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

By

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To Kristin and Ayden.

ACKNOWLEDGEMENTS

This is the acknowledgments tex file, which should have been set in the main file using the command `\setAcknowledgementsFile{Drive:/file/location/acknowledgementsFile}`.

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LIST OF ABBREVIATIONS

$\sum$	Denotes the summation of a series of terms
$\bigcap$	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.

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

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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 regiments 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 picking 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,

$$\beta - \mathrm{D} - \mathrm{glucose} + \mathrm{O_2} \xrightarrow{\mathrm{GOx}} \mathrm{H_2O_2} + \mathrm{GluconicAcid} \tag{2-1}$$

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

$$\mathrm{H_2O_2} \xrightarrow{K_{\mathrm{anodic}}} \mathrm{O_2} + 2\mathrm{H}^+ + 2\mathrm{e}^- \tag{2-2}$$

, 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 $\beta-\mathrm{D}-$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:

$$\mathrm{S}+\mathrm{E}_{\mathrm{ox}} \underset{k_{\mathrm{b},1}}{\overset{k_{\mathrm{f},1}}{\rightleftarrows}} \mathrm{ES} \xrightarrow{k_{\mathrm{f},2}} \mathrm{E}_{\mathrm{red}}+\mathrm{P} \tag{2-3}$$

and the regeneration reaction

$$\mathrm{E}_{\mathrm{red}}+\mathrm{O}_2 \underset{k_{\mathrm{b},3}}{\overset{k_{\mathrm{f},3}}{\rightleftarrows}} \mathrm{EQ} \xrightarrow{k_{\mathrm{f},4}} \mathrm{E}_{\mathrm{ox}}+\mathrm{H}_2\mathrm{O}_2 \tag{2-4}$$

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 $k_{\mathrm{f,i}}$ and $k_{\mathrm{b,i}}$ correspond to the forward and backward rate constants for the individual reactions. All reaction equilibrium coefficients are defined as $K_{\mathrm{eq,i}}=k_{\mathrm{f,i}}/k_{\mathrm{b,i}}$. 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]

$$\mathrm{E} + \mathrm{S} \underset{k_2}{\overset{k_1}{\rightleftarrows}} \mathrm{E} - \mathrm{S} \xrightarrow{k_3} \mathrm{E} + \mathrm{P} \tag{2-5}$$

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 $k_2 >> k_3$, then the rate of product formation is obtained

$$\frac{\mathrm{d}c_\mathrm{P}}{\mathrm{d}t} = \frac{V_\mathrm{max} c_\mathrm{S}}{k_\mathrm{d} + c_\mathrm{S}} \tag{2-6}$$

where $V_\mathrm{max} = k_3 c_{\mathrm{E}_\mathrm{o}}$, $c_{\mathrm{E}_\mathrm{o}} = c_\mathrm{E} + c_{\mathrm{E-S}}$, and $k_\mathrm{d} = k_2/k_1$. 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,

$$R_i = \frac{k_{\mathrm{f},4} k_{\mathrm{f},2} c_{\mathrm{E}_\mathrm{o}} c_\mathrm{glu} c_{\mathrm{O}_2}}{k_{\mathrm{f},2} K_\mathrm{M} c_{\mathrm{O}_2} + k_{\mathrm{f},4} c_\mathrm{glu} c_{\mathrm{O}_2} + k_{\mathrm{f},2} c_\mathrm{glu}} \tag{2-7}$$

where $K_\mathrm{M} = (k_{\mathrm{b},1} + k_{\mathrm{f},2})/k_{\mathrm{f},1}$, 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-Meten 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]

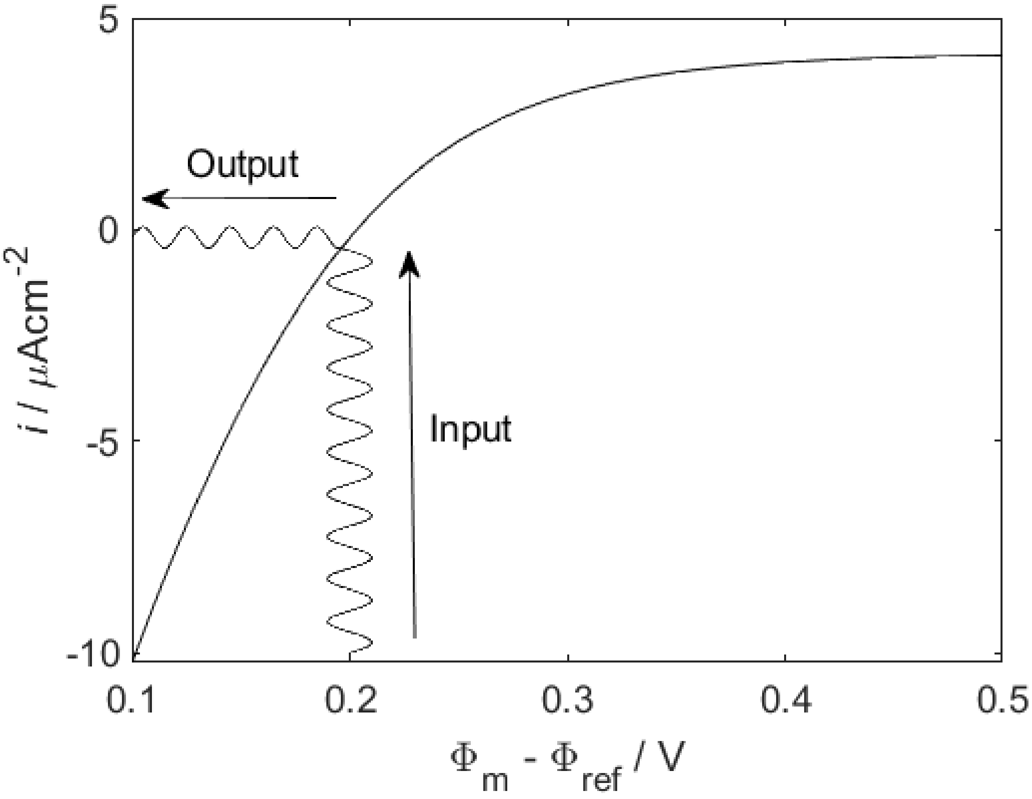


Figure 2-1. Representation of EIS potential input and current output on a polarization curve. The polarization curve is often produced in conjunction with EIS measurements to develop an understanding of the system being analyzed.

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,

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

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

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

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

$$V = \overline{V} + \mathrm{Re}\{\widetilde{V}\exp(\mathrm{j}\omega t)\} \tag{2-10}$$

and

$$I = \overline{I} + \mathrm{Re}\{\widetilde{I}\exp(\mathrm{j}\omega t)\} \tag{2-11}$$

where $\widetilde{V}$ and $\widetilde{I}$ 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, ω, is calculated in a similar relationship to Ohm's Law

$$Z = \frac{\widetilde{V}}{\widetilde{I}} \tag{2-12}$$

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

$$Z = Z_{\mathrm{real}} + \mathrm{j}Z_{\mathrm{j}} \tag{2-13}$$

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
• Series of Voigt elements	• User-defined model representative of system
• Number of Voigt elements arbitrary, but constrained to satisfy the Kramers-Kronig Relations	• Typically fewer parameters, not constrained to circuit analogs
• Provides statistically significant fit to a variety of impedance spectra	• Provides stastically significant fit to data, but not robust like measurement model
• Extract electrolyte resistance, capacitance, and polarization resistance	• Extract parameters specific to electrochemical systems
• Useful with minimal knowledge of the system	• Useful when the system is well understood

2.2.2.1 Measurement Model

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

$$Z = R_0 + \sum_{\mathrm{k}=1}^{\mathrm{K}} \frac{R_{\mathrm{k}}}{1+\mathrm{j}\omega\tau_{\mathrm{k}}} \tag{2-14}$$

where R_0 and R_{k} are resistors and τ_{k} is a time constant equivalent to $R_{\mathrm{k}}C_{\mathrm{k}}$. 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

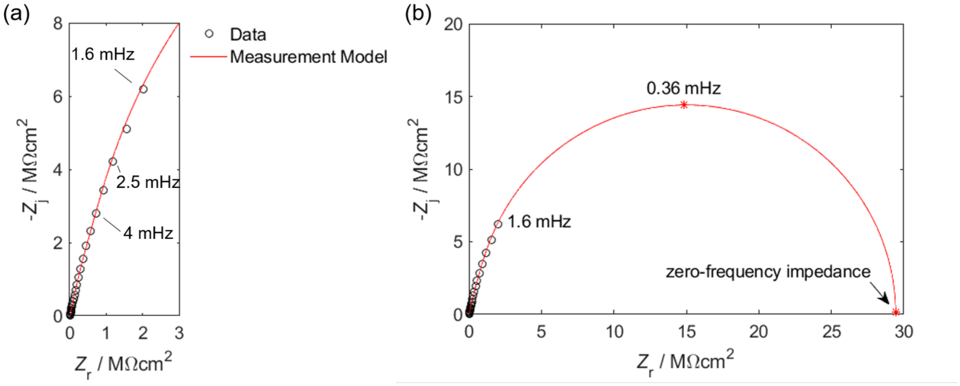


Figure 2-2. Nyquist plots for the measurement model fit with 5 Voigt elements to sample data. Fitting results are presented for (a) Nyquist plot in the high frequency limit and available data and (b) Nyquist plot of the full extrapolated measurement model fit. The measurement model provides estimates 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 / kΩcm^2	τ_k / 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,

$$C = \frac{1}{\sum_{\mathrm{k}=1}^{\mathrm{K}} \frac{1}{C_\mathrm{k}}} = \frac{1}{\sum_{\mathrm{k}=1}^{\mathrm{K}} \frac{R_\mathrm{k}}{\tau_\mathrm{k}}} \tag{2-15}$$

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

$$f_\mathrm{c} = \frac{1}{2\pi C R_\mathrm{p}} \tag{2-16}$$

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 $\| -90^{\mathrm{o}} \|$. 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 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

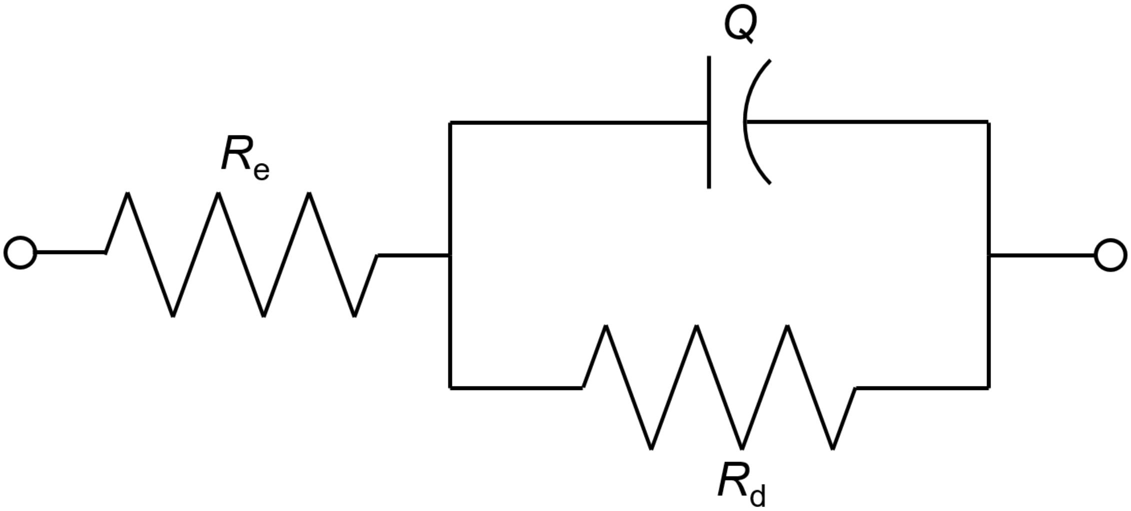


Figure 2-3. Equivalent circuit representation of the sensor impedance model. The electrolyte resistance in series with a parallel constant-phase-element (CPE) and diffusion resistance (R_{d}) yields a single semicircle with a phase angle less than $\| -90^{\mathrm{o}} \|$ at high frequency. This model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

$$C_{\mathrm{eff,surf}} = Q^{1/\alpha} R_{\mathrm{e}}^{(1-\alpha)/\alpha} \tag{2-17}$$

where α, 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

$$Z \ = \ R_{\mathrm{e}} + \frac{R_{\mathrm{d}}}{1 + (\mathrm{j}\omega)^{\alpha} R_{\mathrm{d}} Q} \tag{2-18}$$

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

$$f_{\mathrm{c,ProcessModel}} = \frac{1}{2\pi R_{\mathrm{d}} C_{\mathrm{eff,surf}}} \tag{2-19}$$

, 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.

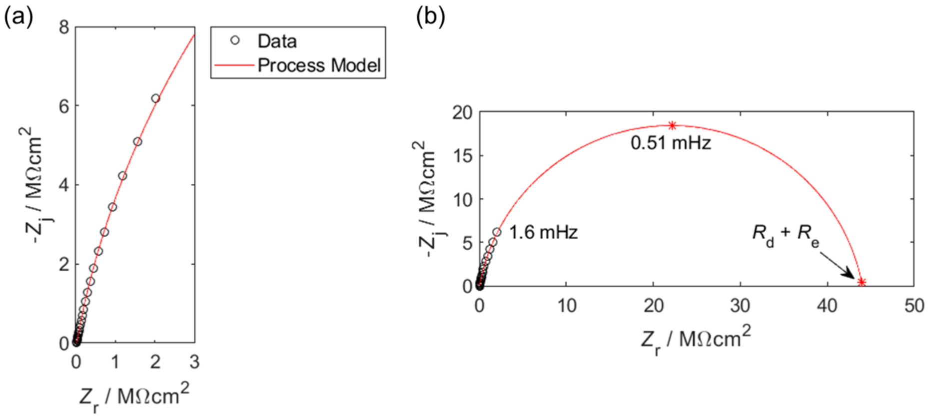


Figure 2-4. Nyquist plots for the process model fit with equation 2-18 to sample data. Fitting results are presented for (a) Nyquist plot in the high frequency limit and available data and (b) Nyquist plot of the full extrapolated process model fit. The process model provides estimates of the CPE parameters,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

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 / kΩ	20.2	18.4
C / μF	6.81	7.02
R_d / MΩ	29.4	44.1
f_c / mHz	0.36	0.51

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

$$\sigma = \alpha \|Z_\mathrm{j}\| + \beta \|Z_\mathrm{r} - R_\mathrm{e}\| + \lambda \|Z\|^2 + \delta \tag{2-20}$$

provides a strategy to estimate the stochastic variation as a function of frequency. σ is the frequency-dependent variation of the data, α is the weighting coefficient for the imaginary part of the impedance, β is the weighting coefficient for the real part of the impedance, γ is the weight coefficient for the modulus of the impedance, and δ 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 α and γ 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.

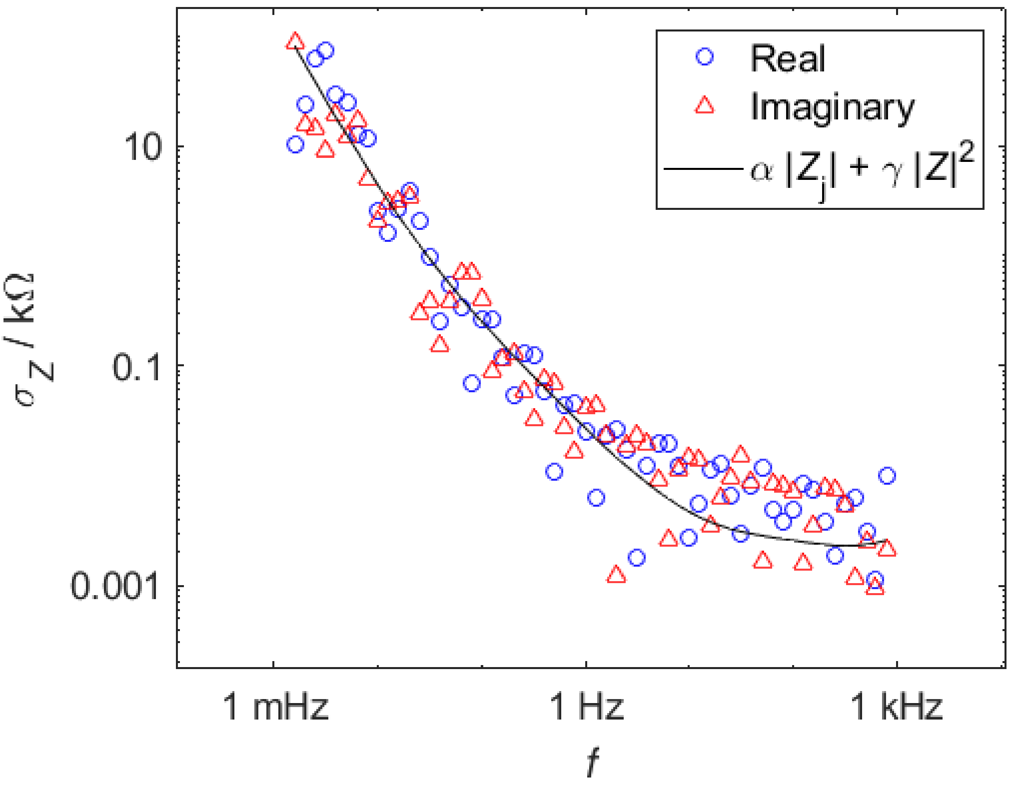


Figure 2-5. Stochastic variation as a function of frequency for the real and imaginary parts of the impedance. An error model of the form presented by equation 2-20 was fit to the data with only α and γ weighting parameters selected. Stochastic error of the data is characterized by a distribution of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

$$\left.\frac{\mathrm{d}c}{\mathrm{d}y}\right|_{\mathrm{J}} = \frac{c(\mathrm{J}+h) - c(\mathrm{J}-h)}{2h} + \mathscr{O}(h^2) \tag{2-21}$$

for a first-order derivative and

$$\left.\frac{\mathrm{d}^2c}{\mathrm{d}y^2}\right|_{\mathrm{J}} = \frac{c(\mathrm{J}+h) - 2c(\mathrm{J}) + c(\mathrm{J}-h)}{h^2} + \mathscr{O}(h^2) \tag{2-22}$$

for second-order derivative approximations of c evaluated at $y = \mathrm{J}$, 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

$$\left.\frac{\mathrm{d}c}{\mathrm{d}y}\right|_{\mathrm{J,n}} = \frac{c^{\mathrm{n+1}}(\mathrm{J}+h)-c^{\mathrm{n+1}}(\mathrm{J}-h)+c^{\mathrm{n}}(\mathrm{J}+h)-c^{\mathrm{n}}(\mathrm{J}-h)}{2h}+\mathscr{O}(h^2)+\mathscr{O}(t^2) \tag{2-23}$$

for a first-order spatial derivative,

$$\left.\frac{\mathrm{d}^2c}{\mathrm{d}y^2}\right|_{\mathrm{J,n}} = \frac{c^{\mathrm{n+1}}(\mathrm{J}+h)-2c^{\mathrm{n+1}}(\mathrm{J})+c^{\mathrm{n+1}}(\mathrm{J}-h)+c^{\mathrm{n}}(\mathrm{J}+h)-2c^{\mathrm{n}}(\mathrm{J})+c^{\mathrm{n}}(\mathrm{J}-h)}{2h^2}+\mathscr{O}(h^2)+\mathscr{O}(t^2) \tag{2-24}$$

for a second-order spatial derivative and

$$\left.\frac{\mathrm{d}c}{\mathrm{d}t}\right|_{\mathrm{J,n}} = \frac{c^{\mathrm{n+1}}(\mathrm{J})-c^{\mathrm{n}}(\mathrm{J})}{\Delta t}+\mathscr{O}(h^2)+\mathscr{O}(t^2) \tag{2-25}$$

for a first-order time derivative evaluated at spatial node J, and temporal node n+1/2 with a temporal step size of Δt. 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

$$\sum_{\mathrm{k}=1}^{\mathrm{n}} A_{\mathrm{i,k}}(\mathrm{J})C_{\mathrm{k}}(\mathrm{J}-1)+B_{\mathrm{i,k}}(\mathrm{J})C_{\mathrm{k}}(\mathrm{J})+D_{\mathrm{i,k}}(\mathrm{J})C_{\mathrm{k}}(\mathrm{J}+1)=G_{\mathrm{i}}(\mathrm{J}) \tag{2-26}$$

where the system must be resolved at all nodes J for all variables i, $A_{\mathrm{i,k}}(\mathrm{J})$, $B_{\mathrm{i,k}}(\mathrm{J})$, and $D_{\mathrm{i,k}}(\mathrm{J})$ 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.

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

Figure 2-6. The BAND algorithm forms a tri-diagonal Jacobian matrix with variables $A_{\mathrm{i,k}}(\mathrm{J})$, $B_{\mathrm{i,k}}(\mathrm{J})$, and $D_{\mathrm{i,k}}(\mathrm{J})$. ΔC is the change variable vector which adjusts the variable guesses for all $c_{\mathrm{i,k}}$ 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 pertubation.

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

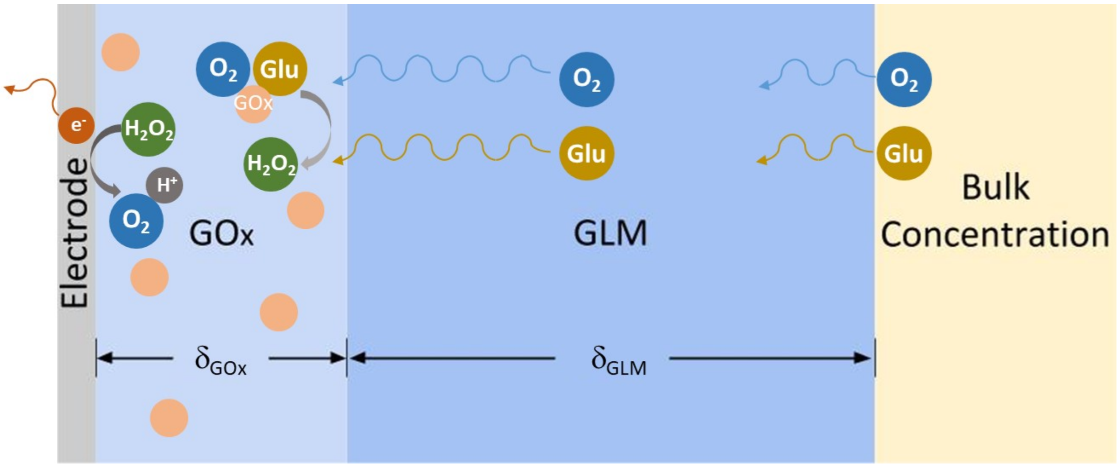


Figure 3-1. A one-dimensional diagram of the continuous glucose monitor showing the diffusion and reaction of the individual species. Glucose and oxygen diffuse through the GLM and into the GOX layer. Glucose reacts with the oxidized enzyme to form the reduced enzyme. Oxygen reacts with the reduced enzyme 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

$$\mathrm{GOx_{ox}} + \beta - \mathrm{D} - \mathrm{glucose} \underset{k_{b,1}}{\overset{k_{f,1}}{\rightleftarrows}} \mathrm{GOx_{red}} - \mathrm{GA} \xrightarrow{k_{f,2}} \mathrm{GOx_{red}} + \mathrm{GA} \tag{3-1}$$

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

$$\mathrm{GOx_{red}} + \mathrm{O_2} \underset{k_{b,3}}{\overset{k_{f,3}}{\rightleftarrows}} \mathrm{GOx_{ox}} - \mathrm{H_2O_2} \xrightarrow{k_{f,4}} \mathrm{GOx_{ox}} + \mathrm{H_2O_2} \tag{3-2}$$

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

$$R_1 = k_{f,1} c_{\mathrm{GOx_{ox}}} c_{\mathrm{glu}} - k_{b,1} c_{\mathrm{GOx_{red}-GA}} \tag{3-3}$$

$$R_2 = k_{f,2} c_{\mathrm{GOx_{red}-GA}} \tag{3-4}$$

$$R_3 = k_{f,3} c_{\mathrm{GOx_{red}}} c_{\mathrm{O_2}} - k_{b,3} c_{\mathrm{GOx_{ox}-H_2O_2}} \tag{3-5}$$

$$R_4 = k_{f,4} c_{\mathrm{GOx_{ox}-H_2O_2}} \tag{3-6}$$

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

$$\frac{\partial c_{\mathrm{GOx_{ox}}}}{\partial t} = R_4 - R_1 \tag{3-7}$$

for oxidized glucose oxidase,

$$\frac{\partial c_{\mathrm{GOx_{red}-GA}}}{\partial t} = R_1 - R_2 \tag{3-8}$$

for the first enzyme complex formed, and

$$\frac{\partial c_{\mathrm{GOx_{red}}}}{\partial t} = R_2 - R_3 \tag{3-9}$$

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

$$c_{\mathrm{GOx_{ox}-H_2O_2}} = E_{\mathrm{o}} - c_{\mathrm{GOx_{ox}}} - c_{\mathrm{GOx_{red}-GA}} - c_{\mathrm{GOx_{red}}} \tag{3-10}$$

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

$$\frac{\partial c_{\mathrm{i}}}{\partial t} = D_{\mathrm{eff,i}} \frac{\partial^2 c_{\mathrm{i}}}{\partial y^2} + \sum_i R_{\mathrm{i}} \tag{3-11}$$

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

$$\mathrm{H_2O_2} \xrightarrow{K_{\mathrm{H_2O_2}}} \mathrm{O_2} + 2\mathrm{H}^+ + 2\mathrm{e}^- \tag{3-12}$$

where $\mathrm{K_i}$ denotes the heterogeneous rate constant. There are two cathodic reactions,

$$\mathrm{O_2} + 2\mathrm{H}^+ + 2\mathrm{e}^- \xrightarrow{K_{\mathrm{O_2}}} \mathrm{H_2O_2} \tag{3-13}$$

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

$$\mathrm{H_2O_2} + 2\mathrm{H}^+ + 2\mathrm{e}^- \xrightarrow{K_{\mathrm{red}}} 2\mathrm{H_2O} \tag{3-14}$$

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

$$j_{\mathrm{H_2O_2}} = \mathrm{K}_{\mathrm{H_2O_2}} c_{\mathrm{H_2O_2}}(0)\exp(b_{\mathrm{H_2O_2}} V) \tag{3-15}$$

where j_{i} is the current density for heterogeneous reaction i, $c_{\mathrm{H_2O_2}}(0)$ 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 $\mathrm{K}_{\mathrm{H_2O_2}}$. 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

$$j_{\mathrm{O_2}} = -\mathrm{K}_{\mathrm{O_2}} c_{\mathrm{O_2}}(0)\exp(-b_{\mathrm{O_2}} V) \tag{3-16}$$

for the reverse reaction, and

$$j_{\mathrm{red}} = -\mathrm{K}_{\mathrm{red}} c_{\mathrm{H_2O_2}}(0)\exp(-b_{\mathrm{red}} V) \tag{3-17}$$

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

$$\left.\frac{dc_{\mathrm{i}}}{dy}\right|_{y=0} = \sum_i \frac{\mathrm{s_i}}{n\mathrm{F}D_{\mathrm{eff,i}}} j_{\mathrm{i}} \tag{3-18}$$

where $\mathrm{s_i}$ 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

$$\left.\frac{dc_{\mathrm{i}}}{dy}\right|_{y=0} = 0 \tag{3-19}$$

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,

$$c_{\mathrm{i}}(\delta_{\mathrm{GOx}}+\delta_{\mathrm{GLM}}) = \mathrm{K}_{\mathrm{i,partition}}c_{\mathrm{i,bulk}} \tag{3-20}$$

where $\mathrm{K}_{\mathrm{i,partition}}$ is the partition coefficient, and $c_{\mathrm{i,bulk}}$ is the concentration of species i in the bulk. Fluxes match at the GOx-GLM interface,

$$D_{\mathrm{GOx,i}}\left.\frac{dc_{\mathrm{i}}}{dy}\right|_{y=\delta_{\mathrm{GOx}}} = D_{\mathrm{GLM,i}}\left.\frac{dc_{\mathrm{i}}}{dy}\right|_{y=\delta_{\mathrm{GOx}}} \tag{3-21}$$

where $D_{\mathrm{GOx,i}}$ and $D_{\mathrm{GLM,i}}$ 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

$$V_{\mathrm{applied}} = \mathrm{R}_{\mathrm{e}}\left(i_{\mathrm{F}}+C\frac{\mathrm{d}V}{\mathrm{d}t}\right)+V \tag{3-22}$$

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

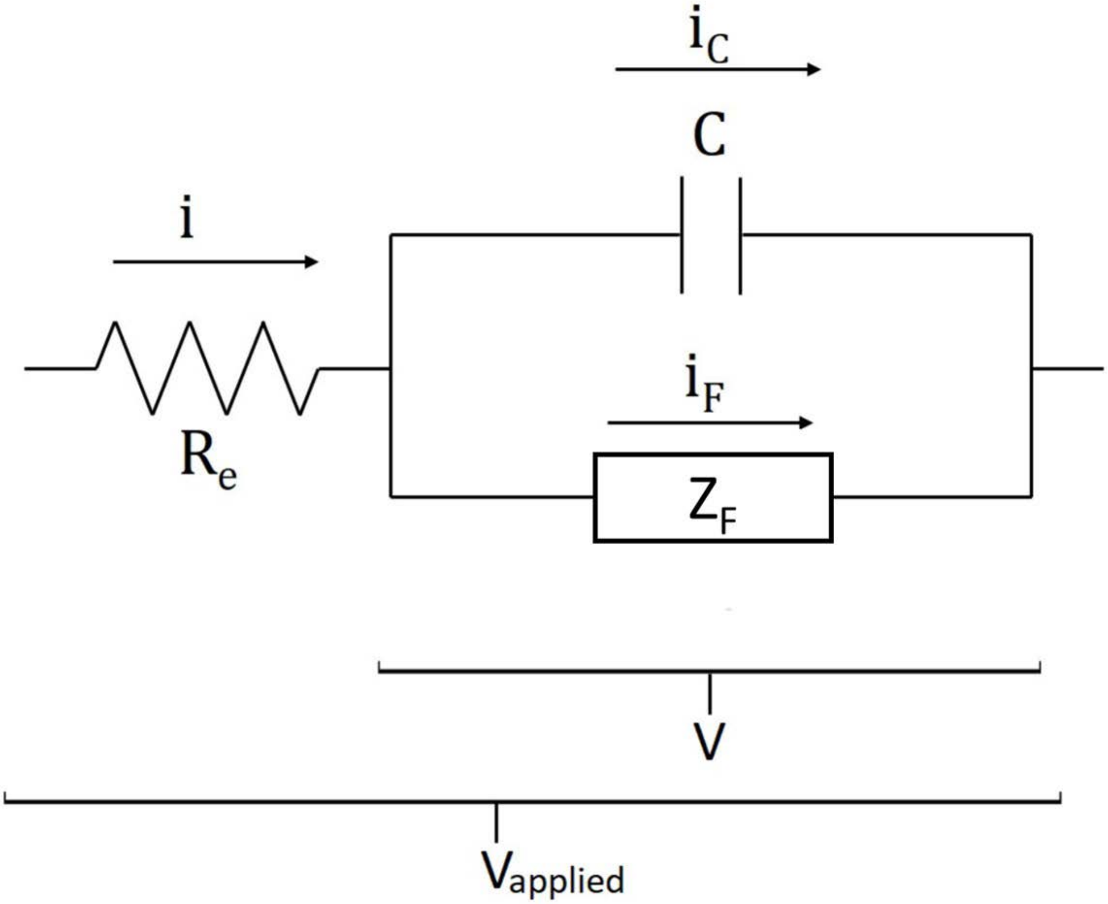


Figure 3-2. Equivalent circuit representation of double-layer. Charging current is modeled as current flow through a capacitor, while the faradaic current is considered a faradaic impedance, Z_F.

