DGLM(10)/H
7040 COEFF11HHHHH=DBULK(11)/HHHHH
7041 COEFF11H=DGLM(11)/H
7042 COEFF12HHHHH=DBULK(12)/HHHHH
7043 COEFF12H=DGLM(12)/H
7044 COEFF13HHHHH=DBULK(13)/HHHHH
7045 COEFF13H=DGLM(13)/H
7046 COEFF14HHHHH=DBULK(14)/HHHHH
7047 COEFF14H=DGLM(14)/H
7048 COEFF15HHHHH=DBULK(15)/HHHHH
7049 COEFF15H=DGLM(15)/H
7050 COEFF16HHHHH=DBULK(16)/HHHHH
7051 COEFF16H=DGLM(16)/H
7052
7053 C For Glucose, being consumed only
7054 G(1)=COEFF1HHHHH/2.*(GLU(2,J+1)+GLU(1,J+1)-GLU(2,J)-GLU(1,J))
7055 1 -COEFF1H/2.*(PARGLUCESE*(GLU(2,J)
7056 2 +GLU(1,J))-GLU(2,J-1)-GLU(1,J-1))
7057 3 +(HHHHH/2.)*(3.*(ANM(2,J)+ANM(1,J))
7058 4 +(ANM(2,J+1)+ANM(1,J+1)))/8.
7059 4 +(H/2.)*(3.*PARGLUCESE*(ANM(2,J)+ANM(1,J))
7060 5 +(ANM(2,J-1)+ANM(1,J-1)))/8.
7061 5 -HHHHH/2.*(3.*(GLU(2,J)-GLU(1,J))
7062 5 +(GLU(2,J+1)-GLU(1,J+1)))/(4.*DT)
7063 6 -H/2.*(3.*PARGLUCESE*(GLU(2,J)-GLU(1,J))
7064 7 +(GLU(2,J-1)-GLU(1,J-1)))/(4.*DT)
7065
7066 B(1,1)=COEFF1HHHHH/2.+PARGLUCESE*COEFF1H/2.+HHHHH/2.*3./(4.*DT)
7067 1 +H/2.*3.*PARGLUCESE/(4.*DT)
7068 D(1,1)=-COEFF1HHHHH/2.+HHHHH/2./(4.*DT)
7069 A(1,1)=-COEFF1H/2.+H/2./(4.*DT)
7070 B(1,13)=-((HHHHH/2.)*(3./8.)-(H/2.)*PARGLUCESE*(3./8.))
7071 D(1,13)=-((HHHHH/2.)*(1./8.))
7072 A(1,13)=-((H/2.)*(1./8.))

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7073
7074     BIG=ABS(COEFF1HHHHH/2.*GLU(2,J+1))
7075     BIG2=ABS(COEFF1HHHHH/2.*GLU(1,J+1))
7076     IF (BIG2.GT.BIG) BIG=BIG2
7077     BIG3=ABS(COEFF1HHHHH/2.*GLU(2,J))
7078     IF (BIG3.GT.BIG) BIG=BIG3
7079     BIG4=ABS(COEFF1HHHHH/2.*GLU(1,J))
7080     IF (BIG4.GT.BIG) BIG=BIG4
7081     BIG5=ABS(COEFF1H/2.*GLU(2,J)*PARGLUCOSE)
7082     IF (BIG5.GT.BIG) BIG=BIG5
7083     BIG6=ABS(COEFF1H/2.*GLU(1,J)*PARGLUCOSE)
7084     IF (BIG6.GT.BIG) BIG=BIG6
7085     BIG7=ABS(COEFF1H/2.*GLU(2,J-1))
7086     IF (BIG7.GT.BIG) BIG=BIG7
7087     BIG8=ABS(COEFF1H/2.*GLU(1,J-1))
7088     IF (BIG8.GT.BIG) BIG=BIG8
7089     BIG13=ABS(HHHHH/2.*3.*GLU(2,J)/(4.*DT))
7090     IF (BIG13.GT.BIG) BIG=BIG13
7091     BIG14=ABS(HHHHH/2.*3.*GLU(1,J)/(4.*DT))
7092     IF (BIG14.GT.BIG) BIG=BIG14
7093     BIG15=ABS(HHHHH/2.*GLU(2,J+1)/(4.*DT))
7094     IF (BIG15.GT.BIG) BIG=BIG15
7095     BIG16=ABS(HHHHH/2.*GLU(1,J+1)/(4.*DT))
7096     IF (BIG16.GT.BIG) BIG=BIG16
7097     BIG17=ABS(H/2.*3.*GLU(2,J)/(4.*DT)*PARGLUCOSE)
7098     IF (BIG17.GT.BIG) BIG=BIG17
7099     BIG18=ABS(H/2.*3.*GLU(1,J)/(4.*DT)*PARGLUCOSE)
7100     IF (BIG18.GT.BIG) BIG=BIG18
7101     BIG19=ABS(H/2.*GLU(2,J-1)/(4.*DT))
7102     IF (BIG19.GT.BIG) BIG=BIG19
7103     BIG20=ABS(H/2.*GLU(1,J-1)/(4.*DT))
7104     IF (BIG20.GT.BIG) BIG=BIG20
7105     BIG21=ABS(HHHHH/2.*3.*ANM(2,J)/8.)
7106     IF (BIG21.GT.BIG) BIG=BIG21
7107     BIG22=ABS(HHHHH/2.*3.*ANM(1,J)/8.)
7108     IF (BIG22.GT.BIG) BIG=BIG22
7109     BIG23=ABS(HHHHH/2.*ANM(2,J+1)/8.)
7110     IF (BIG23.GT.BIG) BIG=BIG23
7111     BIG24=ABS(HHHHH/2.*ANM(1,J+1)/8.)
7112     IF (BIG24.GT.BIG) BIG=BIG24
7113     BIG25=ABS(H/2.*3.*ANM(2,J)/8.*PARGLUCOSE)
7114     IF (BIG25.GT.BIG) BIG=BIG25
7115     BIG26=ABS(H/2.*3.*ANM(1,J)/8.*PARGLUCOSE)
7116     IF (BIG26.GT.BIG) BIG=BIG26
7117     BIG27=ABS(H/2.*ANM(2,J-1)/8.)
7118     IF (BIG27.GT.BIG) BIG=BIG27
7119     BIG28=ABS(H/2.*ANM(1,J-1)/8.)
7120     IF (BIG28.GT.BIG) BIG=BIG28
7121     IF (ABS(G(1)).LT.BIG*EBIG) G(1)=0
7122
7123 C     For GOx, enzyme
7124     G(2)=(GOX(2,J)+GOX(1,J))/2.
7125     B(2,2)=-1./2.
7126
7127 C     For Gluconic Acid, being produced only
7128     G(3)=COEFF3HHHHH/2.*(GLA(2,J+1)+GLA(1,J+1)-GLA(2,J)-GLA(1,J))
7129     1     -COEFF3H/2.*(PARGLUCOSE*(GLA(2,J)+GLA(1,J))
7130     2     -GLA(2,J-1)-GLA(1,J-1))

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7131      2  +COEFF10HHHHH/2. *( GLI(2, J+1)+GLI(1, J+1)-GLI(2, J)-GLI(1, J) )
7132      3  -COEFF10H/2. *( PARGLUCOSE*(GLI(2, J)+GLI(1, J) )
7133      4  -GLI(2, J-1)-GLI(1, J-1) )
7134      5  -HHHHH/2. *( 3. *( GLA(2, J)-GLA(1, J) )
7135      6  +(GLA(2, J+1)-GLA(1, J+1) )/(4. *DT)
7136      6  -H/2. *( 3. * PARGLUCOSE*(GLA(2, J)-GLA(1, J) )
7137      7  +(GLA(2, J-1)-GLA(1, J-1) )/(4. *DT)
7138      7  -HHHHH/2. *( 3. *( GLI(2, J)-GLI(1, J) )
7139      8  +(GLI(2, J+1)-GLI(1, J+1) )/(4. *DT)
7140      8  -H/2. *( 3. * PARGLUCOSE*(GLI(2, J)-GLI(1, J) )
7141      9  +(GLI(2, J-1)-GLI(1, J-1) )/(4. *DT)
7142
7143      B(3, 3)=COEFF3HHHHH/2. +PARGLUCOSE*COEFF3H/2. +HHHHH/2. *3./(4. *DT)
7144      1  +PARGLUCOSE*H/2. *3./(4. *DT)
7145      D(3, 3)=-COEFF3HHHHH/2. +HHHHH/2. /(4. *DT)
7146      A(3, 3)=-COEFF3H/2. +H/2. /(4. *DT)
7147      B(3, 15)=COEFF10HHHHH/2. +PARGLUCOSE*COEFF10H/2.
7148      1  +HHHHH/2. *3./(4. *DT)+PARGLUCOSE*H/2. *3./(4. *DT)
7149      D(3, 15)=-COEFF10HHHHH/2. +HHHHH/2. /(4. *DT)
7150      A(3, 15)=-COEFF10H/2. +H/2. /(4. *DT)
7151
7152
7153      BIG=ABS(COEFF3HHHHH/2. *GLA(2, J+1) )
7154      BIG2=ABS(COEFF3HHHHH/2. *GLA(1, J+1) )
7155      IF (BIG2.GT. BIG) BIG=BIG2
7156      BIG3=ABS(COEFF3HHHHH/2. *GLA(2, J) )
7157      IF (BIG3.GT. BIG) BIG=BIG3
7158      BIG4=ABS(COEFF3HHHHH/2. *GLA(1, J) )
7159      IF (BIG4.GT. BIG) BIG=BIG4
7160      BIG5=ABS(COEFF3H/2. *GLA(2, J)*PARGLUCOSE)
7161      IF (BIG5.GT. BIG) BIG=BIG5
7162      BIG6=ABS(COEFF3H/2. *GLA(1, J)*PARGLUCOSE)
7163      IF (BIG6.GT. BIG) BIG=BIG6
7164      BIG7=ABS(COEFF3H/2. *GLA(2, J-1) )
7165      IF (BIG7.GT. BIG) BIG=BIG7
7166      BIG8=ABS(COEFF3H/2. *GLA(1, J-1) )
7167      IF (BIG8.GT. BIG) BIG=BIG8
7168      BIG13=ABS(HHHHH/2. *3. *GLA(2, J)/(4. *DT) )
7169      IF (BIG13.GT. BIG) BIG=BIG13
7170      BIG14=ABS(HHHHH/2. *3. *GLA(1, J)/(4. *DT) )
7171      IF (BIG14.GT. BIG) BIG=BIG14
7172      BIG15=ABS(HHHHH/2. *GLA(2, J+1)/(4. *DT) )
7173      IF (BIG15.GT. BIG) BIG=BIG15
7174      BIG16=ABS(HHHHH/2. *GLA(1, J+1)/(4. *DT) )
7175      IF (BIG16.GT. BIG) BIG=BIG16
7176      BIG17=ABS(H/2. *3. *GLA(2, J)/(4. *DT)*PARGLUCOSE)
7177      IF (BIG17.GT. BIG) BIG=BIG17
7178      BIG18=ABS(H/2. *3. *GLA(1, J)/(4. *DT)*PARGLUCOSE)
7179      IF (BIG18.GT. BIG) BIG=BIG18
7180      BIG19=ABS(H/2. *GLA(2, J-1)/(4. *DT) )
7181      IF (BIG19.GT. BIG) BIG=BIG19
7182      BIG20=ABS(H/2. *GLA(1, J-1)/(4. *DT) )
7183      IF (BIG20.GT. BIG) BIG=BIG20
7184      BIG21=ABS(COEFF10HHHHH/2. *GLI(2, J+1) )
7185      IF (BIG21.GT. BIG) BIG=BIG21
7186      BIG22=ABS(COEFF10HHHHH/2. *GLI(1, J+1) )
7187      IF (BIG22.GT. BIG) BIG=BIG22
7188      BIG23=ABS(COEFF10HHHHH/2. *GLI(2, J) )

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7189 IF (BIG23.GT.BIG) BIG=BIG23
7190 BIG24=ABS(COEFF10HHHHH/2.*GLI(1,J))
7191 IF (BIG24.GT.BIG) BIG=BIG24
7192 BIG25=ABS(COEFF10H/2.*GLI(2,J)*PARGLUCOSE)
7193 IF (BIG25.GT.BIG) BIG=BIG25
7194 BIG26=ABS(COEFF10H/2.*GLI(1,J)*PARGLUCOSE)
7195 IF (BIG26.GT.BIG) BIG=BIG26
7196 BIG27=ABS(COEFF10H/2.*GLI(2,J-1))
7197 IF (BIG27.GT.BIG) BIG=BIG27
7198 BIG28=ABS(COEFF10H/2.*GLI(1,J-1))
7199 IF (BIG28.GT.BIG) BIG=BIG28
7200 BIG29=ABS(HHHHH/2.*3.*GLI(2,J)/(4.*DT))
7201 IF (BIG29.GT.BIG) BIG=BIG29
7202 BIG30=ABS(HHHHH/2.*3.*GLI(1,J)/(4.*DT))
7203 IF (BIG30.GT.BIG) BIG=BIG30
7204 BIG31=ABS(HHHHH/2.*GLI(2,J+1)/(4.*DT))
7205 IF (BIG31.GT.BIG) BIG=BIG31
7206 BIG32=ABS(HHHHH/2.*GLI(1,J+1)/(4.*DT))
7207 IF (BIG32.GT.BIG) BIG=BIG32
7208 BIG33=ABS(H/2.*3.*GLI(2,J)/(4.*DT)*PARGLUCOSE)
7209 IF (BIG33.GT.BIG) BIG=BIG33
7210 BIG34=ABS(H/2.*3.*GLI(1,J)/(4.*DT)*PARGLUCOSE)
7211 IF (BIG34.GT.BIG) BIG=BIG34
7212 BIG35=ABS(H/2.*GLI(2,J-1)/(4.*DT))
7213 IF (BIG35.GT.BIG) BIG=BIG35
7214 BIG36=ABS(H/2.*GLI(1,J-1)/(4.*DT))
7215 IF (BIG36.GT.BIG) BIG=BIG36
7216 IF (ABS(G(3)).LT.BIG*EBIG) G(3)=0
7217
7218 C For GOx2, enzyme
7219 G(4)=(GOR(2,J)+GOR(1,J))/2.
7220 B(4,4)=-1./2.
7221
7222 C For O2, being consumed only G(5), COEFF5, -EQ2 (11)
7223 G(5)=COEFF5HHHHH/2.*(OXY(2,J+1)+OXY(1,J+1)-OXY(2,J)-OXY(1,J))
7224 1 -COEFF5H/2.*(PAR02*(OXY(2,J)+OXY(1,J))-OXY(2,J-1)-OXY(1,J-1))
7225 3 -HHHHH/2.*(3.*(OXY(2,J)-OXY(1,J)))
7226 4 +(OXY(2,J+1)-OXY(1,J+1))/(4.*DT)
7227 4 -H/2.*(3.*PAR02*(OXY(2,J)-OXY(1,J)))
7228 5 +(OXY(2,J-1)-OXY(1,J-1))/(4.*DT)
7229
7230 B(5,5)=COEFF5HHHHH/2.+PAR02*COEFF5H/2.+HHHHH/2.*3./(4.*DT)
7231 1 +PAR02*H/2.*3./(4.*DT)
7232 D(5,5)=-COEFF5HHHHH/2.+HHHHH/2./(4.*DT)
7233 A(5,5)=-COEFF5H/2.+H/2./(4.*DT)
7234
7235
7236
7237 BIG=ABS(COEFF5HHHHH/2.*OXY(2,J+1))
7238 BIG2=ABS(COEFF5HHHHH/2.*OXY(1,J+1))
7239 IF (BIG2.GT.BIG) BIG=BIG2
7240 BIG3=ABS(COEFF5HHHHH/2.*OXY(2,J))
7241 IF (BIG3.GT.BIG) BIG=BIG3
7242 BIG4=ABS(COEFF5HHHHH/2.*OXY(1,J))
7243 IF (BIG4.GT.BIG) BIG=BIG4
7244 BIG5=ABS(COEFF5H/2.*OXY(2,J)*PAR02)
7245 IF (BIG5.GT.BIG) BIG=BIG5
7246 BIG6=ABS(COEFF5H/2.*OXY(1,J)*PAR02)