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,

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

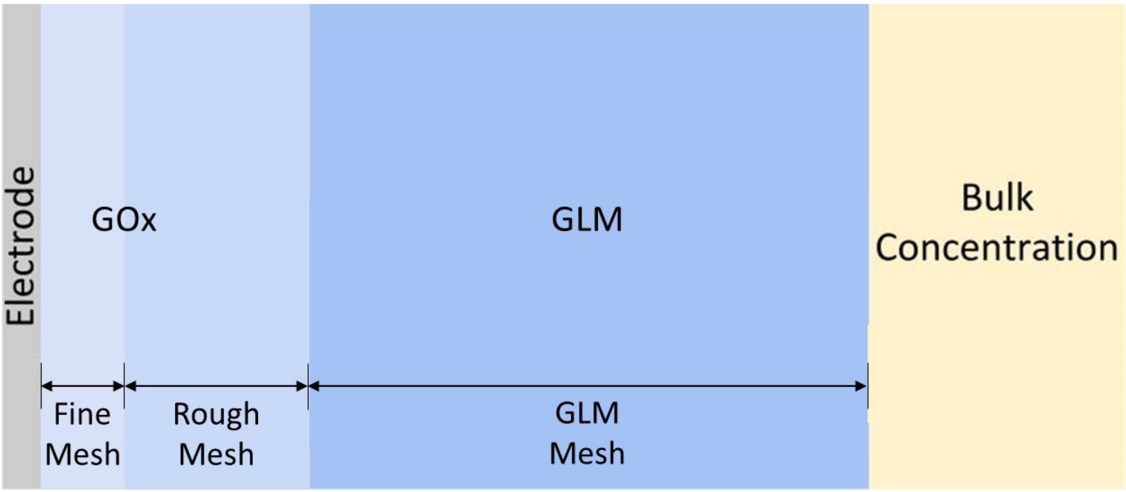


Figure 3-3. Spatial discretization of the entire glucose sensor numerical domain. Each mesh spacing consists of 200 nodes, plus an additional node for the electrode for a total of 601 nodes.

where J is the node of the discretization, and Δy 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

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

and at J+1/4 yields

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

where Δy_{left} and $\Delta y_{\mathrm{right}}$ 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 $N_{\mathrm{i,J}}$ 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

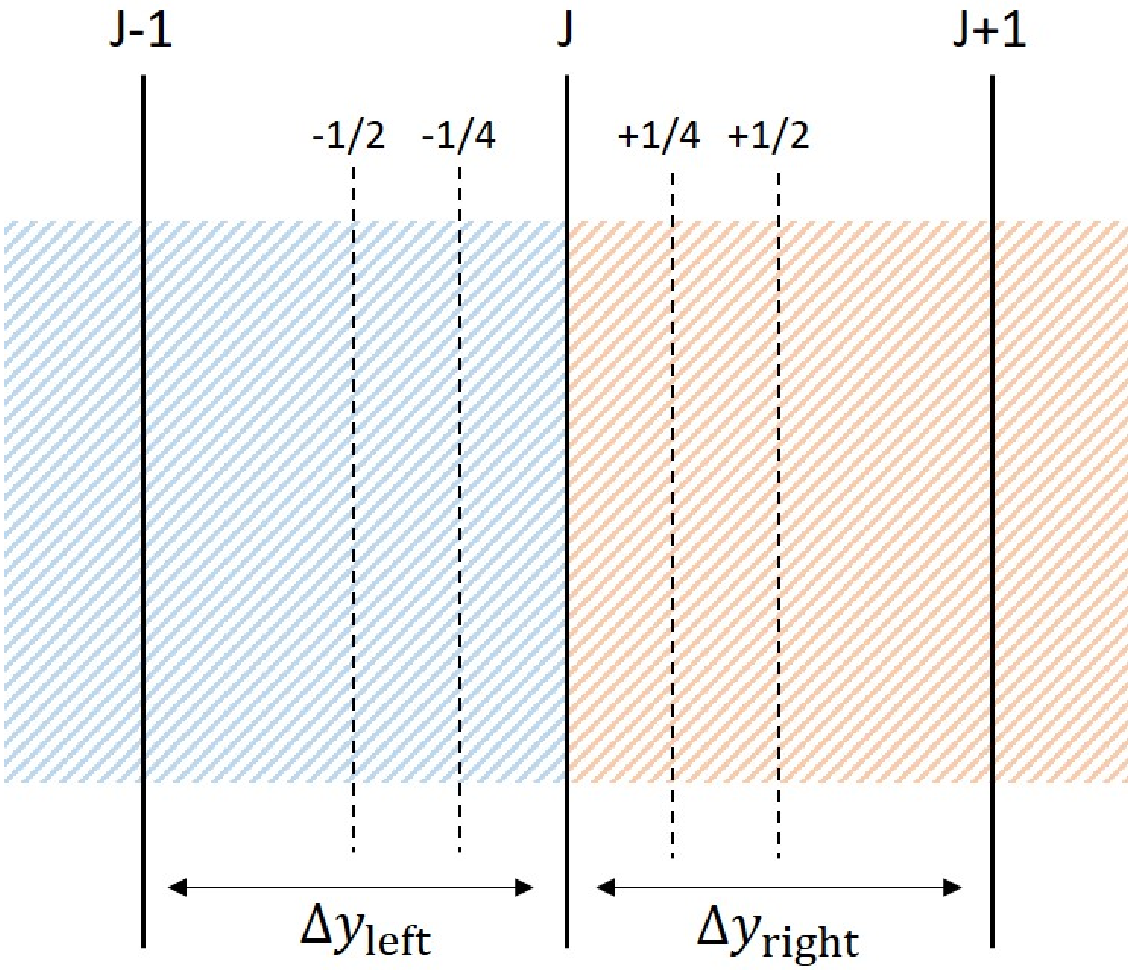


Figure 3-4. Visualization of the quarter-mesh points around node J, where two individually spaced regions interface. A mass balance around J-1/4 and J+1/4 allows for a central difference scheme.

across time and space for transient diffusion yields

$$\frac{c_{\mathrm{i,J}}^{\mathrm{n+1}} - c_{\mathrm{i,J}}^{\mathrm{n}}}{\Delta t} = D_{\mathrm{i}} \frac{c_{\mathrm{i,J+1}}^{\mathrm{n+1}} - 2c_{\mathrm{i,J}}^{\mathrm{n+1}} + c_{\mathrm{i,J-1}}^{\mathrm{n+1}} + c_{\mathrm{i,J+1}}^{\mathrm{n}} - 2c_{\mathrm{i,J}}^{\mathrm{n}} + c_{\mathrm{i,J-1}}^{\mathrm{n}}}{2\Delta y^2} \tag{3-26}$$

where Δt 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^{-1} 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 $R_\mathrm{e}C$, or 0.3 s. After the applied potential is

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

Parameter	Value	Units
Bulk Oxygen Concentration, $c_{\mathrm{O_2,o}}$	52.8	$\mathrm{nmol/cm^3}$
Total Enzyme Loading, $c_{\mathrm{E,o}}$	0.356	$\mu\mathrm{mol/cm^3}$
Diffusion coefficient of Glucose, D_{GLU}	2.98×10^{-6}	$\mathrm{cm^2/s}$
Diffusion coefficient of Gluconic Acid, D_{GLA}	2.98×10^{-6}	$\mathrm{cm^2/s}$
Diffusion coefficient of Oxygen, $D_{\mathrm{O_2}}$	2.46×10^{-5}	$\mathrm{cm^2/s}$
Diffusion coefficient of Hydrogen Peroxide, $D_{\mathrm{H_2O_2}}$	1.83×10^{-5}	$\mathrm{cm^2/s}$
Porosity of GOX Layer	0.8	
Porosity of GLM Layer for O_2 and H_2O_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	$\mu\mathrm{m}$
Glucose Limiting Membrane Layer Thickness	20	$\mu\mathrm{m}$
Electrolyte Resistance, $\mathrm{R_e}$	10	$\Omega\mathrm{cm^2}$
Double Layer Capacitance, C	20×10^{-6}	$\mathrm{F/cm^2}$
Forward rate and equilibrium constants for Reaction 1, $k_{\mathrm{f},1}$ and $k_{\mathrm{b},1}$	1×10^9 and 1×10^7	$\mathrm{cm^3mol^{-1}s^{-1}}$
Forward constant for Reaction 2, $k_{\mathrm{f},2}$	1×10^9	$\mathrm{s^{-1}}$
Forward rate and equilibrium constants for Reaction 3, $k_{\mathrm{f},3}$ and $k_{\mathrm{b},3}$	1×10^9 and 1×10^7	$\mathrm{cm^3mol^{-1}s^{-1}}$
Forward constant for Reaction 4, $k_{\mathrm{f},4}$	1×10^3	$\mathrm{s^{-1}}$
Heterogeneous rate constant, H_2O_2 oxidation, K_{a}	0.2	$\mathrm{A/mol \cdot cm^2}$
Electrode Constant, H_2O_2 oxidation, b_{a}	37.42	$\mathrm{V^{-1}}$
Heterogeneous rate constant, O_2 reduction, K_{a}	5×10^{-6}	$\mathrm{A/mol \cdot cm^2}$
Electrode Constant, O_2 reduction, b_{a}	38.4	$\mathrm{V^{-1}}$
Heterogeneous rate constant, H_2O_2 reduction, K_{a}	5×10^4	$\mathrm{A/mol \cdot cm^2}$
Electrode Constant, H_2O_2 reduction, b_{a}	32	$\mathrm{V^{-1}}$

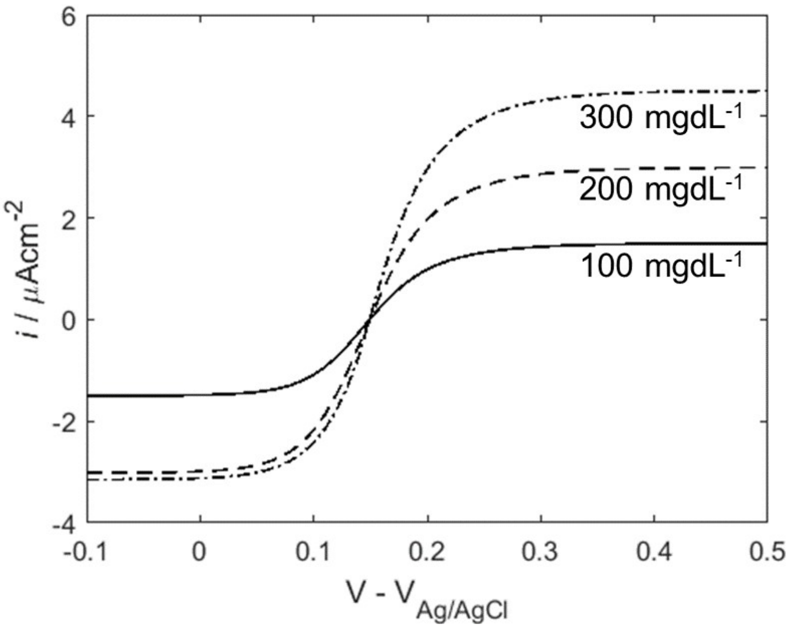


Figure 3-5. Polarization curves from -0.1 to 0.5 V for glucose concentrations of 100, 200 and 300 mgdL^{-1}. Peak anodic current increases with increasing glucose. Mass transfer limited potential is the same for all 3 glucose concentrations.

stepped, charging current jumps to a peak value of $R_e^{-1}\Delta V$ (575 μAcm^{-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 → 0.40 V(Ag/AgCl)	300 mg/dL	Potential Step	3-7,3-8,3-9,3-10
0.40 V(Ag/AgCl)	100 → 300 mg/dL	Glucose Step	3-11
0.35 V(Ag/AgCl)	300 mg/dL	Impedance Response	3-12,3-13
0.30 → 0.40 and 0.40 → 0.30 V(Ag/AgCl)	300 mg/dL	Potential Step	3-14

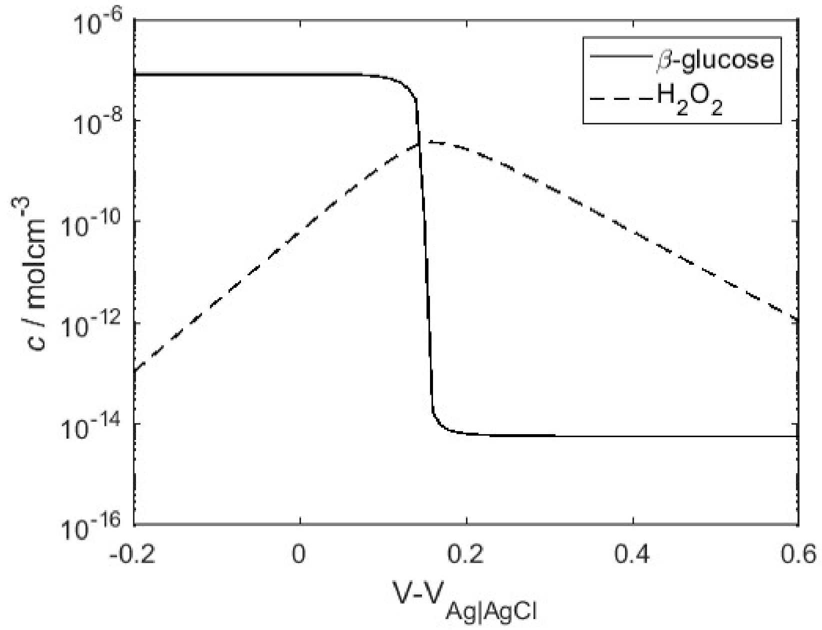


Figure 3-6. Steady concentration of glucose and hydrogen peroxide at the electrode surface as a function of potential for a bulk glucose concentration of 300 mgdL^{-1}. Hydrogen peroxide is mass transfer limited at cathodic and anodic potentials.

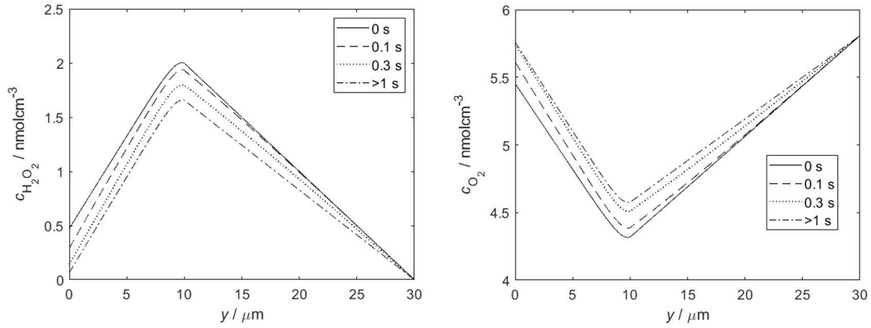


Figure 3-7. Transient concentration profiles for a) Hydrogen Peroxide and b) Oxygen at 0 s, 0.1 s, 0.3 s, and times past 1 s in response to a potential step from 0.3 to 0.4 V at 0 s. In response to the potential step, the anodic reaction rate of hydrogen peroxide is increased. Rate of consumption and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

accumulation of GOx$_{red}$; 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

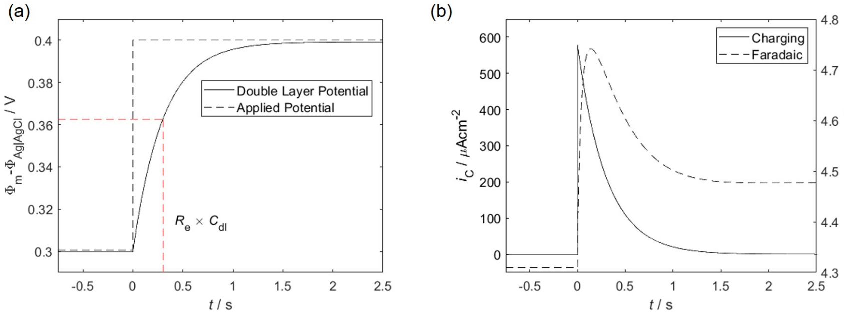


Figure 3-8. Transient response of a) double layer potential and b) charging and faradaic current. Double layer potential charges with a time constant of R_eC from 0.3 to 0.4 V. Charging current begins at peak value as double layer charging rate is maximal, and decays to 0 when fully charged. Faradaic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

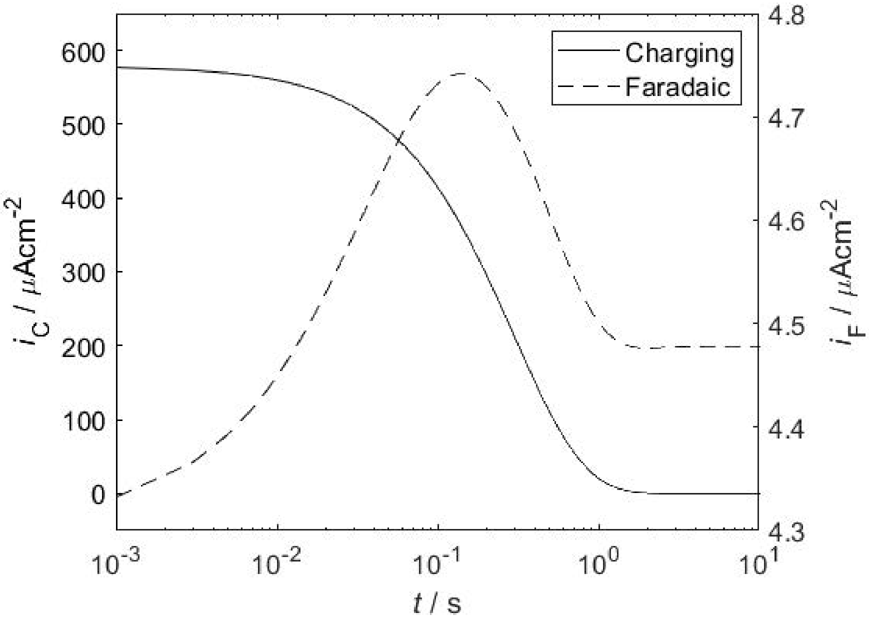


Figure 3-9. Results of Figure 3-8 b) presented on a semi-log time scale. Faradaic current reaches a peak value during the charging process, as excess hydrogen peroxide is consumed at the electrode.

perturbations to glucose concentration. Charging and faradaic current responses to a step change in bulk glucose from 100 to 300 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

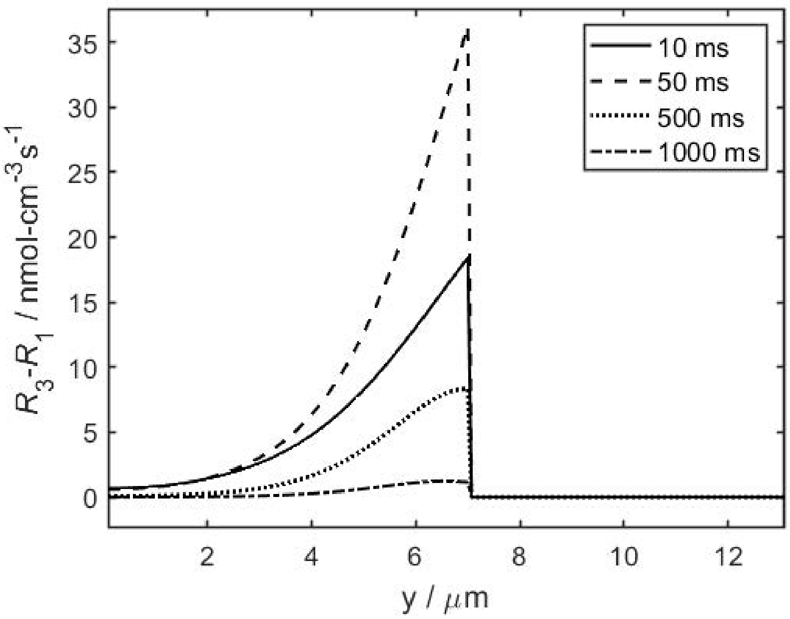


Figure 3-10. Reaction difference between R_3 and R_1 presented from 10 to 1000 ms in response to a potential step from 0.3 to 0.4 V. Complex dissociation for this group of simulations is assumed to occur rapidly. R_2 and R_4 occur at the same rate as R_3 and R_1; thus the difference is also the rate of accumulation of GOx_{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 δ is the domain thickness and D is the diffusion coefficient. For δ 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.

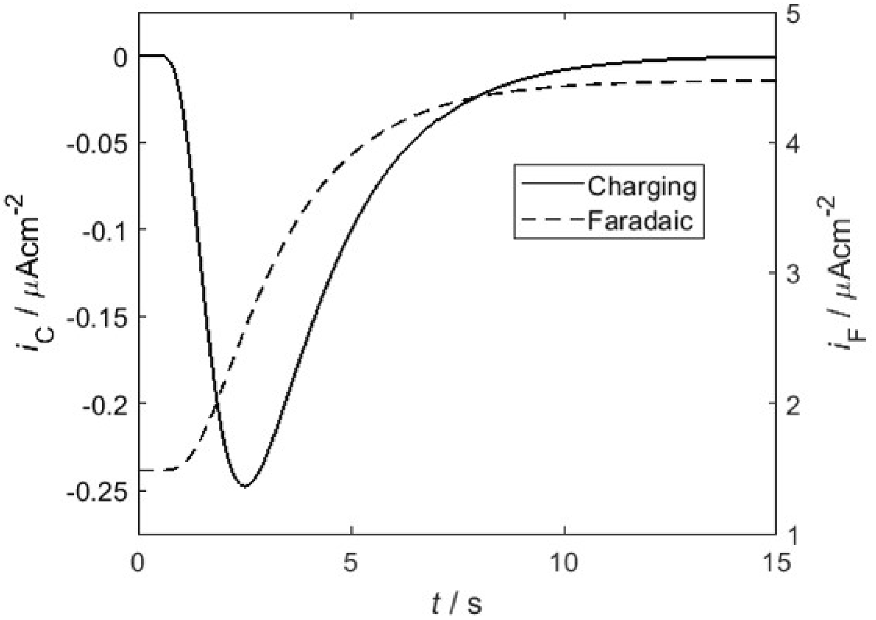


Figure 3-11. Charging and faradaic current response to a step in bulk glucose concentration from 100 mgdL^{-1} to 300 mgdL^{-1} at time = 0 s. The initial delay in the faradaic response is the time for the elevated glucose to transport through the GLM. Charging current is nonzero during the faradaic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

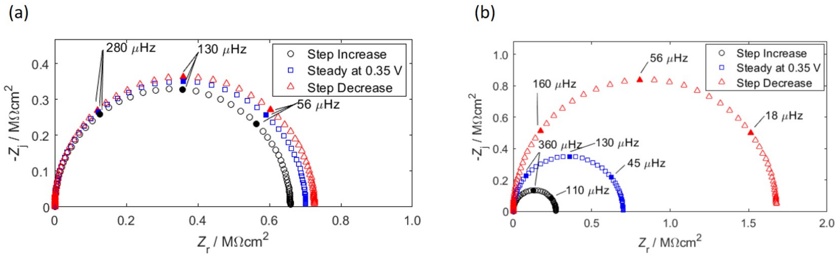


Figure 3-12. Overall impedance response for 3 different initializing conditions: steady state at 0.35 V, and intermediate times for either a potential step increase from 0.3 V to 0.4 V or step decrease from 0.4 V to 0.3 V. For the transient initializing case, the conditions were either chose when (a) 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 μAcm^{-2}

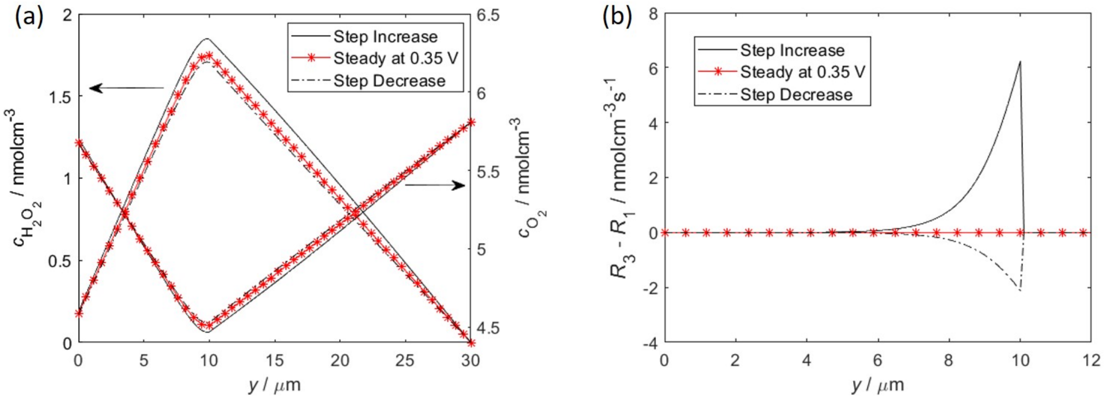


Figure 3-13. Profiles presented at intermediate times for the 3 cases when double layer potential is 0.35 V for (a)concentration of hydrogen peroxide and oxygen, and (b) difference between reactions 3 and 1. At intermediate times for the transient response, reaction profiles are unequal which leads to 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 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

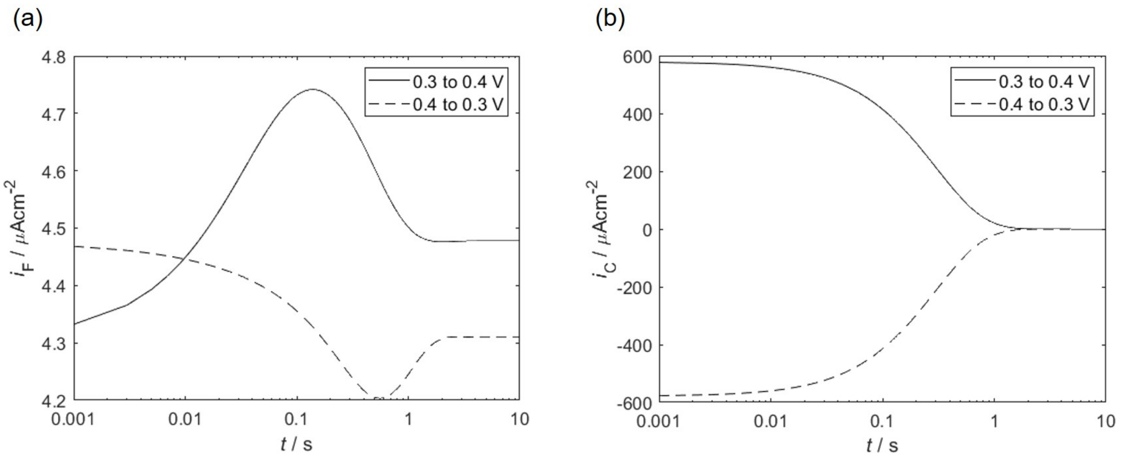


Figure 3-14. A potential step increase from 0.3 to 0.4 V, or decrease from 0.4 to 0.3 V was simulated; during the charging process, the transient results served as initial conditions for the impedance model. For a potential step change there is a corresponding (a) faradaic current response and (b) charging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

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

Only the total enzyme concentration is considered with the Michaelis-Menten kinetcs, individual enzyme species are not explicitly considered. The transient model presented demonstrates unequal enzyme reactions and thus $\mathrm{GOx_{ox}}$ and $\mathrm{GOx_{red}}$ 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

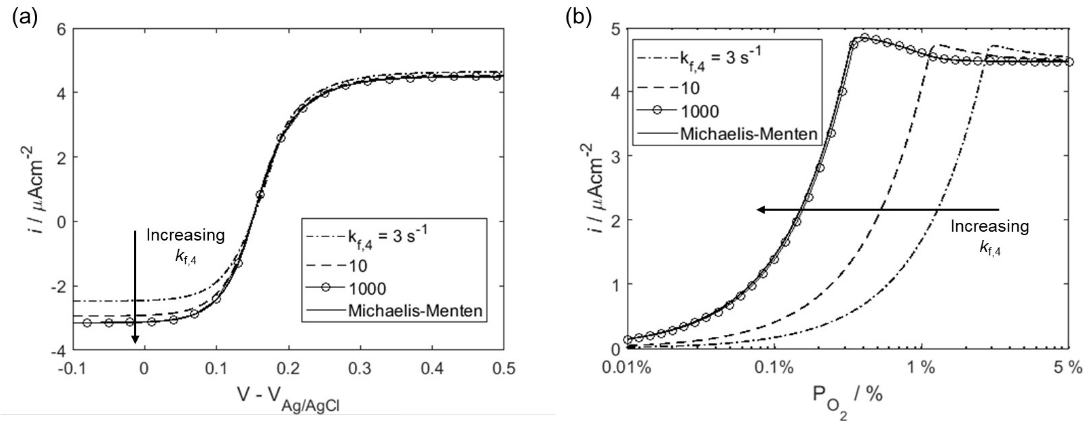


Figure 3-15. Comparison of steady model with Michaelis-Menten model as a function of (a) potential at 5% P_{O_2} and (b) oxygen concentration at 0.4 V. The Michaelis-Menten model assumes equation (2-4) proceeds irreversibly with rapid dissociation of the enzyme complex. Reducing the rate constant, $k_{\mathrm{f},4}$,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

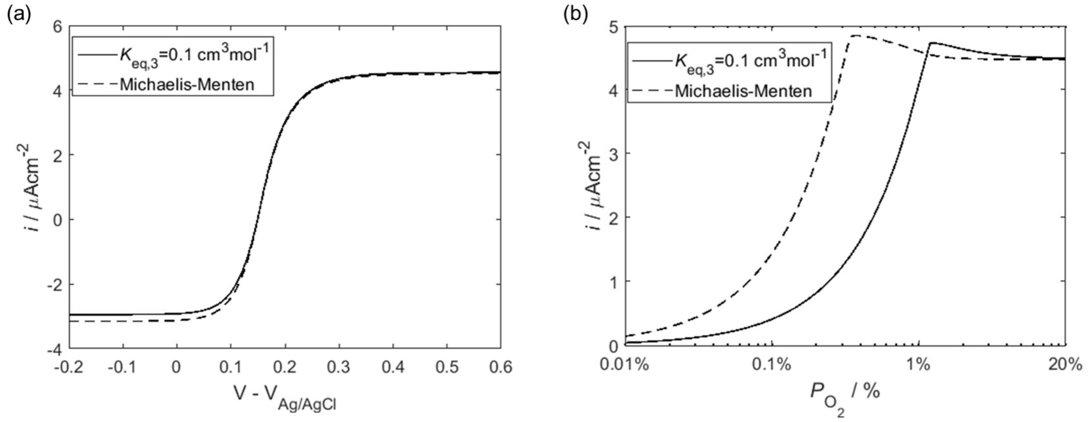


Figure 3-16. Comparison of steady model with Michaelis-Menten model as a function of (a) potential at 5% P_{O_2} and 300 mgdL^{-1} and (b) oxygen concentration at 0.4 V. The Michaelis-Menten model assumes equation (2-4) proceeds irreversibly with rapid dissociation of the enzyme complex. Reducing the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

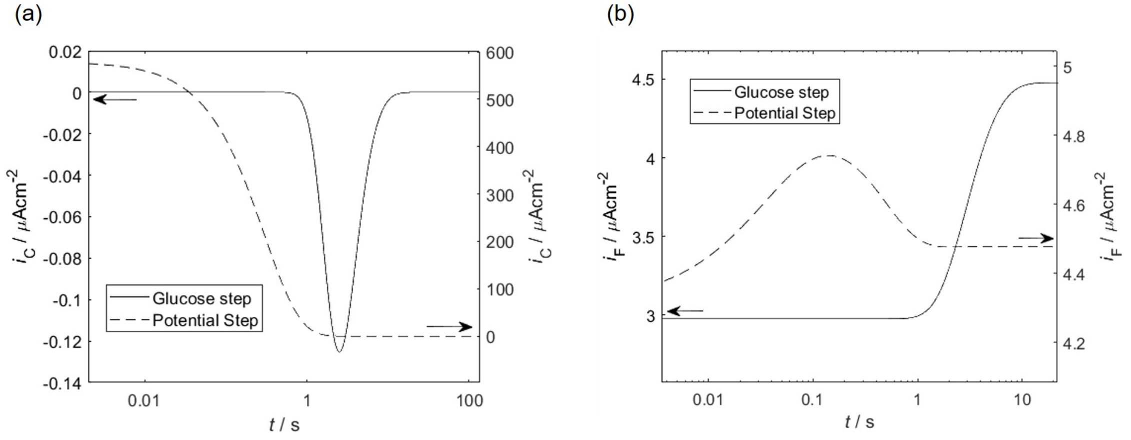


Figure 3-17. Semilog current response to a potential step from 0.3 to 0.4 V and 300 mgdL^{-1} glucose, or a glucose step from 200 to 300 mgdL^{-1} and 0.4 V for the (a)charging current and (b)faradaic current. These results suggest the response to a step change in potential are more rapid than the response 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

$$\tau_{k_{\mathrm{f,2or4}}} = \left(k_{\mathrm{f,2or4}}\right)^{-1} \tag{3-27}$$

where τ is the exponential rate constant fit at long times of the current response according to

$$i \propto \exp(-t/\tau) \tag{3-28}$$

, 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

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

where δ_{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 $k_{\text{f},2}$ and the accompanying time constants are presented in Figure 3-18. The rate constants for reactions 2 and 4 have units of 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 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