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7247 IF (BIG6.GT.BIG) BIG=BIG6
7248 BIG7=ABS(COEFF5H/2.*OXY(2,J-1))
7249 IF (BIG7.GT.BIG) BIG=BIG7
7250 BIG8=ABS(COEFF5H/2.*OXY(1,J-1))
7251 IF (BIG8.GT.BIG) BIG=BIG8
7252 BIG13=ABS(HHHHH/2.*3.*OXY(2,J)/(4.*DT))
7253 IF (BIG13.GT.BIG) BIG=BIG13
7254 BIG14=ABS(HHHHH/2.*3.*OXY(1,J)/(4.*DT))
7255 IF (BIG14.GT.BIG) BIG=BIG14
7256 BIG15=ABS(HHHHH/2.*OXY(2,J+1)/(4.*DT))
7257 IF (BIG15.GT.BIG) BIG=BIG15
7258 BIG16=ABS(HHHHH/2.*OXY(1,J+1)/(4.*DT))
7259 IF (BIG16.GT.BIG) BIG=BIG16
7260 BIG17=ABS(H/2.*3.*OXY(2,J)/(4.*DT)*PAR02)
7261 IF (BIG17.GT.BIG) BIG=BIG17
7262 BIG18=ABS(H/2.*3.*OXY(1,J)/(4.*DT)*PAR02)
7263 IF (BIG18.GT.BIG) BIG=BIG18
7264 BIG19=ABS(H/2.*OXY(2,J-1)/(4.*DT))
7265 IF (BIG19.GT.BIG) BIG=BIG19
7266 BIG20=ABS(H/2.*OXY(1,J-1)/(4.*DT))
7267 IF (BIG20.GT.BIG) BIG=BIG20
7268 IF (ABS(G(5)).LT.BIG*EBIG) G(5)=0
7269
7270 C For H2O2, reacting species COEFF6, G(6), +RHP (12), HPR
7271 G(6)=COEFF6HHHHH/2.*(HPR(2,J+1)+HPR(1,J+1)-HPR(2,J)-HPR(1,J))
7272 1 -COEFF6H/2.*(PARH2O2*(HPR(2,J)+HPR(1,J))-HPR(2,J-1)-HPR(1,J-1))
7273 3 -HHHHH/2.*(3.*(HPR(2,J)-HPR(1,J))
7274 4 +(HPR(2,J+1)-HPR(1,J+1)))/(4.*DT)
7275 4 -H/2.*(3.*PARH2O2*(HPR(2,J)-HPR(1,J))
7276 5 +(HPR(2,J-1)-HPR(1,J-1)))/(4.*DT)
7277
7278 B(6,6)=COEFF6HHHHH/2.+PARH2O2*COEFF6H/2.+HHHHH/2.*3./(4.*DT)
7279 1 +PARH2O2*H/2.*3./(4.*DT)
7280 D(6,6)=-COEFF6HHHHH/2.+HHHHH/2./(4.*DT)
7281 A(6,6)=-COEFF6H/2.+H/2./(4.*DT)
7282
7283
7284 BIG=ABS(COEFF6HHHHH/2.*HPR(2,J+1))
7285 BIG2=ABS(COEFF6HHHHH/2.*HPR(1,J+1))
7286 IF (BIG2.GT.BIG) BIG=BIG2
7287 BIG3=ABS(COEFF6HHHHH/2.*HPR(2,J))
7288 IF (BIG3.GT.BIG) BIG=BIG3
7289 BIG4=ABS(COEFF6HHHHH/2.*HPR(1,J))
7290 IF (BIG4.GT.BIG) BIG=BIG4
7291 BIG5=ABS(COEFF6H/2.*HPR(2,J)*PARH2O2)
7292 IF (BIG5.GT.BIG) BIG=BIG5
7293 BIG6=ABS(COEFF6H/2.*HPR(1,J)*PARH2O2)
7294 IF (BIG6.GT.BIG) BIG=BIG6
7295 BIG7=ABS(COEFF6H/2.*HPR(2,J-1))
7296 IF (BIG7.GT.BIG) BIG=BIG7
7297 BIG8=ABS(COEFF6H/2.*HPR(1,J-1))
7298 IF (BIG8.GT.BIG) BIG=BIG8
7299 BIG13=ABS(HHHHH/2.*3.*HPR(2,J)/(4.*DT))
7300 IF (BIG13.GT.BIG) BIG=BIG13
7301 BIG14=ABS(HHHHH/2.*3.*HPR(1,J)/(4.*DT))
7302 IF (BIG14.GT.BIG) BIG=BIG14
7303 BIG15=ABS(HHHHH/2.*HPR(2,J+1)/(4.*DT))
7304 IF (BIG15.GT.BIG) BIG=BIG15

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7305 BIG16=ABS(HHHHH/2.*HPR(1,J+1)/(4.*DT))
7306 IF (BIG16.GT.BIG) BIG=BIG16
7307 BIG17=ABS(H/2.*3.*HPR(2,J)/(4.*DT)*PARH2O2)
7308 IF (BIG17.GT.BIG) BIG=BIG17
7309 BIG18=ABS(H/2.*3.*HPR(1,J)/(4.*DT)*PARH2O2)
7310 IF (BIG18.GT.BIG) BIG=BIG18
7311 BIG19=ABS(H/2.*HPR(2,J-1)/(4.*DT))
7312 IF (BIG19.GT.BIG) BIG=BIG19
7313 BIG20=ABS(H/2.*HPR(1,J-1)/(4.*DT))
7314 IF (BIG20.GT.BIG) BIG=BIG20
7315 IF (ABS(G(6)).LT.BIG*EBIG) G(6)=0
7316
7317 C For CX-GOx2, enzyme complex
7318 G(7)=(GOA(2,J)+GOA(1,J))/2.
7319 B(7,7)=-1./2.
7320
7321 C For CX-GOx, enzyme complex
7322 G(8)=(GOP(2,J)+GOP(1,J))/2.
7323 B(8,8)=-1./2.
7324
7325 C For Reaction 1 Enzymatic Catalysis
7326 G(9)=(EQ1(2,J)+EQ1(1,J))/2.
7327 B(9,9)=-1./2.
7328
7329 C For Reaction 2
7330 G(10)=(RGA(2,J)+RGA(1,J))/2.
7331 B(10,10)=-1./2.
7332
7333 C For Reaction 3 Meditation/regeneration
7334 G(11)=(EQ2(2,J)+EQ2(1,J))/2.
7335 B(11,11)=-1./2.
7336
7337 C For Reaction 4
7338 G(12)=(RHP(2,J)+RHP(1,J))/2.
7339 B(12,12)=-1./2.
7340
7341 C REACTIONS
7342 218 G(13)=-((ANM(2,J)+ANM(1,J))/2.+ratef5*((GLUA(2,J)+GLUA(1,J))/2.
7343 1 -(GLU(2,J)+GLU(1,J))/2./equilib5)
7344 B(13,1)=ratef5/2./equilib5
7345 B(13,14)=-ratef5/2.
7346 B(13,13)=+1./2.
7347
7348 BIG=ABS(ANM(2,J)/2.)
7349 BIG2=ABS(ANM(1,J)/2.)
7350 IF (BIG2.GT.BIG) BIG=BIG2
7351 BIG3=ABS(ratef5*GLUA(2,J)/2.)
7352 IF (BIG3.GT.BIG) BIG=BIG3
7353 BIG4=ABS(ratef5*GLUA(1,J)/2.)
7354 IF (BIG4.GT.BIG) BIG=BIG4
7355 BIG5=ABS(ratef5*GLU(2,J)/2./equilib5)
7356 IF (BIG5.GT.BIG) BIG=BIG5
7357 BIG6=ABS(ratef5*GLU(1,J)/2./equilib5)
7358 IF (BIG6.GT.BIG) BIG=BIG6
7359 IF (ABS(G(13)).LT.BIG*EBIG) G(13)=0.0
7360
7361 C For alpha Glucose, being consumed only
7362 G(14)=COEFF9HHHHH/2.*(GLUA(2,J+1)+GLUA(1,J+1)-GLUA(2,J)-GLUA(1,J))

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7363 1 -COEFF9H/2.* (PARGLUCOSE*(GLUA(2,J)
7364 2 +GLUA(1,J))-GLUA(2,J-1)-GLUA(1,J-1))
7365 2 -(HHHHH/2.)*(3.*(ANM(2,J)+ANM(1,J))+(ANM(2,J+1)+ANM(1,J+1)))/8.
7366 3 -(H/2.)*(3.*PARGLUCOSE*(ANM(2,J)
7367 4 +ANM(1,J))+(ANM(2,J-1)+ANM(1,J-1)))/8.
7368 4 -HHHHH/2.
7369 5 *(3.*(GLUA(2,J)-GLUA(1,J))+(GLUA(2,J+1)-GLUA(1,J+1)))/(4.*DT)
7370 6 -H/2.
7371 7 *(3.*PARGLUCOSE*(GLUA(2,J)-GLUA(1,J))
7372 8 +(GLUA(2,J-1)-GLUA(1,J-1)))/(4.*DT)
7373
7374
7375 B(14,14)=COEFF9HHHHH/2.+COEFF9H/2.*PARGLUCOSE+HHHHH/2.*3./(4.*DT)
7376 1 +H/2.*3.*PARGLUCOSE/(4.*DT)
7377 D(14,14)=-COEFF9HHHHH/2.+HHHHH/2./(4.*DT)
7378 A(14,14)=-COEFF9H/2.+H/2./(4.*DT)
7379 B(14,13)=+(HHHHH/2.)*(3./8.)+(H/2.)*(3./8.)*PARGLUCOSE
7380 D(14,13)=+(HHHHH/2.)*(1./8.)
7381 A(14,13)=+(H/2.)*(1./8.)
7382
7383 BIG=ABS(COEFF9HHHHH/2.*GLUA(2,J+1))
7384 BIG2=ABS(COEFF9HHHHH/2.*GLUA(1,J+1))
7385 IF (BIG2.GT.BIG) BIG=BIG2
7386 BIG3=ABS(COEFF9HHHHH/2.*GLUA(2,J))
7387 IF (BIG3.GT.BIG) BIG=BIG3
7388 BIG4=ABS(COEFF9HHHHH/2.*GLUA(1,J))
7389 IF (BIG4.GT.BIG) BIG=BIG4
7390 BIG5=ABS(COEFF9H/2.*GLUA(2,J)*PARGLUCOSE)
7391 IF (BIG5.GT.BIG) BIG=BIG5
7392 BIG6=ABS(COEFF9H/2.*GLUA(1,J))
7393 IF (BIG6.GT.BIG) BIG=BIG6
7394 BIG7=ABS(COEFF9H/2.*GLUA(2,J-1))
7395 IF (BIG7.GT.BIG) BIG=BIG7
7396 BIG8=ABS(COEFF9H/2.*GLUA(1,J-1))
7397 IF (BIG8.GT.BIG) BIG=BIG8
7398 BIG9=ABS(HHHHH/2.*3.*GLUA(2,J)/(4.*DT))
7399 IF (BIG9.GT.BIG) BIG=BIG9
7400 BIG10=ABS(HHHHH/2.*3.*GLUA(1,J)/(4.*DT))
7401 IF (BIG10.GT.BIG) BIG=BIG10
7402 BIG11=ABS(HHHHH/2.*GLUA(2,J+1)/(4.*DT))
7403 IF (BIG11.GT.BIG) BIG=BIG11
7404 BIG12=ABS(HHHHH/2.*GLUA(1,J+1)/(4.*DT))
7405 IF (BIG12.GT.BIG) BIG=BIG12
7406 BIG13=ABS(H/2.*3.*GLUA(2,J)/(4.*DT)*PARGLUCOSE)
7407 IF (BIG13.GT.BIG) BIG=BIG13
7408 BIG14=ABS(H/2.*3.*GLUA(1,J)/(4.*DT)*PARGLUCOSE)
7409 IF (BIG14.GT.BIG) BIG=BIG14
7410 BIG15=ABS(H/2.*GLUA(2,J-1)/(4.*DT))
7411 IF (BIG15.GT.BIG) BIG=BIG15
7412 BIG16=ABS(H/2.*GLUA(1,J-1)/(4.*DT))
7413 IF (BIG16.GT.BIG) BIG=BIG16
7414 BIG17=ABS(HHHHH/2.*3.*ANM(2,J)/8.)
7415 IF (BIG17.GT.BIG) BIG=BIG17
7416 BIG18=ABS(HHHHH/2.*3.*ANM(1,J)/8.)
7417 IF (BIG18.GT.BIG) BIG=BIG18
7418 BIG19=ABS(HHHHH/2.*ANM(2,J+1)/8.)
7419 IF (BIG19.GT.BIG) BIG=BIG19
7420 BIG20=ABS(HHHHH/2.*ANM(1,J+1)/8.)

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7421 IF (BIG20.GT.BIG) BIG=BIG20  
 7422 BIG21=ABS(H/2.\*3.\*ANM(2,J)/8.\*PARGLUCOSE)  
 7423 IF (BIG21.GT.BIG) BIG=BIG21  
 7424 BIG22=ABS(H/2.\*3.\*ANM(1,J)/8.\*PARGLUCOSE)  
 7425 IF (BIG22.GT.BIG) BIG=BIG22  
 7426 BIG23=ABS(H/2.\*ANM(2,J-1)/8.)  
 7427 IF (BIG23.GT.BIG) BIG=BIG23  
 7428 BIG24=ABS(H/2.\*ANM(1,J-1)/8.)  
 7429 IF (BIG24.GT.BIG) BIG=BIG24  
 7430 IF (ABS(G(14)).LT.BIG\*EBIG) G(14)=0  
 7431

7432 C Gluconic acid dissociation

7433  
 7434 G(15)=equilib6\*(GLA(2,J)+GLA(1,J))/2.-(GLI(2,J)+GLI(1,J))\*  
 7435 1 (HYD(2,J)+HYD(1,J))/4.  
 7436 B(15,3)=-equilib6/2.  
 7437 B(15,15)=(HYD(2,J)+HYD(1,J))/4.  
 7438 B(15,16)=(GLI(2,J)+GLI(1,J))/4.  
 7439  
 7440 BIG=ABS(equilib6\*GLA(2,J)/2.)  
 7441 BIG2=ABS(equilib6\*GLA(1,J)/2.)  
 7442 IF (BIG2.GT.BIG) BIG=BIG2  
 7443 BIG3=ABS(GLI(2,J)\*HYD(2,J)/4.)  
 7444 IF (BIG3.GT.BIG) BIG=BIG3  
 7445 BIG4=ABS(GLI(2,J)\*HYD(1,J)/4)  
 7446 IF (BIG4.GT.BIG) BIG=BIG4  
 7447 BIG5=ABS(GLI(1,J)\*HYD(2,J)/4)  
 7448 IF (BIG5.GT.BIG) BIG=BIG5  
 7449 BIG6=ABS(GLI(1,J)\*HYD(1,J)/4)  
 7450 IF (BIG6.GT.BIG) BIG=BIG6  
 7451 IF (ABS(G(15)).LT.BIG\*EBIG) G(15)=0  
 7452

7453 C Hydrogen ion, hydroxide ion, gluconate ion, bicarbonate ion flux

7454  
 7455 G(16)=COEFF11HHHHH/2.\*(HYD(2,J+1)+HYD(1,J+1)-HYD(2,J)-HYD(1,J))  
 7456 1 -COEFF11H/2.\*(PARION\*(HYD(2,J)+HYD(1,J))-HYD(2,J-1)-HYD(1,J-1))  
 7457 2 -COEFF15HHHHH/2.\*(OHI(2,J+1)+OHI(1,J+1)-OHI(2,J)-OHI(1,J))  
 7458 3 +COEFF15H/2.\*(PARION\*(OHI(2,J)+OHI(1,J))-OHI(2,J-1)-OHI(1,J-1))  
 7459 4 -COEFF10HHHHH/2.\*(GLI(2,J+1)+GLI(1,J+1)-GLI(2,J)-GLI(1,J))  
 7460 5 +COEFF10H/2.\*(PARGLUCOSE\*(GLI(2,J)+GLI(1,J))  
 7461 6 -GLI(2,J-1)-GLI(1,J-1))  
 7462 6 -COEFF14HHHHH/2.\*(CBI(2,J+1)+CBI(1,J+1)-CBI(2,J)-CBI(1,J))  
 7463 7 +COEFF14H/2.\*(PARION\*(CBI(2,J)+CBI(1,J))-CBI(2,J-1)-CBI(1,J-1))  
 7464 8 -HHHHH/2.\*(3.\*(HYD(2,J)-HYD(1,J))  
 7465 9 +(HYD(2,J+1)-HYD(1,J+1)))/(4.\*DT)  
 7466 9 -H/2.\*(3.\*PARION\*(HYD(2,J)-HYD(1,J))  
 7467 1 +(HYD(2,J-1)-HYD(1,J-1)))/(4.\*DT)  
 7468 1 +HHHHH/2.\*(3.\*(OHI(2,J)-OHI(1,J))  
 7469 2 +(OHI(2,J+1)-OHI(1,J+1)))/(4.\*DT)  
 7470 2 +H/2.\*(3.\*PARION\*(OHI(2,J)-OHI(1,J))  
 7471 3 +(OHI(2,J-1)-OHI(1,J-1)))/(4.\*DT)  
 7472 3 +HHHHH/2.\*(3.\*(GLI(2,J)-GLI(1,J))  
 7473 4 +(GLI(2,J+1)-GLI(1,J+1)))/(4.\*DT)  
 7474 4 +H/2.\*(3.\*PARGLUCOSE\*(GLI(2,J)-GLI(1,J))  
 7475 5 +(GLI(2,J-1)-GLI(1,J-1)))/(4.\*DT)  
 7476 5 +HHHHH/2.\*(3.\*(CBI(2,J)-CBI(1,J))  
 7477 6 +(CBI(2,J+1)-CBI(1,J+1)))/(4.\*DT)  
 7478 6 +H/2.\*(3.\*PARION\*(CBI(2,J)-CBI(1,J))