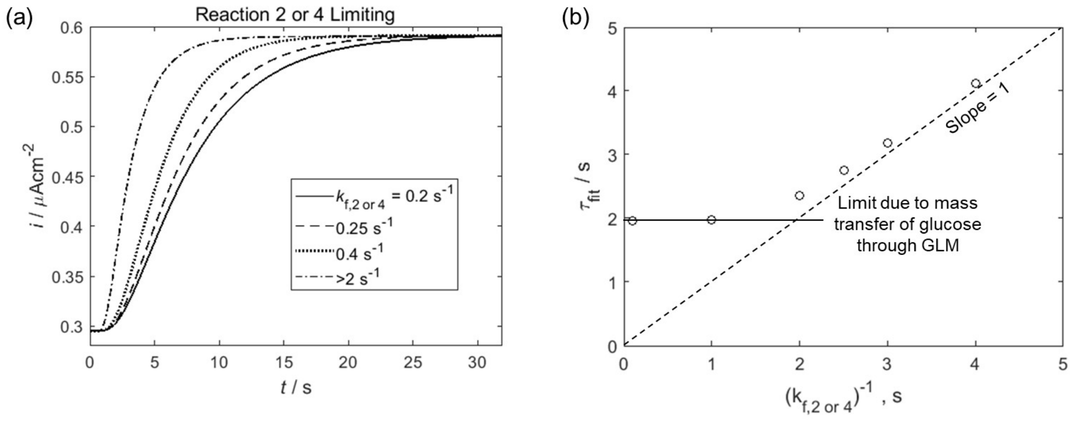


Figure 3-18. (a) Current response to glucose step from 20 to 40 mgdL^{-1} at 0.4V for varied values of the limiting rate constant when the limiting constant is $k_{\text{f},2}$ or $k_{\text{f},4}$. (b) Exponential time constant fits of the current response follow a slope of 1 vs. $(k_{\text{f},2})^{-1}$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

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

$$\tau_{k_{\mathrm{f},1}} = \left(c_{\mathrm{E_o}} k_{\mathrm{f},1}\right)^{-1} \tag{3-30}$$

where $c_{\mathrm{E_o}}$ 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

$$\frac{R_\mathrm{t}}{R_\mathrm{d}} \ll 1 \tag{3-31}$$

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 $R_\mathrm{d}C_\mathrm{dl}$. 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 $M\Omega\mathrm{cm}^2$ for a potential step increase and decrease, at 0.35 V, respectively. Charging of the electrode occurs with a time constant of $R_\mathrm{e}C_\mathrm{dl}$. 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

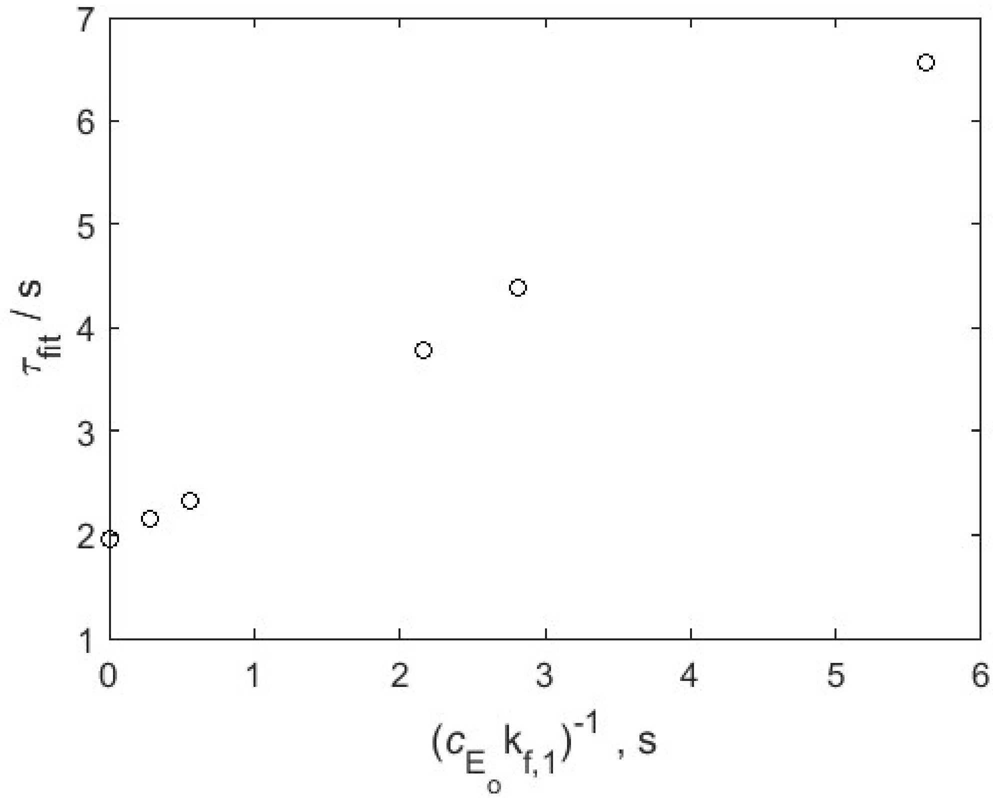


Figure 3-19. Exponential time constant fits of the current response when equation (3-3) is the limiting reaction. A lower limit time constant of approximately 2 s is reached due to the time required for glucose diffusion through the GLM.

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 GOx_{ox} is accumulating and GOx_{red} is depleting. Excess GOx_{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

$$D_{\mathrm{GLM,i}} \frac{\mathrm{d}c_{\mathrm{GLM,i}}}{\mathrm{d}y}\bigg|_{y=\delta_{\mathrm{GOx}}+\delta_{\mathrm{GLM}}} = D_{\mathrm{tissue,i}} \frac{\mathrm{d}c_{\mathrm{tissue,i}}}{\mathrm{d}y}\bigg|_{y=\delta_{\mathrm{GOx}}+\delta_{\mathrm{GLM}}} \tag{4-1}$$

where the distance $\delta_{\mathrm{GOx}} + \delta_{\mathrm{GLM}}$ 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

$$c_{\mathrm{GLM,i}}\left(\delta_{\mathrm{GLM}} + \delta_{\mathrm{tissue}}\right) = K_{\mathrm{partition,i}} c_{\mathrm{tissue,i}}\left(\delta_{\mathrm{GLM}} + \delta_{\mathrm{tissue}}\right) \tag{4-2}$$

where $K_{\mathrm{partition,i}}$ 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.

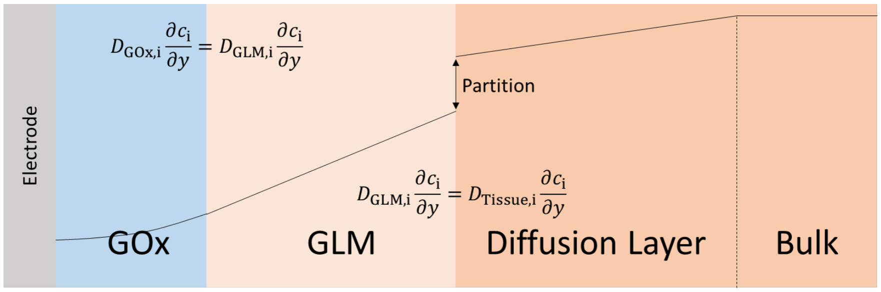


Figure 4-1. One-dimensional cross section of the glucose sensor with an adjacent diffusion layer. Species flux at the GLM-tissue interface match. The outer boundary of the diffusion layer matches a bulk concentration of an adjacent well mixed region.

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

$$\left(D_{\mathrm{GLM,i}}\frac{\mathrm{d}^2 c_\mathrm{i}}{\mathrm{d}y^2}\right)\Bigg|_{\mathrm{J}-1/4} + \left(D_{\mathrm{tissue,i}}\frac{\mathrm{d}^2 c_\mathrm{i}}{\mathrm{d}y^2}\right)\Bigg|_{\mathrm{J}+1/4} = D_{\mathrm{GLM,i}}\frac{K_\mathrm{i}c_\mathrm{i}(\mathrm{J})-c_\mathrm{i}(\mathrm{J}-1)}{\Delta y_{\mathrm{GLM}}} + D_{\mathrm{tissue,i}}\frac{c_\mathrm{i}(\mathrm{J}+1)-c_\mathrm{i}(\mathrm{J})}{\Delta y_{\mathrm{tissue}}} \tag{4-3}$$

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

$$\frac{\mathrm{d}c_\mathrm{i}}{\mathrm{d}t}\bigg|_{\mathrm{J}-1/4} = \frac{3K_\mathrm{i}\left(c_\mathrm{i}^{\mathrm{n}+1}(\mathrm{J}) - c_\mathrm{i}^{\mathrm{n}}(\mathrm{J})\right) + \left(c_\mathrm{i}^{\mathrm{n}+1}(\mathrm{J}-1) - c_\mathrm{i}^{\mathrm{n}}(\mathrm{J}-1)\right)}{4\Delta t} \tag{4-4}$$

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

$$D_{\mathrm{GLM,i}}\frac{\mathrm{d}^2 c_\mathrm{i}}{\mathrm{d}y^2}\bigg|_{\mathrm{J}-1} = \frac{K_\mathrm{i}c_\mathrm{i}(J) - 2c_\mathrm{i}(J-1) + c_\mathrm{i}(J-2)}{\Delta y^2} \tag{4-5}$$

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.

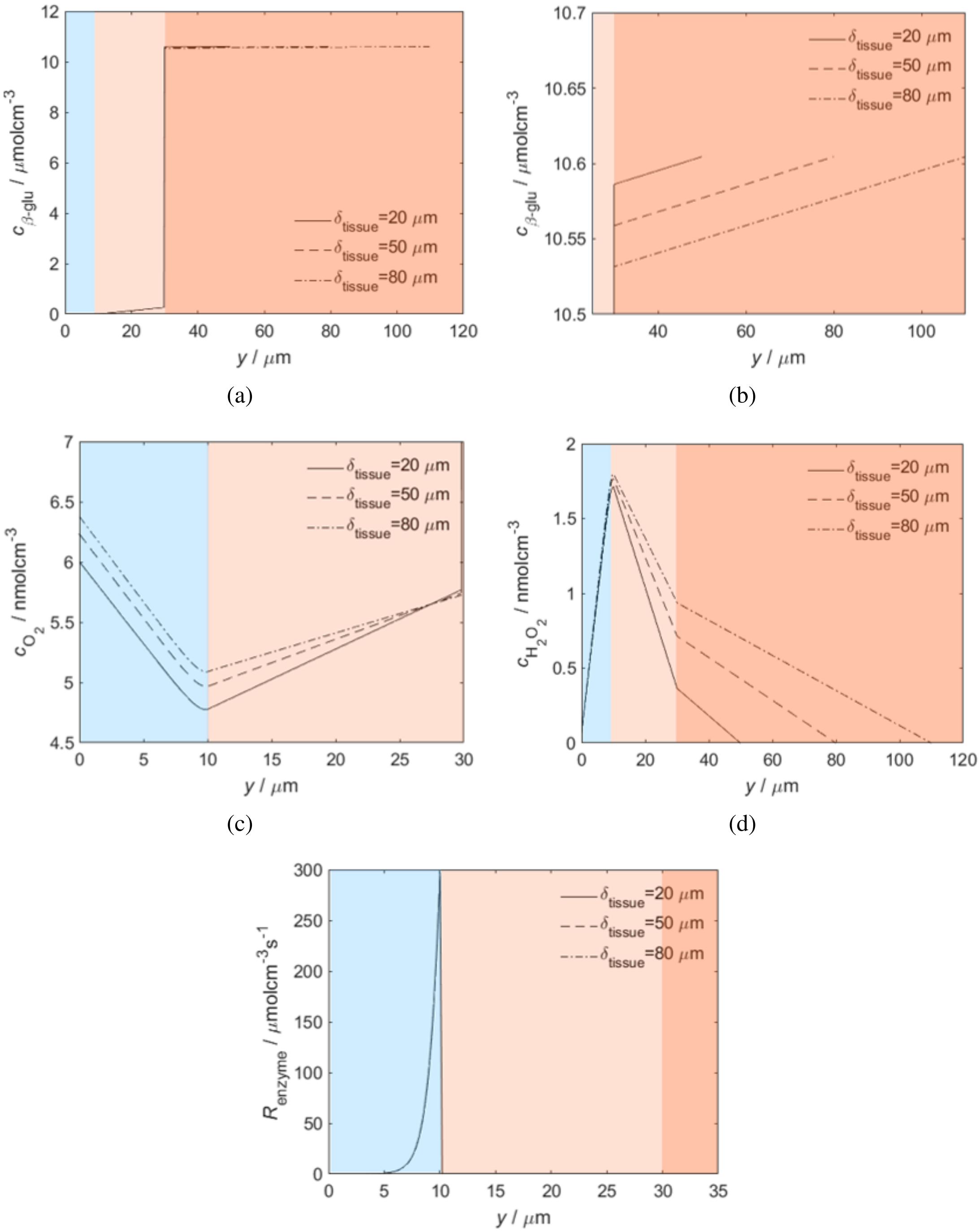
Parameter	Value	Units
Applied Potential, $\Phi - \Phi_{\mathrm{Ag\backslash AgCl}}$	0.4	V
Total Enzyme Loading, $c_{\mathrm{E,o}}$	0.356	$\mu\mathrm{mol/cm^3}$
Diffusion coefficient of Glucose, D_{GLU}	2.98×10^{-6}	$\mathrm{cm^2/s}$
Diffusion coefficient of Gluconic Acid, D_{GLA}	2.98×10^{-6}	$\mathrm{cm^2/s}$
Diffusion coefficient of Oxygen, $D_{\mathrm{O_2}}$	2.46×10^{-5}	$\mathrm{cm^2/s}$
Diffusion coefficient of Hydrogen Peroxide, $D_{\mathrm{H_2O_2}}$	1.83×10^{-5}	$\mathrm{cm^2/s}$
Porosity of GOX Layer	0.8	
Porosity of GLM Layer for O_2 and H_2O_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	μm
Glucose Limiting Membrane Layer Thickness	20	μm
Electrolyte Resistance, $\mathrm{R_e}$	10	$\Omega\mathrm{cm^2}$
Double Layer Capacitance, C	20×10^{-6}	$\mathrm{F/cm^2}$
Forward rate and equilibrium constants for Reaction 1, $k_{\mathrm{f,1}}$ and $k_{\mathrm{b,1}}$	1×10^9 and 1×10^7	$\mathrm{cm^3mol^{-1}s^{-1}}$
Forward constant for Reaction 2, $k_{\mathrm{f,2}}$	1×10^9	$\mathrm{s^{-1}}$
Forward rate and equilibrium constants for Reaction 3, $k_{\mathrm{f,3}}$ and $k_{\mathrm{b,3}}$	1×10^9 and 1×10^7	$\mathrm{cm^3mol^{-1}s^{-1}}$
Forward constant for Reaction 4, $k_{\mathrm{f,4}}$	1×10^3	$\mathrm{s^{-1}}$
Heterogeneous rate constant, H_2O_2 oxidation, K_{a}	0.2	$\mathrm{A/mol \cdot cm^2}$
Electrode Constant, H_2O_2 oxidation, b_{a}	37.42	$\mathrm{V^{-1}}$
Heterogeneous rate constant, O_2 reduction, K_{a}	5×10^{-6}	$\mathrm{A/mol \cdot cm^2}$
Electrode Constant, O_2 reduction, b_{a}	38.4	$\mathrm{V^{-1}}$
Heterogeneous rate constant, H_2O_2 reduction, K_{a}	5×10^4	$\mathrm{A/mol \cdot cm^2}$
Electrode Constant, H_2O_2 reduction, b_{a}	32	$\mathrm{V^{-1}}$

4.3.1 Steady Model

Steady-state calculations were made at 20, 50, and 80 μm tissue diffusion layer thickness, applied potential of 0.4 V vs. Ag\AgCl, and 300 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 μm. 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 mgdL^{-1} total glucose and diffusion layer thickness was varied from 5 μm 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 μm. This peak is more pronounced for additional glucose in the system. As the diffusion layer thickness is increased past 400 μm, 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 μm, 100 μm, and 1 mm diffusion layer thickness as presented in Figure 4-4. For the 10 and 100 μm 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



(a) (b) (c) (d) (e)

Figure 4-2. Steady profiles for tissue diffusion layer thicknesses of 20, 50, and 80 μm, total glucose concentration of 300 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.

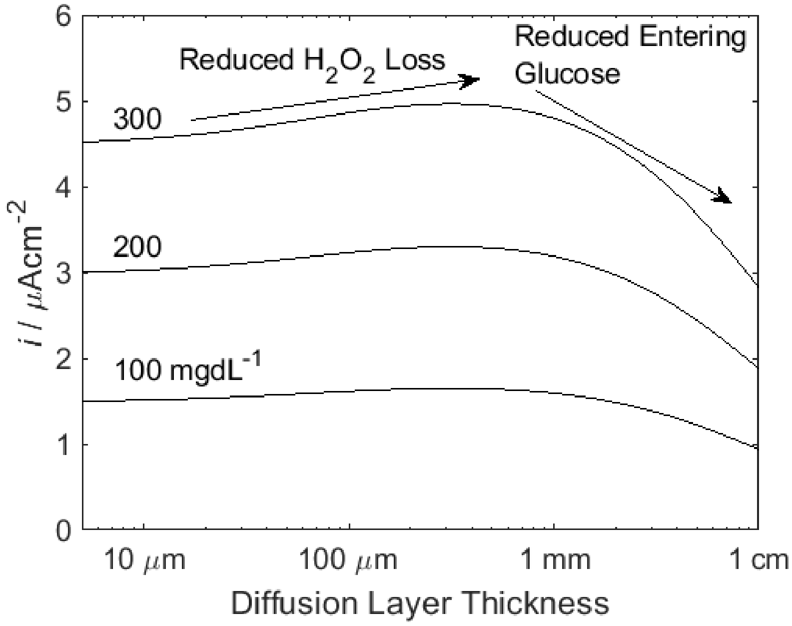


Figure 4-3. Steady current for a diffusion layer thickness from 5 μm to 1 cm calculated for 100, 200, and 300 mgdL^{-1} glucose. A peak in current is reached at 400 μm due to the reduced diffusion of hydrogen peroxide out of the sensor, additional diffusion layer thickness leads to a decline in current 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 mgdL^{-1} which served as the initial condition for transient calculations. An immediate step in glucose concentration was made from 100 to 300 mgdL^{-1} directly adjacent to the outer boundary of a 100 μm 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

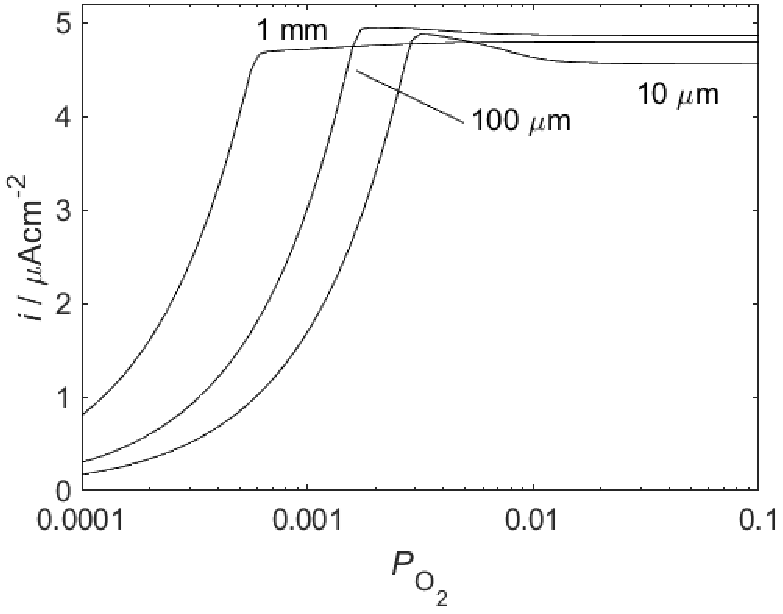
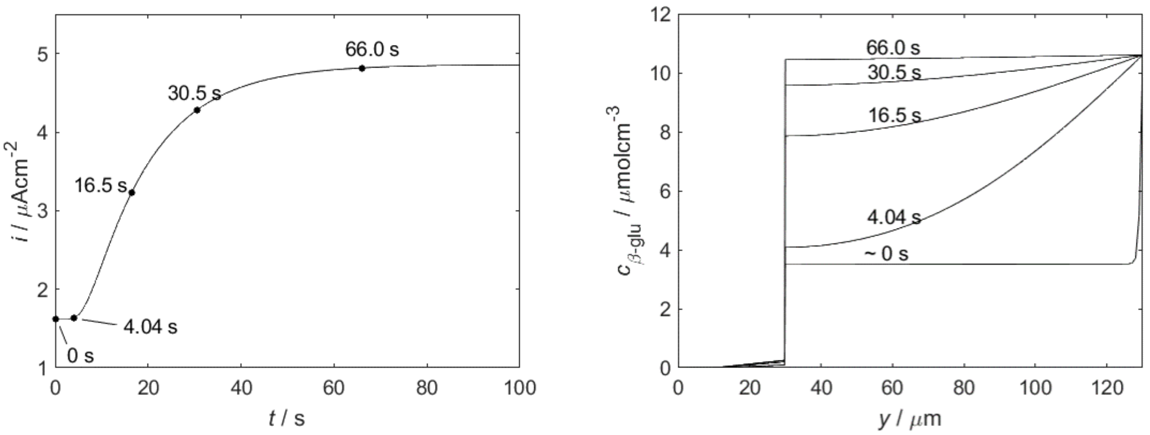


Figure 4-4. Steady current for 0.01 % to 10% partial pressure oxygen and 10 μm, 100 μm, and 1 mm diffusion layer thickness. For the two smaller diffusion layer thickness values, a peak in current is observed at an intermediate value for the oxygen concentration. This peak is absent, and current continues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



(a)

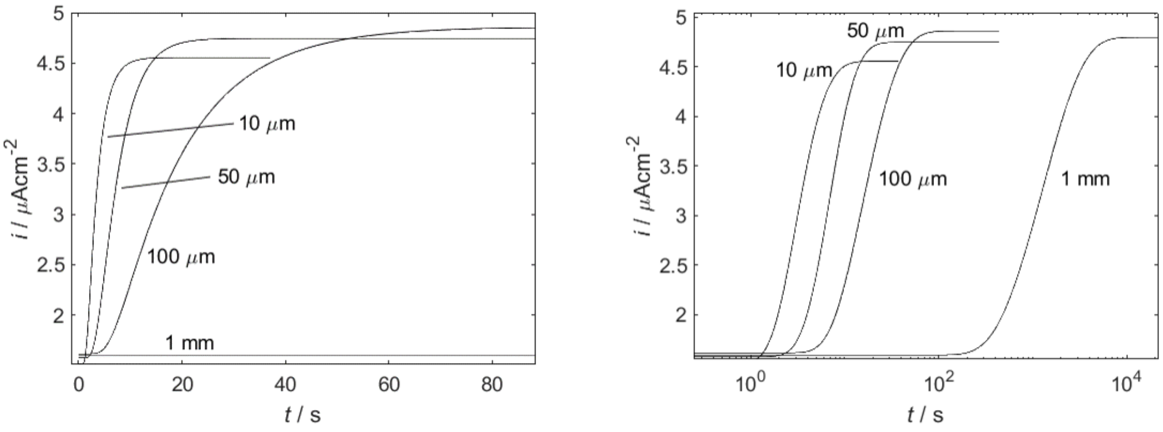
(b)

Figure 4-5. Glucose is stepped from 100 to 300 mgdL^{-1} at the outer boundary of a 100 μm 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 $\mathrm{mgdL^{-1}}$ was applied to a sensor with 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 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.

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



(a)

(b)

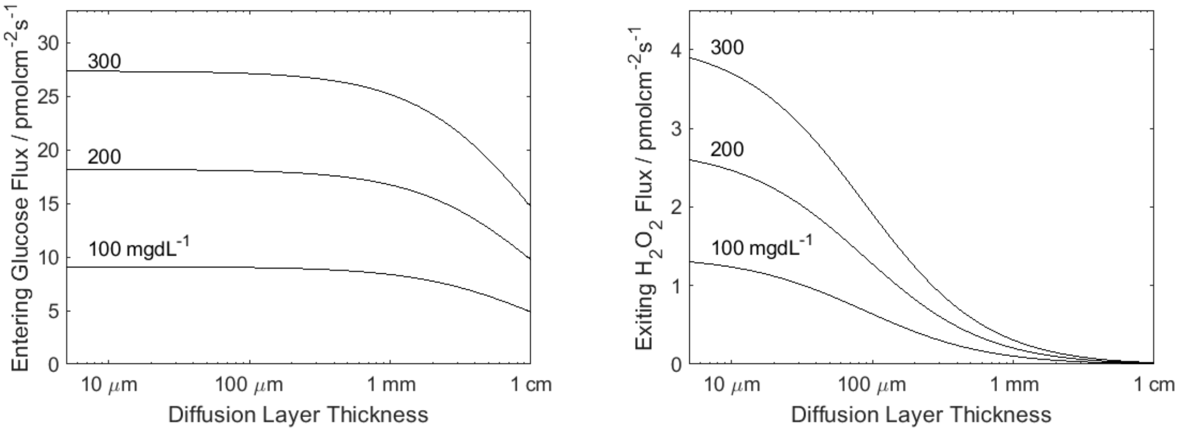
Figure 4-6. Glucose is stepped from 100 to 300 $\mathrm{mgdL^{-1}}$ at the outer boundary of diffusion layer thicknesses of 10 μm, 50 μm, 100 μm, and 1 mm. Results are presented: (a) linear time scale; (b) log time scale. The 1 mm diffusion layer demonstrates a response lag of 200 s.

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 μm. Current then decreases for additional thickness as presented in Figure 4-3. The initial rise in current when going from a 5 to 400 μm 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 μm to 1 cm and 100, 200, and 300 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 μm. 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

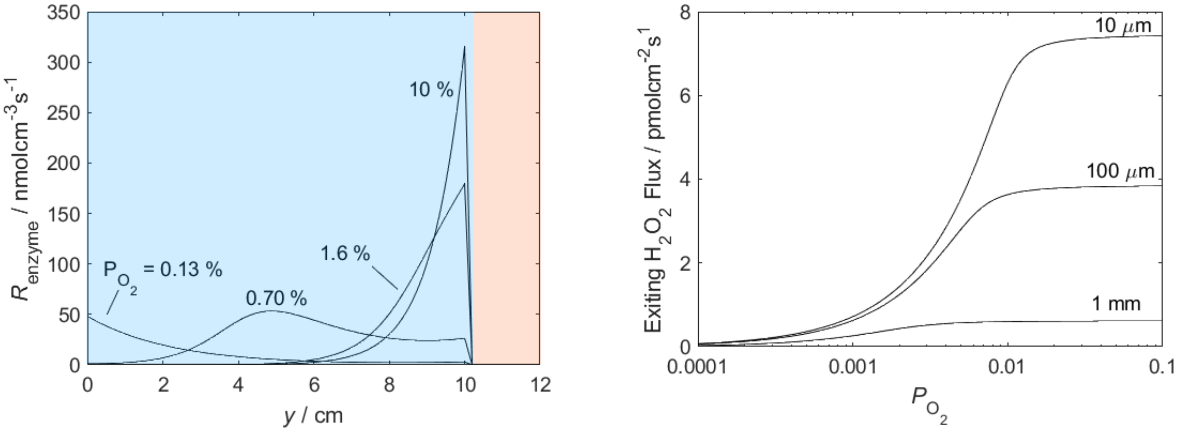


(a) (b)

Figure 4-7. Steady flux of individual species for diffusion layer thickness varied from 5 μm to 1 cm and 100, 200, and 300 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



(a)

(b)

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 μm) 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 $\mu mathrmm$, an initial lag of 4 seconds is observed. The initial lag is

$$t_{\mathrm{lag}} = \frac{\delta^2}{\pi^2 D_{\mathrm{i}}} \tag{4-6}$$

where t_{lag} is the lag time before the initial change in current and δ 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.

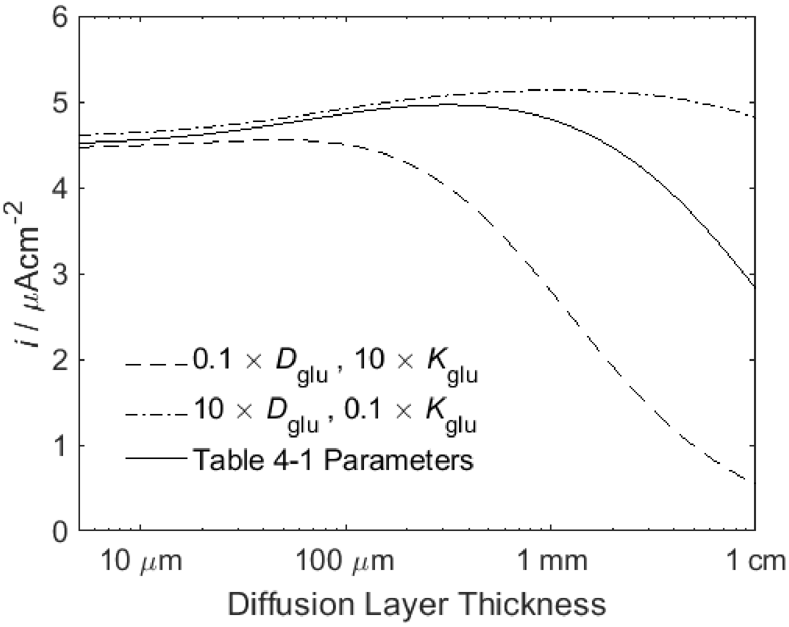


Figure 4-9. Steady state current for 300 mgdL^{-1} glucose and diffusion layer thickness varied from 5 μm to 1 cm. Diffusion coefficient was either 0.1×, 1×, or 10× the stated value in Table 4-1. The partition coefficient was maintained such that $K_{\text{glu}} \times D_{\text{glu}}$ is a constant between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

$$i(t) \propto \exp(-t/\tau) \tag{4-7}$$

where τ is the exponential time constant. τ was obtained by nonlinear regression of the current response. Current response to a step in glucose concentration from 100 to 300 mgdL^{-1} 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

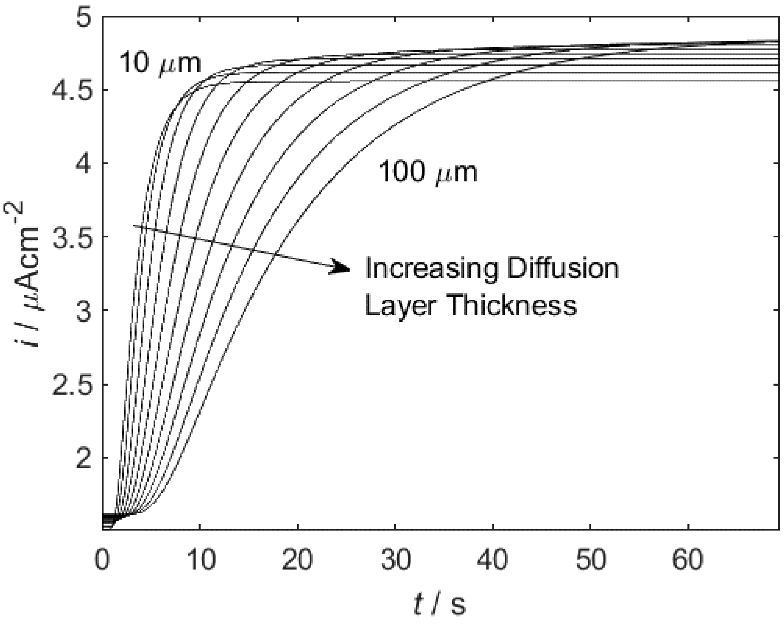


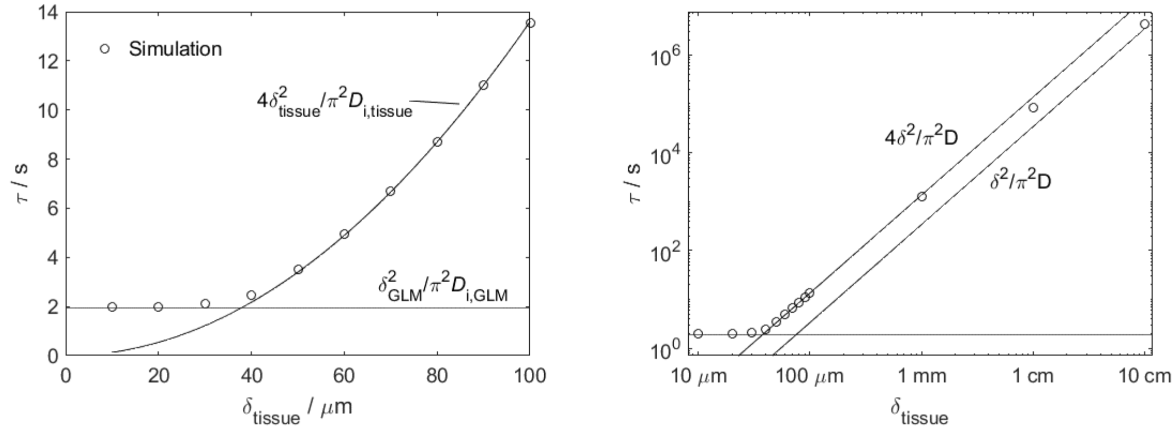
Figure 4-10. The current response to a glucose step from 100 to 300 mgdL^{-1} for diffusion layer thicknesses from 10 to 100 μm. As diffusion layer thickness is increased, the lag time and time to reach the final steady state is increased. Each response may be fit to a characteristic time constant from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

glucose the time constant is observed,

$$\tau \propto \frac{4\delta^2}{\pi^2 D_\mathrm{i}} \tag{4-8}$$

, 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

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



(a) (b)

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 μm (b) Fit time constants for diffusion layer thickness from 10 μm 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 μm to 50 μm 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_∞ is the concentration in the bulk, n is an integer from 0 to ∞, 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 μm 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

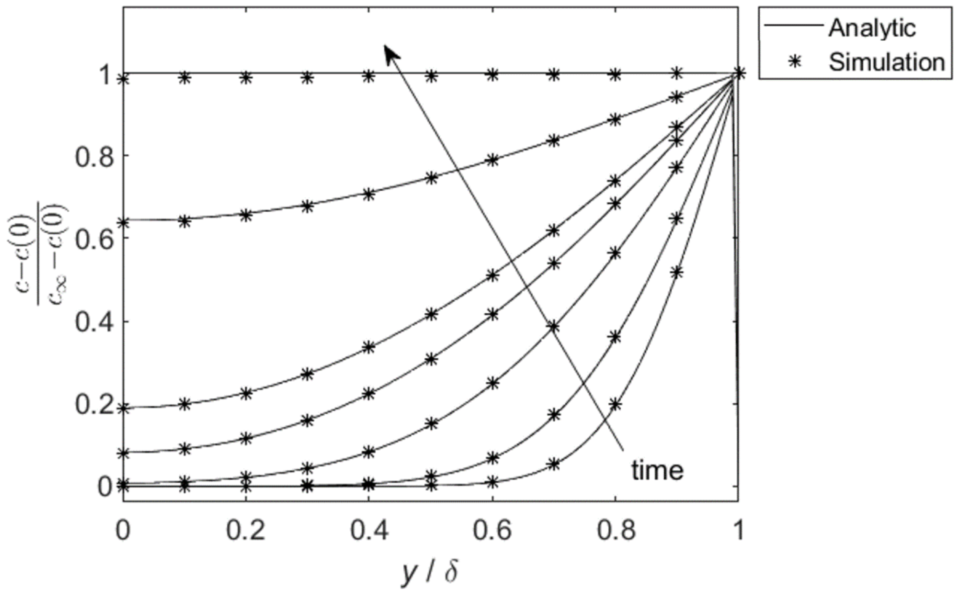


Figure 4-12. Comparison of equation 4-9 for n = 0 to 10^4 and simulation of a glucose step from 100 to 300 mgdL^{-1} across a 100 μm diffusion layer. $c(0)$ is the initial concentration in the domain. The simulation and analytic expression are in good agreement. Maximum error is 1% for all positions 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

$$\frac{\partial c_{\mathrm{i}}}{\partial t} = D_{\mathrm{Blocking,i}} \frac{\partial^2 c_{\mathrm{i}}}{\partial y^2} \tag{5-1}$$

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

$$\mathrm{Acetaminophen} \xrightarrow{K_{\mathrm{acet}}} \mathrm{N-acetyl-4-Quinoneimine} + 2\mathrm{e}^- \tag{5-2}$$

which yields an anodic current density

$$j_{\mathrm{acet.}} = \mathrm{K}_{\mathrm{Acet.}} c_{\mathrm{Acet.}}(0) \exp\left(b_{\mathrm{Acet.}} V\right) \tag{5-3}$$

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

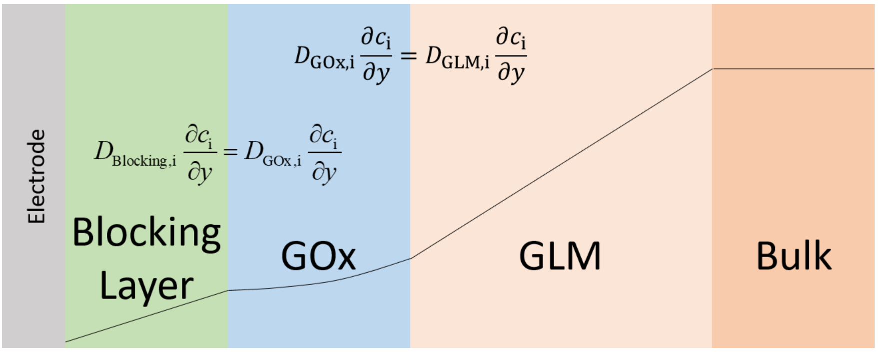


Figure 5-1. One-dimensional cross section of the glucose sensor with a blocking layer between the electrode and GOx enzyme layer. Species flux and concentration at the blocking layer-GOx interface match.

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 mgdL^{-1} of glucose, and 0, 10, and 20 μgcm^{-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, $c_{\mathrm{E,o}}$	0.356 μmol/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 μm
Glucose Limiting Membrane Layer Thickness	20 μm
Electrolyte Resistance, $\mathrm{R_e}$	170 Ωcm^2
Double Layer Capacitance, C	1.7×10^{-3} F/cm^2
Forward rate constant for Reaction 1, $k_{\mathrm{f,1}}$	1×10^{9} cm^{3}mol^{-1}s^{-1}
Equilibrium constant for Reaction 1, $k_{\mathrm{EQ,1}}$	1×10^{7} cm^{3}mol^{-1}
Forward constant for Reaction 2, $k_{\mathrm{f,2}}$	1×10^{9} s^{-1}
Forward rate constant for Reaction 3, $k_{\mathrm{f,3}}$	1×10^{9} cm^{3}mol^{-1}s^{-1}
Equilibrium constant for Reaction 3, $k_{\mathrm{EQ,3}}$	1×10^{7} cm^{3}mol^{-1}
Forward constant for Reaction 4, $k_{\mathrm{f,4}}$	1×10^{3} s^{-1}
Heterogeneous rate constant, H_2O_2 oxidation, K_{a}	20 Acm/mol
Electrode Constant, H_2O_2 oxidation, b_{a}	22.4 V^{-1}
Heterogeneous rate constant, O_2 reduction, K_{a}	5×10^{15} Acm^7/mol^3
Electrode Constant, O_2 reduction, b_{a}	38.4 V^{-1}
Heterogeneous rate constant, H_2O_2 reduction, K_{a}	7.5×10^{23} Acm^7/mol^3
Electrode Constant, H_2O_2 reduction, b_{a}	30 V^{-1}
Heterogeneous rate constant, H_2 evolution, $K_{\mathrm{H_2}}$	2.8×10^{16} Acm^4/mol^2
Electrode Constant, H_2 Evolution, $b_{\mathrm{H_2}}$	15 V^{-1}
Heterogeneous rate constant, Acetaminophen oxidation, K_{a}	20 Acm/mol
Electrode Constant, Acetaminophen oxidation, b_{a}	22.4 V^{-1}

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

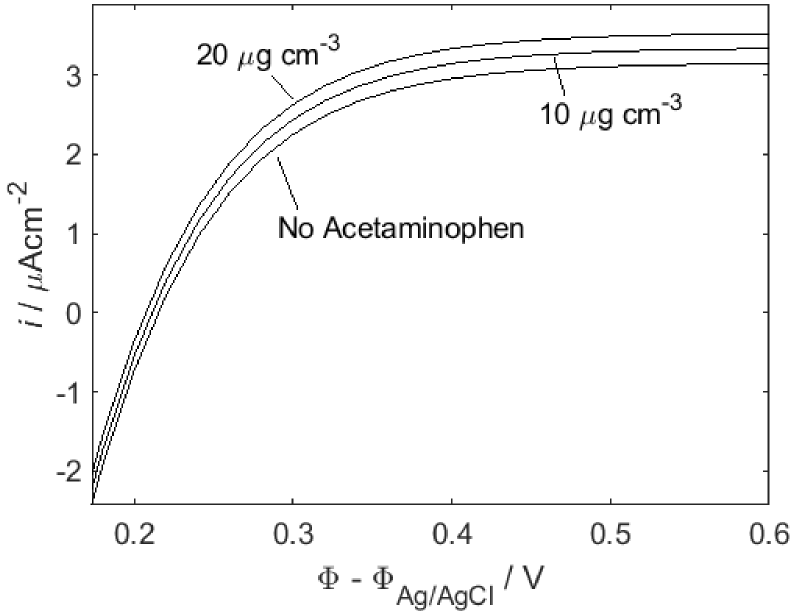


Figure 5-2. Calculated current density as a function of applied potential for a glucose concentration of 200 mg/dL with acetaminophen concentration as a parameter. The increased current density associated with the acetaminophen could be incorrectly interpreted as being due to a higher concentration of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

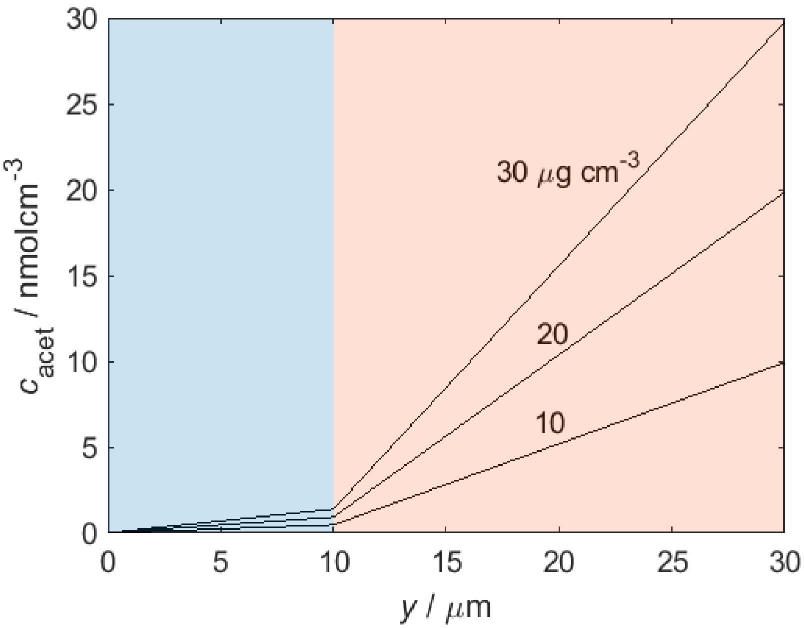


Figure 5-3. Steady acetaminophen concentration profiles at 0.4 V applied potential with acetaminophen concentration as a parameter. The acetaminophen is assumed to not interact with the other species of the model; the concentration profile is characteristic of purely diffusive behavior with no reaction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

μm blocking layer at 200 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 μm 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

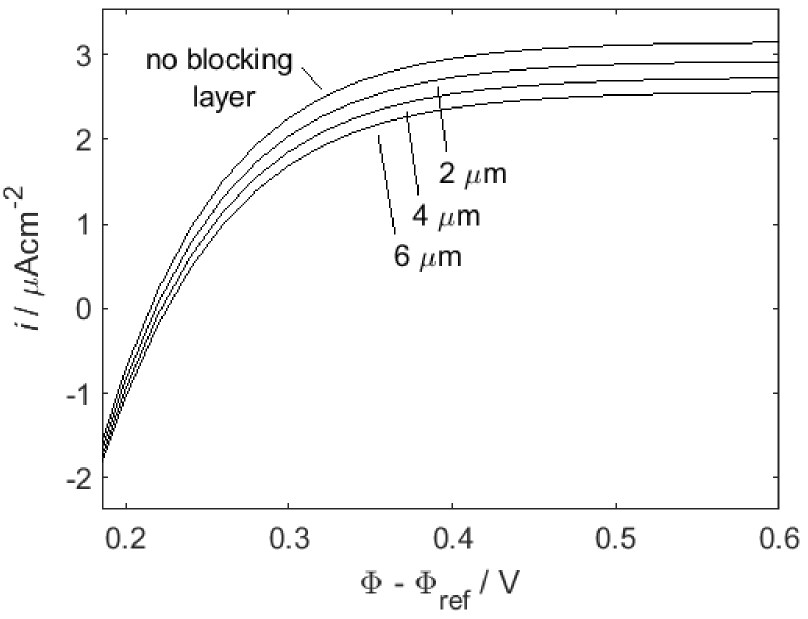
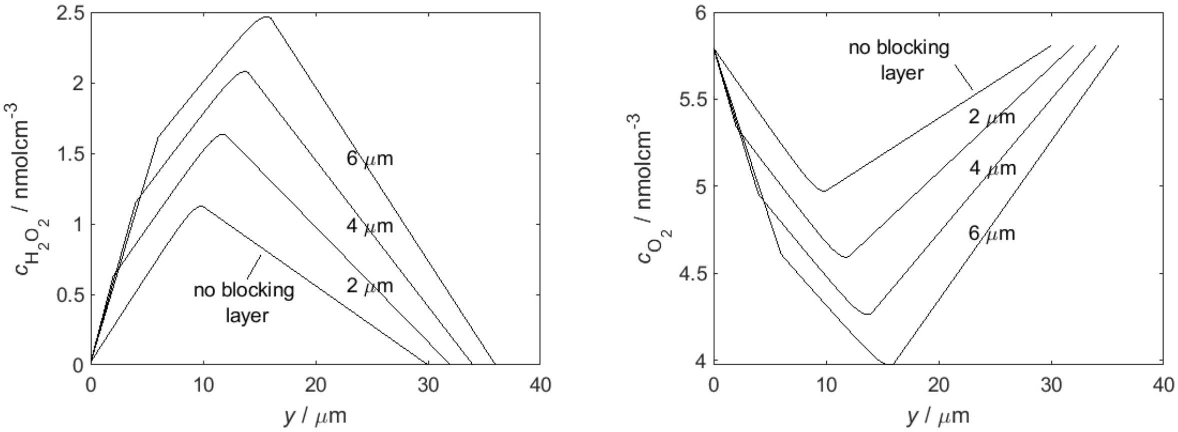


Figure 5-4. Current density as a function of applied potential at 5% partial pressure of oxygen and 200 mg/dL total glucose with the blocking layer thickness as a parameter. The flux of hydrogen peroxide to the electrode decreases as the blocking layer thickness is increased, and the current decreases.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

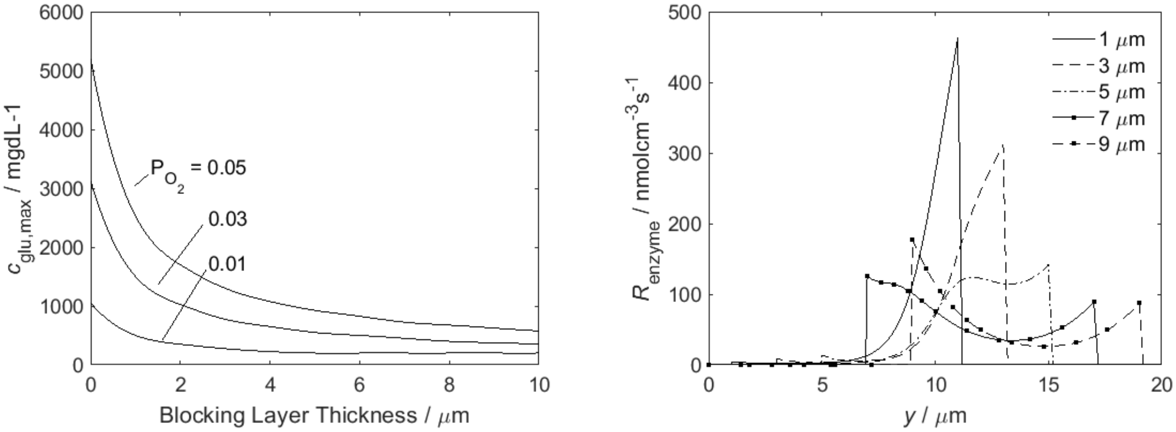
plateaus as the oxidized glucose oxidase is depleted. The maximum glucose a sensor may detect is presented in Figure 5-6(a) as a function of the blocking layer thickness and partial pressure of oxygen. The capacity of the sensor is most greatly affected by the introduction of any blocking layer thickness, as maximum glucose reacted decreases by 40% when adding a 1 μm 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



(a) (b)

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.



(a) (b)

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 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 acetaminphen is 2.07×10^{-7} cm^{2}s^{-1}. Thus the smallest value of the diffusion coefficient in the blocking layer modeled is 2.07×10^{-8} cm^{2}s^{-1}. At this diffusion coefficient, the acetaminophen signal was decreased to 17% while maintaining 70% of the glucose signal for a 10 μm 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 μm 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 μmu. 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 μm block layer, but reduced by over 70% for a 5 μm blocking layer.

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

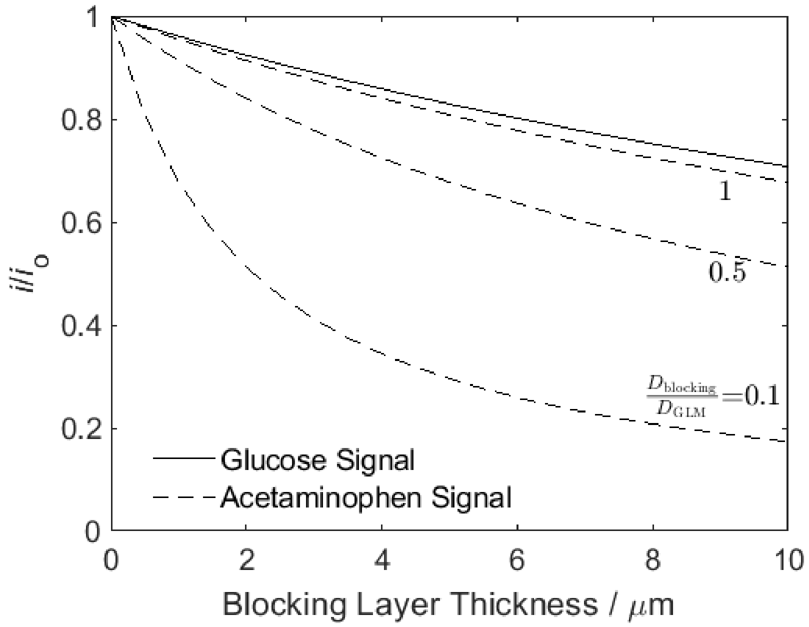
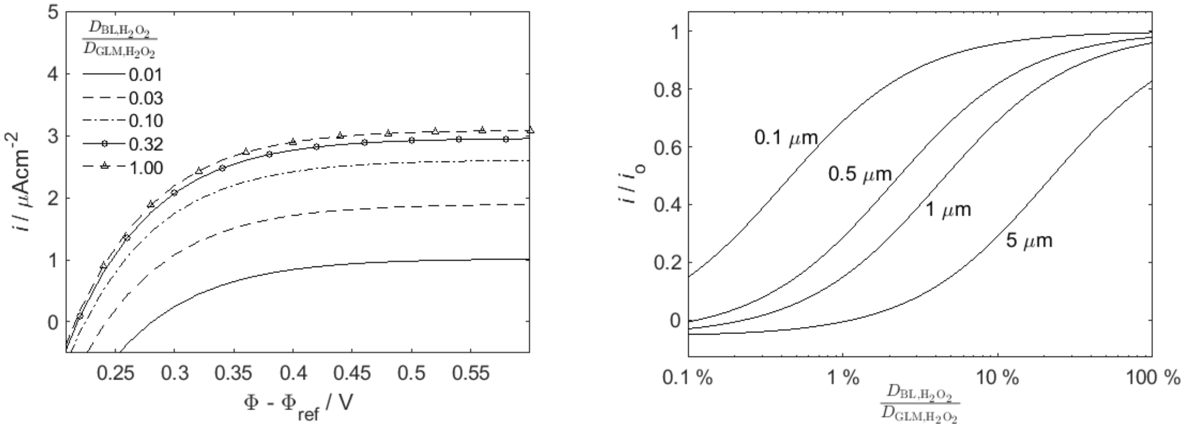


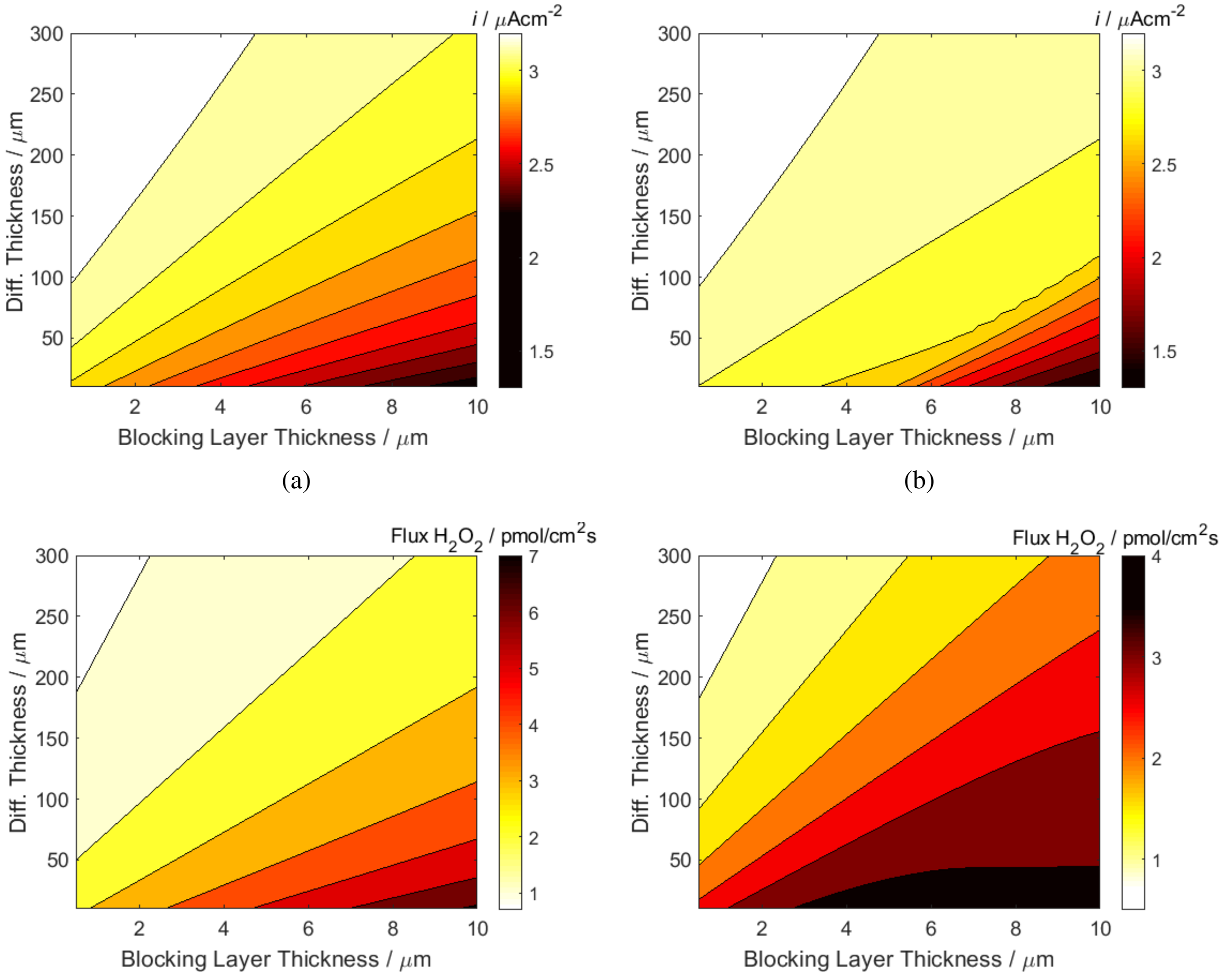
Figure 5-7. Glucose signal(solid line) and acetaminophen signal (dashed line) as a function of blocking layer thickness with the acetaminophen diffusion coefficient in the blocking layer as a parameter. The acetaminophen diffusion coefficient in the blocking layer is presented as 10%, 50%, and 100% of 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 μm blocking layer when a diffusion region of 250 μm 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.



(a) (b)

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 μm 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.



(a)

(b)

(c)

(d)

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

$$\text{Gluconic Acid} \overset{K_{\text{EQ,GA}}}{\rightleftarrows} \text{Gluconate}^- + \text{H}^+ \tag{6-1}$$

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,

$$\text{CO}_2 + \text{H}_2\text{O} \overset{K_{\text{EQ,CO}_2}}{\rightleftarrows} \text{H}_2\text{CO}_3 \tag{6-2}$$

where $K_{\text{EQ,CO}_2}$ is the equilibrium constant of CO_2 hydration. Next, the dissociation of carbonic acid to bicarbonate and a hydrogen ion,

$$\text{H}_2\text{CO}_3 \overset{K_{\text{EQ,H}_2\text{CO}_3}}{\rightleftarrows} \text{HCO}_3^- + \text{H}^+ \tag{6-3}$$

where $K_{\mathrm{EQ,H_2CO_3}}$ is the equilibrium constant of carbonic acid dissociation. The dissociation of water to hydrogen and hydroxide ions is also considered

$$\mathrm{H_2O} \overset{K_{\mathrm{EQ,w}}}{\rightleftarrows} \mathrm{H^+} + \mathrm{OH^-} \tag{6-4}$$

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

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

for gluconic acid dissociation,

$$R_7 = k_{\mathrm{f,CO_2}} \left(c_{\mathrm{CO_2}} - \frac{1}{K_{\mathrm{EQ,CO_2}}} c_{\mathrm{H_2CO_3}} \right) \tag{6-6}$$

for carbon dioxide hydration,

$$R_8 = k_{\mathrm{f,H_2CO_3}} \left(c_{\mathrm{H_2CO_3}} - \frac{1}{K_{\mathrm{EQ,H_2CO_3}}} c_{\mathrm{HCO_3^-}} c_{\mathrm{H^+}} \right) \tag{6-7}$$

for carbonic acid dissociation, and

$$R_9 = k_{\mathrm{f,H_2O}} \left(1 - \frac{1}{K_{\mathrm{EQ,H_2O}}} c_{\mathrm{OH^-}} c_{\mathrm{H^+}} \right) \tag{6-8}$$

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

$$\frac{\partial c_{\mathrm{Gl^-}}}{\partial t} = D_{\mathrm{Gl^-}} \frac{\partial^2 c_{\mathrm{Gl^-}}}{\partial y^2} + R_6 \tag{6-9}$$

for the concentration of gluconate ion,

$$\frac{\partial c_{\mathrm{CO_2}}}{\partial t} = D_{\mathrm{CO_2}} \frac{\partial^2 c_{\mathrm{CO_2}}}{\partial y^2} - R_7 \tag{6-10}$$

for the concentration of carbon dioxide,

$$\frac{\partial c_{\mathrm{H_2CO_3}}}{\partial t} = D_{\mathrm{H_2CO_3}} \frac{\partial^2 c_{\mathrm{H_2CO_3}}}{\partial y^2} + R_7 - R_8 \tag{6-11}$$

for the concentration of carbonic acid,

$$\frac{\partial c_{\mathrm{HCO_3^-}}}{\partial t} = D_{\mathrm{HCO_3^-}} \frac{\partial^2 c_{\mathrm{HCO_3^-}}}{\partial y^2} + R_8 \tag{6-12}$$

for the concentration of bicarbonate ion,

$$\frac{\partial c_{\mathrm{H^+}}}{\partial t} = D_{\mathrm{H^+}} \frac{\partial^2 c_{\mathrm{H^+}}}{\partial y^2} + R_6 + R_8 + R_9 \tag{6-13}$$

for the concentration of hydrogen ion, and

$$\frac{\partial c_{\mathrm{OH^-}}}{\partial t} = D_{\mathrm{OH^-}} \frac{\partial^2 c_{\mathrm{OH^-}}}{\partial y^2} + R_9 \tag{6-14}$$

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 dissocation 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

$$0 = k_{\mathrm{EQ,acid}} c_{\mathrm{HI}} - c_{\mathrm{H^+}} c_{\mathrm{I^-}} \tag{6-15}$$

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

$$2\mathrm{H^+} + 2\mathrm{e^-} \xrightarrow{K_{\mathrm{H_2}}} \mathrm{H_2} \tag{6-16}$$

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

$$j_{\mathrm{H_2}} = \mathrm{K}_{\mathrm{H_2}} c_{\mathrm{H^+}}(0)^2 \exp(-b_{\mathrm{H_2}} V) \tag{6-17}$$

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

Finally, the influence of the anomerization between α-glucose and β-glucose was introduced. These two anomers exist in equilibrium following

$$\alpha - \text{glucose} \underset{k_{\text{b,glu}}}{\overset{k_{\text{f,glu}}}{\rightleftarrows}} \beta - \text{glucose} \tag{6-18}$$

where $k_{\text{f,glu}}$ and $k_{\text{b,glu}}$ 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 β-glucose. The β-glucose concentration is greatly reduced in the GOx layer and the anomerization of α-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^{-1} glucose the rate of hydrogen ion formation is four times greater than at 100 mgdL^{-1}. 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, $c_{\mathrm{E,o}}$	0.356 μmol/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 μm
Glucose Limiting Membrane Layer Thickness	20 μm
Electrolyte Resistance, $\mathrm{R_e}$	170 Ωcm^2
Double Layer Capacitance, C	1.7×10^{-3} F/cm^2
Forward rate constant for Reaction 1, $k_{\mathrm{f,1}}$	1×10^9 cm^{3}mol^{-1}s^{-1}
Equilibrium constant for Reaction 1, $k_{\mathrm{EQ,1}}$	1×10^7 cm^{3}mol^{-1}
Forward constant for Reaction 2, $k_{\mathrm{f,2}}$	1×10^9 s^{-1}
Forward rate constant for Reaction 3, $k_{\mathrm{f,3}}$	1×10^9 cm^{3}mol^{-1}s^{-1}
Equilibrium constant for Reaction 3, $k_{\mathrm{EQ,3}}$	1×10^7 cm^{3}mol^{-1}
Forward constant for Reaction 4, $k_{\mathrm{f,4}}$	1×10^3 s^{-1}
Heterogeneous rate constant, H_2O_2 oxidation, K_{a}	20 Acm/mol
Electrode Constant, H_2O_2 oxidation, b_{a}	22.4 V^{-1}
Heterogeneous rate constant, O_2 reduction, K_{a}	5×10^{15} Acm^7/mol^3
Electrode Constant, O_2 reduction, b_{a}	38.4 V^{-1}
Heterogeneous rate constant, H_2O_2 reduction, K_{a}	7.5×10^{23} Acm^7/mol^3
Electrode Constant, H_2O_2 reduction, b_{a}	30 V^{-1}
Heterogeneous rate constant, H_2 evolution, $K_{\mathrm{H_2}}$	2.8×10^{16} Acm^4/mol^2
Electrode Constant, H_2 Evolution, $b_{\mathrm{H_2}}$	15 V^{-1}

Table 6-2. Acid and buffer dissociation equilibrium constants

Parameter	Value
Gluconic Acid Equilibrium Constant, $K_{\mathrm{EQ,GA}}$	2×10^{-4} mol/cm^3
CO_2 Hydration Equilibrium Constant, $K_{\mathrm{EQ,CO_2}}$	1.7×10^{-3}
Carbonic Acid Equilibrium Constant, $K_{\mathrm{EQ,H_2CO_3}}$	5.26×10^{-7} mol/cm^3
Water Dissociation, $K_{\mathrm{EQ,H_2O}}$	$10^{-}20$ mol^2/cm^6

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

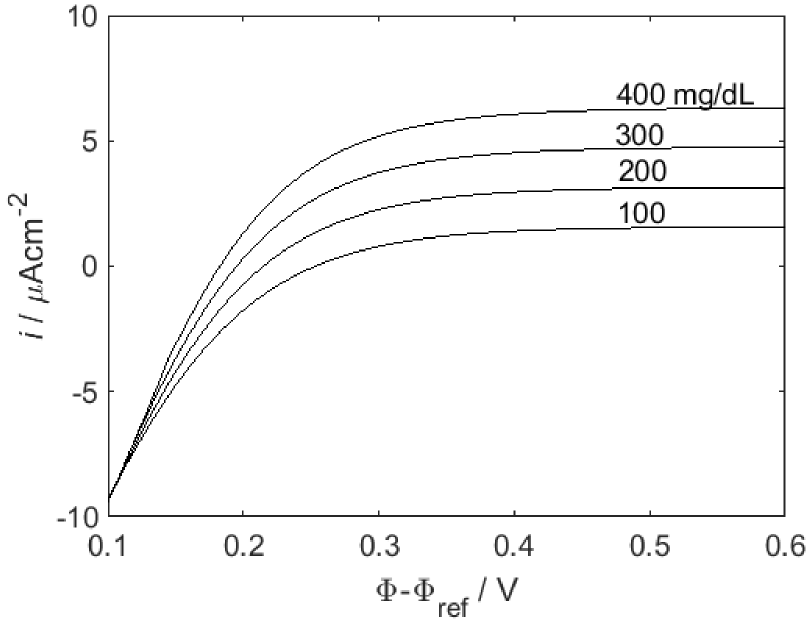


Figure 6-1. Current density as a function of potential with glucose concentration as a parameter. At anodic potentials, the oxidation of hydrogen peroxide dominates and the dependence on glucose concentration is similar to the polarization curve presented in Figure 3-5. At cathodic potentials the buffer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

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

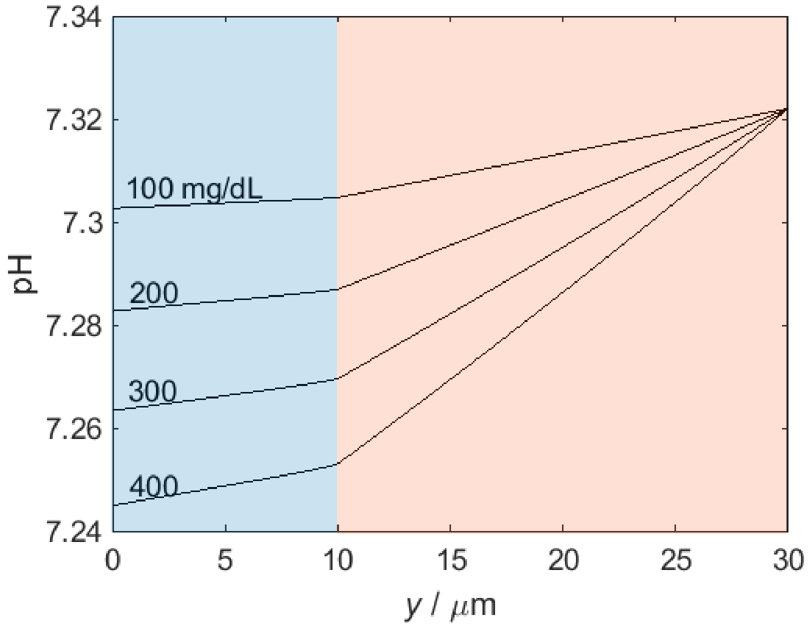


Figure 6-2. Steady pH profiles as a function of position with glucose concentration as a parameter. Applied potential is 0.4 V and oxygen partial pressure is 5 %. At anodic potentials, the decrease in pH is proportional to the increase in glucose concentration.