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7479      7  +(CBI(2 ,J -1)-CBI(1 ,J -1)))/(4 . *DT)
7480
7481      B(16 ,16)=COEFF11HHHHH/2 . +PARION*COEFF11H/2 . +HHHHH/2 . *3 ./(4 . *DT)
7482      1  +H/2 . *3 . *PARION/(4 . *DT)
7483      D(16 ,16)=-COEFF11HHHHH/2 . +HHHHH/2 ./(4 . *DT)
7484      A(16 ,16)=-COEFF11H/2 . +H/2 ./(4 . *DT)
7485
7486      B(16 ,17)=-COEFF15HHHHH/2 . -PARION*COEFF15H/2 . -HHHHH/2 . *3 ./(4 . *DT)
7487      1  -H/2 . *3 . *PARION/(4 . *DT)
7488      D(16 ,17)=+COEFF15HHHHH/2 . -HHHHH/2 ./(4 . *DT)
7489      A(16 ,17)=+COEFF15H/2 . -H/2 ./(4 . *DT)
7490
7491      B(16 ,15)=-COEFF10HHHHH/2 . -PARGLUCOSE*COEFF10H/2 .
7492      1  -HHHHH/2 . *3 ./(4 . *DT)-H/2 . *3 . *PARGLUCOSE/(4 . *DT)
7493      D(16 ,15)=+COEFF10HHHHH/2 . -HHHHH/2 ./(4 . *DT)
7494      A(16 ,15)=+COEFF10H/2 . -H/2 ./(4 . *DT)
7495
7496      B(16 ,20)=-COEFF14HHHHH/2 . -PARION*COEFF14H/2 . -HHHHH/2 . *3 ./(4 . *DT)
7497      1  -H/2 . *3 . *PARION/(4 . *DT)
7498      D(16 ,20)=+COEFF14HHHHH/2 . -HHHHH/2 ./(4 . *DT)
7499      A(16 ,20)=+COEFF14H/2 . -H/2 ./(4 . *DT)
7500
7501      BIG=ABS(COEFF11HHHHH/2 . *HYD(2 ,J +1))
7502      BIG2=ABS(COEFF11HHHHH/2 . *HYD(1 ,J +1))
7503      IF (BIG2 .GT. BIG) BIG=BIG2
7504      BIG3=ABS(COEFF11HHHHH/2 . *HYD(2 ,J ))
7505      IF (BIG3 .GT. BIG) BIG=BIG3
7506      BIG4=ABS(COEFF11HHHHH/2 . *HYD(1 ,J ))
7507      IF (BIG4 .GT. BIG) BIG=BIG4
7508      BIG5=ABS(COEFF11H/2 . *HYD(2 ,J ) *PARION)
7509      IF (BIG5 .GT. BIG) BIG=BIG5
7510      BIG6=ABS(COEFF11H/2 . *HYD(1 ,J ) *PARION)
7511      IF (BIG6 .GT. BIG) BIG=BIG6
7512      BIG7=ABS(COEFF11H/2 . *HYD(2 ,J -1))
7513      IF (BIG7 .GT. BIG) BIG=BIG7
7514      BIG8=ABS(COEFF11H/2 . *HYD(1 ,J -1))
7515      IF (BIG8 .GT. BIG) BIG=BIG8
7516      BIG9=ABS(HHHHH/2 . *3 . *HYD(2 ,J )/(4 . *DT))
7517      IF (BIG9 .GT. BIG) BIG=BIG9
7518      BIG10=ABS(HHHHH/2 . *3 . *HYD(1 ,J )/(4 . *DT))
7519      IF (BIG10 .GT. BIG) BIG=BIG10
7520      BIG11=ABS(HHHHH/2 . *HYD(2 ,J +1)/(4 . *DT))
7521      IF (BIG11 .GT. BIG) BIG=BIG11
7522      BIG12=ABS(HHHHH/2 . *HYD(1 ,J +1)/(4 . *DT))
7523      IF (BIG12 .GT. BIG) BIG=BIG12
7524      BIG13=ABS(H/2 . *3 . *HYD(2 ,J ) *PARION/(4 . *DT))
7525      IF (BIG13 .GT. BIG) BIG=BIG13
7526      BIG14=ABS(H/2 . *3 . *HYD(1 ,J ) *PARION/(4 . *DT))
7527      IF (BIG14 .GT. BIG) BIG=BIG14
7528      BIG15=ABS(H/2 . *HYD(2 ,J -1)/(4 . *DT))
7529      IF (BIG15 .GT. BIG) BIG=BIG15
7530      BIG16=ABS(H/2 . *HYD(1 ,J -1)/(4 . *DT))
7531      IF (BIG16 .GT. BIG) BIG=BIG16
7532      BIG17=ABS(COEFF15HHHHH/2 . *OHI(2 ,J +1))
7533      IF (BIG17 .GT. BIG) BIG=BIG17
7534      BIG18=ABS(COEFF15HHHHH/2 . *OHI(1 ,J +1))
7535      IF (BIG18 .GT. BIG) BIG=BIG18
7536      BIG19=ABS(COEFF15HHHHH/2 . *OHI(2 ,J ))

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7537 IF (BIG19.GT.BIG) BIG=BIG19
7538 BIG20=ABS(COEFF15HHHHH/2.*OHI(1,J))
7539 IF (BIG20.GT.BIG) BIG=BIG20
7540 BIG21=ABS(COEFF15H/2.*OHI(2,J)*PARION)
7541 IF (BIG21.GT.BIG) BIG=BIG21
7542 BIG22=ABS(COEFF15H/2.*OHI(1,J)*PARION)
7543 IF (BIG22.GT.BIG) BIG=BIG22
7544 BIG23=ABS(COEFF15H/2.*OHI(2,J-1))
7545 IF (BIG23.GT.BIG) BIG=BIG23
7546 BIG24=ABS(COEFF15H/2.*OHI(1,J-1))
7547 IF (BIG24.GT.BIG) BIG=BIG24
7548 BIG25=ABS(HHHHH/2.*3.*OHI(2,J)/(4.*DT))
7549 IF (BIG25.GT.BIG) BIG=BIG25
7550 BIG26=ABS(HHHHH/2.*3.*OHI(1,J)/(4.*DT))
7551 IF (BIG26.GT.BIG) BIG=BIG26
7552 BIG27=ABS(HHHHH/2.*OHI(2,J+1)/(4.*DT))
7553 IF (BIG27.GT.BIG) BIG=BIG27
7554 BIG28=ABS(HHHHH/2.*OHI(1,J+1)/(4.*DT))
7555 IF (BIG28.GT.BIG) BIG=BIG28
7556 BIG29=ABS(H/2.*3.*OHI(2,J)/(4.*DT)*PARION)
7557 IF (BIG29.GT.BIG) BIG=BIG29
7558 BIG30=ABS(H/2.*3.*OHI(1,J)/(4.*DT)*PARION)
7559 IF (BIG30.GT.BIG) BIG=BIG30
7560 BIG31=ABS(H/2.*OHI(2,J-1)/(4.*DT))
7561 IF (BIG31.GT.BIG) BIG=BIG31
7562 BIG32=ABS(H/2.*OHI(1,J-1)/(4.*DT))
7563 IF (BIG32.GT.BIG) BIG=BIG32
7564 BIG33=ABS(COEFF10HHHHH/2.*GLI(2,J+1))
7565 IF (BIG33.GT.BIG) BIG=BIG33
7566 BIG34=ABS(COEFF10HHHHH/2.*GLI(1,J+1))
7567 IF (BIG34.GT.BIG) BIG=BIG34
7568 BIG35=ABS(COEFF10HHHHH/2.*GLI(2,J))
7569 IF (BIG35.GT.BIG) BIG=BIG35
7570 BIG36=ABS(COEFF10HHHHH/2.*GLI(1,J))
7571 IF (BIG36.GT.BIG) BIG=BIG36
7572 BIG37=ABS(COEFF10H/2.*GLI(2,J)*PARGLUCOSE)
7573 IF (BIG37.GT.BIG) BIG=BIG37
7574 BIG38=ABS(COEFF10H/2.*GLI(1,J)*PARGLUCOSE)
7575 IF (BIG38.GT.BIG) BIG=BIG38
7576 BIG39=ABS(COEFF10H/2.*GLI(2,J-1))
7577 IF (BIG39.GT.BIG) BIG=BIG39
7578 BIG40=ABS(COEFF10H/2.*GLI(1,J-1))
7579 IF (BIG40.GT.BIG) BIG=BIG40
7580 BIG41=ABS(HHHHH/2.*3.*GLI(2,J)/(4.*DT))
7581 IF (BIG41.GT.BIG) BIG=BIG41
7582 BIG42=ABS(HHHHH/2.*3.*GLI(1,J)/(4.*DT))
7583 IF (BIG42.GT.BIG) BIG=BIG42
7584 BIG43=ABS(HHHHH/2.*GLI(2,J+1)/(4.*DT))
7585 IF (BIG43.GT.BIG) BIG=BIG43
7586 BIG44=ABS(HHHHH/2.*GLI(1,J+1)/(4.*DT))
7587 IF (BIG44.GT.BIG) BIG=BIG44
7588 BIG45=ABS(H/2.*3.*GLI(2,J)/(4.*DT)*PARGLUCOSE)
7589 IF (BIG45.GT.BIG) BIG=BIG45
7590 BIG46=ABS(H/2.*3.*GLI(1,J)/(4.*DT)*PARGLUCOSE)
7591 IF (BIG46.GT.BIG) BIG=BIG46
7592 BIG47=ABS(H/2.*GLI(2,J-1)/(4.*DT))
7593 IF (BIG47.GT.BIG) BIG=BIG47
7594 BIG48=ABS(H/2.*GLI(1,J-1)/(4.*DT))

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7595 IF (BIG48.GT.BIG) BIG=BIG48
7596 BIG49=ABS(COEFF14HHHHH/2.*CBI(2,J+1))
7597 IF (BIG49.GT.BIG) BIG=BIG49
7598 BIG50=ABS(COEFF14HHHHH/2.*CBI(1,J+1))
7599 IF (BIG50.GT.BIG) BIG=BIG50
7600 BIG51=ABS(COEFF14HHHHH/2.*CBI(2,J))
7601 IF (BIG51.GT.BIG) BIG=BIG51
7602 BIG52=ABS(COEFF14HHHHH/2.*CBI(1,J))
7603 IF (BIG52.GT.BIG) BIG=BIG52
7604 BIG53=ABS(COEFF14H/2.*CBI(2,J)*PARION)
7605 IF (BIG53.GT.BIG) BIG=BIG53
7606 BIG54=ABS(COEFF14H/2.*CBI(1,J)*PARION)
7607 IF (BIG54.GT.BIG) BIG=BIG54
7608 BIG55=ABS(COEFF14H/2.*CBI(2,J-1))
7609 IF (BIG55.GT.BIG) BIG=BIG55
7610 BIG56=ABS(COEFF14H/2.*CBI(1,J-1))
7611 IF (BIG56.GT.BIG) BIG=BIG56
7612 BIG57=ABS(HHHHH/2.*3.*CBI(2,J)/(4.*DT))
7613 IF (BIG57.GT.BIG) BIG=BIG57
7614 BIG58=ABS(HHHHH/2.*3.*CBI(1,J)/(4.*DT))
7615 IF (BIG58.GT.BIG) BIG=BIG58
7616 BIG59=ABS(HHHHH/2.*CBI(2,J+1)/(4.*DT))
7617 IF (BIG59.GT.BIG) BIG=BIG59
7618 BIG60=ABS(HHHHH/2.*CBI(1,J+1)/(4.*DT))
7619 IF (BIG60.GT.BIG) BIG=BIG60
7620 BIG61=ABS(H/2.*3.*CBI(2,J)/(4.*DT)*PARION)
7621 IF (BIG61.GT.BIG) BIG=BIG61
7622 BIG62=ABS(H/2.*3.*CBI(1,J)/(4.*DT)*PARION)
7623 IF (BIG62.GT.BIG) BIG=BIG62
7624 BIG63=ABS(H/2.*CBI(2,J-1)/(4.*DT))
7625 IF (BIG63.GT.BIG) BIG=BIG63
7626 BIG64=ABS(H/2.*CBI(1,J-1)/(4.*DT))
7627 IF (BIG64.GT.BIG) BIG=BIG64
7628 IF (ABS(G(16)).LT.BIG*EBIG) G(16)=0
7629
7630 c Water Dissociation
7631 G(17)=equilib9-(HYD(2,J)+HYD(1,J))*(OHI(2,J)+OHI(1,J))/4.
7632 B(17,17)=(HYD(2,J)+HYD(1,J))/4.
7633 B(17,16)=(OHI(2,J)+OHI(1,J))/4.
7634
7635 BIG=ABS(equilib9)
7636 BIG2=ABS(HYD(2,J)*OHI(2,J)/4.)
7637 IF (BIG2.GT.BIG) BIG=BIG2
7638 BIG3=ABS(HYD(2,J)*OHI(1,J)/4.)
7639 IF (BIG3.GT.BIG) BIG=BIG3
7640 BIG4=ABS(HYD(1,J)*OHI(2,J)/4.)
7641 IF (BIG4.GT.BIG) BIG=BIG4
7642 BIG5=ABS(HYD(1,J)*OHI(1,J)/4.)
7643 IF (BIG5.GT.BIG) BIG=BIG5
7644 IF (ABS(G(17)).LT.BIG*EBIG) G(17)=0
7645
7646 C CO2 Hydration
7647
7648 G(18)=equilib7*(CO2(2,J)+CO2(1,J))/2.-(CBA(2,J)+CBA(1,J))/2.
7649 B(18,18)=-equilib7/2.
7650 B(18,19)=1./2.
7651
7652 BIG=ABS(equilib7*CO2(2,J)/2.)

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7653     BIG2=ABS(equilib7*CO2(1,J)/2.)
7654     IF (BIG2.GT.BIG) BIG=BIG2
7655     BIG3=ABS(CBA(2,J)/2.)
7656     IF (BIG3.GT.BIG) BIG=BIG3
7657     BIG4=ABS(CBA(1,J)/2.)
7658     IF (BIG4.GT.BIG) BIG=BIG4
7659     IF (ABS(G(18)).LT.BIG*EBIG) G(18)=0
7660
7661 C Carbonic acid dissociation
7662
7663     G(19)=equilib8*(CBA(2,J)+CBA(1,J))/2.-(CBI(2,J)+CBI(1,J))
7664     1 *(HYD(2,J)+HYD(1,J))/4.
7665     B(19,19)=-equilib8/2.
7666     B(19,20)=(HYD(2,J)+HYD(1,J))/4.
7667     B(19,16)=(CBI(2,J)+CBI(1,J))/4.
7668
7669     BIG=ABS(equilib8*CBA(2,J)/2.)
7670     BIG2=ABS(equilib8*CBA(1,J)/2.)
7671     IF (BIG2.GT.BIG) BIG=BIG2
7672     BIG3=ABS(CBI(2,J)*HYD(2,J)/4.)
7673     IF (BIG3.GT.BIG) BIG=BIG3
7674     BIG4=ABS(CBI(2,J)*HYD(1,J)/4.)
7675     IF (BIG4.GT.BIG) BIG=BIG4
7676     BIG5=ABS(CBI(1,J)*HYD(2,J)/4.)
7677     IF (BIG5.GT.BIG) BIG=BIG5
7678     BIG6=ABS(CBI(1,J)*HYD(1,J)/4.)
7679     IF (BIG6.GT.BIG) BIG=BIG6
7680     IF (ABS(G(19)).LT.BIG*EBIG) G(19)=0
7681
7682 C FLUX OF CO2, CARBONIC ACID, BICARBONATE ION
7683     G(20)=COEFF12HHHHH/2.*(CO2(2,J+1)+CO2(1,J+1)-CO2(2,J)-CO2(1,J))
7684     1 -COEFF12H/2.*(PARION*(CO2(2,J)+CO2(1,J))-CO2(2,J-1)-CO2(1,J-1))
7685     2 +COEFF13HHHHH/2.*(CBA(2,J+1)+CBA(1,J+1)-CBA(2,J)-CBA(1,J))
7686     3 -COEFF13H/2.*(PARION*(CBA(2,J)+CBA(1,J))-CBA(2,J-1)-CBA(1,J-1))
7687     4 +COEFF14HHHHH/2.*(CBI(2,J+1)+CBI(1,J+1)-CBI(2,J)-CBI(1,J))
7688     5 -COEFF14H/2.*(PARION*(CBI(2,J)+CBI(1,J))-CBI(2,J-1)-CBI(1,J-1))
7689     6 -HHHHH/2.*(3.*(CO2(2,J)-CO2(1,J))
7690     7 +(CO2(2,J+1)-CO2(1,J+1)))/(4.*DT)
7691     7 -H/2.*(3.*PARION*(CO2(2,J)-CO2(1,J))
7692     8 +(CO2(2,J-1)-CO2(1,J-1)))/(4.*DT)
7693     8 -HHHHH/2.*(3.*(CBA(2,J)-CBA(1,J))
7694     9 +(CBA(2,J+1)-CBA(1,J+1)))/(4.*DT)
7695     9 -H/2.*(3.*PARION*(CBA(2,J)-CBA(1,J))
7696     1 +(CBA(2,J-1)-CBA(1,J-1)))/(4.*DT)
7697     1 -HHHHH/2.*(3.*(CBI(2,J)-CBI(1,J))
7698     2 +(CBI(2,J+1)-CBI(1,J+1)))/(4.*DT)
7699     2 -H/2.*(3.*PARION*(CBI(2,J)-CBI(1,J))
7700     3 +(CBI(2,J-1)-CBI(1,J-1)))/(4.*DT)
7701
7702     B(20,20)=COEFF14HHHHH/2.+PARION*COEFF14H/2.+HHHHH/2.*3./(4.*DT)
7703     1 +H/2.*3./(4.*DT)*PARION
7704     D(20,20)=-COEFF14HHHHH/2.+HHHHH/2./(4.*DT)
7705     A(20,20)=-COEFF14H/2.+H/2./(4.*DT)
7706     B(20,18)=COEFF12HHHHH/2.+PARION*COEFF12H/2.+HHHHH/2.*3./(4.*DT)
7707     1 +H/2.*3./(4.*DT)*PARION
7708     D(20,18)=-COEFF12HHHHH/2.+HHHHH/2./(4.*DT)
7709     A(20,18)=-COEFF12H/2.+H/2./(4.*DT)
7710     B(20,19)=COEFF13HHHHH/2.+PARION*COEFF13H/2.+HHHHH/2.*3./(4.*DT)