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.

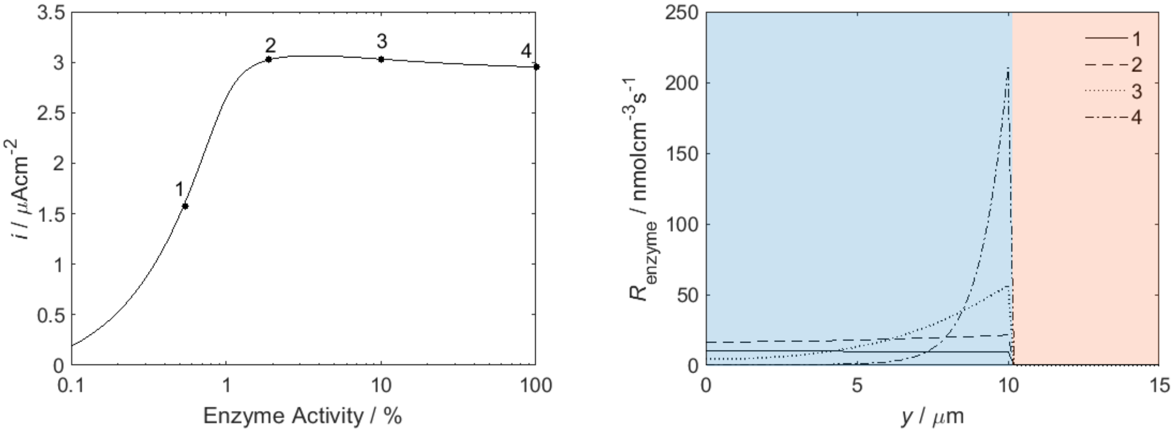
Failure Mode	Parameter	Value Range
Enzyme deactivation	Total enzyme concentration	0.1 to 100 % of 0.356 μmol/cm^3
Oxygen deficiency	Oxygen partial pressure	0.01 to 10 %
Membrane deterioration	Global multiplier for diffusion coefficients	0.1 to 10 × default diffusion coefficient

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 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]

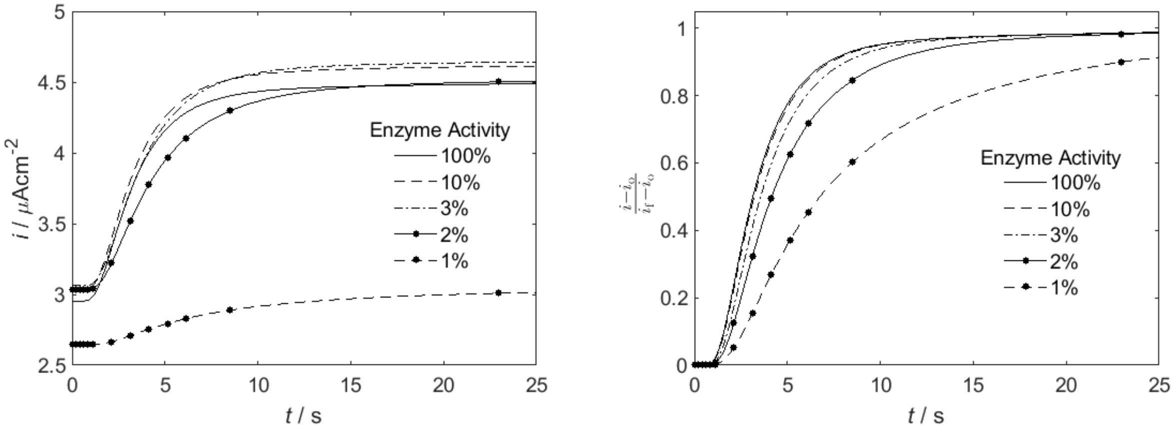
Current as a function of enzyme activity is presented in Figure 6-3(a). Reduced enzyme activity is initially marked by a small increase in current, followed by a rapid decrease as the active enzyme is reduced below the concentration required to react all the glucose. A decrease in enzyme activity yields 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 mgdL^{-1} was modeled for individual enzyme activity and an applied potential of 0.4 V. Steady calculations at 200 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 %.



(a) (b)

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.



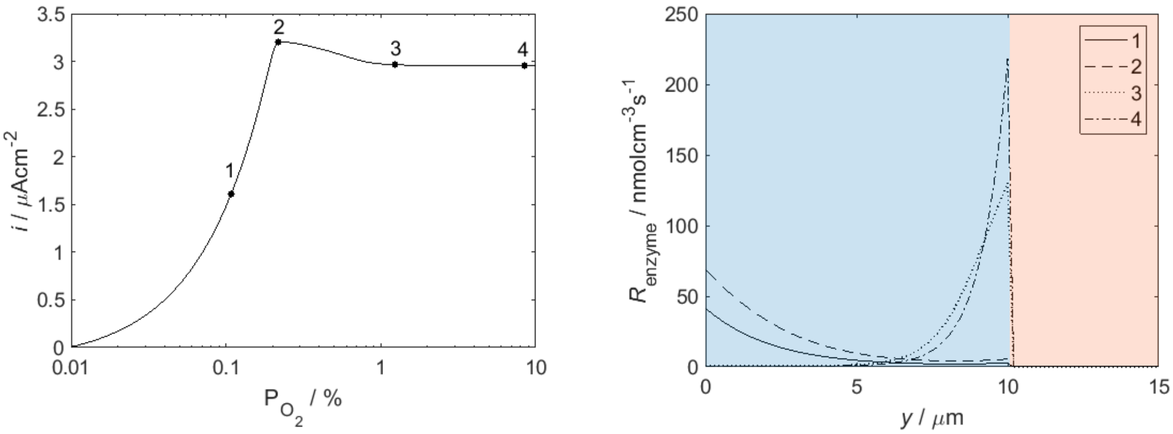
(a) (b)

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.

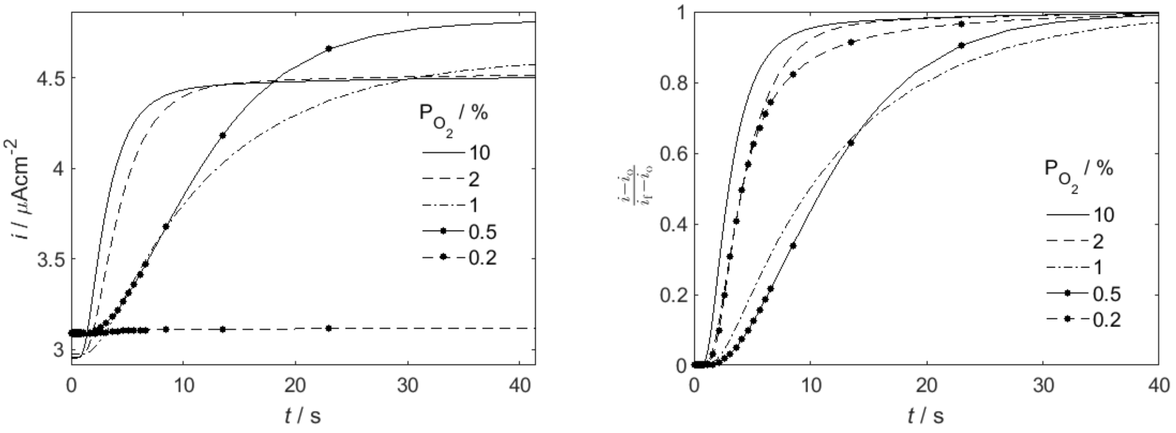
Current as a function of partial pressure of oxygen is presented in Figure 6-5(a). A current peak is observed at 0.2 % partial pressure of oxygen. This peak in current develops as the reaction profile shifts from the GLM interface to the electrode interface in the enzyme layer. The shift occurs as oxidized 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.



(a) (b)

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.

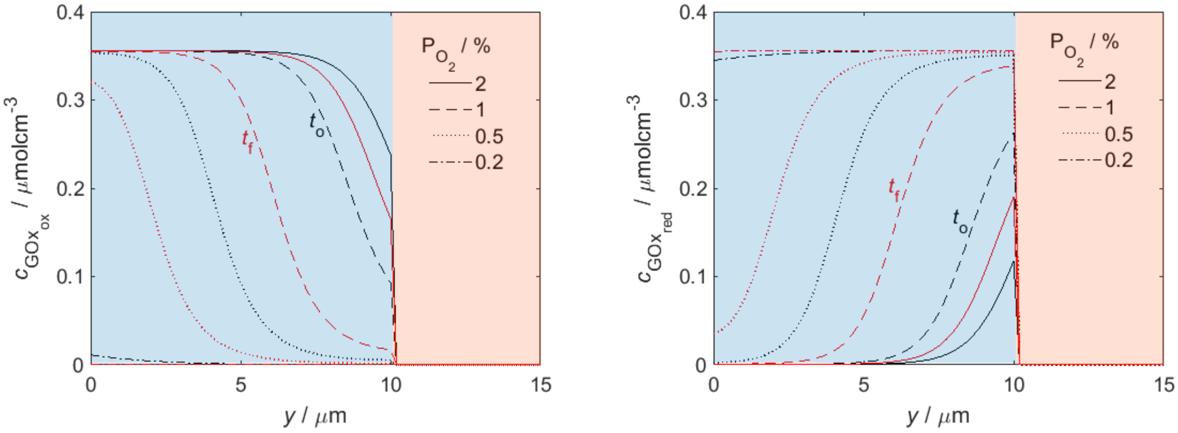
Transient calculations were made for a glucose step from 200 to 300 mgdL^{-1} with the partial pressure of oxygen varied as a parameter. Current is presented as a function of time in Figure 6-6 with oxygen partial pressure as a parameter. At 10 % oxygen, the current reaches a new steady state by 10 seconds. 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.



(a) (b)

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.

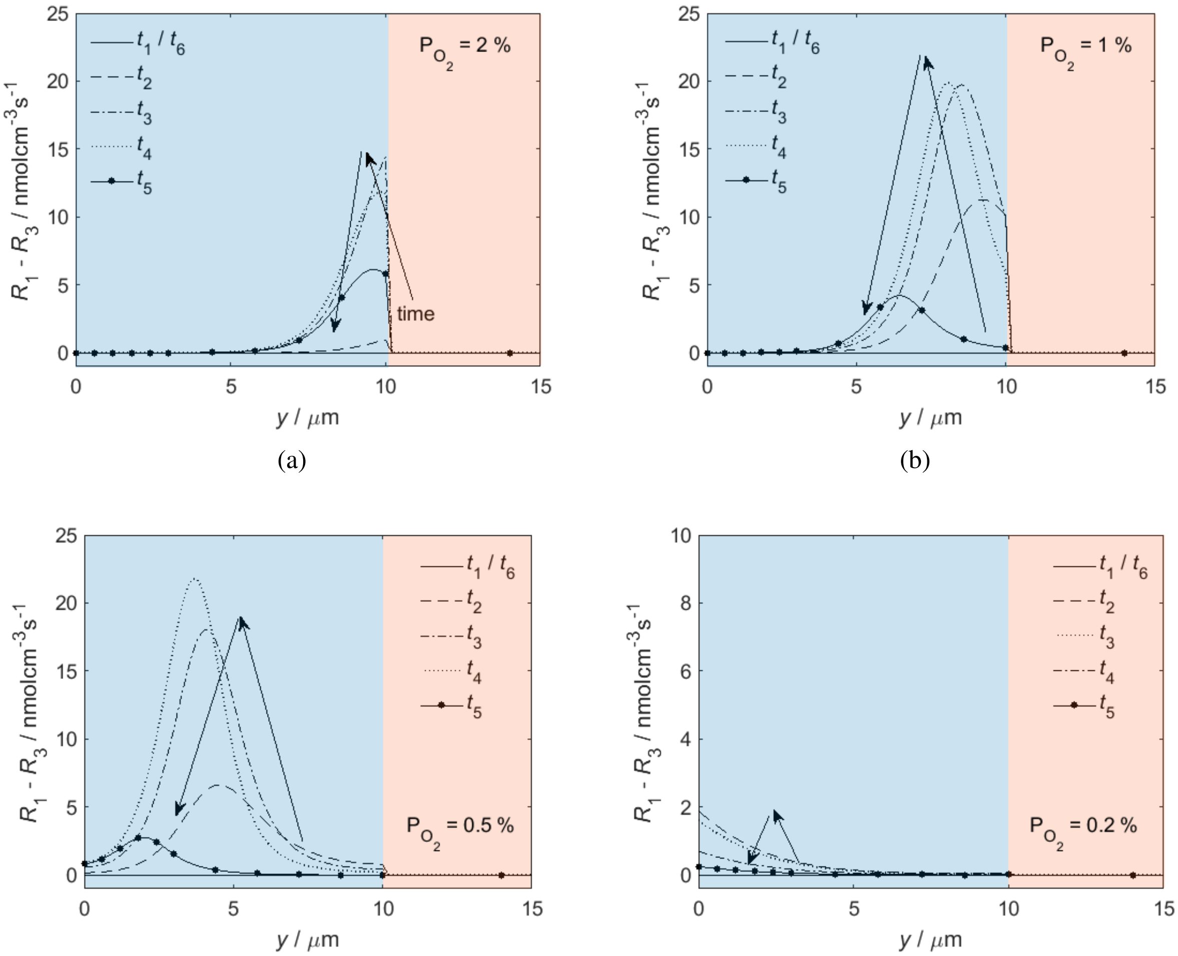
A difference in response time correlates to a shifting in the location of the enzyme reaction peak within the GOx layer; as glucose is elevated in the sensor, the reaction peak first increases, then shifts towards the electrode as the available GOx$_{\text{ox}}$. When excess GOx$_{\text{ox}}$ is present 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 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 GOx_{ox} and GOx_{red} as a function of position. A large shift in the enzyme concentration, away from the edge of the GOx/GLM interface, was observed for 1 % and 0.05 % partial pressure of oxygen when glucose was perturbed from 200 to 300 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 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 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.



(a)

(b)

Figure 6-7. Calculated concentration profiles before and after a step change in glucose from 200 to 300 mgdL^{-1} for (a) GOx_{ox},oxidized glucose oxidase, and (b) GOx_{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.



(a)

(b)

(c)

(d)

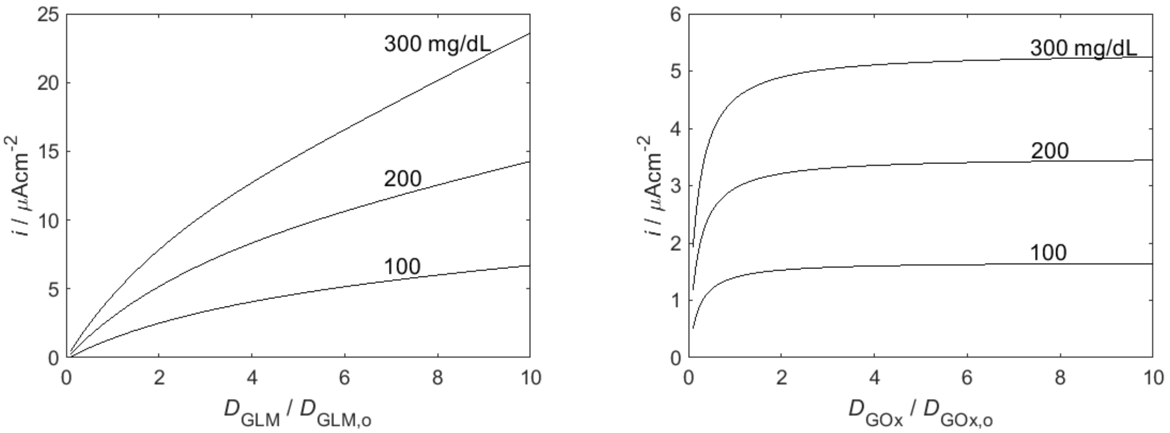
Figure 6-8. Calculated difference between enzyme reaction profiles in equations (3-3) and (3-5) during transient operation of sensor due to a glucose perturbation for partial pressure oxygen of (a) 2 %, (b) 1 %, (c) 0.5 %, and (d) 0.2 %. Conditions which demonstrated the slowest current response in Figure 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^{-1} 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 $\delta^2/\pi^2 D_{\mathrm{GLM,glu}}$. 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

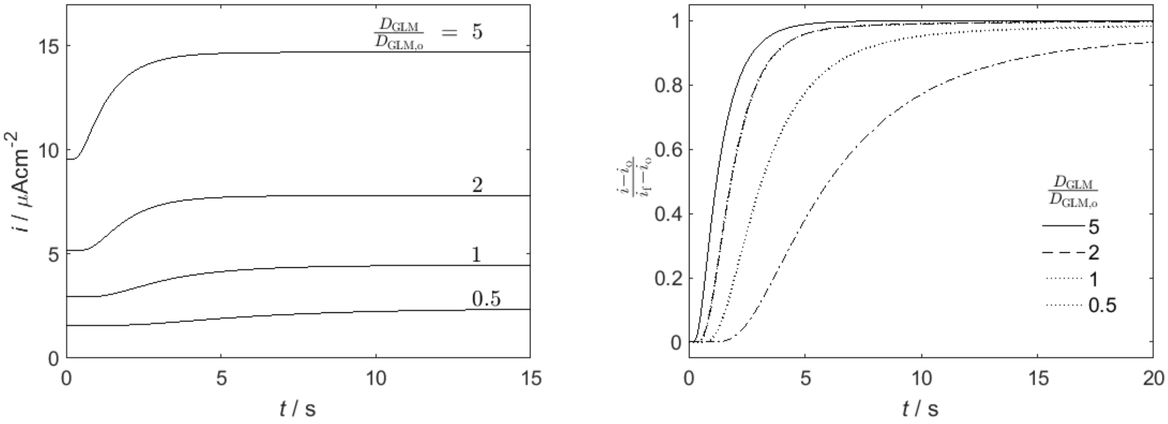


(a) (b)

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 ($D_{\mathrm{GLM,o}}$) and GOx ($D_{\mathrm{GOx,o}}$) 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.



(a)

(b)

Figure 6-10. Transient (a) current and (b) normalized current calculations to a glucose perturbation from 200 to 300 mgdL^{-1} 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 peremeability. 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, δ_{GLM}	1 to 100 μm
GOx Thickness, δ_{GOx}	1 to 50 μm
Selectivity	0.1 to 10 × 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

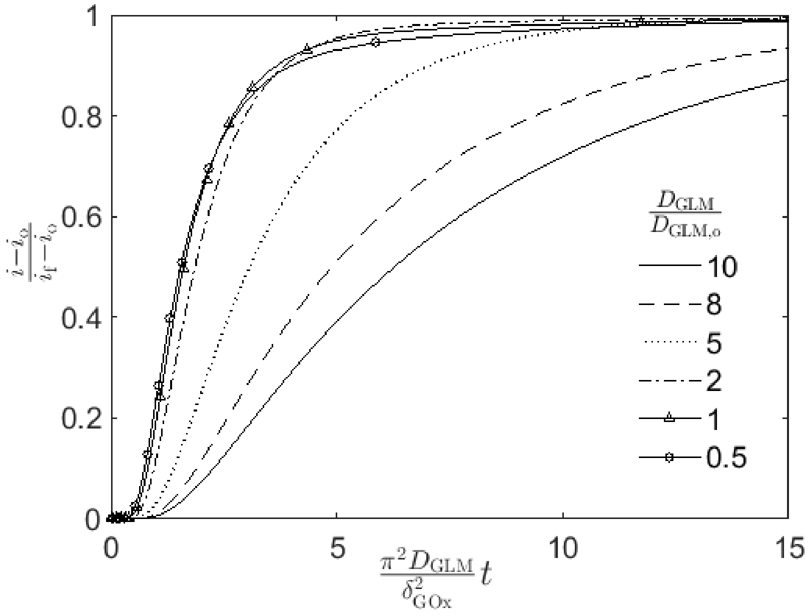
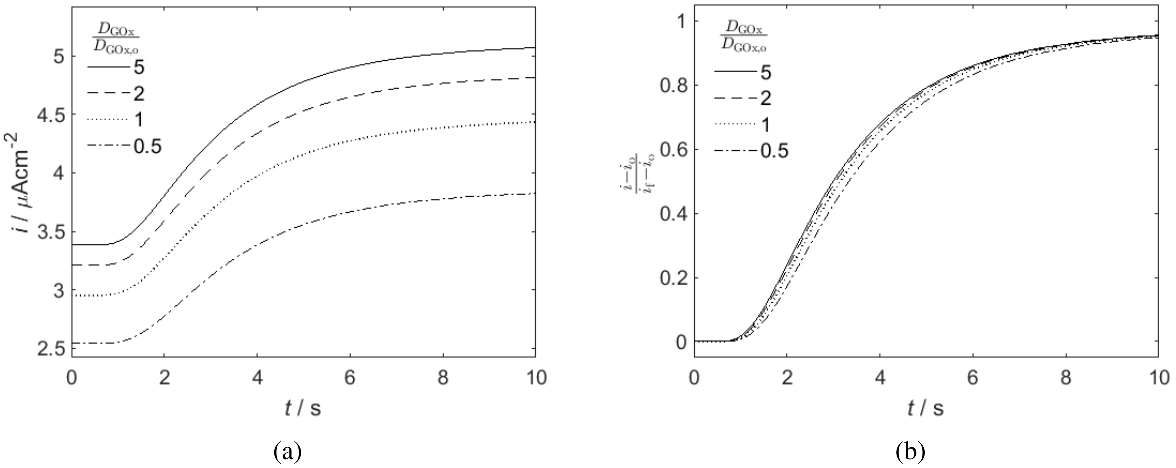


Figure 6-11. Current response as a function of the dimensionless time with the diffusion coefficients in the GLM as a parameter. When $D_{\mathrm{GLM}}/D_{\mathrm{GLM,o}}$ exceeds 2, a deviation from the time constant for glucose transport through the GLM is observed. As the GLM permeability increases,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



(a)

(b)

Figure 6-12. Transient (a) current and (b) normalized current calculations to a glucose perturbation from 200 to 300 mgdL^{-1} at 0.4 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 μm 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

$$i \propto \left.\frac{\mathrm{d}c_{\mathrm{glu}}}{\mathrm{d}y}\right|_{y=\delta_{\mathrm{GOx}}} = \frac{c_{\mathrm{glu,bulk}}}{\delta_{\mathrm{GLM}}} \tag{6-19}$$

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 mgdL^{-1} glucose. For a 5 μm 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 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 μm GLM thickness. Deviation from this response rate is observed for a 5 μm GLM. For a

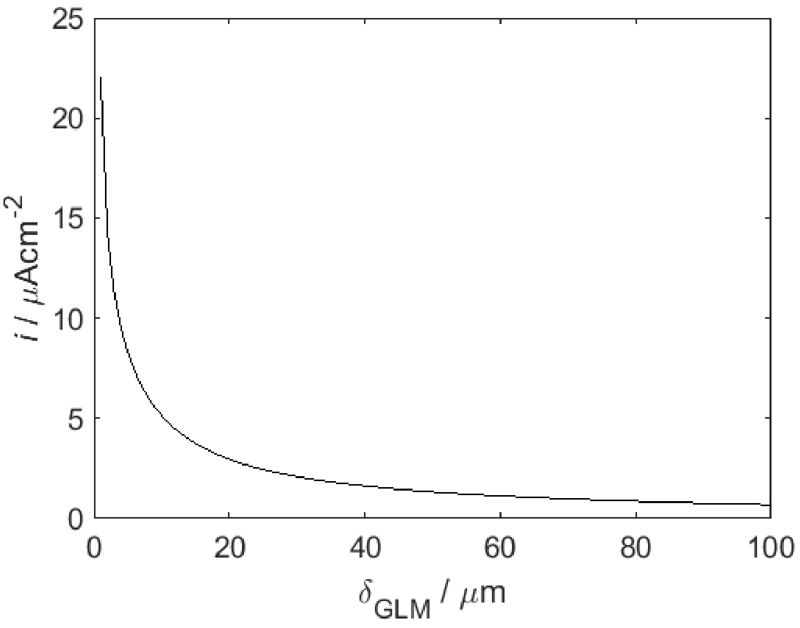


Figure 6-13. Current as a function of GLM thickness at 0.4 V and 200 mgdL^{-1} of glucose. Upon introduction of the GLM a large drop in the steady current is observed and tapers as GLM thickness is continually increased.

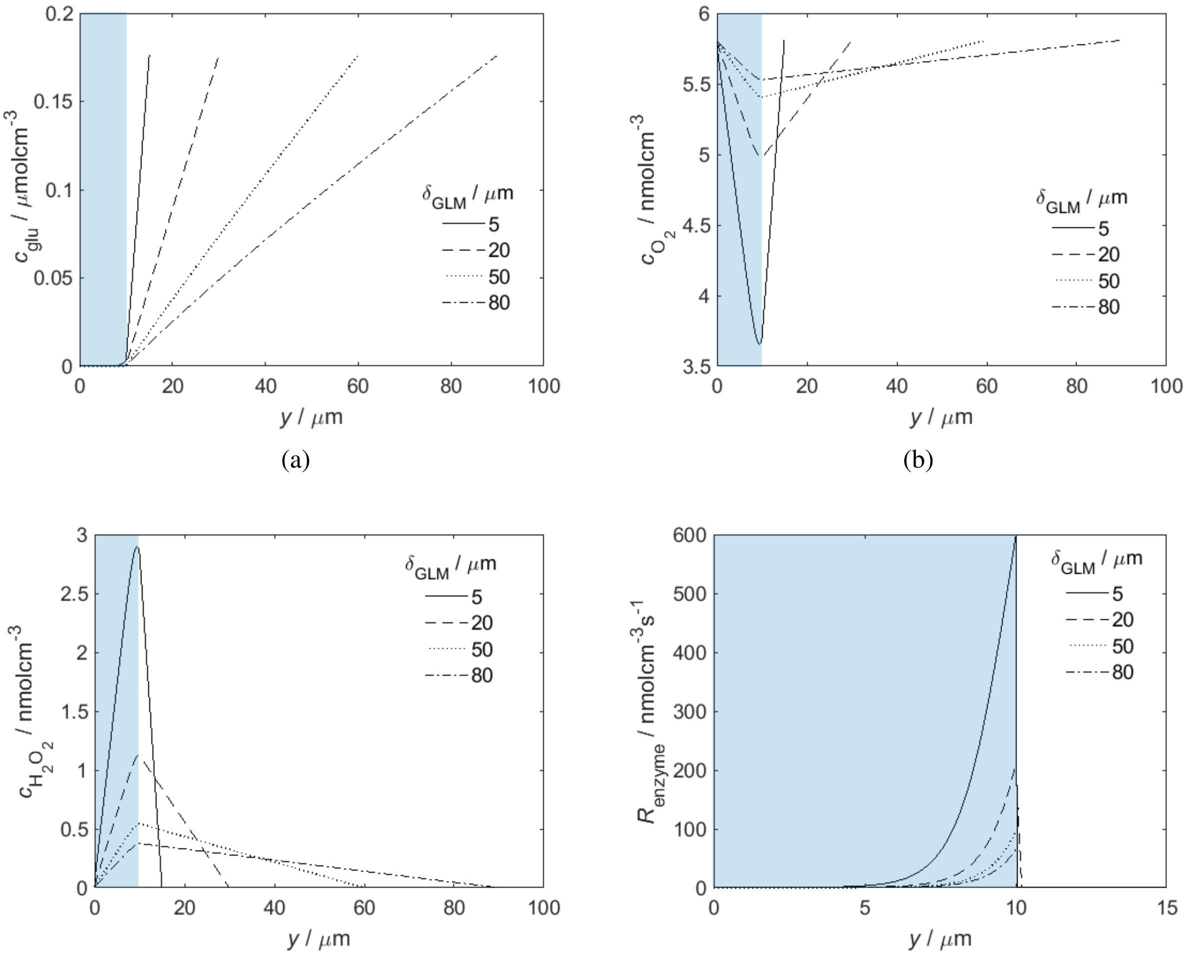
thin GLM, the response is determined by diffusion-reaction rates in the GOx enzyme layer.

These results demonstrate an expected response time to steady state within seconds for a GOx thickness of 50 μm 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.

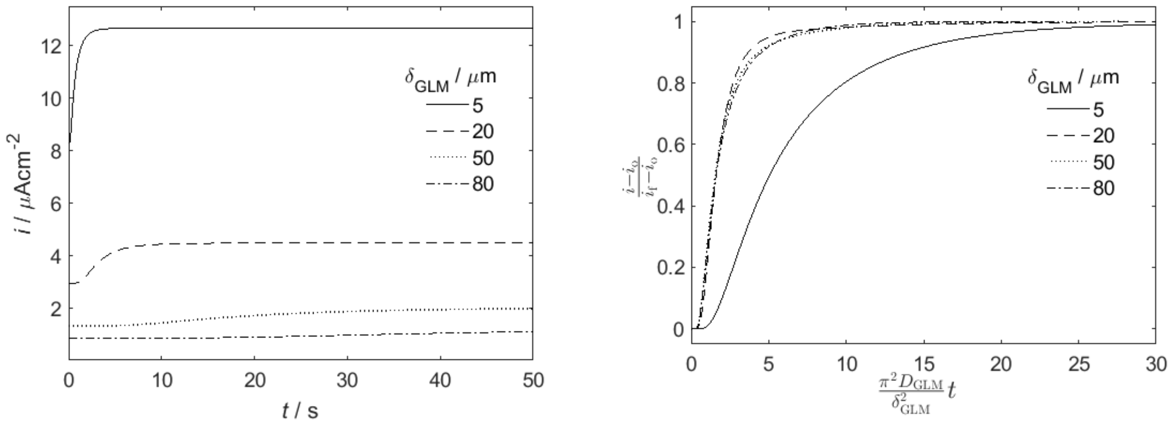
Steady current as a function of GOx thickness is presented in Figure 6-16 with glucose as a



(a) (b)

(c) (d)

Figure 6-14. Steady profiles for the concentration of (a) β-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 μm. The light blue region from 0 to 10 μm is the GOx layer.

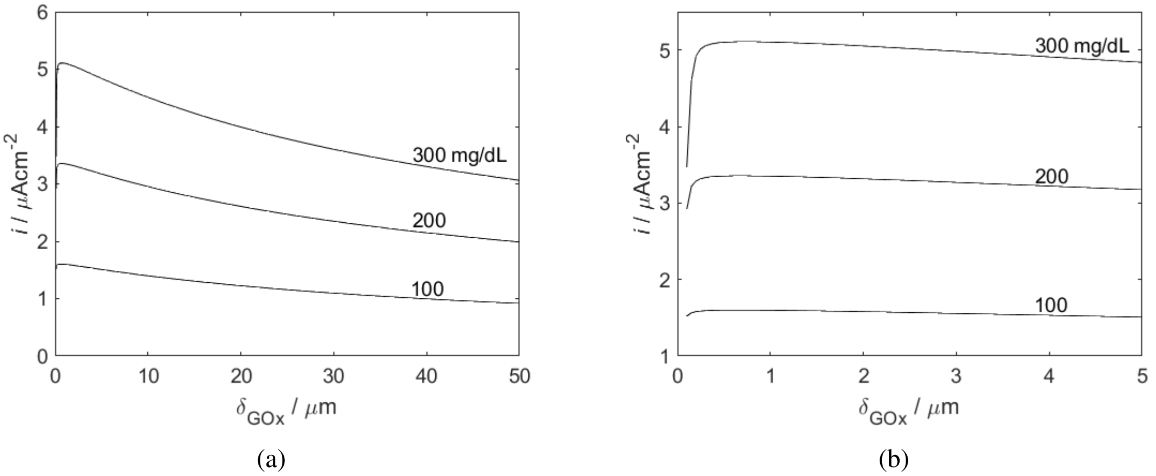


(a) (b)

Figure 6-15. Transient current response to a step change in glucose from 200 to 300 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 μm, 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 μm; 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 μm to 50 μm, 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.

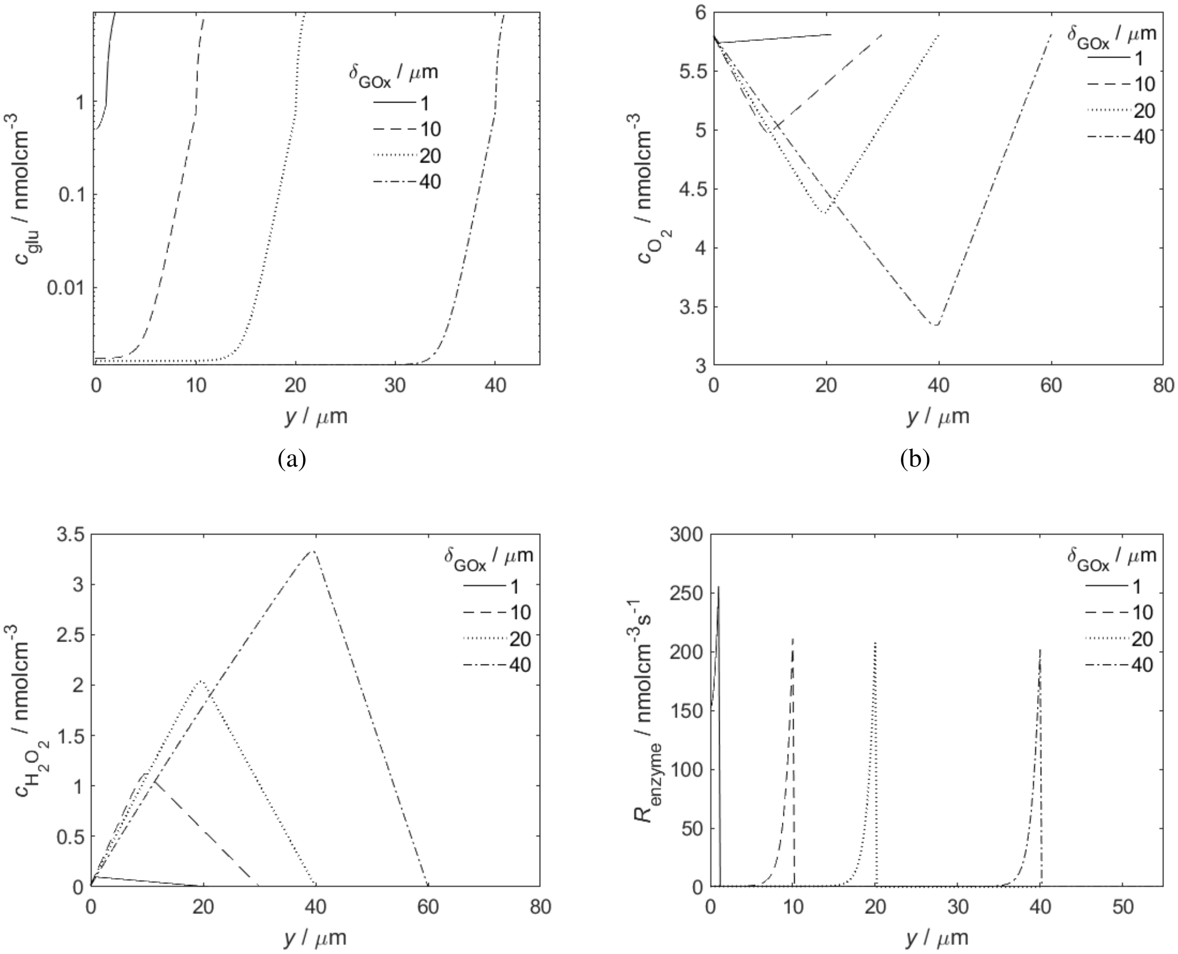
Steady concentration and reaction profiles are presented in Figure 6-16 with GOx thickness as a parameter. The glucose concentration profile (Figure 6-17(a) is presented with a log scale for concentration due to its rapid consumption in the GOx region. For the thinnest GOx region of 1 μm, the residence time of glucose in the enzyme layer is not sufficient to fully react and minimal oxygen is consume. For GOx layers of 10, 20 and , 40 μm 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 nmolcm^{-3} for a 10 μm GOx region, but drops to 3.3 nmolcm^{-3} for a 40 μm 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 an is responsible for the current decrease for the thicker Gox layers conditions in Figure 6-16.



(a) (b)

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 μm and (b) 0.1 to 5 μm GOx layer thickness. Current decrease is observed for thickness increases to the GOx region, except when less than 1 μm.

Influence of the GOx thickness on the transient response to a glucose perturbation from 200 to 300 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 (¡0.5 s) difference in the initial increase in the current. Despite the presence of unreacted glucose in the 1 μm 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



(a)

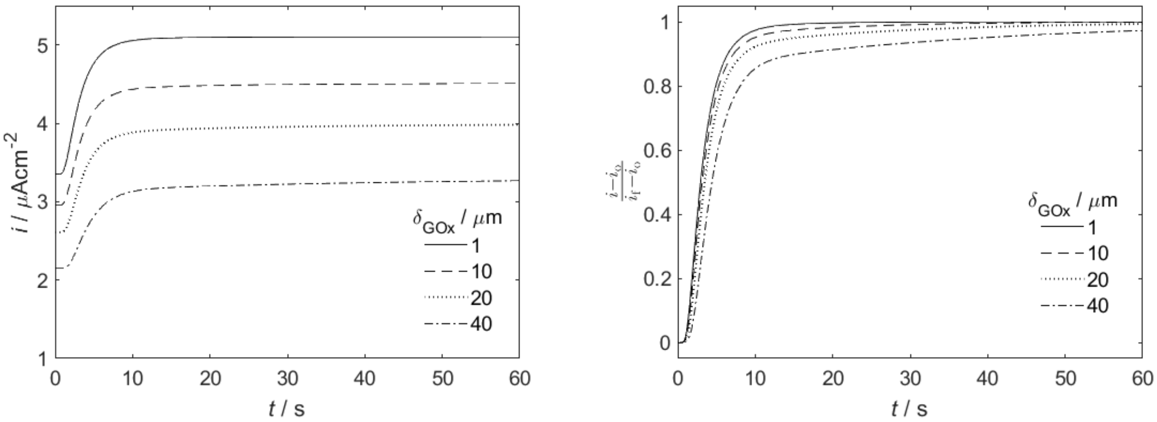
(b)

(c)

(d)

Figure 6-17. Steady profiles for the concentration of (a) β-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 μm. Simulations conducted at an applied potential of 0.4 V and 200 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 μm GOx layer condition. This was found to be due to the increased degree in anomerization of α-glucose to β-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 β-glucose.



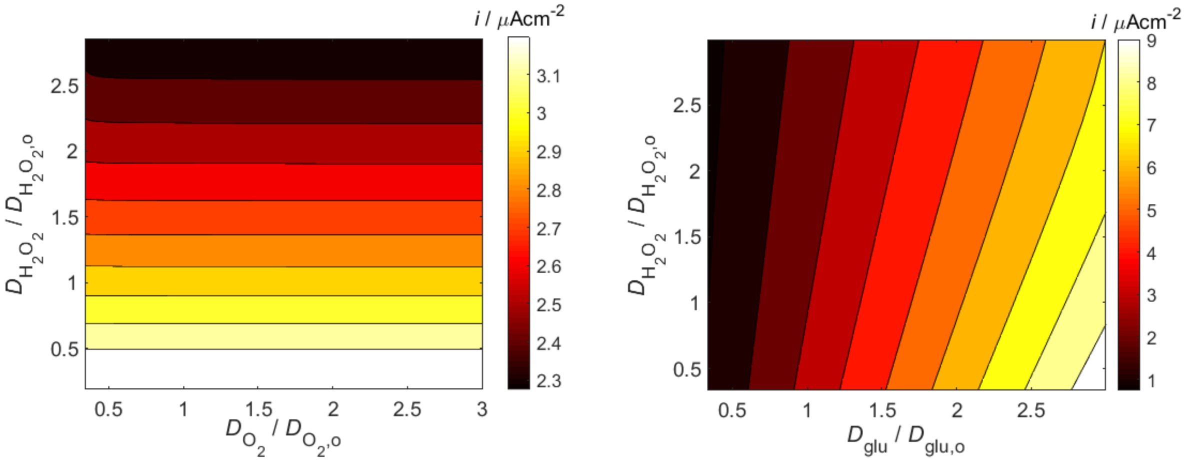
(a) (b)

Figure 6-18. Transient current response to a glucose perturbation from 200 to 300 mgdL^{-1} 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 α-glucose to β-glucose, as the β-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.



(a)

(b)

Figure 6-19. Steady current as a function of GLM diffusion coefficients for (a)H_2O_2 and O_2 and (b)H_2O_2 and glucose. Applied potential was 0.4 V, bulk glucose was 200mgdL^{-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.

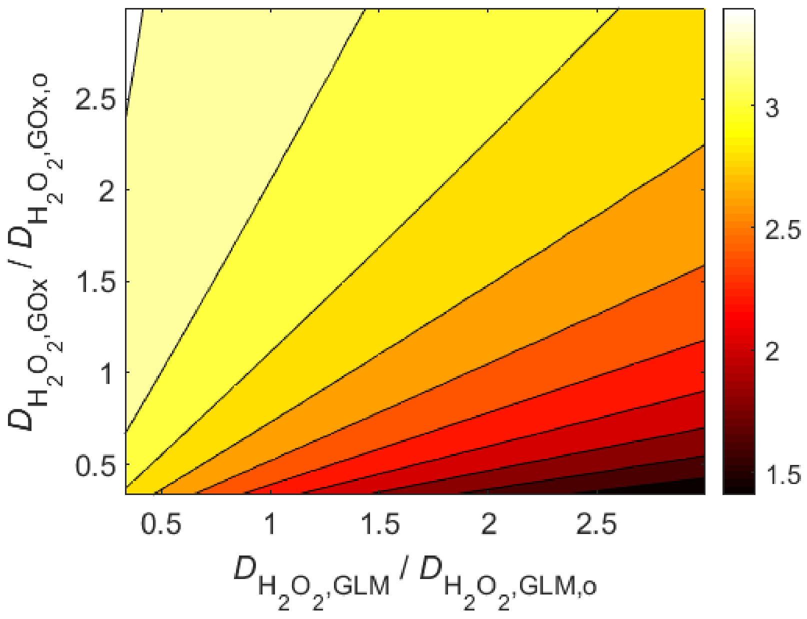
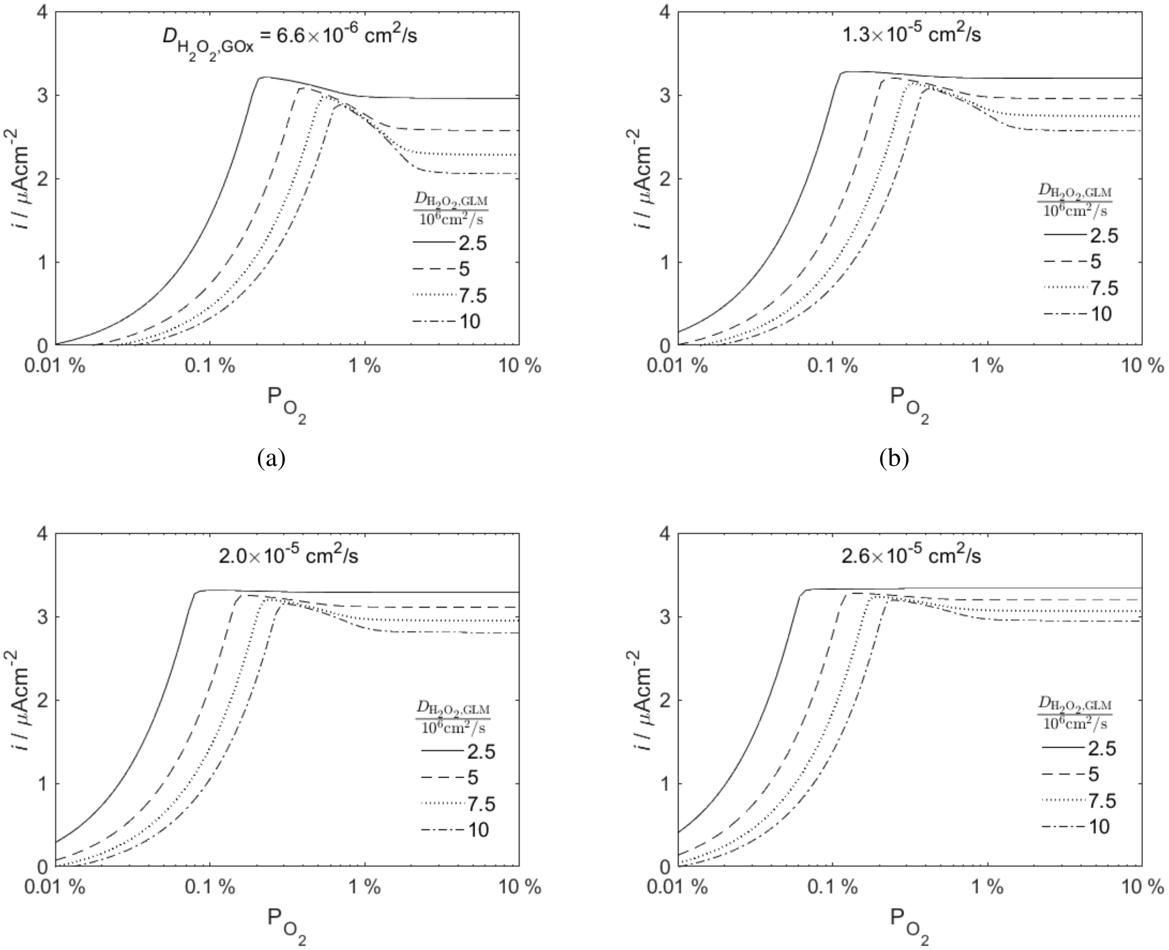


Figure 6-20. Steady current as a function of GOx and GLM diffusion coefficient for hydrogen peroxide. Current increases with increased diffusivity in the GOx layer, and decreased diffusivity in the GLM layer for hydrogen peroxide.

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, $D_{\mathrm{H_2O_2,GOx}}/D_{\mathrm{H_2O_2,GLM}}$, 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.

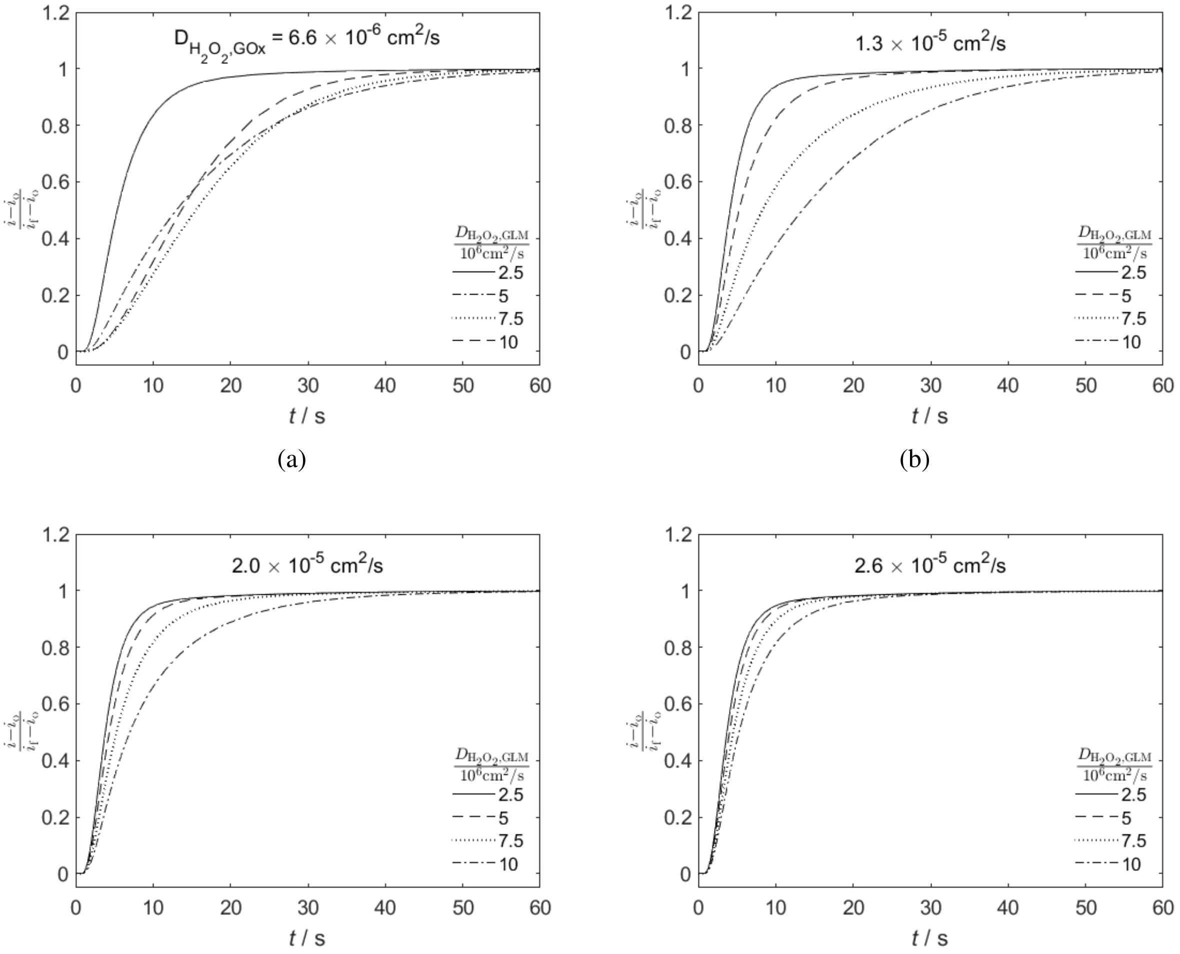
The transient response to a glucose perturbation from 200 to 300 $\mathrm{mgdL^{-1}}$ was made with the hydrogen peroxide diffusion coefficients in the GOx and GLM layers from the previous oxygen curve study. The current response are presented in Figure 6-22 with the diffusion coefficient of hydrogen 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).



(a) (b)

(c) (d)

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 $\times 10^{-6}$ cm^2/s.



(a) (b)

(c) (d)

Figure 6-22. Transient current response to a glucose perturbation from 200 to 300 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 $\times 10^{-6}$ cm^2/s. Applied potential was 0.4 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 ^{o}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 spergers, 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.

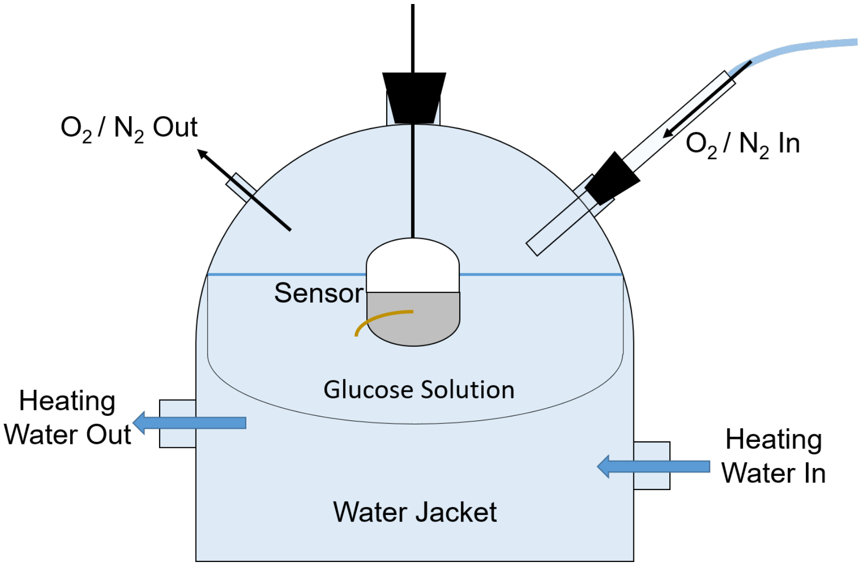


Figure 7-1. Experimental setup includes: glass temperature controlled jacket vessel, glucose solution with gas inlet and outlet, and glucose sensor.

100 mL solutions were prepared by combining a stock solution of 2000 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 sperger. One of the ports was covered with PARAFILM and gas was allowed to exit via a pinhole. The sperger 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^{-1} 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.

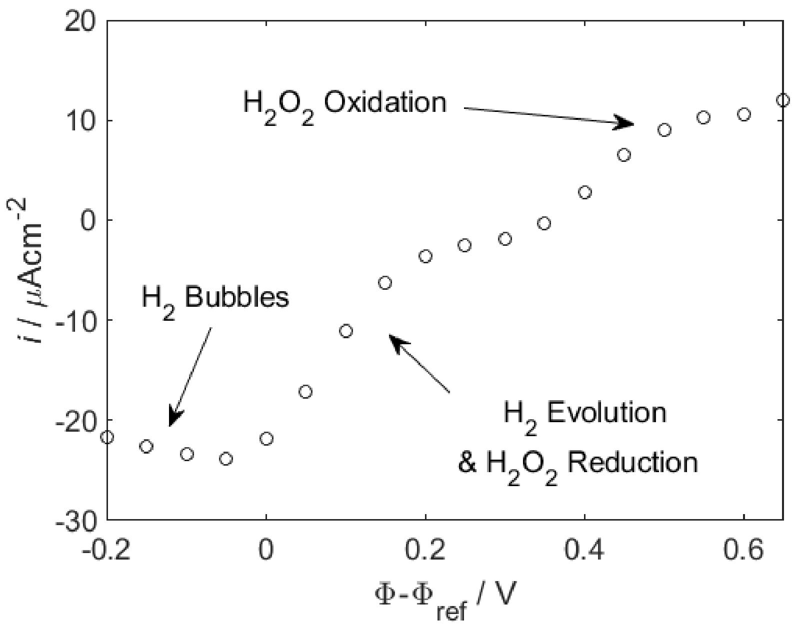
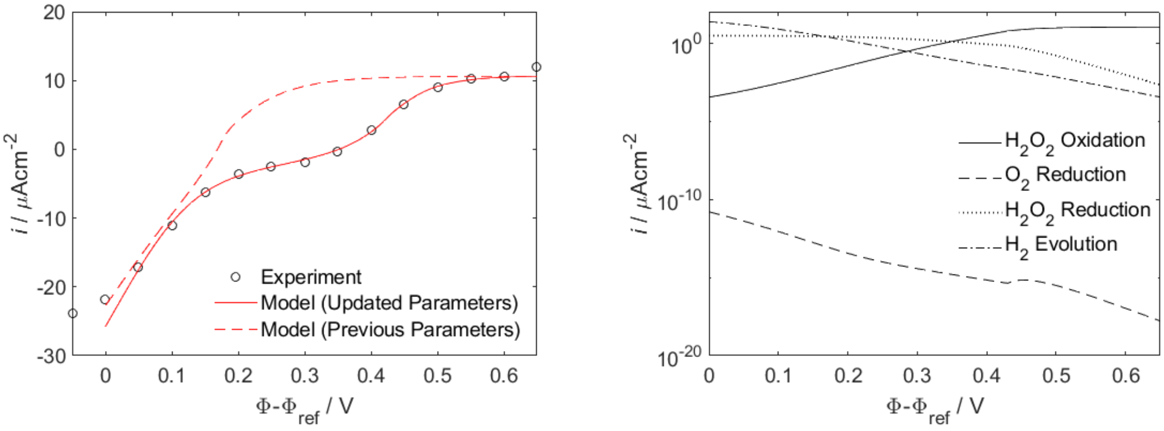


Figure 7-2. Polarization behavior obtained from a series of chronoamperometric steps from 0.65 V to -0.2 V in 50 mV increments with 4500 second potential holds between steps. Hypothesized mechanisms are provided to explain behavior along the curve.

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, $K_{H_2O_2}$; the slope approaching this plateau was matched by reducing the exponential electrode constant, $b_{H_2O_2}$. The kinetic plateau observed from 0.2 to 0.35 V was fit by increasing the rate constant for hydrogen peroxide reduction, K_{red}, and reducing the electrode constant, b_{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



(a) (b)

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
$D_{\mathrm{GOx,glu}}$ / cm^2/s	3×10^{-7}	2.13×10^{-6}
$K_{\mathrm{H_2O_2}}$ / $\mathrm{Acm/mol}$	0.7	20
K_{red} / $\mathrm{Acm^7/mol^3}$	1×10^{25}	7.5×10^{23}
$K_{\mathrm{H_2}}$ / $\mathrm{Acm^4/mol^2}$	3.8×10^{16}	2.8×10^{16}
$b_{\mathrm{H_2O_2}}$ / V^{-1}	17	22.4
b_{red} / V^{-1}	13	30
$b_{\mathrm{H_2}}$ / 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 mgdL^{-1} glucose steps were made from 100 to 900 mgdL^{-1}. 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 $\mu\mathrm{Acm}^{-2}/\mathrm{mgdL}^{-1}$. The steady model was fit with to the data by setting the glucose diffusion coefficient in the GLM to 5.1 $\times 10^{-7}$ $\mathrm{cm}^2\mathrm{s}^{-1}$. 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

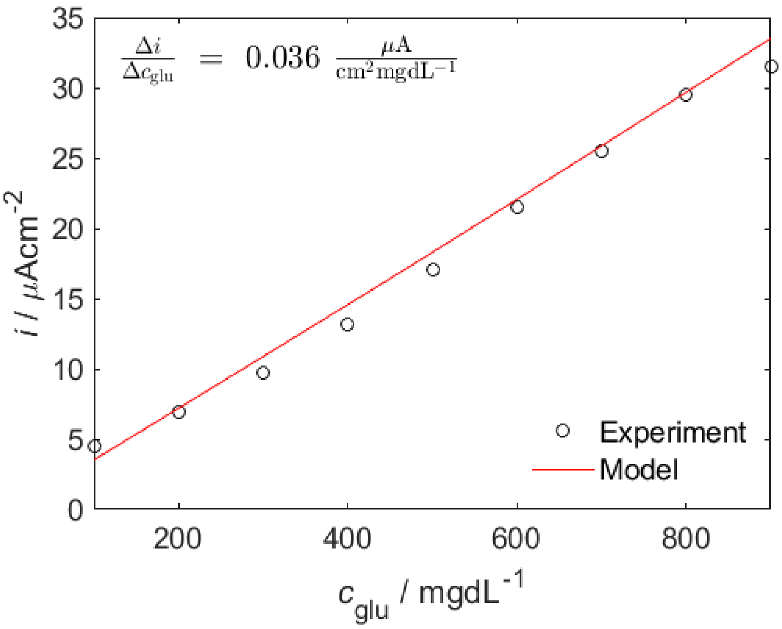
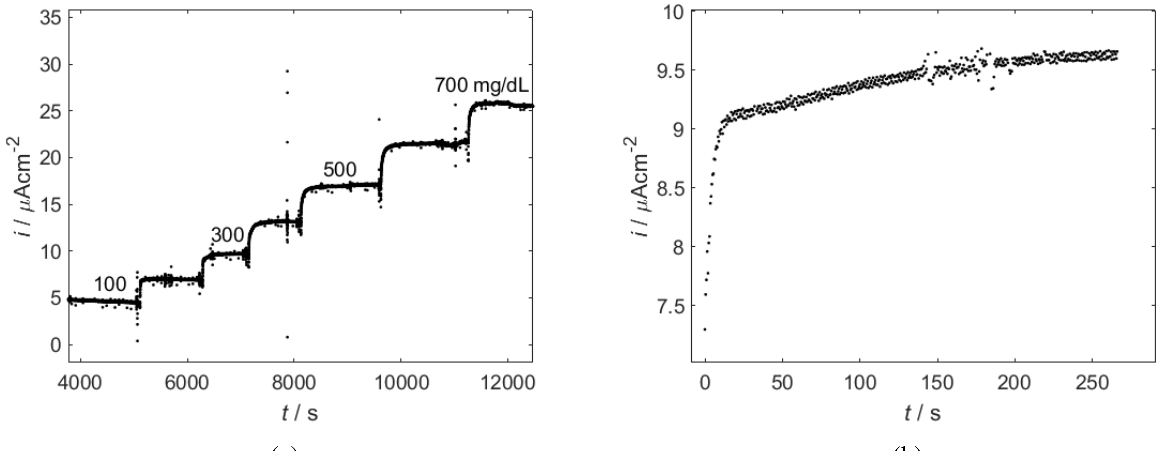


Figure 7-4. Polarization behavior obtained from a series of chronoamperometric steps from 0.65 V to -0.2 V in 50 mV increments with 4500 second potential holds between steps. Hypothesized mechanisms are provided to explain behavior along the curve.