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7711 1 +H/2.*3./(4.*DT)*PARION
7712 D(20,19)=-COEFF13HHHHH/2.+HHHHH/2./(4.*DT)
7713 A(20,19)=-COEFF13H/2.+H/2./(4.*DT)
7714
7715 BIG=ABS(COEFF12HHHHH/2.*CO2(2,J+1))
7716 BIG2=ABS(COEFF12HHHHH/2.*CO2(1,J+1))
7717 IF (BIG2.GT.BIG) BIG=BIG2
7718 BIG3=ABS(COEFF12HHHHH/2.*CO2(2,J))
7719 IF (BIG3.GT.BIG) BIG=BIG3
7720 BIG4=ABS(COEFF12HHHHH/2.*CO2(1,J))
7721 IF (BIG4.GT.BIG) BIG=BIG4
7722 BIG5=ABS(COEFF12H/2.*CO2(2,J)*PARION)
7723 IF (BIG5.GT.BIG) BIG=BIG5
7724 BIG6=ABS(COEFF12H/2.*CO2(1,J)*PARION)
7725 IF (BIG6.GT.BIG) BIG=BIG6
7726 BIG7=ABS(COEFF12H/2.*CO2(2,J-1))
7727 IF (BIG7.GT.BIG) BIG=BIG7
7728 BIG8=ABS(COEFF12H/2.*CO2(1,J-1))
7729 IF (BIG8.GT.BIG) BIG=BIG8
7730 BIG9=ABS(HHHHH/2.*3.*CO2(2,J)/(4.*DT))
7731 IF (BIG9.GT.BIG) BIG=BIG9
7732 BIG10=ABS(HHHHH/2.*3.*CO2(1,J)/(4.*DT))
7733 IF (BIG10.GT.BIG) BIG=BIG10
7734 BIG11=ABS(HHHHH/2.*CO2(2,J+1)/(4.*DT))
7735 IF (BIG11.GT.BIG) BIG=BIG11
7736 BIG12=ABS(HHHHH/2.*CO2(1,J+1)/(4.*DT))
7737 IF (BIG12.GT.BIG) BIG=BIG12
7738 BIG13=ABS(H/2.*3.*CO2(2,J)/(4.*DT)*PARION)
7739 IF (BIG13.GT.BIG) BIG=BIG13
7740 BIG14=ABS(H/2.*3.*CO2(1,J)/(4.*DT)*PARION)
7741 IF (BIG14.GT.BIG) BIG=BIG14
7742 BIG15=ABS(H/2.*CO2(2,J-1)/(4.*DT))
7743 IF (BIG15.GT.BIG) BIG=BIG15
7744 BIG16=ABS(H/2.*CO2(1,J-1)/(4.*DT))
7745 IF (BIG16.GT.BIG) BIG=BIG16
7746 BIG17=ABS(COEFF13HHHHH/2.*CBA(2,J+1))
7747 IF (BIG17.GT.BIG) BIG=BIG17
7748 BIG18=ABS(COEFF13HHHHH/2.*CBA(1,J+1))
7749 IF (BIG18.GT.BIG) BIG=BIG18
7750 BIG19=ABS(COEFF13HHHHH/2.*CBA(2,J))
7751 IF (BIG19.GT.BIG) BIG=BIG19
7752 BIG20=ABS(COEFF13HHHHH/2.*CBA(1,J))
7753 IF (BIG20.GT.BIG) BIG=BIG20
7754 BIG21=ABS(COEFF13H/2.*CBA(2,J)*PARION)
7755 IF (BIG21.GT.BIG) BIG=BIG21
7756 BIG22=ABS(COEFF13H/2.*CBA(1,J)*PARION)
7757 IF (BIG22.GT.BIG) BIG=BIG22
7758 BIG23=ABS(COEFF13H/2.*CBA(2,J-1))
7759 IF (BIG23.GT.BIG) BIG=BIG23
7760 BIG24=ABS(COEFF13H/2.*CBA(1,J-1))
7761 IF (BIG24.GT.BIG) BIG=BIG24
7762 BIG25=ABS(HHHHH/2.*3.*CBA(2,J)/(4.*DT))
7763 IF (BIG25.GT.BIG) BIG=BIG25
7764 BIG26=ABS(HHHHH/2.*3.*CBA(1,J)/(4.*DT))
7765 IF (BIG26.GT.BIG) BIG=BIG26
7766 BIG27=ABS(HHHHH/2.*CBA(2,J+1)/(4.*DT))
7767 IF (BIG27.GT.BIG) BIG=BIG27
7768 BIG28=ABS(HHHHH/2.*CBA(1,J+1)/(4.*DT))

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7769 IF (BIG28.GT.BIG) BIG=BIG28
7770 BIG29=ABS(H/2.*3.*CBA(2,J)/(4.*DT)*PARION)
7771 IF (BIG29.GT.BIG) BIG=BIG29
7772 BIG30=ABS(H/2.*3.*CBA(1,J)/(4.*DT)*PARION)
7773 IF (BIG30.GT.BIG) BIG=BIG30
7774 BIG31=ABS(H/2.*CBA(2,J-1)/(4.*DT))
7775 IF (BIG31.GT.BIG) BIG=BIG31
7776 BIG32=ABS(H/2.*CBA(1,J-1)/(4.*DT))
7777 IF (BIG32.GT.BIG) BIG=BIG32
7778 BIG33=ABS(COEFF14HHHHH/2.*CBI(2,J+1))
7779 IF (BIG33.GT.BIG) BIG=BIG33
7780 BIG34=ABS(COEFF14HHHHH/2.*CBI(1,J+1))
7781 IF (BIG34.GT.BIG) BIG=BIG34
7782 BIG35=ABS(COEFF14HHHHH/2.*CBI(2,J))
7783 IF (BIG35.GT.BIG) BIG=BIG35
7784 BIG36=ABS(COEFF14HHHHH/2.*CBI(1,J))
7785 IF (BIG36.GT.BIG) BIG=BIG36
7786 BIG37=ABS(COEFF14H/2.*CBI(2,J)*PARION)
7787 IF (BIG37.GT.BIG) BIG=BIG37
7788 BIG38=ABS(COEFF14H/2.*CBI(1,J)*PARION)
7789 IF (BIG38.GT.BIG) BIG=BIG38
7790 BIG39=ABS(COEFF14H/2.*CBI(2,J-1))
7791 IF (BIG39.GT.BIG) BIG=BIG39
7792 BIG40=ABS(COEFF14H/2.*CBI(1,J-1))
7793 IF (BIG40.GT.BIG) BIG=BIG40
7794 BIG41=ABS(HHHHH/2.*3.*CBI(2,J)/(4.*DT))
7795 IF (BIG41.GT.BIG) BIG=BIG41
7796 BIG42=ABS(HHHHH/2.*3.*CBI(1,J)/(4.*DT))
7797 IF (BIG42.GT.BIG) BIG=BIG42
7798 BIG43=ABS(HHHHH/2.*CBI(2,J+1)/(4.*DT))
7799 IF (BIG43.GT.BIG) BIG=BIG43
7800 BIG44=ABS(HHHHH/2.*CBI(1,J+1)/(4.*DT))
7801 IF (BIG44.GT.BIG) BIG=BIG44
7802 BIG45=ABS(H/2.*3.*CBI(2,J)/(4.*DT)*PARION)
7803 IF (BIG45.GT.BIG) BIG=BIG45
7804 BIG46=ABS(H/2.*3.*CBI(1,J)/(4.*DT)*PARION)
7805 IF (BIG46.GT.BIG) BIG=BIG46
7806 BIG47=ABS(H/2.*CBI(2,J-1)/(4.*DT))
7807 IF (BIG47.GT.BIG) BIG=BIG47
7808 BIG48=ABS(H/2.*CBI(1,J-1)/(4.*DT))
7809 IF (BIG48.GT.BIG) BIG=BIG48
7810 IF (ABS(G(20)).LT.BIG*EBIG) G(20)=0
7811
7812 C For acetaminophen, reacting species
7813 G(21)=COEFF16HHHHH/2.*(ACE(2,J+1)+ACE(1,J+1)-ACE(2,J)-ACE(1,J))
7814 1 -COEFF16H/2.*(PARACE*(ACE(2,J)+ACE(1,J))-ACE(2,J-1)-ACE(1,J-1))
7815 4 -HHHHH/2.*(3.*(ACE(2,J)-ACE(1,J))
7816 5 +(ACE(2,J+1)-ACE(1,J+1)))/(4.*DT)
7817 5 -H/2.*(3.*PARACE*(ACE(2,J)-ACE(1,J))
7818 6 +(ACE(2,J-1)-ACE(1,J-1)))/(4.*DT)
7819
7820 B(21,21)=COEFF16HHHHH/2.+COEFF16H/2.*PARACE
7821 1 +HHHHH/2.*3./(4.*DT)+H/2.*3./(4.*DT)*PARACE
7822 D(21,21)=-COEFF16HHHHH/2.+HHHHH/2./(4.*DT)
7823 A(21,21)=-COEFF16H/2.+H/2./(4.*DT)
7824
7825
7826 BIG=ABS(COEFF16HHHHH/2.*ACE(2,J+1))

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7827     BIG2=ABS(COEFF16HHHHH/2.*ACE(1,J+1))
7828     IF (BIG2.GT.BIG) BIG=BIG2
7829     BIG3=ABS(COEFF16HHHHH/2.*ACE(2,J))
7830     IF (BIG3.GT.BIG) BIG=BIG3
7831     BIG4=ABS(COEFF16HHHHH/2.*ACE(1,J))
7832     IF (BIG4.GT.BIG) BIG=BIG4
7833     BIG5=ABS(COEFF16H/2.*ACE(2,J)*PARACE)
7834     IF (BIG5.GT.BIG) BIG=BIG5
7835     BIG6=ABS(COEFF16H/2.*ACE(1,J)*PARACE)
7836     IF (BIG6.GT.BIG) BIG=BIG6
7837     BIG7=ABS(COEFF16H/2.*ACE(2,J-1))
7838     IF (BIG7.GT.BIG) BIG=BIG7
7839     BIG8=ABS(COEFF16H/2.*ACE(1,J-1))
7840     IF (BIG8.GT.BIG) BIG=BIG8
7841     BIG17=ABS(HHHHH/2.*3.*ACE(2,J)/(4.*DT))
7842     IF (BIG17.GT.BIG) BIG=BIG17
7843     BIG18=ABS(HHHHH/2.*3.*ACE(1,J)/(4.*DT))
7844     IF (BIG18.GT.BIG) BIG=BIG18
7845     BIG19=ABS(HHHHH/2.*ACE(2,J+1)/(4.*DT))
7846     IF (BIG19.GT.BIG) BIG=BIG19
7847     BIG20=ABS(HHHHH/2.*ACE(1,J+1)/(4.*DT))
7848     IF (BIG20.GT.BIG) BIG=BIG20
7849     BIG21=ABS(H/2.*3.*ACE(2,J)/(4.*DT)*PARACE)
7850     IF (BIG21.GT.BIG) BIG=BIG21
7851     BIG22=ABS(H/2.*3.*ACE(1,J)/(4.*DT)*PARACE)
7852     IF (BIG22.GT.BIG) BIG=BIG22
7853     BIG23=ABS(H/2.*ACE(2,J-1)/(4.*DT))
7854     IF (BIG23.GT.BIG) BIG=BIG23
7855     BIG24=ABS(H/2.*ACE(1,J-1)/(4.*DT))
7856     IF (BIG24.GT.BIG) BIG=BIG24
7857     IF (ABS(G(21)).LT.BIG*EBIG) G(21)=0
7858
7859 C     DOUBLE LAYER voLTAGE - DUMMY
7860     G(22)=(VDL(2,J)+VDL(1,J))/2.
7861
7862     B(22,22)=-1./2.
7863
7864     BIG=ABS(VDL(2,J)/2.)
7865     BIG2=ABS(VDL(1,J)/2.)
7866     IF (BIG2.GT.BIG) BIG=BIG2
7867     IF (ABS(G(22)).LT.BIG*EBIG) G(22)=0
7868
7869 C 212 WRITE(12,301) J, (G(K),K=1,N)
7870     RETURN
7871     END
7872
7873     SUBROUTINE BULKDIFF(J)
7874     IMPLICIT DOUBLE PRECISION (A-H, O-Z)
7875     COMMON/BAB/ A(22,22),B(22,22),C(22,80001),D(22,45),G(22),X(22,22)
7876     1 ,Y(22,22)
7877     COMMON/NSN/ N, NJ
7878     COMMON/GLC/ NTIME,LL
7879     COMMON/VAR/ DIFF(16),H,EBIG,HH,IJ,KJ,TT,VAP,HHH,DT,RE,AKB,BB,CDL
7880     COMMON/VARR/ HHHH,HHHHH,MJ,LJ
7881     COMMON/DIN/ DGOX(16),DGLM(16),DIRM(16),DBULK(16)
7882     COMMON/SPCI/ GLU(2,80001),GOX(2,80001),GLA(2,80001),GOR(2,80001)
7883     COMMON/SPCII/ OXY(2,80001),HPR(2,80001),GOA(2,80001),GOP(2,80001)
7884     COMMON/RXT/ EQ1(2,80001),RGA(2,80001),EQ2(2,80001),RHP(2,80001)

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7885 COMMON/SPCIII/ ANM(2,80001),GLUA(2,80001),GLI(2,80001)
7886 COMMON/SPCIV/ HYD(2,80001),OHI(2,80001),CO2(2,80001),CBA(2,80001)
7887 COMMON/SPCV/ CBI(2,80001),ACE(2,800001)
7888 COMMON/VOL/ VDL(2,80001)
7889 COMMON/POR/ POR1,POR2,PORGLU,PARION,PARACE
7890 COMMON/RTE/ ratef1,equilib1,ratef2,ratef3,equilib3,ratef4
7891 COMMON/RTD/ ratef5,equilib5,equilib6,equilib7,equilib8,equilib9
7892 COMMON/BUL/ CBULK(16),PARH2O2,PARO2,PARGLUCESE,JCOUNT
7893
7894 301 FORMAT (5x,'J=' I5, 12E18.9)
7895
7896 C For Glucose, being consumed only
7897 G(1)=DBULK(1)*(GLU(2,J+1)-2.*GLU(2,J)+GLU(2,J-1)
7898 1 +GLU(1,J+1)-2.*GLU(1,J)+GLU(1,J-1))/(2.*HHHHH**2.)
7899 2 +(ANM(2,J)+ANM(1,J))/2.-(GLU(2,J)-GLU(1,J))/DT
7900
7901 B(1,1)=DBULK(1)/HHHHH**2.+1./DT
7902 D(1,1)=-DBULK(1)/(2.*HHHHH**2.)
7903 A(1,1)=-DBULK(1)/(2.*HHHHH**2.)
7904 B(1,13)=-1./2.
7905
7906 BIG=ABS(DBULK(1)*(GLU(2,J+1))/(2.*HHHHH**2.))
7907 BIG2=ABS(DBULK(1)*(GLU(2,J))/(HHHHH**2.))
7908 IF (BIG2.GT.BIG) BIG=BIG2
7909 BIG3=ABS(DBULK(1)*(GLU(2,J-1))/(2.*HHHHH**2.))
7910 IF (BIG3.GT.BIG) BIG=BIG3
7911 BIG4=ABS(DBULK(1)*(GLU(1,J+1))/(2.*HHHHH**2.))
7912 IF (BIG4.GT.BIG) BIG=BIG4
7913 BIG5=ABS(DBULK(1)*(GLU(1,J))/(HHHHH**2.))
7914 IF (BIG5.GT.BIG) BIG=BIG5
7915 BIG6=ABS(DBULK(1)*(GLU(1,J-1))/(2.*HHHHH**2.))
7916 IF (BIG6.GT.BIG) BIG=BIG6
7917 BIG7=ABS(GLU(2,J)/DT)
7918 IF (BIG7.GT.BIG) BIG=BIG7
7919 BIG8=ABS(GLU(1,J)/DT)
7920 IF (BIG8.GT.BIG) BIG=BIG8
7921 BIG9=ABS(ANM(2,J)/2.)
7922 IF (BIG9.GT.BIG) BIG=BIG9
7923 BIG10=ABS(ANM(1,J)/2.)
7924 IF (BIG10.GT.BIG) BIG=BIG10
7925 IF (ABS(G(1)).LT.BIG*EBIG) G(1)=0
7926
7927 C For GOx, enzyme
7928 G(2)=(GOX(2,J)+GOX(1,J))/2.
7929 B(2,2)=-1./2.
7930
7931 C For Gluconic Acid, being produced only
7932 G(3)=DBULK(3)*(GLA(2,J+1)-2.*GLA(2,J)+GLA(2,J-1)
7933 1 +GLA(1,J+1)-2.*GLA(1,J)+GLA(1,J-1))/(2.*HHHHH**2.)
7934 2 +DBULK(10)*(GLI(2,J+1)-2.*GLI(2,J)+GLI(2,J-1)
7935 3 +GLI(1,J+1)-2.*GLI(1,J)+GLI(1,J-1))/(2.*HHHHH**2.)
7936 2 -(GLA(2,J)-GLA(1,J))/DT-(GLI(2,J)-GLI(1,J))/DT
7937
7938 B(3,3)=DBULK(3)/HHHHH**2.+1./DT
7939 D(3,3)=-DBULK(3)/(2.*HHHHH**2.)
7940 A(3,3)=-DBULK(3)/(2.*HHHHH**2.)
7941 B(3,15)=DBULK(10)/HHHHH**2.+1./DT
7942 D(3,15)=-DBULK(10)/(2.*HHHHH**2.)