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^{-1} glucose steps were made from 100 to 700 mgdL^{-1}, 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

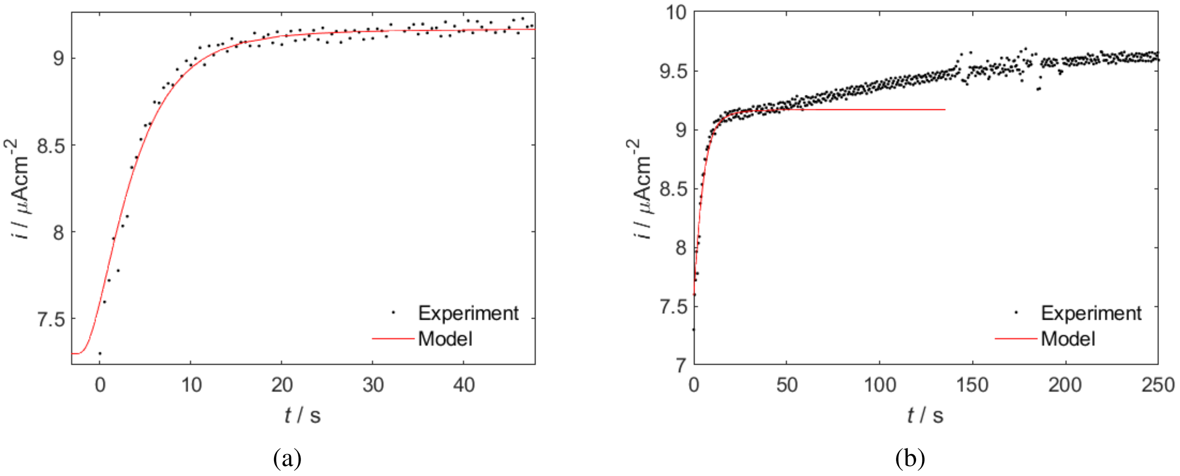


(a)

(b)

Figure 7-5. Glucose step experiments conducted from 100 to 700 mgdL^{-1} in 100 mgdL^{-1} increments. Current as a function of time for (a) all 6 glucose perturbations and (b) 200 to 300 mgdL^{-1}. 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, $k_{\mathrm{f},2}$ was set to a value of 0.245 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



(a) (b)

Figure 7-6. Comparison of the glucose step experiment and model fit for a perturbation from 200 to 300 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

$$\mathrm{GOx_{red}} + \mathrm{H_2O_2} \underset{k_{\mathrm{act.}}}{\overset{k_{\mathrm{deact}}}{\rightleftarrows}} \mathrm{GOx_{deact.}} \tag{7-1}$$

where $k_{\mathrm{deact.}}$ and $k_{\mathrm{activ.}}$ 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 $\mathrm{GOX_{red}}$. 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

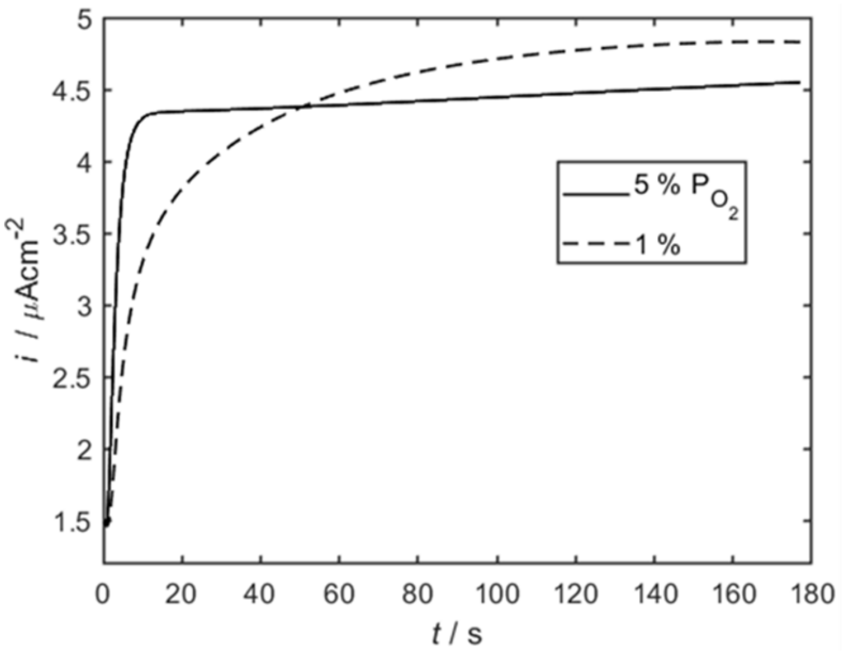
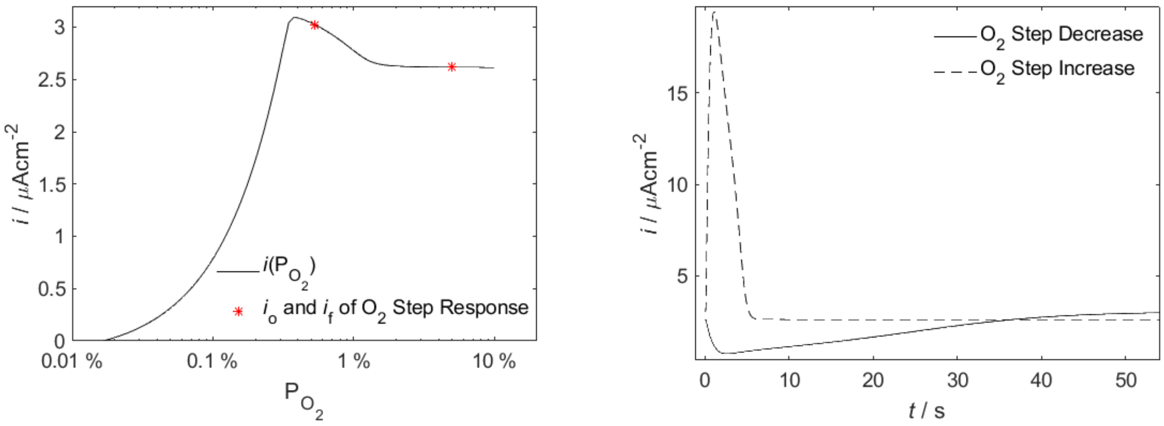


Figure 7-7. Transient current response to an arbitrary step change in glucose with oxygen partial pressure as a parameter. The introduction of enzyme deactivation into the model has the ability to produce large time constants decoupled from the rapid mass transfer time constants in the sensor.

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 GOx_{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



(a) (b)

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 mgdL^{-1} glucose solution, with an applied potential of 0.4 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 sperger 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 sperger 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 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

$$\frac{\mathrm{d}P_{O_2}}{\mathrm{d}t} = -k_{\mathrm{gas}}\left(P_{O_2} - P_{O_2,o}\right) \tag{7-2}$$

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

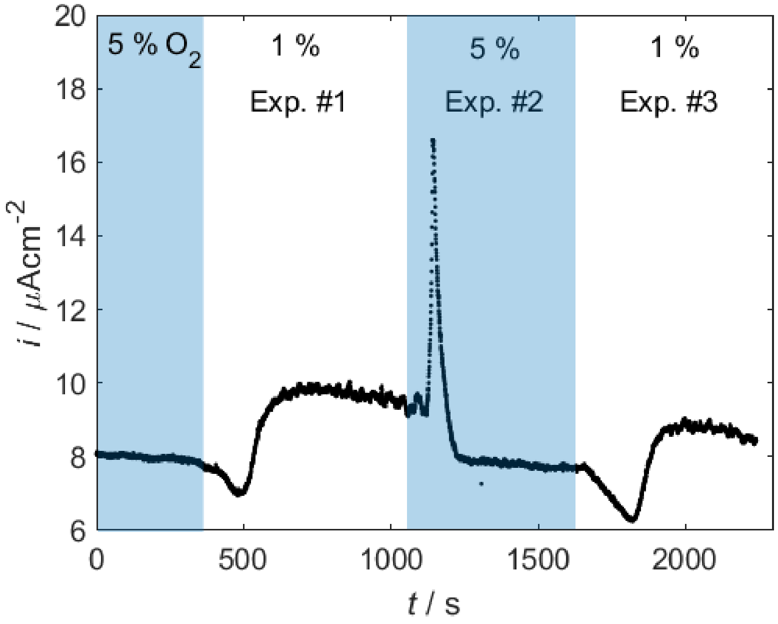


Figure 7-9. Transient current in response to changing of the oxygen partial pressure in the supply air. A decrease in oxygen yields an initial current decrease, followed by a recovery to a current value higher than the initial. The opposite occurs with an increase in oxygen, but the level of current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

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

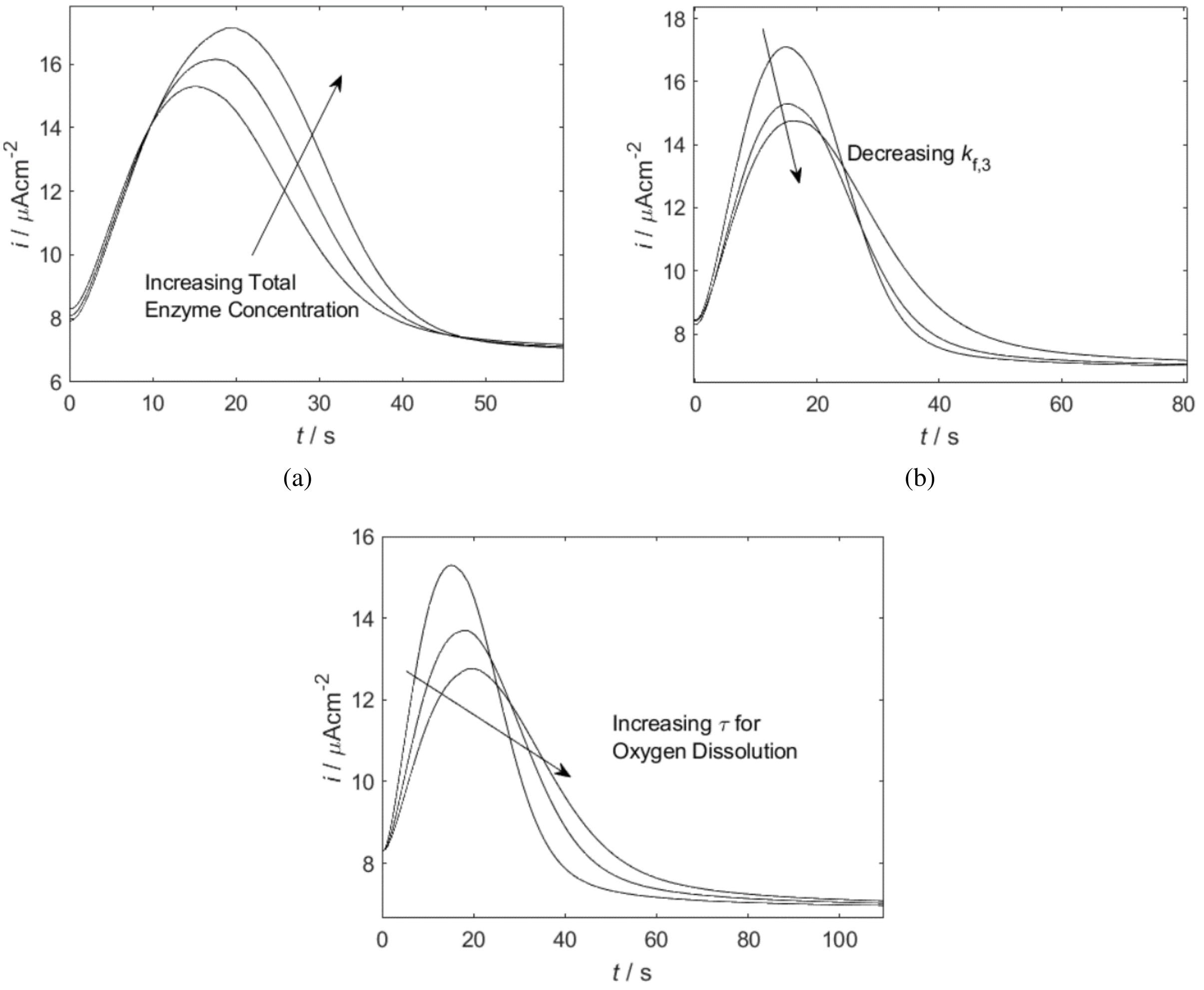
$$\mathrm{P}_{\mathrm{O}_2}(t) \;=\; \left(\mathrm{P}_{\mathrm{O}_2,\mathrm{o}} - \mathrm{P}_{\mathrm{O}_2,\mathrm{f}}\right)\exp(-k_{\mathrm{gas}}t) + \mathrm{P}_{\mathrm{O}_2,\mathrm{f}} \tag{7-3}$$

where $\mathrm{P}_{\mathrm{O}_2,\mathrm{f}}$ 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 ($k_{\mathrm{f},3}$ for this example), and k_{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 $\mathrm{GOx}_{\mathrm{red}}$. The current and integral of the peak during an oxygen ramp was found to increase proportional to the initial concentration of accumulated $\mathrm{GOx}_{\mathrm{red}}$. The enzyme rate constant, $k_{\mathrm{f},3}$, 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.

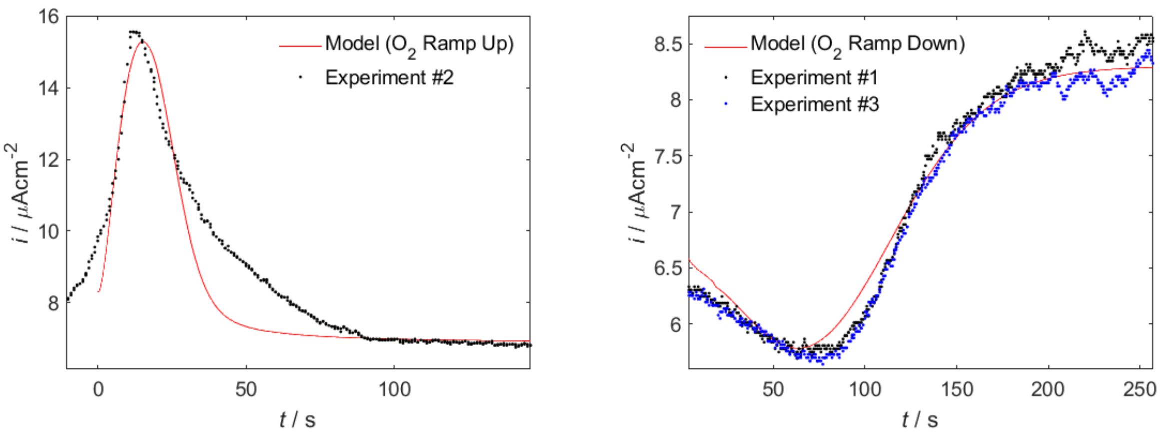


(a)

(b)

(c)

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) $k_{\mathrm{f},3}$, enzyme rate constant for reaction 3, and (c) k_{gas}, oxygen dissolution rate in the supplied gas.



(a) (b)

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^{-1} 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

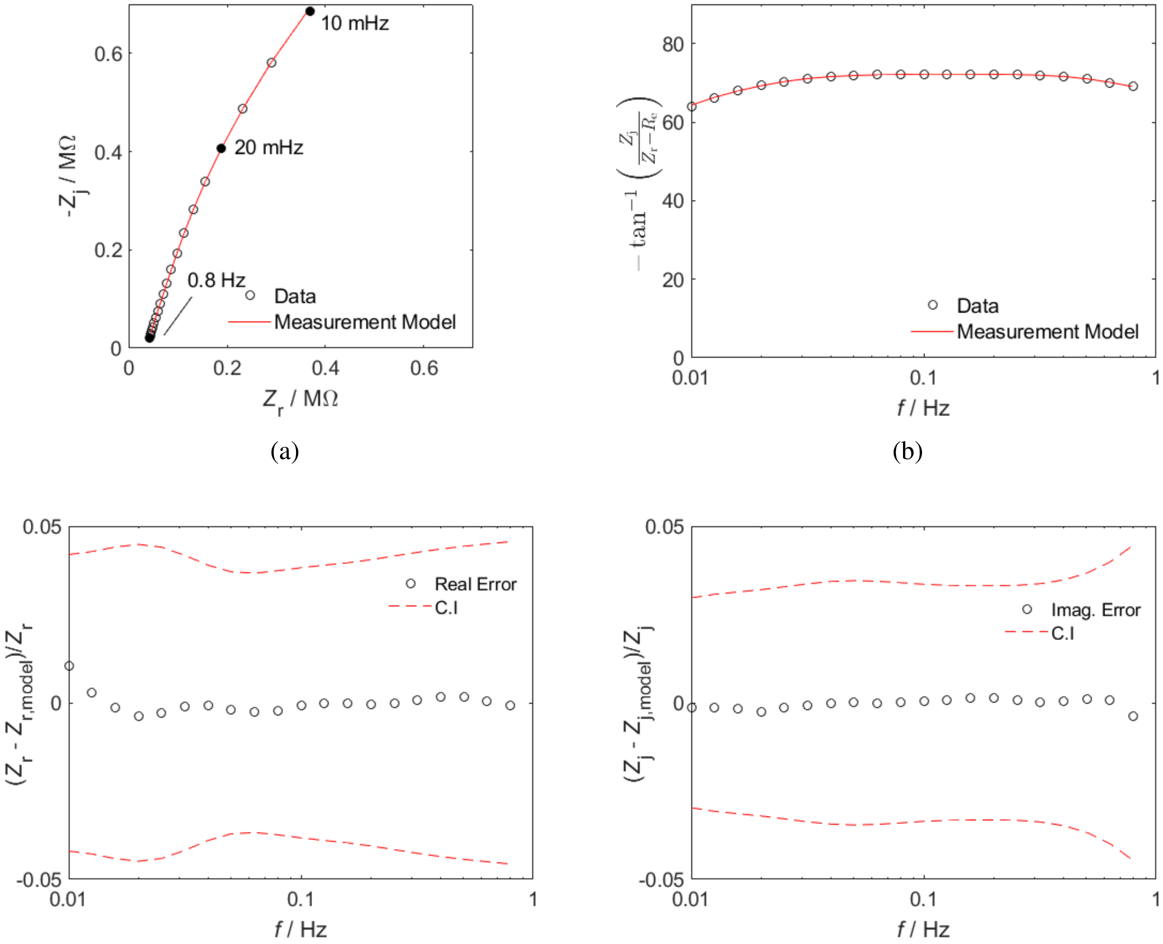
Real, imaginary and complex impedance data was fit with a series of Voigt elements, as discussed in Chapter 2.2.2.1. A complex fit was conducted with a modulus error weighting of $\gamma = 0.002$ as a first approximation of the error structure. This was repeated for all replicates and the resulting error 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

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

where γ is the modulus weighting factor with units Ω^{-1}. δ is the proportional weight constant with units of Ω. 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



(a) (b)

(c) (d)

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 (1σ)
γ / Ω^{-1}	1.635E-9 (3.14E-10)
δ / Ω	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

$$Z_\mathrm{F} = R_\mathrm{t} + R_\mathrm{d}\left(-\frac{1}{\theta'}\right) \tag{7-5}$$

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

$$R_\mathrm{d} C_\mathrm{eff} \gg \frac{\delta^2}{D_\mathrm{i}} \tag{7-6}$$

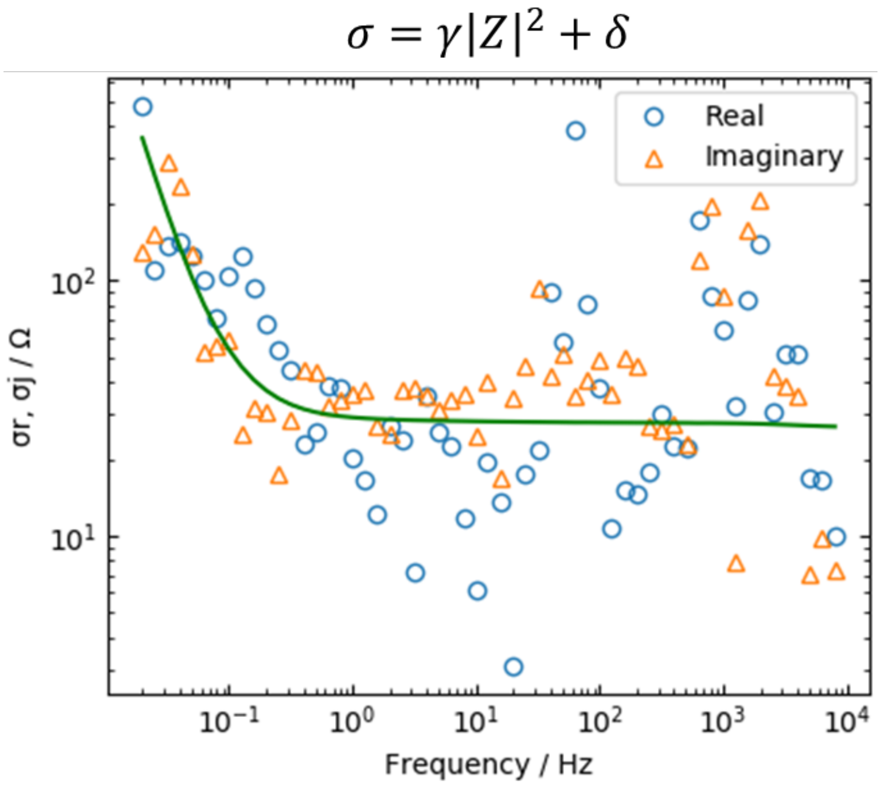


Figure 7-13. Stochastic error of the real and imaginary variation as a function of frequency. Lack of overlap of the real and imaginary variation above 1 Hz is believed to be due to frequency dispersion from a rough electrode.

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

$$Z = R_\mathrm{e} + \frac{R_\mathrm{d}}{1 + (j\omega)^\alpha Q R_\mathrm{d}} \tag{7-7}$$

where R_e is the electrolyte resistance, α is the high frequency phase angle as a fraction of 90^{o}, 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_3, R_d, α, 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

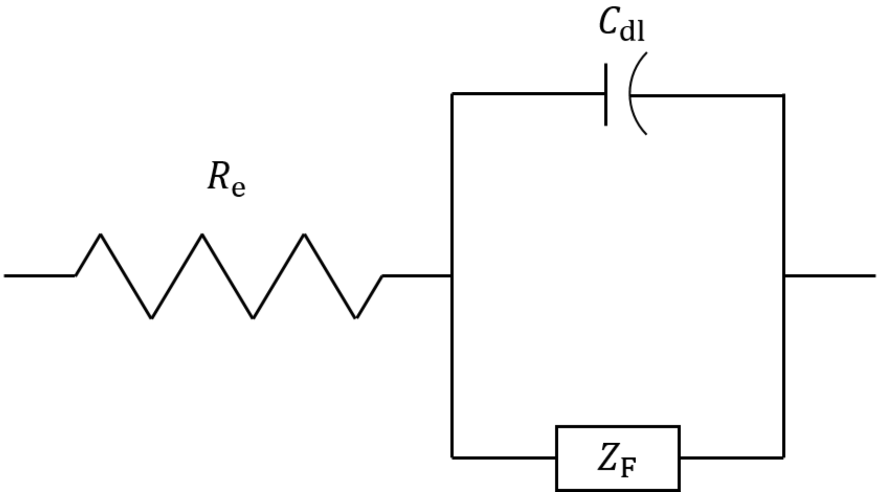


Figure 7-14. Equivalent circuit diagram for the glucose sensor. Individual faradaic reactions are not distinguished during impedance measurements and are lumped together into the circuit element, Z_{F}.

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} / kΩ	36.9 (10.7%)
R_{d} / MΩ	3.68 (22.8%)
Q / $\mu\mathrm{Fs}^{1-\alpha}$	12.89 (2.58%)
α	0.852 (1.92%)

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

$$C_{\mathrm{eff}} = Q^{1/\alpha} R_{\mathrm{e}}^{(1-\alpha)/\alpha} \tag{7-8}$$

, 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

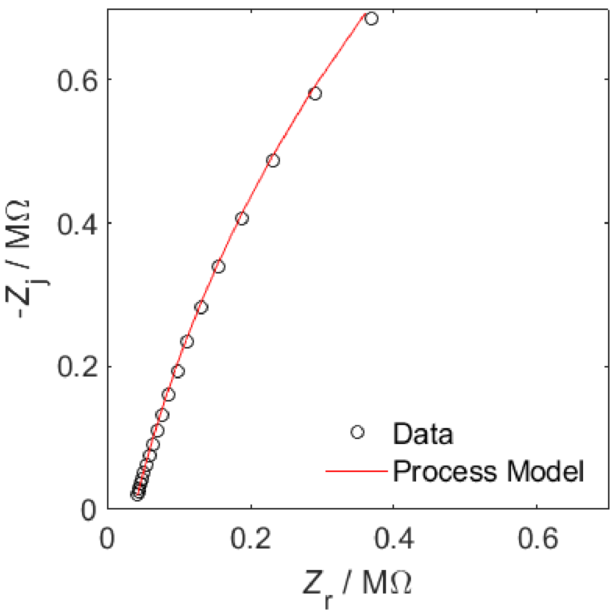


Figure 7-15. Nonlinear regression of the process model, Equation 7-7, to a Nyquist plot of the impedance data.

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 $R_\mathrm{d}C_\mathrm{eff}$ 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 μF and a diffusion resistance of 3 MΩ. Capacitance and ohmic resistance values were scaled by the sensor area of 3.42×10^{-3} 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 / kΩ	33.5	36.9
R_d / MΩ	2.57	3.68
C_eff / μF	5.56	11.3

CHAPTER 8
CONCLUSIONS

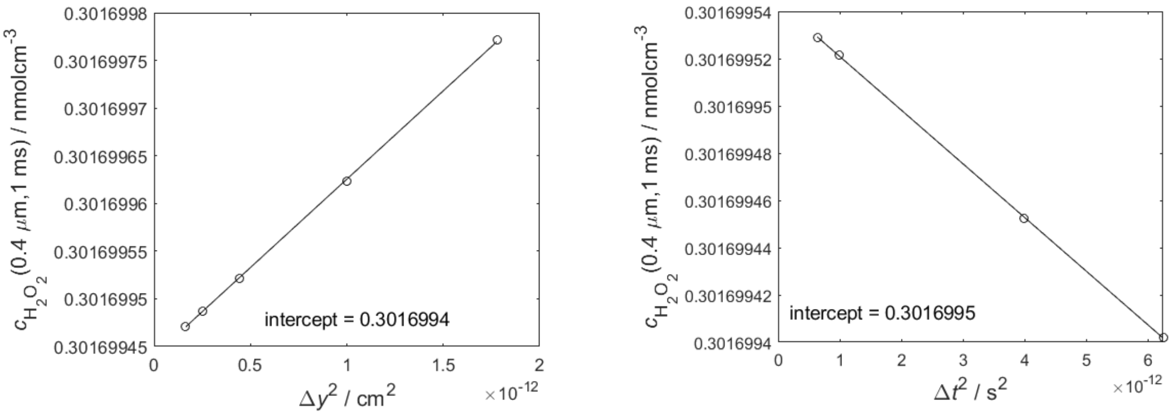
Steady and transient models were developed for the glucose sensor with varying complexity and dimensions. The model accounts for the individual reaction steps of the enzyme as opposed to the assumptions involved under Michaelis-Menten kinetics. The transient model developed is unique. The charging and 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.



(a)

(b)

Figure A-1. Calculated hydrogen peroxide concentration 0.4 μm from electrode and 1 ms after potential perturbation as a function of (a) spatial-mesh spacing squared, Δy^2 and (b) temporal-mesh spacing squared, Δt^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

```
21
501
301
201
0.0003
0.0007
0.002
0.8
0.42
0.169
1
0.11
0.025
1e+09
1e+07
1000
1e+09
1e+07
1e+09
0.006
1.7397
0.0002
0.0017
5.26e-07
1e-20
20
22.4
5e+15
38.4
7.5e+23
30
2.8e+16
15
1e-14
101
0.0001
20
22.4
401
0.01
0.7
0.15
```