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7943 A(3,15)=-DBULK(10)/(2.*HHHHH**2.)
7944
7945 BIG=ABS(DBULK(3)*(GLA(2,J+1))/(2.*HHHHH**2.))
7946 BIG2=ABS(DBULK(3)*(GLA(2,J))/(HHHHH**2.))
7947 IF (BIG2.GT.BIG) BIG=BIG2
7948 BIG3=ABS(DBULK(3)*(GLA(2,J-1))/(2.*HHHHH**2.))
7949 IF (BIG3.GT.BIG) BIG=BIG3
7950 BIG4=ABS(DBULK(3)*(GLA(1,J+1))/(2.*HHHHH**2.))
7951 IF (BIG4.GT.BIG) BIG=BIG4
7952 BIG5=ABS(DBULK(3)*(GLA(1,J))/(HHHHH**2.))
7953 IF (BIG5.GT.BIG) BIG=BIG5
7954 BIG6=ABS(DBULK(3)*(GLA(1,J-1))/(2.*HHHHH**2.))
7955 IF (BIG6.GT.BIG) BIG=BIG6
7956 BIG7=ABS(GLA(2,J)/DT)
7957 IF (BIG7.GT.BIG) BIG=BIG7
7958 BIG8=ABS(GLA(1,J)/DT)
7959 IF (BIG8.GT.BIG) BIG=BIG8
7960 BIG9=ABS(DBULK(10)*(GLI(2,J+1))/(2.*HHHHH**2.))
7961 IF (BIG9.GT.BIG) BIG=BIG9
7962 BIG10=ABS(DBULK(10)*(GLI(2,J))/(HHHHH**2.))
7963 IF (BIG10.GT.BIG) BIG=BIG10
7964 BIG11=ABS(DBULK(10)*(GLI(2,J-1))/(2.*HHHHH**2.))
7965 IF (BIG11.GT.BIG) BIG=BIG11
7966 BIG12=ABS(DBULK(10)*(GLI(1,J+1))/(2.*HHHHH**2.))
7967 IF (BIG12.GT.BIG) BIG=BIG12
7968 BIG13=ABS(DBULK(10)*(GLI(1,J))/(HHHHH**2.))
7969 IF (BIG13.GT.BIG) BIG=BIG13
7970 BIG14=ABS(DBULK(10)*(GLI(1,J-1))/(2.*HHHHH**2.))
7971 IF (BIG14.GT.BIG) BIG=BIG14
7972 BIG15=ABS(GLI(2,J)/DT)
7973 IF (BIG15.GT.BIG) BIG=BIG15
7974 BIG16=ABS(GLI(1,J)/DT)
7975 IF (BIG16.GT.BIG) BIG=BIG16
7976 IF (ABS(G(3)).LT.BIG*EBIG) G(3)=0
7977
7978 C For GOx2, enzyme
7979 G(4)=(GOR(2,J)+GOR(1,J))/2.
7980 B(4,4)=-1./2.
7981
7982 C For O2, being consumed only
7983 G(5)=DBULK(5)*(OXY(2,J+1)-2.*OXY(2,J)+OXY(2,J-1)
7984 1 +OXY(1,J+1)-2.*OXY(1,J)+OXY(1,J-1))/(2.*HHHHH**2.)
7985 2 -(OXY(2,J)-OXY(1,J))/DT
7986
7987 B(5,5)=DBULK(5)/HHHHH**2.+1./DT
7988 D(5,5)=-DBULK(5)/(2.*HHHHH**2.)
7989 A(5,5)=-DBULK(5)/(2.*HHHHH**2.)
7990
7991
7992 BIG=ABS(DBULK(5)*(OXY(2,J+1))/(2.*HHHHH**2.))
7993 BIG2=ABS(DBULK(5)*(OXY(2,J))/(HHHHH**2.))
7994 IF (BIG2.GT.BIG) BIG=BIG2
7995 BIG3=ABS(DBULK(5)*(OXY(2,J-1))/(2.*HHHHH**2.))
7996 IF (BIG3.GT.BIG) BIG=BIG3
7997 BIG4=ABS(DBULK(5)*(OXY(1,J+1))/(2.*HHHHH**2.))
7998 IF (BIG4.GT.BIG) BIG=BIG4
7999 BIG5=ABS(DBULK(5)*(OXY(1,J))/(HHHHH**2.))
8000 IF (BIG5.GT.BIG) BIG=BIG5

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8001     BIG6=ABS(DBULK(5)*(OXY(1,J-1))/(2.*HHHHH**2.))
8002     IF (BIG6.GT.BIG) BIG=BIG6
8003     BIG7=ABS(OXY(2,J)/DT)
8004     IF (BIG7.GT.BIG) BIG=BIG7
8005     BIG8=ABS(OXY(1,J)/DT)
8006     IF (BIG8.GT.BIG) BIG=BIG8
8007     IF (ABS(G(5)).LT.BIG*EBIG) G(5)=0
8008
8009 C     For H2O2, reacting species
8010     G(6)=DBULK(6)*(HPR(2,J+1)-2.*HPR(2,J)+HPR(2,J-1)
8011 1     +HPR(1,J+1)-2.*HPR(1,J)+HPR(1,J-1))/(2.*HHHHH**2.)
8012 2     -(HPR(2,J)-HPR(1,J))/DT
8013
8014     B(6,6)=DBULK(6)/HHHHH**2.+1./DT
8015     D(6,6)=-DBULK(6)/(2.*HHHHH**2.)
8016     A(6,6)=-DBULK(6)/(2.*HHHHH**2.)
8017
8018     BIG=ABS(DBULK(6)*(HPR(2,J+1))/(2.*HHHHH**2.))
8019     BIG2=ABS(DBULK(6)*(HPR(2,J))/(HHHHH**2.))
8020     IF (BIG2.GT.BIG) BIG=BIG2
8021     BIG3=ABS(DBULK(6)*(HPR(2,J-1))/(2.*HHHHH**2.))
8022     IF (BIG3.GT.BIG) BIG=BIG3
8023     BIG4=ABS(DBULK(6)*(HPR(1,J+1))/(2.*HHHHH**2.))
8024     IF (BIG4.GT.BIG) BIG=BIG4
8025     BIG5=ABS(DBULK(6)*(HPR(1,J))/(HHHHH**2.))
8026     IF (BIG5.GT.BIG) BIG=BIG5
8027     BIG6=ABS(DBULK(6)*(HPR(1,J-1))/(2.*HHHHH**2.))
8028     IF (BIG6.GT.BIG) BIG=BIG6
8029     BIG7=ABS(HPR(2,J)/DT)
8030     IF (BIG7.GT.BIG) BIG=BIG7
8031     BIG8=ABS(HPR(1,J)/DT)
8032     IF (BIG8.GT.BIG) BIG=BIG8
8033     IF (ABS(G(6)).LT.BIG*EBIG) G(6)=0
8034
8035 C     For CX-GOx2, enzyme complex
8036     G(7)=(GOA(2,J)+GOA(1,J))/2.
8037     B(7,7)=-1./2.
8038
8039 C     For CX-GOx, enzyme complex
8040     G(8)=(GOP(2,J)+GOP(1,J))/2.
8041     B(8,8)=-1./2.
8042
8043 C     For Reaction 1 Enzymatic Catalysis
8044     G(9)=(EQ1(2,J)+EQ1(1,J))/2.
8045     B(9,9)=-1./2.
8046
8047 C     For Reaction 2
8048     G(10)=(RGA(2,J)+RGA(1,J))/2.
8049     B(10,10)=-1./2.
8050
8051 C     For Reaction 3 Meditation/regeneration
8052     G(11)=(EQ2(2,J)+EQ2(1,J))/2.
8053     B(11,11)=-1./2.
8054
8055 C     For Reaction 4
8056     G(12)=(RHP(2,J)+RHP(1,J))/2.
8057     B(12,12)=-1./2.
8058

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8059 C REACTIONS
8060 218 G(13)=-((ANM(2,J)+ANM(1,J))/2.+ratef5*((GLUA(2,J)+GLUA(1,J))/2.
8061 1 -(GLU(2,J)+GLU(1,J))/2./equilib5)
8062 B(13,1)=ratef5/2./equilib5
8063 B(13,14)=-ratef5/2.
8064 B(13,13)=+1./2.
8065
8066 BIG=ABS(ANM(2,J)/2.)
8067 BIG2=ABS(ANM(1,J)/2.)
8068 IF (BIG2.GT.BIG) BIG=BIG2
8069 BIG3=ABS(ratef5*GLUA(2,J)/2.)
8070 IF (BIG3.GT.BIG) BIG=BIG3
8071 BIG4=ABS(ratef5*GLUA(1,J)/2.)
8072 IF (BIG4.GT.BIG) BIG=BIG4
8073 BIG5=ABS(ratef5*GLU(2,J)/2./equilib5)
8074 IF (BIG5.GT.BIG) BIG=BIG5
8075 BIG6=ABS(ratef5*GLU(1,J)/2./equilib5)
8076 IF (BIG6.GT.BIG) BIG=BIG6
8077 IF (ABS(G(13)).LT.BIG*EBIG) G(13)=0.0
8078
8079 C For alpha Glucose, being consumed only
8080 G(14)=DBULK(9)*(GLUA(2,J+1)-2.*GLUA(2,J)+GLUA(2,J-1)
8081 1 +GLUA(1,J+1)-2.*GLUA(1,J)+GLUA(1,J-1))/(2.*HHHHH**2.)
8082 2 -(ANM(2,J)+ANM(1,J))/2.-(GLUA(2,J)-GLUA(1,J))/DT
8083 B(14,14)=DBULK(9)/HHHHH**2.+1./DT
8084 D(14,14)=-DBULK(9)/(2.*HHHHH**2.)
8085 A(14,14)=-DBULK(9)/(2.*HHHHH**2.)
8086 B(14,13)=1./2.
8087
8088 BIG=ABS(DBULK(9)*(GLUA(2,J+1))/(2.*HHHHH**2.))
8089 BIG2=ABS(DBULK(9)*(GLUA(2,J))/(HHHHH**2.))
8090 IF (BIG2.GT.BIG) BIG=BIG2
8091 BIG3=ABS(DBULK(9)*(GLUA(2,J-1))/(2.*HHHHH**2.))
8092 IF (BIG3.GT.BIG) BIG=BIG3
8093 BIG4=ABS(DBULK(9)*(GLUA(1,J+1))/(2.*HHHHH**2.))
8094 IF (BIG4.GT.BIG) BIG=BIG4
8095 BIG5=ABS(DBULK(9)*(GLUA(1,J))/(HHHHH**2.))
8096 IF (BIG5.GT.BIG) BIG=BIG5
8097 BIG6=ABS(DBULK(9)*(GLUA(1,J-1))/(2.*HHHHH**2.))
8098 IF (BIG6.GT.BIG) BIG=BIG6
8099 BIG7=ABS(ANM(2,J)/2.)
8100 IF (BIG7.GT.BIG) BIG=BIG7
8101 BIG8=ABS(ANM(1,J)/2.)
8102 IF (BIG8.GT.BIG) BIG=BIG8
8103 BIG9=ABS(GLUA(2,J)/DT)
8104 IF (BIG9.GT.BIG) BIG=BIG9
8105 BIG10=ABS(GLUA(1,J)/DT)
8106 IF (BIG10.GT.BIG) BIG=BIG10
8107 IF (ABS(G(14)).LT.BIG*EBIG) G(14)=0.0
8108
8109 C Gluconic acid dissociation
8110
8111 G(15)=equilib6*(GLA(2,J)+GLA(1,J))/2.-(GLI(2,J)+GLI(1,J))*
8112 1 (HYD(2,J)+HYD(1,J))/4.
8113 B(15,3)=-equilib6/2.
8114 B(15,15)=(HYD(2,J)+HYD(1,J))/4.
8115 B(15,16)=(GLI(2,J)+GLI(1,J))/4.
8116

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8117 BIG=ABS(equilib6*GLA(2,J)/2.)
8118 BIG2=ABS(equilib6*GLA(1,J)/2.)
8119 IF (BIG2.GT.BIG) BIG=BIG2
8120 BIG3=ABS(GLI(2,J)*HYD(2,J)/4.)
8121 IF (BIG3.GT.BIG) BIG=BIG3
8122 BIG4=ABS(GLI(2,J)*HYD(1,J)/4)
8123 IF (BIG4.GT.BIG) BIG=BIG4
8124 BIG5=ABS(GLI(1,J)*HYD(2,J)/4)
8125 IF (BIG5.GT.BIG) BIG=BIG5
8126 BIG6=ABS(GLI(1,J)*HYD(1,J)/4)
8127 IF (BIG6.GT.BIG) BIG=BIG6
8128 IF (ABS(G(15)).LT.BIG*EBIG) G(15)=0
8129 C Hydrogen ion, hydroxide ion, gluconate ion, bicarbonate ion flux
8130 G(16)=DBULK(11)*(HYD(2,J+1)-2.*HYD(2,J)+HYD(2,J-1)
8131 1 +HYD(1,J+1)-2.*HYD(1,J)+HYD(1,J-1))/(2.*HHHHH**2.)
8132 2 -DBULK(15)*(OHI(2,J+1)-2.*OHI(2,J)+OHI(2,J-1)
8133 3 +OHI(1,J+1)-2.*OHI(1,J)+OHI(1,J-1))/(2.*HHHHH**2.)
8134 4 -DBULK(10)*(GLI(2,J+1)-2.*GLI(2,J)+GLI(2,J-1)
8135 5 +GLI(1,J+1)-2.*GLI(1,J)+GLI(1,J-1))/(2.*HHHHH**2.)
8136 6 -DBULK(14)*(CBI(2,J+1)-2.*CBI(2,J)+CBI(2,J-1)
8137 7 +CBI(1,J+1)-2.*CBI(1,J)+CBI(1,J-1))/(2.*HHHHH**2.)
8138 8 -(HYD(2,J)-HYD(1,J))/DT+(OHI(2,J)-OHI(1,J))/DT
8139 9 +(GLI(2,J)-GLI(1,J))/DT+(CBI(2,J)-CBI(1,J))/DT
8140
8141 B(16,16)=DBULK(11)/HHHHH**2.+1./DT
8142 D(16,16)=-DBULK(11)/(2.*HHHHH**2.)
8143 A(16,16)=-DBULK(11)/(2.*HHHHH**2.)
8144 B(16,17)=-DBULK(15)/HHHHH**2.-1./DT
8145 D(16,17)=DBULK(15)/(2.*HHHHH**2.)
8146 A(16,17)=DBULK(15)/(2.*HHHHH**2.)
8147 B(16,15)=-DBULK(10)/HHHHH**2.-1./DT
8148 D(16,15)=DBULK(10)/(2.*HHHHH**2.)
8149 A(16,15)=DBULK(10)/(2.*HHHHH**2.)
8150 B(16,20)=-DBULK(14)/HHHHH**2.-1./DT
8151 D(16,20)=DBULK(14)/(2.*HHHHH**2.)
8152 A(16,20)=DBULK(14)/(2.*HHHHH**2.)
8153
8154 BIG=ABS(DBULK(11)*(HYD(2,J+1))/(2.*HHHHH**2.))
8155 BIG2=ABS(DBULK(11)*(HYD(2,J))/(HHHHH**2.))
8156 IF (BIG2.GT.BIG) BIG=BIG2
8157 BIG3=ABS(DBULK(11)*(HYD(2,J-1))/(2.*HHHHH**2.))
8158 IF (BIG3.GT.BIG) BIG=BIG3
8159 BIG4=ABS(DBULK(11)*(HYD(1,J+1))/(2.*HHHHH**2.))
8160 IF (BIG4.GT.BIG) BIG=BIG4
8161 BIG5=ABS(DBULK(11)*(HYD(1,J))/(HHHHH**2.))
8162 IF (BIG5.GT.BIG) BIG=BIG5
8163 BIG6=ABS(DBULK(11)*(HYD(1,J-1))/(2.*HHHHH**2.))
8164 IF (BIG6.GT.BIG) BIG=BIG6
8165 BIG7=ABS(DBULK(15)*OHI(2,J+1)/(2.*HHHHH**2.))
8166 IF (BIG7.GT.BIG) BIG=BIG7
8167 BIG8=ABS(DBULK(15)*OHI(2,J)/(HHHHH**2.))
8168 IF (BIG8.GT.BIG) BIG=BIG8
8169 BIG9=ABS(DBULK(15)*OHI(2,J-1)/(2.*HHHHH**2.))
8170 IF (BIG9.GT.BIG) BIG=BIG9
8171 BIG10=ABS(DBULK(15)*OHI(1,J+1)/(2.*HHHHH**2.))
8172 IF (BIG10.GT.BIG) BIG=BIG10
8173 BIG11=ABS(DBULK(15)*OHI(1,J)/(HHHHH**2.))
8174 IF (BIG11.GT.BIG) BIG=BIG11

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8175 BIG12=ABS(DBULK(15)*OHI(1,J-1)/(2.*HHHHH**2.))
8176 IF (BIG12.GT.BIG) BIG=BIG12
8177 BIG13=ABS(DBULK(10)*GLI(2,J+1)/(2.*HHHHH**2.))
8178 IF (BIG13.GT.BIG) BIG=BIG13
8179 BIG14=ABS(DBULK(10)*GLI(2,J)/(HHHHH**2.))
8180 IF (BIG14.GT.BIG) BIG=BIG14
8181 BIG15=ABS(DBULK(10)*GLI(2,J-1)/(2.*HHHHH**2.))
8182 IF (BIG15.GT.BIG) BIG=BIG15
8183 BIG16=ABS(DBULK(10)*GLI(1,J+1)/(2.*HHHHH**2.))
8184 IF (BIG16.GT.BIG) BIG=BIG16
8185 BIG17=ABS(DBULK(10)*GLI(1,J)/(HHHHH**2.))
8186 IF (BIG17.GT.BIG) BIG=BIG17
8187 BIG18=ABS(DBULK(10)*GLI(1,J-1)/(2.*HHHHH**2.))
8188 IF (BIG18.GT.BIG) BIG=BIG18
8189 BIG19=ABS(DBULK(14)*CBI(2,J+1)/(2.*HHHHH**2.))
8190 IF (BIG19.GT.BIG) BIG=BIG19
8191 BIG20=ABS(DBULK(14)*CBI(2,J)/(HHHHH**2.))
8192 IF (BIG20.GT.BIG) BIG=BIG20
8193 BIG21=ABS(DBULK(14)*CBI(2,J-1)/(2.*HHHHH**2.))
8194 IF (BIG21.GT.BIG) BIG=BIG21
8195 BIG22=ABS(DBULK(14)*CBI(1,J+1)/(2.*HHHHH**2.))
8196 IF (BIG22.GT.BIG) BIG=BIG22
8197 BIG23=ABS(DBULK(14)*CBI(1,J)/(HHHHH**2.))
8198 IF (BIG23.GT.BIG) BIG=BIG23
8199 BIG24=ABS(DBULK(14)*CBI(1,J-1)/(2.*HHHHH**2.))
8200 IF (BIG24.GT.BIG) BIG=BIG24
8201 BIG25=ABS(HYD(2,J)/DT)
8202 IF (BIG25.GT.BIG) BIG=BIG25
8203 BIG26=ABS(HYD(1,J)/DT)
8204 IF (BIG26.GT.BIG) BIG=BIG26
8205 BIG27=ABS(OHI(2,J)/DT)
8206 IF (BIG27.GT.BIG) BIG=BIG27
8207 BIG28=ABS(OHI(1,J)/DT)
8208 IF (BIG28.GT.BIG) BIG=BIG28
8209 BIG29=ABS(GLI(2,J)/DT)
8210 IF (BIG29.GT.BIG) BIG=BIG29
8211 BIG30=ABS(GLI(1,J)/DT)
8212 IF (BIG30.GT.BIG) BIG=BIG30
8213 BIG31=ABS(CBI(2,J)/DT)
8214 IF (BIG31.GT.BIG) BIG=BIG31
8215 BIG32=ABS(CBI(1,J)/DT)
8216 IF (BIG32.GT.BIG) BIG=BIG32
8217 IF (ABS(G(16)).LT.BIG*EBIG) G(16)=0
8218
8219 c Water Dissociation
8220 G(17)=equilib9 -(HYD(2,J)+HYD(1,J))*(OHI(2,J)+OHI(1,J))/4.
8221 B(17,17)=(HYD(2,J)+HYD(1,J))/4.
8222 B(17,16)=(OHI(2,J)+OHI(1,J))/4.
8223
8224 BIG=ABS(equilib9)
8225 BIG2=ABS(HYD(2,J)*OHI(2,J)/4.)
8226 IF (BIG2.GT.BIG) BIG=BIG2
8227 BIG3=ABS(HYD(2,J)*OHI(1,J)/4.)
8228 IF (BIG3.GT.BIG) BIG=BIG3
8229 BIG4=ABS(HYD(1,J)*OHI(2,J)/4.)
8230 IF (BIG4.GT.BIG) BIG=BIG4
8231 BIG5=ABS(HYD(1,J)*OHI(1,J)/4.)
8232 IF (BIG5.GT.BIG) BIG=BIG5

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8233     IF (ABS(G(17)).LT.BIG*EBIG) G(17)=0
8234
8235 C CO2 Hydration
8236     G(18)=equilib7*(CO2(2,J)+CO2(1,J))/2.-(CBA(2,J)+CBA(1,J))/2.
8237     B(18,18)=-equilib7/2.
8238     B(18,19)=1./2.
8239
8240     BIG=ABS(equilib7*CO2(2,J)/2.)
8241     BIG2=ABS(equilib7*CO2(1,J)/2.)
8242     IF (BIG2.GT.BIG) BIG=BIG2
8243     BIG3=ABS(CBA(2,J)/2.)
8244     IF (BIG3.GT.BIG) BIG=BIG3
8245     BIG4=ABS(CBA(1,J)/2.)
8246     IF (BIG4.GT.BIG) BIG=BIG4
8247     IF (ABS(G(18)).LT.BIG*EBIG) G(18)=0
8248
8249 C Carbonic acid dissociation
8250     G(19)=equilib8*(CBA(2,J)+CBA(1,J))/2.-(CBI(2,J)+CBI(1,J))
8251     1 *(HYD(2,J)+HYD(1,J))/4.
8252     B(19,19)=-equilib8/2.
8253     B(19,20)=(HYD(2,J)+HYD(1,J))/4.
8254     B(19,16)=(CBI(2,J)+CBI(1,J))/4.
8255
8256     BIG=ABS(equilib8*CBA(2,J)/2.)
8257     BIG2=ABS(equilib8*CBA(1,J)/2.)
8258     IF (BIG2.GT.BIG) BIG=BIG2
8259     BIG3=ABS(CBI(2,J)*HYD(2,J)/4.)
8260     IF (BIG3.GT.BIG) BIG=BIG3
8261     BIG4=ABS(CBI(2,J)*HYD(1,J)/4.)
8262     IF (BIG4.GT.BIG) BIG=BIG4
8263     BIG5=ABS(CBI(1,J)*HYD(2,J)/4.)
8264     IF (BIG5.GT.BIG) BIG=BIG5
8265     BIG6=ABS(CBI(1,J)*HYD(1,J)/4.)
8266     IF (BIG6.GT.BIG) BIG=BIG6
8267     IF (ABS(G(19)).LT.BIG*EBIG) G(19)=0
8268
8269 C FLUX OF CO2, CARBONIC ACID, BICARBONATE ION
8270     G(20)=DBULK(12)*(CO2(2,J+1)-2.*CO2(2,J)+CO2(2,J-1)
8271     1 +CO2(1,J+1)-2.*CO2(1,J)+CO2(1,J-1))/(2.*HHHHH**2.)
8272     2 +DBULK(13)*(CBA(2,J+1)-2.*CBA(2,J)+CBA(2,J-1)
8273     3 +CBA(1,J+1)-2.*CBA(1,J)+CBA(1,J-1))/(2.*HHHHH**2.)
8274     4 +DBULK(14)*(CBI(2,J+1)-2.*CBI(2,J)+CBI(2,J-1)
8275     5 +CBI(1,J+1)-2.*CBI(1,J)+CBI(1,J-1))/(2.*HHHHH**2.)
8276     8 -(CO2(2,J)-CO2(1,J))/DT-(CBA(2,J)-CBA(1,J))/DT
8277     9 -(CBI(2,J)-CBI(1,J))/DT
8278
8279     B(20,20)=DBULK(14)/HHHHH**2.+1./DT
8280     D(20,20)=-DBULK(14)/(2.*HHHHH**2.)
8281     A(20,20)=-DBULK(14)/(2.*HHHHH**2.)
8282     B(20,18)=DBULK(12)/HHHHH**2.+1./DT
8283     D(20,18)=-DBULK(12)/(2.*HHHHH**2.)
8284     A(20,18)=-DBULK(12)/(2.*HHHHH**2.)
8285     B(20,19)=DBULK(13)/HHHHH**2.+1./DT
8286     D(20,19)=-DBULK(13)/(2.*HHHHH**2.)
8287     A(20,19)=-DBULK(13)/(2.*HHHHH**2.)
8288
8289     BIG=ABS(DBULK(12)*(CO2(2,J+1))/(2.*HHHHH**2.))
8290     BIG2=ABS(DBULK(12)*(CO2(2,J))/(HHHHH**2.))

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8291 IF (BIG2.GT.BIG) BIG=BIG2
8292 BIG3=ABS(DBULK(12)*(CO2(2,J-1))/(2.*HHHHH**2.))
8293 IF (BIG3.GT.BIG) BIG=BIG3
8294 BIG4=ABS(DBULK(12)*(CO2(1,J+1))/(2.*HHHHH**2.))
8295 IF (BIG4.GT.BIG) BIG=BIG4
8296 BIG5=ABS(DBULK(12)*(CO2(1,J))/(HHHHH**2.))
8297 IF (BIG5.GT.BIG) BIG=BIG5
8298 BIG6=ABS(DBULK(12)*(CO2(1,J-1))/(2.*HHHHH**2.))
8299 IF (BIG6.GT.BIG) BIG=BIG6
8300 BIG7=ABS(DBULK(13)*CBA(2,J+1)/(2.*HHHHH**2.))
8301 IF (BIG7.GT.BIG) BIG=BIG7
8302 BIG8=ABS(DBULK(13)*CBA(2,J)/(HHHHH**2.))
8303 IF (BIG8.GT.BIG) BIG=BIG8
8304 BIG9=ABS(DBULK(13)*CBA(2,J-1)/(2.*HHHHH**2.))
8305 IF (BIG9.GT.BIG) BIG=BIG9
8306 BIG10=ABS(DBULK(13)*CBA(1,J+1)/(2.*HHHHH**2.))
8307 IF (BIG10.GT.BIG) BIG=BIG10
8308 BIG11=ABS(DBULK(13)*CBA(1,J)/(HHHHH**2.))
8309 IF (BIG11.GT.BIG) BIG=BIG11
8310 BIG12=ABS(DBULK(13)*CBA(1,J-1)/(2.*HHHHH**2.))
8311 IF (BIG12.GT.BIG) BIG=BIG12
8312 BIG13=ABS(DBULK(14)*CBI(2,J+1)/(2.*HHHHH**2.))
8313 IF (BIG13.GT.BIG) BIG=BIG13
8314 BIG14=ABS(DBULK(14)*CBI(2,J)/(HHHHH**2.))
8315 IF (BIG14.GT.BIG) BIG=BIG14
8316 BIG15=ABS(DBULK(14)*CBI(2,J-1)/(2.*HHHHH**2.))
8317 IF (BIG15.GT.BIG) BIG=BIG15
8318 BIG16=ABS(DBULK(14)*CBI(1,J+1)/(2.*HHHHH**2.))
8319 IF (BIG16.GT.BIG) BIG=BIG16
8320 BIG17=ABS(DBULK(14)*CBI(1,J)/(HHHHH**2.))
8321 IF (BIG17.GT.BIG) BIG=BIG17
8322 BIG18=ABS(DBULK(14)*CBI(1,J-1)/(2.*HHHHH**2.))
8323 IF (BIG18.GT.BIG) BIG=BIG18
8324 BIG19=ABS(CO2(2,J)/DT)
8325 IF (BIG19.GT.BIG) BIG=BIG19
8326 BIG20=ABS(CO2(1,J)/DT)
8327 IF (BIG20.GT.BIG) BIG=BIG20
8328 BIG21=ABS(CBA(2,J)/DT)
8329 IF (BIG21.GT.BIG) BIG=BIG21
8330 BIG22=ABS(CBA(1,J)/DT)
8331 IF (BIG22.GT.BIG) BIG=BIG22
8332 BIG23=ABS(CBI(2,J)/DT)
8333 IF (BIG23.GT.BIG) BIG=BIG23
8334 BIG24=ABS(CBI(1,J)/DT)
8335 IF (BIG24.GT.BIG) BIG=BIG24
8336 IF (ABS(G(20)).LT.BIG*EBIG) G(20)=0
8337
8338 C For Acetaminophen
8339 G(21)=DBULK(16)*(ACE(2,J+1)-2.*ACE(2,J)+ACE(2,J-1)
8340 1 +ACE(1,J+1)-2.*ACE(1,J)+ACE(1,J-1))/(2.*HHHHH**2.)
8341 2 -(ACE(2,J)-ACE(1,J))/DT
8342
8343 B(21,21)=DBULK(16)/HHHHH**2.+1./DT
8344 D(21,21)=-DBULK(16)/(2.*HHHHH**2.)
8345 A(21,21)=-DBULK(16)/(2.*HHHHH**2.)
8346
8347
8348 BIG=ABS(DBULK(16)*(ACE(2,J+1))/(2.*HHHHH**2.))

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8349     BIG2=ABS(DBULK(16)*(ACE(2,J))/(HHHHH**2.))
8350     IF (BIG2.GT.BIG) BIG=BIG2
8351     BIG3=ABS(DBULK(16)*(ACE(2,J-1))/(2.*HHHHH**2.))
8352     IF (BIG3.GT.BIG) BIG=BIG3
8353     BIG4=ABS(DBULK(16)*(ACE(1,J+1))/(2.*HHHHH**2.))
8354     IF (BIG4.GT.BIG) BIG=BIG4
8355     BIG5=ABS(DBULK(16)*(ACE(1,J))/(HHHHH**2.))
8356     IF (BIG5.GT.BIG) BIG=BIG5
8357     BIG6=ABS(DBULK(16)*(ACE(1,J-1))/(2.*HHHHH**2.))
8358     IF (BIG6.GT.BIG) BIG=BIG6
8359     BIG7=ABS(ACE(2,J)/DT)
8360     IF (BIG7.GT.BIG) BIG=BIG7
8361     BIG8=ABS(ACE(1,J)/DT)
8362     IF (BIG8.GT.BIG) BIG=BIG8
8363     IF (ABS(G(21)).LT.BIG*EBIG) G(21)=0
8364
8365 c     INTERFACE VOLTAGE - DUMMY
8366     G(22)=(VDL(2,J)+VDL(1,J))/2.
8367
8368     B(22,22)=-1./2.
8369
8370     BIG=ABS(VDL(2,J)/2.)
8371     BIG2=ABS(VDL(1,J)/2.)
8372     IF (BIG2.GT.BIG) BIG=BIG2
8373     IF (ABS(G(22)).LT.BIG*EBIG) G(22)=0
8374
8375     RETURN
8376     END
8377
8378     SUBROUTINE BCNJ(J)
8379     IMPLICIT DOUBLE PRECISION (A-H, O-Z)
8380     COMMON/BAB/ A(22,22),B(22,22),C(22,80001),D(22,45),G(22),X(22,22)
8381     1 ,Y(22,22)
8382     COMMON/NSN/ N, NJ
8383     COMMON/GLC/ NTIME,LL
8384     COMMON/VAR/ DIFF(16),H,EBIG,HH,IJ ,KJ,TT,VAP,HHH,DT,RE,AKB,BB,CDL
8385     COMMON/VARR/ HHHH,HHHHH,MJ,LJ
8386     COMMON/DIN/ DGOX(16),DGLM(16),DIRM(16),DBULK(16)
8387     COMMON/SPCI/ GLU(2,80001),GOX(2,80001),GLA(2,80001),GOR(2,80001)
8388     COMMON/SPCII/ OXY(2,80001),HPR(2,80001),GOA(2,80001),GOP(2,80001)
8389     COMMON/RXT/ EQ1(2,80001),RGA(2,80001),EQ2(2,80001),RHP(2,80001)
8390     COMMON/SPCIII/ ANM(2,80001),GLUA(2,80001),GLI(2,80001)
8391     COMMON/SPCIV/ HYD(2,80001),OHI(2,80001),CO2(2,80001),CBA(2,80001)
8392     COMMON/SPCV/ CBI(2,80001),ACE(2,80001)
8393     COMMON/VOL/ VDL(2,80001)
8394     COMMON/POR/ POR1,POR2,PORGLU,PARION,PARACE
8395     COMMON/RTE/ ratef1,equilib1 ,ratef2 ,ratef3 ,equilib3 ,ratef4
8396     COMMON/RTD/ ratef5 ,equilib5 ,equilib6 ,equilib7 ,equilib8 ,equilib9
8397     COMMON/BUL/ CBULK(16),PARH2O2,PARO2,PARGLUCESE,JCOUNT
8398
8399     301 FORMAT (5x,'J=' I5 , 13E18.9)
8400
8401 c     For Glucose , being consumed only
8402     G(1)=CBULK(1)-(GLU(2,J)+GLU(1,J))/2.
8403     B(1,1)=1./2.
8404
8405     BIG=ABS(CBULK(1))
8406     IF (ABS((GLU(2,J)+GLU(1,J))/2.).GT.BIG)

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8407 1 BIG=ABS((GLU(2,J)+GLU(1,J))/2.)
8408 IF (ABS(G(1)).LT.BIG*EBIG) G(1)=0
8409
8410 C For GOx, enzyme
8411 G(2)=(GOX(2,J)+GOX(1,J))/2.
8412 B(2,2)=-1./2.
8413
8414 BIG=ABS((GOX(2,J)+GOX(1,J))/2.)
8415 IF (ABS(G(2)).LT.BIG*EBIG) G(2)=0
8416
8417 C For Gluconic Acid, being produced only
8418 G(3)=CBULK(3)-(GLA(2,J)+GLA(1,J))/2.
8419 1 +CBULK(10)-(GLI(2,J)+GLI(1,J))/2.
8420 B(3,3)=1./2.
8421 B(3,15)=1./2.
8422
8423 BIG=ABS(CBULK(3))
8424 IF (ABS((GLA(2,J)+GLA(1,J))/2.).GT.BIG)
8425 1 BIG=ABS((GLA(2,J)+GLA(1,J))/2.)
8426 IF (ABS((GLI(2,J)+GLI(1,J))/2.).GT.BIG)
8427 2 BIG=ABS((GLI(2,J)+GLA(1,J))/2.)
8428 IF (ABS(G(3)).LT.BIG*EBIG) G(3)=0
8429
8430 C For GOx2, enzyme
8431 G(4)=(GOR(2,J)+GOR(1,J))/2.
8432 B(4,4)=-1./2.
8433
8434 BIG=ABS((GOR(2,J)+GOR(1,J))/2.)
8435 IF (ABS(G(4)).LT.BIG*EBIG) G(4)=0
8436
8437 C For O2, being consumed only
8438 G(5)=CBULK(5)-(OXY(2,J)+OXY(1,J))/2.
8439 B(5,5)=1./2.
8440
8441 BIG=ABS(CBULK(5))
8442 IF (ABS((OXY(2,J)+OXY(1,J))/2.).GT.BIG)
8443 1 BIG=ABS((OXY(2,J)+OXY(1,J))/2.)
8444 IF (ABS(G(5)).LT.BIG*EBIG) G(5)=0
8445
8446 C For H2O2, reacting species
8447 G(6)=CBULK(6)-(HPR(2,J)+HPR(1,J))/2.
8448 B(6,6)=1./2.
8449
8450 BIG=ABS(CBULK(6))
8451 IF (ABS((HPR(2,J)+HPR(1,J))/2.).GT.BIG)
8452 1 BIG=ABS((HPR(2,J)+HPR(1,J))/2.)
8453 IF (ABS(G(6)).LT.BIG*EBIG) G(6)=0
8454
8455 C For CX-GOx2, enzyme complex
8456 G(7)=(GOA(2,J)+GOA(1,J))/2.
8457 B(7,7)=-1./2.
8458
8459 BIG=ABS((GOA(2,J)+GOA(1,J))/2.)
8460 IF (ABS(G(7)).LT.BIG*EBIG) G(7)=0
8461
8462 C For CX-GOx, enzyme complex
8463 G(8)=(GOP(2,J)+GOP(1,J))/2.
8464 B(8,8)=-1./2.

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8465
8466     BIG=ABS((GOP(2,J)+GOP(1,J))/2.)
8467     IF (ABS(G(8)).LT.BIG*EBIG) G(8)=0
8468
8469 C     For Reaction 1 Enzymatic Catalysis
8470     G(9)=(EQ1(2,J)+EQ1(1,J))/2.
8471     B(9,9)=-1./2.
8472
8473     BIG=ABS((EQ1(2,J)+EQ1(1,J))/2.)
8474     IF (ABS(G(9)).LT.BIG*EBIG) G(9)=0
8475
8476 C     For Reaction 2
8477     G(10)=(RGA(2,J)+RGA(1,J))/2.
8478     B(10,10)=-1./2.
8479
8480     BIG=ABS((RGA(2,J)+RGA(1,J))/2.)
8481     IF (ABS(G(10)).LT.BIG*EBIG) G(10)=0
8482
8483 C     For Reaction 3 Meditation/regeneration
8484     G(11)=(EQ2(2,J)+EQ2(1,J))/2.
8485     B(11,11)=-1./2.
8486
8487     BIG=ABS((EQ2(2,J)+EQ2(1,J))/2.)
8488     IF (ABS(G(11)).LT.BIG*EBIG) G(11)=0
8489
8490 C     For Reaction 4
8491     G(12)=(RHP(2,J)+RHP(1,J))/2.
8492     B(12,12)=-1./2.
8493
8494     BIG=ABS((RHP(2,J)+RHP(1,J))/2.)
8495     IF (ABS(G(12)).LT.BIG*EBIG) G(12)=0
8496
8497 C     For Reaction 5, Anomerization
8498 218 G(13)=-((ANM(2,J)+ANM(1,J))/2.+ratef5*((GLUA(2,J)+GLUA(1,J))/2.
8499 1  -(GLU(2,J)+GLU(1,J))/2./equilib5)
8500     B(13,1)=ratef5/2./equilib5
8501     B(13,14)=-ratef5/2.
8502     B(13,13)=+1./2.
8503
8504     BIG=ABS(ANM(2,J)/2.)
8505     BIG2=ABS(ANM(1,J)/2.)
8506     IF (BIG2.GT.BIG) BIG=BIG2
8507     BIG3=ABS(ratef5*GLUA(2,J)/2.)
8508     IF (BIG3.GT.BIG) BIG=BIG3
8509     BIG4=ABS(ratef5*GLUA(1,J)/2.)
8510     IF (BIG4.GT.BIG) BIG=BIG4
8511     BIG5=ABS(ratef5*GLU(2,J)/2./equilib5)
8512     IF (BIG5.GT.BIG) BIG=BIG5
8513     BIG6=ABS(ratef5*GLU(1,J)/2./equilib5)
8514     IF (BIG6.GT.BIG) BIG=BIG6
8515     IF (ABS(G(13)).LT.BIG*EBIG) G(13)=0
8516
8517 C     Alpha-Glucose
8518     G(14)=CBULK(9)-(GLUA(2,J)+GLUA(1,J))/2.
8519     B(14,14)=1./2
8520
8521     BIG=ABS(CBULK(9))
8522     BIG2=ABS(GLUA(2,J)/2.)

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8523 IF (BIG2.GT.BIG) BIG=BIG2
8524 BIG3=ABS(GLUA(1,J)/2.)
8525 IF (BIG3.GT.BIG) BIG=BIG3
8526 IF (ABS(G(14)).LT.BIG*EBIG) G(14)=0
8527
8528 C Gluconic acid dissociation
8529 G(15)=equilib6*(GLA(2,J)+GLA(1,J))/2.-(GLI(2,J)+GLI(1,J))*
8530 1 (HYD(2,J)+HYD(1,J))/4.
8531 B(15,3)=-equilib6/2.
8532 B(15,15)=(HYD(2,J)+HYD(1,J))/4.
8533 B(15,16)=(GLI(2,J)+GLI(1,J))/4.
8534
8535 BIG=ABS(equilib6*GLA(2,J)/2.)
8536 BIG2=ABS(equilib6*GLA(1,J)/2.)
8537 IF (BIG2.GT.BIG) BIG=BIG2
8538 BIG3=ABS(GLI(2,J)*HYD(2,J)/4.)
8539 IF (BIG3.GT.BIG) BIG=BIG3
8540 BIG4=ABS(GLI(2,J)*HYD(1,J)/4)
8541 IF (BIG4.GT.BIG) BIG=BIG4
8542 BIG5=ABS(GLI(1,J)*HYD(2,J)/4)
8543 IF (BIG5.GT.BIG) BIG=BIG5
8544 BIG6=ABS(GLI(1,J)*HYD(1,J)/4)
8545 IF (BIG6.GT.BIG) BIG=BIG6
8546 IF (ABS(G(15)).LT.BIG*EBIG) G(15)=0
8547
8548
8549 C Flux balance of hydrogen, hydroxide, gluconate, bicarbonate ion
8550 G(16)=CBULK(11)-(HYD(2,J)+HYD(1,J))/2.
8551 1 -CBULK(15)+(OHI(2,J)+OHI(1,J))/2.
8552 2 -CBULK(10)+(GLI(2,J)+GLI(1,J))/2.
8553 3 -CBULK(14)+(CBI(2,J)+CBI(1,J))/2.
8554 B(16,16)=1./2.
8555 B(16,17)=-1./2.
8556 B(16,15)=-1./2.
8557 B(16,20)=-1./2.
8558
8559 BIG=ABS(CBULK(11))
8560 BIG2=ABS(CBULK(15))
8561 IF (BIG2.GT.BIG) BIG=BIG2
8562 BIG3=ABS(CBULK(10))
8563 IF (BIG3.GT.BIG) BIG=BIG3
8564 BIG4=ABS(CBULK(14))
8565 IF (BIG4.GT.BIG) BIG=BIG4
8566 BIG5=ABS(HYD(2,J)/2.)
8567 IF (BIG5.GT.BIG) BIG=BIG5
8568 BIG6=ABS(HYD(1,J)/2.)
8569 IF (BIG6.GT.BIG) BIG=BIG6
8570 BIG7=ABS(OHI(2,J)/2.)
8571 IF (BIG7.GT.BIG) BIG=BIG7
8572 BIG8=ABS(OHI(1,J)/2.)
8573 IF (BIG8.GT.BIG) BIG=BIG8
8574 BIG9=ABS(GLI(2,J)/2.)
8575 IF (BIG9.GT.BIG) BIG=BIG9
8576 BIG10=ABS(GLI(1,J)/2.)
8577 IF (BIG10.GT.BIG) BIG=BIG10
8578 BIG11=ABS(CBI(2,J)/2.)
8579 IF (BIG11.GT.BIG) BIG=BIG11
8580 BIG12=ABS(CBI(1,J)/2.)

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8581 IF (BIG12.GT.BIG) BIG=BIG12
8582 IF (ABS(G(16)).LT.BIG*EBIG) G(16)=0
8583
8584 C Water Dissociation
8585 G(17)=equilib9 -(HYD(2,J)+HYD(1,J))*(OHI(2,J)+OHI(1,J))/4.
8586 B(17,17)=(HYD(2,J)+HYD(1,J))/4.
8587 B(17,16)=(OHI(2,J)+OHI(1,J))/4.
8588
8589 BIG=ABS(equilib9)
8590 BIG2=ABS(HYD(2,J)*OHI(2,J)/4.)
8591 IF (BIG2.GT.BIG) BIG=BIG2
8592 BIG3=ABS(HYD(2,J)*OHI(1,J)/4.)
8593 IF (BIG3.GT.BIG) BIG=BIG3
8594 BIG4=ABS(HYD(1,J)*OHI(2,J)/4.)
8595 IF (BIG4.GT.BIG) BIG=BIG4
8596 BIG5=ABS(HYD(1,J)*OHI(1,J)/4.)
8597 IF (BIG5.GT.BIG) BIG=BIG5
8598 IF (ABS(G(17)).LT.BIG*EBIG) G(17)=0
8599
8600 C CO2 hydration
8601 G(18)=equilib7 *(CO2(2,J)+CO2(1,J))/2. -(CBA(2,J)+CBA(1,J))/2.
8602 B(18,18)=-equilib7/2.
8603 B(18,19)=1./2.
8604
8605 BIG=ABS(equilib7*CO2(2,J)/2.)
8606 BIG2=ABS(equilib7*CO2(1,J)/2.)
8607 IF (BIG2.GT.BIG) BIG=BIG2
8608 BIG3=ABS(CBA(2,J)/2.)
8609 IF (BIG3.GT.BIG) BIG=BIG3
8610 BIG4=ABS(CBA(1,J)/2.)
8611 IF (BIG4.GT.BIG) BIG=BIG4
8612 IF (ABS(G(18)).LT.BIG*EBIG) G(18)=0
8613
8614 C Carbonic acid dissociation
8615 G(19)=equilib8 *(CBA(2,J)+CBA(1,J))/2. -(CBI(2,J)+CBI(1,J))
8616 1 *(HYD(2,J)+HYD(1,J))/4.
8617 B(19,19)=-equilib8/2.
8618 B(19,20)=(HYD(2,J)+HYD(1,J))/4.
8619 B(19,16)=(CBI(2,J)+CBI(1,J))/4.
8620
8621 BIG=ABS(equilib8*CBA(2,J)/2.)
8622 BIG2=ABS(equilib8*CBA(1,J)/2.)
8623 IF (BIG2.GT.BIG) BIG=BIG2
8624 BIG3=ABS(CBI(2,J)*HYD(2,J)/4.)
8625 IF (BIG3.GT.BIG) BIG=BIG3
8626 BIG4=ABS(CBI(2,J)*HYD(1,J)/4.)
8627 IF (BIG4.GT.BIG) BIG=BIG4
8628 BIG5=ABS(CBI(2,J)*HYD(2,J)/4.)
8629 IF (BIG5.GT.BIG) BIG=BIG5
8630 BIG6=ABS(CBI(2,J)*HYD(1,J)/4.)
8631 IF (BIG6.GT.BIG) BIG=BIG6
8632 IF (ABS(G(19)).LT.BIG*EBIG) G(19)=0
8633
8634 C Carbonate ion flux balance
8635 G(20)=CBULK(12)-(CO2(2,J)+CO2(1,J))/2.
8636 1 +CBULK(13)-(CBA(2,J)+CBA(1,J))/2.
8637 2 +CBULK(14)-(CBI(2,J)+CBI(1,J))/2.
8638 B(20,20)=1./2.

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8639     B(20,18) = 1./2.
8640     B(20,19) = 1./2.
8641
8642     BIG=ABS(CBULK(12))
8643     BIG2=ABS(CBULK(13))
8644     IF (BIG2.GT.BIG) BIG=BIG2
8645     BIG3=ABS(CBULK(14))
8646     IF (BIG3.GT.BIG) BIG=BIG3
8647     BIG4=ABS(CO2(2,J)/2.)
8648     IF (BIG4.GT.BIG) BIG=BIG4
8649     BIG5=ABS(CO2(1,J)/2.)
8650     IF (BIG5.GT.BIG) BIG=BIG5
8651     BIG6=ABS(CBA(2,J)/2.)
8652     IF (BIG6.GT.BIG) BIG=BIG6
8653     BIG7=ABS(CBA(1,J)/2.)
8654     IF (BIG7.GT.BIG) BIG=BIG7
8655     BIG8=ABS(CBI(2,J)/2.)
8656     IF (BIG8.GT.BIG) BIG=BIG8
8657     BIG9=ABS(CBI(1,J)/2.)
8658     IF (BIG9.GT.BIG) BIG=BIG9
8659     IF (ABS(G(20)).LT.BIG*EBIG) G(20)=0
8660
8661 C     For Acetaminophen
8662     G(21)=CBULK(16)-(ACE(2,J)+ACE(1,J))/2.
8663
8664     B(21,21) = 1./2.
8665
8666     BIG=ABS(CBULK(16))
8667     BIG2=ABS(ACE(2,J)/2.)
8668     IF (ABS((ACE(2,J)+ACE(1,J))/2.).GT.BIG)
8669 1     BIG=ABS((ACE(2,J)+ACE(1,J))/2.)
8670     IF (ABS(G(21)).LT.BIG*EBIG) G(21)=0
8671
8672 C     DOUBLE LAYER VOLTAGE - DUMMY
8673
8674     G(22)=(VDL(2,J)+VDL(1,J))/2.
8675
8676     B(22,22) = -1./2.
8677
8678     BIG=ABS(VDL(2,J)/2.)
8679     BIG2=ABS(VDL(1,J)/2.)
8680     IF (BIG2.GT.BIG) BIG=BIG2
8681     IF (ABS(G(22)).LT.BIG*EBIG) G(22)=0
8682
8683     RETURN
8684     END
8685
8686 C     Subroutine MATINV
8687     SUBROUTINE MATINV(N,M,DETERM)
8688     IMPLICIT DOUBLE PRECISION (A-H,O-Z)
8689     COMMON/BAB/ A(22,22),B(22,22),C(22,80001),D(22,45),G(22),X(22,22)
8690 1     ,Y(22,22)
8691     COMMON/NSN/ NTEMP, NJ
8692     DIMENSION ID(22)
8693     DETERM=1.01
8694     DO 1 I=1,N
8695 1     ID(I)=0
8696     DO 18 NN=1,N

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8697     BMAX=1.1
8698     DO 6 I=1,N
8699     IF (ID(I).NE.0) GO TO 6
8700     BNEXT=0.0
8701     BTRY=0.0
8702     DO 5 J=1,N
8703     IF (ID(J).NE.0) GO TO 5
8704     IF (DABS(B(I,J)).LE.BNEXT) GO TO 5
8705     BNEXT=DABS(B(I,J))
8706     IF (BNEXT.LE.BTRY) GO TO 5
8707     BNEXT=BTRY
8708     BTRY=DABS(B(I,J))
8709     JC=J
8710 5     CONTINUE
8711     IF (BNEXT.GE.BMAX*BTRY) GO TO 6
8712     BMAX=BNEXT/BTRY
8713     IROW=I
8714     JCOL=JC
8715 6     CONTINUE
8716     IF (ID(JC).EQ.0) GO TO 8
8717     DETERM=0.0
8718     RETURN
8719 8     ID(JCOL)=1
8720     IF (JCOL.EQ.IROW) GO TO 12
8721     DO 10 J=1,N
8722     SAVE=B(IROW,J)
8723     B(IROW,J)=B(JCOL,J)
8724 10    B(JCOL,J)=SAVE
8725     DO 11 K=1,M
8726     SAVE=D(IROW,K)
8727     D(IROW,K)=D(JCOL,K)
8728 11    D(JCOL,K)=SAVE
8729 12    F=1.0/B(JCOL,JCOL)
8730     DO 13 J=1,N
8731 13    B(JCOL,J)=B(JCOL,J)*F
8732     DO 14 K=1,M
8733 14    D(JCOL,K)=D(JCOL,K)*F
8734     DO 18 I=1,N
8735     IF (I.EQ.JCOL) GO TO 18
8736     F=B(I,JCOL)
8737     DO 16 J=1,N
8738 16    B(I,J)=B(I,J)-F*B(JCOL,J)
8739     DO 17 K=1,M
8740 17    D(I,K)=D(I,K)-F*D(JCOL,K)
8741 18    CONTINUE
8742     RETURN
8743     END
8744
8745 C     SUBROUTINE BAND(J)
8746     SUBROUTINE BAND(J)
8747     IMPLICIT DOUBLE PRECISION (A-H,O-Z)
8748     DIMENSION E(22,23,80001)
8749     COMMON/BAB/ A(22,22),B(22,22),C(22,80001),D(22,45),G(22),X(22,22)
8750     1  ,Y(22,22)
8751     COMMON/NSN/ N,NJ
8752     SAVE E, NP1
8753 101   FORMAT(15H DETERM=0 AT J=,I4)
8754     IF (J-2) 1,6,8

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8755 1 NP1=N+1
8756 DO 2 I=1,N
8757 D(I,2*N+1)=G(I)
8758 DO 2 L=1,N
8759 LPN=L+N
8760 2 D(I,LPN)=X(I,L)
8761 CALL MATINV(N, 2*N+1,DETERM)
8762 IF (DETERM) 4,3,4
8763 3 PRINT 101,J
8764 4 DO 5 K=1,N
8765 E(K,NP1,1)=D(K,2*N+1)
8766 DO 5 L=1,N
8767 E(K,L,1)=-D(K,L)
8768 LPN=L+N
8769 5 X(K,L)=-D(K,LPN)
8770 RETURN
8771 6 DO 7 I=1,N
8772 DO 7 K=1,N
8773 DO 7 L=1,N
8774 7 D(I,K)=D(I,K)+A(I,L)*X(L,K)
8775 8 IF (J-NJ) 11,9,9
8776 9 DO 10 I=1,N
8777 DO 10 L=1,N
8778 G(I)=G(I)-Y(I,L)*E(L,NP1,J-2)
8779 DO 10 M=1,N
8780 10 A(I,L)=A(I,L)+Y(I,M)*E(M,L,J-2)
8781 11 DO 12 I=1,N
8782 D(I,NP1)=-G(I)
8783 DO 12 L=1,N
8784 D(I,NP1)=D(I,NP1)+A(I,L)*E(L,NP1,J-1)
8785 DO 12 K=1,N
8786 12 B(I,K)=B(I,K)+A(I,L)*E(L,K,J-1)
8787 CALL MATINV(N, NP1,DETERM)
8788 IF (DETERM) 14, 13, 14
8789 13 PRINT 101,J
8790 14 DO 15 K=1,N
8791 DO 15 M=1, NP1
8792 15 E(K,M,J)=-D(K,M)
8793 IF (J-NJ) 20,16,16
8794 16 DO 17 K=1,N
8795 17 C(K,J)=E(K, NP1, J)
8796 DO 18 JJ=2, NJ
8797 M=NJ-JJ+1
8798 DO 18 K=1,N
8799 C(K,M)=E(K, NP1, M)
8800 DO 18 L=1,N
8801 18 C(K,M)=C(K,M)+E(K,L,M)*C(L,M+1)
8802 DO 19 L=1,N
8803 DO 19 K=1,N
8804 19 C(K,1)=C(K,1)+X(K,L)*C(L,3)
8805 20 RETURN
8806 END

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## REFERENCES

- [1] Timothy S. Bailey, Anna Chang, and Mark Christiansen, *Clinical accuracy of a continuous glucose monitoring system with an advanced algorithm*, Journal of Diabetes Science and Technology **9** (2014), no. 2, 209–214.
- [2] George Edward Briggs and John Burdon Sanderson Haldane, *A note on the kinetics of enzyme action*, Biochemical Journal **19** (1925), no. 2, 338–339.
- [3] H J Bright and M Appleby, *The pH dependence of the individual steps in the glucose oxidase reaction*, Journal of Biological Chemistry **244** (1969), no. 13, 3625–3634.
- [4] Harold J. Bright and Quentin H. Gibson, *The oxidation of 1-deuterated glucose by glucose oxidase*, Journal of Biological Chemistry **242** (1967), no. 5, 994–1003.
- [5] G.J. Brug, A.L.G. van den Eeden, M. Sluyters-Rehbach, and J.H. Sluyters, *The analysis of electrode impedances complicated by the presence of a constant phase element*, Journal of Electroanalytical Chemistry and Interfacial Electrochemistry **176** (1984), no. 1-2, 275–295.
- [6] D. A. G. Bruggeman, *Berechnung verschiedener physikalischer konstanten von heterogenen substanzen. i. dielektrizitätskonstanten und leitfähigkeiten der mischkörper aus isotropen substanzen*, Annalen der Physik **416** (1935), no. 7, 636–664.
- [7] Giacomo Cappon, Martina Vettoretti, Giovanni Sparacino, and Andrea Facchinetti, *Continuous glucose monitoring sensors for diabetes management: A review of technologies and applications*, Diabetes & Metabolism Journal **43** (2019), no. 4, 383.
- [8] Anthony E. G. Cass, Graham. Davis, Graeme D. Francis, H. Allen O. Hill, William J. Aston, I. John. Higgins, Elliot V. Plotkin, Lesley D. L. Scott, and Anthony P. F. Turner, *Ferrocene-mediated enzyme electrode for amperometric determination of glucose*, Analytical Chemistry **56** (1984), no. 4, 667–671.
- [9] Hongjun Chen, Yuling Wang, Ying Liu, Yizhe Wang, Li Qi, and Shaojun Dong, *Direct electrochemistry and electrocatalysis of horseradish peroxidase immobilized in nafion-RTIL composite film*, Electrochemistry Communications **9** (2007), no. 3, 469–474.
- [10] Leland C. Clark and Champ Lyons, *ELECTRODE SYSTEMS FOR CONTINUOUS MONITORING IN CARDIOVASCULAR SURGERY*, Annals of the New York Academy of Sciences **102** (2006), no. 1, 29–45.
- [11] J. Crank and P. Nicolson, *A practical method for numerical evaluation of solutions of partial differential equations of the heat-conduction type*, Mathematical Proceedings of the Cambridge Philosophical Society **43** (1947), no. 1, 50–67.
- [12] Raymond J. Davey, Chee Low, Timothy W. Jones, and Paul A. Fournier, *Contribution of an intrinsic lag of continuous glucose monitoring systems to differences in measured and actual glucose concentrations changing at variable rates in vitro*, Journal of Diabetes Science and Technology **4** (2010), no. 6, 1393–1399.
- [13] Y. Degani and Adam. Heller, *Direct electrical communication between chemically modified enzymes and metal electrodes. i. electron transfer from glucose oxidase to metal electrodes via electron relays, bound covalently to the enzyme*, The Journal of Physical Chemistry **91** (1987), no. 6, 1285–1289.

- [14] Israel Epelboin and Michel Keddam, *Faradaic impedances: Diffusion impedance and reaction impedance*, Journal of The Electrochemical Society **117** (1970), no. 8, 1052.
- [15] I Frateur, C Deslouis, M.E Orazem, and B Tribollet, *Modeling of the cast iron/drinking water system by electrochemical impedance spectroscopy*, Electrochimica Acta **44** (1999), no. 24, 4345–4356.
- [16] Jane E. Frew and H. Allen O. Hill, *Electrochemical biosensors*, Analytical Chemistry **59** (1987), no. 15, 933A–944A.
- [17] R. Gaikwad, P. R. Thangaraj, and A. K. Sen, *Direct and rapid measurement of hydrogen peroxide in human blood using a microfluidic device*, Scientific Reports **11** (2021), no. 1.
- [18] J. Galceran, S.L. Taylor, and P.N. Bartlett, *Modelling the steady-state current at the inlaid disc microelectrode for homogeneous mediated enzyme catalysed reactions*, Journal of Electroanalytical Chemistry **506** (2001), no. 2, 65–81.
- [19] Ming Gao, Morgan S. Hazelbaker, Rui Kong, and Mark E. Orazem, *Mathematical model for the electrochemical impedance response of a continuous glucose monitor*, Electrochimica Acta **275** (2018), 119 – 132.
- [20] Ming Gao and Mark E. Orazem, *The development of advanced mathematical models for continuous glucose sensors*, Electrochimica Acta **382** (2021), 138226.
- [21] Quentin H. Gibson, Bennett E.P. Swoboda, and Vincent Massey, *Kinetics and mechanism of action of glucose oxidase*, Journal of Biological Chemistry **239** (1964), no. 11, 3927–3934.
- [22] David A. Gough, Joseph Y. Lucisano, and Pius H. S. Tse, *Two-dimensional enzyme electrode sensor for glucose*, Analytical Chemistry **57** (1985), no. 12, 2351–2357.
- [23] G.G. Guilbault and G.J. Lubrano, *An enzyme electrode for the amperometric determination of glucose*, Analytica Chimica Acta **64** (1973), no. 3, 439–455.
- [24] Norio Hamamatsu, Akitoshi Suzumura, Yukiko Nomiya, Masaaki Sato, Takuyo Aita, Motowo Nakajima, Yuzuru Husimi, and Yasuhiko Shibasaki, *Modified substrate specificity of pyrroloquinoline quinone glucose dehydrogenase by biased mutation assembling with optimized amino acid substitution*, Applied Microbiology and Biotechnology **73** (2006), no. 3, 607–617.
- [25] Morgan S. Harding, Bernard Tribollet, Vincent Vivier, and Mark E. Orazem, *The influence of homogeneous reactions on the impedance response of a rotating disk electrode*, Journal of The Electrochemical Society **164** (2017), no. 11, E3418–E3428.
- [26] Celia Henry, *Getting under the skin: Implantable glucose sensors*, Analytical Chemistry **70** (1998), no. 17, 594A–598A.
- [27] E M Hudak, J T Mortimer, and H B Martin, *Platinum for neural stimulation: voltammetry considerations*, Journal of Neural Engineering **7** (2010), no. 2, 026005.

- [28] Satoshi Igarashi, Takatsugu Hirokawa, and Koji Sode, *Engineering PQQ glucose dehydrogenase with improved substrate specificity*, *Biomolecular Engineering* **21** (2004), no. 2, 81–89.
- [29] A KICELA and S DANIELE, *Platinum black coated microdisk electrodes for the determination of high concentrations of hydrogen peroxide in phosphate buffer solutions*, *Talanta* **68** (2006), no. 5, 1632–1639.
- [30] Insu Kim, Dohyung Kwon, Dongtak Lee, Tae Hoon Lee, Jeong Hoon Lee, Gyudo Lee, and Dae Sung Yoon, *A highly permselective electrochemical glucose sensor using red blood cell membrane*, *Biosensors and Bioelectronics* **102** (2018), 617–623.
- [31] J. Kropff, D. Bruttomesso, W. Doll, A. Farret, S. Galasso, Y. M. Luijf, J. K. Mader, J. Place, F. Boscari, T. R. Pieber, E. Renard, and J. H. DeVries, *Accuracy of two continuous glucose monitoring systems: a head-to-head comparison under clinical research centre and daily life conditions*, *Diabetes, Obesity and Metabolism* **17** (2014), no. 4, 343–349.
- [32] A. Ledo, E. Fernandes, A. Salvador, J. Laranjinha, and R.M. Barbosa, *In vivo hydrogen peroxide diffusivity in brain tissue supports volume signaling activity*, *Redox Biology* **50** (2022), 102250.
- [33] David M. Maahs, Daniel DeSalvo, Laura Pyle, Trang Ly, Laurel Messer, Paula Clinton, Emily Westfall, R. Paul Wadwa, and Bruce Buckingham, *Effect of acetaminophen on CGM glucose in an outpatient setting*, *Diabetes Care* **38** (2015), no. 10, e158–e159.
- [34] Andrei R. Manolescu, Kate Witkowska, Adam Kinnaird, Tara Cessford, and Chris Cheeseman, *Facilitated hexose transporters: New perspectives on form and function*, *Physiology* **22** (2007), no. 4, 234–240.
- [35] L. Michaelis and Miss Maud L. Menten, *The kinetics of invertin action*, *FEBS Letters* **587** (2013), no. 17, 2712–2720.
- [36] John Newman, *Numerical solution of coupled, ordinary differential equations*, *Industrial & Engineering Chemistry Fundamentals* **7** (1968), no. 3, 514–517.
- [37] John Newman and Karen E. Thomas-Alyea, *Electrochemical systems, 3rd edition*, Wiley-Interscience, 2004.
- [38] Matthew T. Novak, Fan Yuan, and William M. Reichert, *Predicting glucose sensor behavior in blood using transport modeling: Relative impacts of protein biofouling and cellular metabolic effects*, *Journal of Diabetes Science and Technology* **7** (2013), no. 6, 1547–1560.
- [39] Karin Obermaier, Günther Schmelzeisen-Redeker, Michael Schoemaker, Hans-Martin Klötzer, Harald Kirchsteiger, Heino Eikmeier, and Luigi del Re, *Performance evaluations of continuous glucose monitoring systems: Precision absolute relative deviation is part of the assessment*, *Journal of Diabetes Science and Technology* **7** (2013), no. 4, 824–832.

- [40] Timothy J. Ohara, Ravi. Rajagopalan, and Adam. Heller, "wired" enzyme electrodes for amperometric determination of glucose or lactate in the presence of interfering substances, *Analytical Chemistry* **66** (1994), no. 15, 2451–2457.
- [41] Junko Okuda-Shimazaki, Hiromi Yoshida, and Koji Sode, *FAD dependent glucose dehydrogenases – discovery and engineering of representative glucose sensing enzymes -*, *Bioelectrochemistry* **132** (2020), 107414.
- [42] David Olczuk and Ronny Priefer, *A history of continuous glucose monitors (CGMs) in self-monitoring of diabetes mellitus*, *Diabetes & Metabolic Syndrome: Clinical Research & Reviews* **12** (2018), no. 2, 181–187.
- [43] Mark E. Orazem, Pankaj Agarwal, Andrew N. Jansen, Paul T. Wojcik, and Luis H. Garcia-Rubio, *Development of physico-chemical models for electrochemical impedance spectroscopy*, *Electrochimica Acta* **38** (1993), no. 14, 1903–1911.
- [44] Mark E. Orazem, Isabelle Frateur, Bernard Tribollet, Vincent Vivier, Sabrina Marcelin, Nadine Pébère, Annette L. Bunge, Erick A. White, Douglas P. Riemer, and Marco Musiani, *Dielectric properties of materials showing constant-phase-element (CPE) impedance response*, *Journal of The Electrochemical Society* **160** (2013), no. 6, C215–C225.
- [45] Mark E. Orazem and Bernard Tribollet, *Electrochemical impedance spectroscopy*, John Wiley & Sons, Inc., feb 2008.
- [46] V. V. Tuchin, A. N. Bashkatov, É. A. Genina, Yu. P. Sinichkin, and N. A. Lakodina, *In vivo investigation of the immersion-liquid-induced human skin clearing dynamics*, *Technical Physics Letters* **27** (2001), no. 6, 489–490.
- [47] DiABETES UK, *Differences between type 1 and type 2 diabetes*, DiABETES UK (2022), 1.
- [48] S. J. UPDIKE and G. P. HICKS, *The enzyme electrode*, *Nature* **214** (1967), no. 5092, 986–988.
- [49] T. I. Valdes and F. Moussy, *In vitro and in vivo degradation of glucose oxidase enzyme used for an implantable glucose biosensor*, *Diabetes Technology & Therapeutics* **2** (2000), no. 3, 367–376.
- [50] William Watson and Mark Edward Orazem, *EIS: Measurement model program*, (2020).
- [51] Itamar Willner, Vered Heleg-Shabtai, Ron Blonder, Eugenii Katz, Guoliang Tao, Andreas F. Bückmann, and Adam Heller, *Electrical wiring of glucose oxidase by reconstitution of FAD-modified monolayers assembled onto au-electrodes*, *Journal of the American Chemical Society* **118** (1996), no. 42, 10321–10322.
- [52] Nongnoot Wongkaew, Marcel Simsek, Christian Griesche, and Antje J. Baeumner, *Functional nanomaterials and nanostructures enhancing electrochemical biosensors and lab-on-a-chip performances: Recent progress, applications, and future perspective*, *Chemical Reviews* **119** (2018), no. 1, 120–194.

- [53] Hideaki Yamaoka, Yuki Yamashita, Stefano Ferri, and Koji Sode, *Site directed mutagenesis studies of FAD-dependent glucose dehydrogenase catalytic subunit of burkholderia cepacia*, *Biotechnology Letters* **30** (2008), no. 11, 1967–1972.
- [54] Dessi P. Zaharieva, Kamuran Turksoy, Sarah M. McGaugh, Rubin Pooni, Todd Vienneau, Trang Ly, and Michael C. Riddell, *Lag time remains with newer real-time continuous glucose monitoring technology during aerobic exercise in adults living with type 1 diabetes*, *Diabetes Technology & Therapeutics* **21** (2019), no. 6, 313–321.
- [55] Feng-Qi Zhao and Aileen Keating, *Functional properties and genomics of glucose transporters*, *Current Genomics* **8** (2007), no. 2, 113–128.
- [56] B Zhou and Y Lu, *Worldwide trends in diabetes since 1980: a pooled analysis of 751 population-based studies with 4.4 million participants*, *The Lancet* **387** (2016), no. 10027, 1513–1530.

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