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

```fortran
C     Convective Diffusion Equation with Homogeneous Reaction
C     Enzyme kinetics added
C     8 species system
C     SPECIES 1 = glucose, SPECIES 2 = GOx-FAD, SPECIES 3 = Gluconic acid
C     SPECIES 4 = GOx-FADH2, SPECIES 5 = O2, SPECIES 6 = H2O2
C     SPECIES 7 = GOx-FADH2-GA, SPECIES 8 = GOx-FAD-H2O2
C     Species 6 is the reacting species
C     This is the steady state solution only
C     It should be ran prior to cdhgox_os.for
C     The input file is the same for both
C     This version of the code is reversible normal kinetics for reactions 1 and 3
C     Reactions 2 and 4 are irreversible

C     Copy and paste the appropriate lines to create the executable
C     cd D:\0006 - Simple Transient Sensor Part 2
C     gfortran -static FullTransCGMvA.for -o FullTransCGMvA.exe

      PROGRAM FullTransCGMvA
      IMPLICIT DOUBLE PRECISION (A-H, O-Z)
      COMMON/BAB/ A(22,22),B(22,22),C(22,80001),D(22,45),G(22),X(22,22)
     1   ,Y(22,22)
      COMMON/NSN/ N, NJ
      COMMON/GLC/ NTIME,LL
      COMMON/VAR/ DIFF(16),H,EBIG,HH,IJ,KJ,TT,VAP,HHH,DT,RE,AKB,BB,CDL
      COMMON/VARR/ HHHH,HHHHH,MJ,LJ
      COMMON/DIN/ DGOX(16),DGLM(16),DIRM(16),DBULK(16)
      COMMON/SPCI/ GLU(2,80001),GOX(2,80001),GLA(2,80001),GOR(2,80001)
      COMMON/SPCII/ OXY(2,80001),HPR(2,80001),GOA(2,80001),GOP(2,80001)
      COMMON/RXT/ EQ1(2,80001),RGA(2,80001),EQ2(2,80001),RHP(2,80001)
      COMMON/SPCIII/ ANM(2,80001),GLUA(2,80001),GLI(2,80001)
      COMMON/SPCIV/ HYD(2,80001),OHI(2,80001),CO2(2,80001),CBA(2,80001)
      COMMON/SPCV/ CBI(2,80001),ACE(2,800001)
      COMMON/VOL/ VDL(2,80001)
      COMMON/POR/ POR1,POR2,PORGLU,PARION,PARACE
      COMMON/BCI/ FLUX,FLUX2,FLUX3,FLUX4,FLUX5,AKO,BO,AKR,BR,AKH,BH
      COMMON/BCII/ AKA,BA
      COMMON/RTE/ ratef1,equilib1,ratef2,ratef3,equilib3,ratef4
      COMMON/RTD/ ratef5,equilib5,equilib6,equilib7,equilib8,equilib9
      COMMON/BUL/ CBULK(16),PARH2O2,PAR02,PARGLUCOSE,JCOUNT
      COMMON/EXTRA/ REF(16)
      CHARACTER REF*16


  102 FORMAT (/30H THE NEXT RUN DID NOT CONVERGE)
  103 FORMAT ('Error=',E16.6/(1X,'Species=',A6,2X,'C at Electrode=',
     1 E12.5,2X,'C at Bulk=',E12.5))
  300 FORMAT (18x,'Glucose'14x,'GOx',14x,'GA',14x,'GOx2',14x,'O2',14x,
     1     'H2O2',14x,'CX-GOx2',14x,'CX-GOx',14x,'EQ1',14x,'RGA',14x,
     1     'EQ2',14x,'RHP',14X,'VDL')
  301 FORMAT (5x,'J=' I5,  13E18.9)
  334 FORMAT (21(D25.15,5X))
  302 FORMAT ('Iteration='I4)

      OPEN(UNIT=13, FILE='cdhGLU_out.txt')
      CLOSE(UNIT=13, STATUS='DELETE')
      OPEN(UNIT=13, FILE='cdhGLU_out.txt')
```

```

      OPEN(UNIT=17, FILE='cdhGOX_out.txt')
      CLOSE(UNIT=17, STATUS='DELETE')
      OPEN(UNIT=17, FILE='cdhGOX_out.txt')

      OPEN(UNIT=19, FILE='cdhGLA_out.txt')
      CLOSE(UNIT=19, STATUS='DELETE')
      OPEN(UNIT=19, FILE='cdhGLA_out.txt')

      OPEN(UNIT=20, FILE='cdhGOR_out.txt')
      CLOSE(UNIT=20, STATUS='DELETE')
      OPEN(UNIT=20, FILE='cdhGOR_out.txt')

      OPEN(UNIT=26, FILE='cdhOXY_out.txt')
      CLOSE(UNIT=26, STATUS='DELETE')
      OPEN(UNIT=26, FILE='cdhOXY_out.txt')

      OPEN(UNIT=27, FILE='cdhHPR_out.txt')
      CLOSE(UNIT=27, STATUS='DELETE')
      OPEN(UNIT=27, FILE='cdhHPR_out.txt')

      OPEN(UNIT=28, FILE='cdhGOA_out.txt')
      CLOSE(UNIT=28, STATUS='DELETE')
      OPEN(UNIT=28, FILE='cdhGOA_out.txt')

      OPEN(UNIT=29, FILE='cdhGOP_out.txt')
      CLOSE(UNIT=29, STATUS='DELETE')
      OPEN(UNIT=29, FILE='cdhGOP_out.txt')

      OPEN(UNIT=30, FILE='cdhEQ1_out.txt')
      CLOSE(UNIT=30, STATUS='DELETE')
      OPEN(UNIT=30, FILE='cdhEQ1_out.txt')

      OPEN(UNIT=31, FILE='cdhRGA_out.txt')
      CLOSE(UNIT=31, STATUS='DELETE')
      OPEN(UNIT=31, FILE='cdhRGA_out.txt')

      OPEN(UNIT=32, FILE='cdhEQ2_out.txt')
      CLOSE(UNIT=32, STATUS='DELETE')
      OPEN(UNIT=32, FILE='cdhEQ2_out.txt')

      OPEN(UNIT=34, FILE='cdhRHP_out.txt')
      CLOSE(UNIT=34, STATUS='DELETE')
      OPEN(UNIT=34, FILE='cdhRHP_out.txt')

      OPEN(UNIT=38, FILE='cdhANM_out.txt')
      CLOSE(UNIT=38, STATUS='DELETE')
      OPEN(UNIT=38, FILE='cdhANM_out.txt')

      OPEN(UNIT=39, FILE='cdhGLUA_out.txt')
      CLOSE(UNIT=39, STATUS='DELETE')
      OPEN(UNIT=39, FILE='cdhGLUA_out.txt')

      OPEN(UNIT=40, FILE='cdhGLI_out.txt')
      CLOSE(UNIT=40, STATUS='DELETE')
      OPEN(UNIT=40, FILE='cdhGLI_out.txt')

      OPEN(UNIT=41, FILE='cdhHYD_out.txt')
```

```
      CLOSE(UNIT=41, STATUS='DELETE')
      OPEN(UNIT=41, FILE='cdhHYD_out.txt')

      OPEN(UNIT=42, FILE='cdhOHI_out.txt')
      CLOSE(UNIT=42, STATUS='DELETE')
      OPEN(UNIT=42, FILE='cdhOHI_out.txt')

      OPEN(UNIT=43, FILE='cdhCO2_out.txt')
      CLOSE(UNIT=43, STATUS='DELETE')
      OPEN(UNIT=43, FILE='cdhCO2_out.txt')

      OPEN(UNIT=44, FILE='cdhCBA_out.txt')
      CLOSE(UNIT=44, STATUS='DELETE')
      OPEN(UNIT=44, FILE='cdhCBA_out.txt')

      OPEN(UNIT=45, FILE='cdhCBI_out.txt')
      CLOSE(UNIT=45, STATUS='DELETE')
      OPEN(UNIT=45, FILE='cdhCBI_out.txt')

      OPEN(UNIT=53, FILE='cdhACE_out.txt')
      CLOSE(UNIT=53, STATUS='DELETE')
      OPEN(UNIT=53, FILE='cdhACE_out.txt')

      OPEN(UNIT=35, FILE='cdhVDL_out.txt')
      CLOSE(UNIT=35, STATUS='DELETE')
      OPEN(UNIT=35, FILE='cdhVDL_out.txt')

      OPEN(UNIT=36, FILE='cdhTIME_out.txt')
      CLOSE(UNIT=36, STATUS='DELETE')
      OPEN(UNIT=36, FILE='cdhTIME_out.txt')

      OPEN(12,FILE='cdhgox_G_out.txt')
      CLOSE(12, STATUS='DELETE')
      OPEN(12, FILE='cdhgox_G_out.txt')
      WRITE(12,300)

      open(14,file='cdhgox_inFastKineticsAcid.txt',status='old')
  106 FORMAT (I2/I7/I7/E15.4/E15.4/E15.4/E15.4/E15.4/E15.4/E15.4/E15.4
     1    /E15.4/E15.4/E15.4/E15.4/E15.4/E15.4/E15.4/E15.4/E15.4/E15.4)
       print *, 'does this work'
      read(14,*) N,NJ,IJ ,KJ,Y1,Y2,Y3,POR1,POR2,POR3,PARH2O2,PAR02,
     1      PARGLUCOSE,ratef1 ,equilib1 ,ratef2 ,ratef3 ,equilib3 ,ratef4 ,
     2       ratef5 ,equilib5 ,equilib6 ,equilib7 ,equilib8 ,equilib9 ,
     3      AKB,BB,AKO,BO,AKR,BR,AKH,BH,EBIG,MJ,Y4,AKA,BA,LJ ,Y5,PARION,
     4      PARACE

      N=N+1

      open(55,file='DiffBulk_in.txt',status='old')
      read(55,*) (DBULK(I),I=1,(N-6))

      open(47,file='DiffGox_in.txt',status='old')
      read(47,*) (DGOX(I),I=1,(N-6))

      open(48,file='DiffGLM_in.txt',status='old')
      read(48,*) (DGLM(I),I=1,(N-6))

      open(54,file='DiffIRM_in.txt',status='old')
```

```
      read(54,*) (DIRM(I),I=1,(N-6))

      open(49,file='CBulk_in.txt',status='old')
      read(49,*) (CBULK(I),I=1,(N-6))

      open(50,file='REF_in.txt',status='old')
      read(50,*) (REF(I),I=1,(N-6))




       print *, 'CBULK(1)=',CBULK(1)
      PRINT *, 'CBULK(13)=',CBULK(13)
       open(37,file='cdhgoxSS_out.txt',status='old')
       read(37,334) (GLU(1,J),GOX(1,J),GLA(1,J),GOR(1,J),OXY(1,J),
     1    HPR(1,J),GOA(1,J),GOP(1,J),GLUA(1,J),GLI(1,J),HYD(1,J),
     2    CO2(1,J),CBA(1,J),CBI(1,J),OHI(1,J),ACE(1,J),
     3    EQ1(1,J),RGA(1,J),EQ2(1,J),RHP(1,J),ANM(1,J),J=1,NJ)

       print *, GLU(1,NJ)
       print *, GOX(1,NJ)
       print *, GLA(1,NJ)
       print *, GOR(1,NJ)
       print *, OXY(1,NJ)
       print *, HPR(1,NJ)

      open(51,file='potTrans_in.txt',status='old')
      read(51,*) VAP
      PRINT*, 'Vapplied = ',VAP

      open(52,file='pot_in.txt',status='old')
      read(52,*) VDL(1,1)

      open(16,file='O2_in.txt',status='old')
  305 FORMAT (E25.15E3)
      read(16,305) CBULK(5)

      open(46,file='pH_in.txt',status='old')
      read(46,*) CBULK(11)


      POR1=1.
      POR2=1.
      PORGLU=1.
      CBULK(1)=equilib5/(equilib5+1.)*CBULK(1)
      CBULK(9)=CBULK(1)/equilib5

      CBULK(11)=10**(-CBULK(11))/1000.
      CBULK(15)=equilib9/CBULK(11)

C     Constants
      F=96487.

c     THIS IS SPACING FOR OUTER LAYER, BCNJ
      HHHHH=Y5/(NJ-LJ)
      PRINT *, 'HHHHH=', HHHHH
      PRINT *, 'Y3=', Y5
      PRINT *, 'NJ-IJ=', NJ-LJ
```

```fortran

c     THIS IS SPACING FOR OUTER LAYER, GLM
      H=Y3/(LJ-IJ)
      PRINT *, 'H=', H
      PRINT *, 'Y3=', Y3
      PRINT *, 'NJ-IJ=', LJ-IJ

c     THIS IS SPACING FOR INNER LAYER
      HH=(Y2)/(IJ-KJ)
      PRINT *, 'HH=', HH
      PRINT *, 'Y2=', Y2
      PRINT *, 'IJ-KJ=', IJ-KJ

c     THIS IS SPACING FOR REACTION LAYER
      HHH=(Y1)/(KJ-MJ)
      PRINT *, 'Y1=', Y1
      PRINT *, 'KJ-1=', KJ-MJ
      PRINT *, 'HHH=', HHH

c     THIS IS SPACING FOR INSULATION LAYER
      HHHH=(Y4)/(MJ-1.)
      PRINT *, 'Y1=', Y4
      PRINT *, 'KJ-1=', MJ-1.
      PRINT *, 'HHHH=', HHHH


      OPEN(15,FILE='cdhgox_ssvalues_out.txt')
      CLOSE(15, STATUS='DELETE')
      OPEN(15, FILE='cdhgox_ssvalues_out.txt')
  337 FORMAT (I2/I7/I7/I7/E25.15/E25.15/E25.15/E15.8/E15.8/E15.4/E15.4
     1     /E15.4/E15.4/E25.15)
      WRITE (15,337) N,NJ,IJ ,KJ,H,HH,HHH,DIFF(6),AKB,BB,VAP,POR1

C       TIME DEPENDENCE PARAMTERS (TIME STEP & # STEPS
      NTIME = 3001
      DT = 1.E-8
      TT=0.0

C       DBL CAPACITANCE F/cm^2 & ELECTROLYTE RESISTANCE ohm-cm^2
      CDL=(6E-6/(3.429E-3))
      RE = (5.E4)*(3.429E-3)

C     Create flux of the reacting species constants
      FLUX=AKB/F/2.
      FLUX2=AKO/F/2.
      FLUX3=AKR/F/2.
      FLUX4=AKH/F/2.
      FLUX5=AKA/F/2.
      PRINT *, 'FLUX=', FLUX
      PRINT *, 'FLUX2=', FLUX2
      PRINT *, 'FLUX3=', FLUX3
      PRINT *, 'VAP=', VAP
      PRINT *, 'RE=', RE
      PRINT *, 'CDL', CDL
      PRINT *, ' '

c     THIS IS THE MAIN PART OF THE PROGRAM
      GLU(1,NJ)=CBULK(1)
```

```fortran
      GLUA(1,NJ)=CBULK(9)
      OXY(1,NJ)=CBULK(5)
      ACE(1,NJ)=CBULK(16)

      DO 111 LL=2,NTIME
      IF (MOD(LL,1000).EQ.0) PRINT *, 'N=', LL
      IF (MOD(LL,1000).EQ.0) PRINT *, 'VAP=', VAP
          IF (LL.LT.1000) DT=1.E-3
          IF (LL.GE.1000 .AND. LL.LT.1600) DT=5.E-3
          IF (LL.GE.1600 .AND. LL.LT.1800) DT=5.E-3
          IF (LL.GE.1800 .AND. LL.LT.2000) DT=5.E-3
          IF (LL.GE.2000 .AND. LL.LT.2200) DT=5.E-3
          IF (LL.GE.2200 .AND. LL.LT.2400) DT=5.E-2
          IF (LL.GE.2400 .AND. LL.LT.3002) DT=2.E-1

C     RECORD CURRENT TIME
      TT=TT+DT

      DO 113 J=1,NJ
      IF (LL.GT.2) GLU(1,J)=GLU(2,J)
      IF (LL.GT.2) GOX(1,J)=GOX(2,J)
      IF (LL.GT.2) GLA(1,J)=GLA(2,J)
      IF (LL.GT.2) GOR(1,J)=GOR(2,J)
      IF (LL.GT.2) OXY(1,J)=OXY(2,J)
      IF (LL.GT.2) HPR(1,J)=HPR(2,J)
      IF (LL.GT.2) GOA(1,J)=GOA(2,J)
      IF (LL.GT.2) GOP(1,J)=GOP(2,J)
      IF (LL.GT.2) EQ1(1,J)=EQ1(2,J)
      IF (LL.GT.2) RGA(1,J)=RGA(2,J)
      IF (LL.GT.2) EQ2(1,J)=EQ2(2,J)
      IF (LL.GT.2) RHP(1,J)=RHP(2,J)
      IF (LL.GT.2) ANM(1,J)=ANM(2,J)
      IF (LL.GT.2) GLUA(1,J)=GLUA(2,J)
      IF (LL.GT.2) GLI(1,J)=GLI(2,J)
      IF (LL.GT.2) HYD(1,J)=HYD(2,J)
      IF (LL.GT.2) OHI(1,J)=OHI(2,J)
      IF (LL.GT.2) CO2(1,J)=CO2(2,J)
      IF (LL.GT.2) CBA(1,J)=CBA(2,J)
      IF (LL.GT.2) CBI(1,J)=CBI(2,J)
      IF (LL.GT.2) ACE(1,J)=ACE(2,J)
      IF (LL.GT.2) VDL(1,J)=VDL(2,J)
      GLU(2,J)=GLU(1,J)
      GOX(2,J)=GOX(1,J)
      GLA(2,J)=GLA(1,J)
      GOR(2,J)=GOR(1,J)
      OXY(2,J)=OXY(1,J)
      HPR(2,J)=HPR(1,J)
      GOA(2,J)=GOA(1,J)
      GOP(2,J)=GOP(1,J)
      EQ1(2,J)=EQ1(1,J)
      RGA(2,J)=RGA(1,J)
      EQ2(2,J)=EQ2(1,J)
      RHP(2,J)=RHP(1,J)
      ANM(2,J)=ANM(1,J)
      GLUA(2,J)=GLUA(1,J)
      GLI(2,J)=GLI(1,J)
      HYD(2,J)=HYD(1,J)
      OHI(2,J)=OHI(1,J)
```

```
      CO2(2,J)=CO2(1,J)
      CBA(2,J)=CBA(1,J)
      CBI(2,J)=CBI(1,J)
      ACE(2,J)=ACE(1,J)
  113 VDL(2,J)=VDL(1,J)

      JCOUNT=0
      TOL=1.E-10*N*NJ/1.E6
C          PRINT *, 'TOL=', TOL

   22 JCOUNT=JCOUNT+1
      AMP=0.0
      J=0
      DO 23  I=1,N
      DO 23 K=1,N
      Y(I,K)=0.0
   23 X(I,K)=0.0
   24 J=J+1
      DO 25   I=1,N
      G(I)=0.0
      DO 25 K=1,N
      A(I,K)=0.0
      B(I,K)=0.0
   25 D(I,K)=0.0


      IF (J.EQ.1) CALL BC1(J)
      IF (J.GT.1  .AND.  J.LT.MJ)   CALL INSULATION(J)
      IF (J.EQ.MJ) CALL COUPLERINS(J)
      IF (J.GT.MJ  .AND.  J.LT.KJ) CALL REACTION(J)
      IF (J.EQ.KJ) CALL COUPLER1(J)
      IF (J.GT.KJ  .AND.  J.LT.IJ) CALL INNER(J)
      IF (J.EQ.IJ) CALL COUPLER2(J)
      IF (J.GT.IJ  .AND.  J.LT.(LJ-1)) CALL OUTER(J)
      IF (J.EQ.(LJ-1)) CALL FORCEC(J)
      IF (J.EQ.LJ) CALL COUPLER3(J)
      IF (J.GT.LJ  .AND.  J.LT.NJ) CALL BULKDIFF(J)
      IF (J.EQ.NJ)   CALL BCNJ(J)
      CALL BAND(J)

      AMP=AMP+DABS(G(1))+DABS(G(2))+DABS(G(3))+DABS(G(4))+DABS(G(5))
     1     +DABS(G(6))+DABS(G(7))+DABS(G(8))+DABS(G(9))+DABS(G(10))
     2     +DABS(G(11))+DABS(G(12))+DABS(G(13))+DABS(G(14))+DABS(G(15))
     3     +DABS(G(16))+DABS(G(17))+DABS(G(18))+DABS(G(19))+DABS(G(20))
     4     +DABS(G(21))+DABS(G(22))

      IF (J.LT.NJ)   GO TO 24

      IF (MOD(LL,100).EQ.0) PRINT *, 'ERROR=', AMP

      DO 16 K=1,NJ
      IF (C(1,K).LT.-0.999*GLU(2,K)) C(1,K)=-0.999*GLU(2,K)
      IF (C(1,K).GT.  999.*GLU(2,K)) C(1,K)=  999.*GLU(2,K)
      IF (C(2,K).LT.-0.999*GOX(2,K)) C(2,K)=-0.999*GOX(2,K)
      IF (C(2,K).GT.  999.*GOX(2,K)) C(2,K)=  999.*GOX(2,K)
      IF (C(3,K).LT.-0.999*GLA(2,K)) C(3,K)=-0.999*GLA(2,K)
      IF (C(3,K).GT.  999.*GLA(2,K)) C(3,K)=  999.*GLA(2,K)
      IF (C(4,K).LT.-0.999*GOR(2,K)) C(4,K)=-0.999*GOR(2,K)
```

```
       IF (C(4,K).GT. 999.*GOR(2,K)) C(4,K)= 999.*GOR(2,K)
       IF (C(5,K).LT.-0.999*OXY(2,K)) C(5,K)=-0.999*OXY(2,K)
       IF (C(5,K).GT. 999.*OXY(2,K)) C(5,K)= 999.*OXY(2,K)
       IF (C(6,K).LT.-0.999*HPR(2,K)) C(6,K)=-0.999*HPR(2,K)
       IF (C(6,K).GT. 999.*HPR(2,K)) C(6,K)= 999.*HPR(2,K)
       IF (C(7,K).LT.-0.999*GOA(2,K)) C(7,K)=-0.999*GOA(2,K)
       IF (C(7,K).GT. 999.*GOA(2,K)) C(7,K)= 999.*GOA(2,K)
       IF (C(8,K).LT.-0.999*GOP(2,K)) C(8,K)=-0.999*GOP(2,K)
       IF (C(8,K).GT. 999.*GOP(2,K)) C(8,K)= 999.*GOP(2,K)
       IF (C(14,K).LT.-0.999*GLUA(2,K)) C(14,K)=-0.999*GLUA(2,K)
       IF (C(14,K).GT. 999.*GLUA(2,K)) C(14,K)= 999.*GLUA(2,K)
       IF (C(15,K).LT.-0.999*GLI(2,K)) C(15,K)=-0.999*GLI(2,K)
       IF (C(15,K).GT. 999.*GLI(2,K)) C(15,K)= 999.*GLI(2,K)
       IF (C(16,K).LT.-0.999*HYD(2,K)) C(16,K)=-0.999*HYD(2,K)
       IF (C(16,K).GT. 999.*HYD(2,K)) C(16,K)= 999.*HYD(2,K)
       IF (C(17,K).LT.-0.999*OHI(2,K)) C(17,K)=-0.999*OHI(2,K)
       IF (C(17,K).GT. 999.*OHI(2,K)) C(17,K)= 999.*OHI(2,K)
       IF (C(18,K).LT.-0.999*CO2(2,K)) C(18,K)=-0.999*CO2(2,K)
       IF (C(18,K).GT. 999.*CO2(2,K)) C(18,K)= 999.*CO2(2,K)
       IF (C(19,K).LT.-0.999*CBA(2,K)) C(19,K)=-0.999*CBA(2,K)
       IF (C(19,K).GT. 999.*CBA(2,K)) C(19,K)= 999.*CBA(2,K)
       IF (C(20,K).LT.-0.999*CBI(2,K)) C(20,K)=-0.999*CBI(2,K)
       IF (C(20,K).GT. 999.*CBI(2,K)) C(20,K)= 999.*CBI(2,K)
       IF (C(21,K).LT.-0.999*ACE(2,K)) C(21,K)=-0.999*ACE(2,K)
       IF (C(21,K).GT. 999.*ACE(2,K)) C(21,K)= 999.*ACE(2,K)
      GLU(2,K)=GLU(2,K)+C(1,K)
      GOX(2,K)=GOX(2,K)+C(2,K)
      GLA(2,K)=GLA(2,K)+C(3,K)
      GOR(2,K)=GOR(2,K)+C(4,K)
      OXY(2,K)=OXY(2,K)+C(5,K)
      HPR(2,K)=HPR(2,K)+C(6,K)
      GOA(2,K)=GOA(2,K)+C(7,K)
      GOP(2,K)=GOP(2,K)+C(8,K)
      EQ1(2,K)=EQ1(2,K)+C(9,K)
      RGA(2,K)=RGA(2,K)+C(10,K)
      EQ2(2,K)=EQ2(2,K)+C(11,K)
      RHP(2,K)=RHP(2,K)+C(12,K)
      ANM(2,K)=ANM(2,K)+C(13,K)
      GLUA(2,K)=GLUA(2,K)+C(14,K)
      GLI(2,K)=GLI(2,K)+C(15,K)
      HYD(2,K)=HYD(2,K)+C(16,K)
      OHI(2,K)=OHI(2,K)+C(17,K)
      CO2(2,K)=CO2(2,K)+C(18,K)
      CBA(2,K)=CBA(2,K)+C(19,K)
      CBI(2,K)=CBI(2,K)+C(20,K)
      ACE(2,K)=ACE(2,K)+C(21,K)
      VDL(2,K)=VDL(2,K)+C(22,K)

   16 CONTINUE


      WRITE(12,302) (JCOUNT)

c      If the error is less then the tolerance, finish program
       IF (DABS(AMP).LT.DABS(TOL)) GO TO  15

c      If the error is greater then tolerance, do another iteration
   33  IF (JCOUNT.LE.100) GO TO 22
```

```
      PRINT 102

C     15    PRINT 103, AMP,(REF(I),CONC(I,1),CONC(I,NJ),I=1,N-4)
   15 CONTINUE
C           PRINT *,'JCOUNT=',JCOUNT


      IF (MOD(LL,2).EQ.0) WRITE(13,305)((GLU(2,J)), J=1,NJ)
      IF (MOD(LL,2).EQ.0) WRITE(17,305)((GOX(2,J)), J=1,NJ)
      IF (MOD(LL,2).EQ.0) WRITE(19,305)((GLA(2,J)), J=1,NJ)
      IF (MOD(LL,2).EQ.0) WRITE(20,305)((GOR(2,J)), J=1,NJ)
      IF (MOD(LL,2).EQ.0) WRITE(26,305)((OXY(2,J)), J=1,NJ)
      IF (MOD(LL,2).EQ.0) WRITE(27,305)((HPR(2,J)), J=1,NJ)
      IF (MOD(LL,2).EQ.0) WRITE(28,305)((GOA(2,J)), J=1,NJ)
      IF (MOD(LL,2).EQ.0) WRITE(29,305)((GOP(2,J)), J=1,NJ)
      IF (MOD(LL,2).EQ.0) WRITE(30,305)((EQ1(2,J)), J=1,NJ)
      IF (MOD(LL,2).EQ.0) WRITE(31,305)((RGA(2,J)), J=1,NJ)
      IF (MOD(LL,2).EQ.0) WRITE(32,305)((EQ2(2,J)), J=1,NJ)
      IF (MOD(LL,2).EQ.0) WRITE(34,305)((RHP(2,J)), J=1,NJ)
      IF (MOD(LL,2).EQ.0) WRITE(38,305)((ANM(2,J)), J=1,NJ)
      IF (MOD(LL,2).EQ.0) WRITE(39,305)((GLUA(2,J)), J=1,NJ)
      IF (MOD(LL,2).EQ.0) WRITE(40,305)((GLI(2,J)), J=1,NJ)
      IF (MOD(LL,2).EQ.0) WRITE(41,305)((HYD(2,J)), J=1,NJ)
      IF (MOD(LL,2).EQ.0) WRITE(42,305)((OHI(2,J)), J=1,NJ)
      IF (MOD(LL,2).EQ.0) WRITE(43,305)((CO2(2,J)), J=1,NJ)
      IF (MOD(LL,2).EQ.0) WRITE(44,305)((CBA(2,J)), J=1,NJ)
      IF (MOD(LL,2).EQ.0) WRITE(45,305)((CBI(2,J)), J=1,NJ)
      IF (MOD(LL,2).EQ.0) WRITE(53,305)((ACE(2,J)), J=1,NJ)
      IF (MOD(LL,2).EQ.0) WRITE(35,305)(VDL(2,1))
      IF (MOD(LL,2).EQ.0) WRITE(36,305)(TT)

  111 CONTINUE
      END PROGRAM FullTransCGMvA

      SUBROUTINE BC1(J)
      IMPLICIT DOUBLE PRECISION (A-H, O-Z)
      COMMON/BAB/ A(22,22),B(22,22),C(22,80001),D(22,45),G(22),X(22,22)
     1    ,Y(22,22)
      COMMON/NSN/ N, NJ
      COMMON/GLC/ NTIME,LL
      COMMON/VAR/ DIFF(16),H,EBIG,HH,IJ,KJ,TT,VAP,HHH,DT,RE,AKB,BB,CDL
      COMMON/VARR/ HHHH,HHHHH,MJ,LJ
      COMMON/DIN/ DGOX(16),DGLM(16),DIRM(16),DBULK(16)
      COMMON/SPCI/ GLU(2,80001),GOX(2,80001),GLA(2,80001),GOR(2,80001)
      COMMON/SPCII/ OXY(2,80001),HPR(2,80001),GOA(2,80001),GOP(2,80001)
      COMMON/RXT/ EQ1(2,80001),RGA(2,80001),EQ2(2,80001),RHP(2,80001)
      COMMON/SPCIII/ ANM(2,80001),GLUA(2,80001),GLI(2,80001)
      COMMON/SPCIV/ HYD(2,80001),OHI(2,80001),CO2(2,80001),CBA(2,80001)
      COMMON/SPCV/ CBI(2,80001),ACE(2,800001)
      COMMON/VOL/ VDL(2,80001)
      COMMON/POR/ POR1,POR2,PORGLU,PARION,PARACE
      COMMON/BCI/ FLUX,FLUX2,FLUX3,FLUX4,FLUX5,AKO,BO,AKR,BR,AKH,BH
      COMMON/BCII/ AKA,BA
      COMMON/RTE/ ratef1,equilib1,ratef2,ratef3,equilib3,ratef4
      COMMON/RTD/ ratef5,equilib5,equilib6,equilib7,equilib8,equilib9
      COMMON/BUL/ CBULK(16),PARH2O2,PAR02,PARGLUCOSE,JCOUNT

  301 FORMAT (5x,'J=' I5,  22E18.9)
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C     For Glucose, being consumed only
      G(1)=DIRM(1)
     1  *(GLU(2,J+1)-GLU(2,J)+GLU(1,J+1)-GLU(1,J))/HHHH**2.
     3  +(3.*(ANM(2,J)+ANM(1,J))+(ANM(2,J+1)+ANM(1,J+1)))/8.
     4  -(3.*(GLU(2,J)-GLU(1,J))+(GLU(2,J+1)-GLU(1,J+1)))/(4.*DT)

      B(1,1)=DIRM(1)/HHHH**2.+3./(4.*DT)
      D(1,1)=-DIRM(1)/HHHH**2.+1./(4.*DT)
      B(1,13)=-3./8.
      D(1,13)=-1./8.

      BIG=ABS(DIRM(1)*GLU(2,J+1)/HHHH**2.)
C      PRINT *, ”BIG=”, BIG
      BIG2=ABS(DIRM(1)*GLU(2,J)/HHHH**2.)
C      PRINT *, ”BIG2=”, BIG2
      IF (BIG2.GT.BIG) BIG=BIG2
      BIG3=ABS(DIRM(1)*GLU(1,J+1)/HHHH**2.)
      IF (BIG3.GT.BIG) BIG=BIG3
      BIG4=ABS(DIRM(1)*GLU(1,J)/HHHH**2.)
      IF (BIG4.GT.BIG) BIG=BIG4
      BIG13=ABS(3.*GLU(2,J)/(4.*DT))
      IF (BIG13.GT.BIG) BIG=BIG13
      BIG14=ABS(3.*GLU(1,J)/(4.*DT))
      IF (BIG14.GT.BIG) BIG=BIG14
      BIG15=ABS(GLU(2,J+1)/(4.*DT))
      IF (BIG15.GT.BIG) BIG=BIG15
      BIG16=ABS(GLU(1,J+1)/(4.*DT))
      IF (BIG16.GT.BIG) BIG=BIG16

C      PRINT *, ”G(1)=”, ABS(G(1))
      IF (ABS(G(1)).LT.BIG*EBIG) G(1)=0

C     For GOx, enzyme
      G(2)=(GOX(2,J)+GOX(1,J))/2.
      B(2,2)=-1./2.


C     For Gluconic Acid, being produced only
      G(3)=DIRM(3)
     1  *(GLA(2,J+1)-GLA(2,J)+GLA(1,J+1)-GLA(1,J))/HHHH**2.
     2  +DIRM(10)*(GLI(2,J+1)-GLI(2,J)+GLI(1,J+1)-GLI(1,J))/HHHH**2.
     4  -(3.*(GLA(2,J)-GLA(1,J))+(GLA(2,J+1)-GLA(1,J+1)))/(4.*DT)
     5  -(3.*(GLI(2,J)-GLI(1,J))+(GLI(2,J+1)-GLI(1,J+1)))/(4.*DT)

      B(3,3)=DIRM(3)/HHHH**2.+3./(4.*DT)
      D(3,3)=-DIRM(3)/HHHH**2.+1./(4.*DT)
      B(3,15)=DIRM(10)/HHHH**2.+3./(4.*DT)
      D(3,15)=-DIRM(10)/HHHH**2.+1./(4.*DT)

      BIG=ABS(DIRM(3)*GLA(2,J+1)/HHHH**2.)
      BIG2=ABS(DIRM(3)*GLA(2,J)/HHHH**2.)
      IF (BIG2.GT.BIG) BIG=BIG2
      BIG3=ABS(DIRM(3)*GLA(1,J+1)/HHHH**2.)
      IF (BIG3.GT.BIG) BIG=BIG3
      BIG4=ABS(DIRM(3)*GLA(1,J)/HHHH**2.)
      IF (BIG4.GT.BIG) BIG=BIG4
      BIG5=ABS(DIRM(10)*GLI(2,J+1)/HHHH**2.)
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      IF (BIG5.GT.BIG) BIG=BIG5
      BIG6=ABS(DIRM(10)*GLI(2,J)/HHHH**2.)
      IF (BIG6.GT.BIG) BIG=BIG6
      BIG7=ABS(DIRM(10)*GLI(1,J+1)/HHHH**2.)
      IF (BIG7.GT.BIG) BIG=BIG7
      BIG8=ABS(DIRM(10)*GLI(1,J)/HHHH**2.)
      IF (BIG8.GT.BIG) BIG=BIG8
      BIG13=ABS(3.*GLA(2,J)/(4.*DT))
      IF (BIG13.GT.BIG) BIG=BIG13
      BIG14=ABS(3.*GLA(1,J)/(4.*DT))
      IF (BIG14.GT.BIG) BIG=BIG14
      BIG15=ABS(GLA(2,J+1)/(4.*DT))
      IF (BIG15.GT.BIG) BIG=BIG15
      BIG16=ABS(GLA(1,J+1)/(4.*DT))
      IF (BIG16.GT.BIG) BIG=BIG16
      BIG17=ABS(3.*GLI(2,J)/(4.*DT))
      IF (BIG17.GT.BIG) BIG=BIG17
      BIG18=ABS(3.*GLI(1,J)/(4.*DT))
      IF (BIG18.GT.BIG) BIG=BIG18
      BIG19=ABS(GLI(2,J+1)/(4.*DT))
      IF (BIG19.GT.BIG) BIG=BIG19
      BIG20=ABS(GLI(1,J+1)/(4.*DT))
      IF (BIG20.GT.BIG) BIG=BIG20
      IF (ABS(G(3)).LT.BIG*EBIG) G(3)=0

C     For GOx2, enzyme
      G(4)=(GOR(2,J)+GOR(1,J))/2.
      B(4,4)=-1./2.


C     For O2, being consumed only. *NOTES G 5 DIFF 5 CONC 5 (FLUX DEPENDS ON CONC 6) RXN(3)

      G(5)=DIRM(5)
     1 *(OXY(2,J+1)-OXY(2,J)+OXY(1,J+1)-OXY(1,J))/HHHH**2.
     2 +FLUX*EXP(BB*(VDL(2,J)+VDL(1,J))/2.)*(HPR(2,J)+HPR(1,J))/(HHHH)
     3 -FLUX2*EXP(-BO*(VDL(2,J)+VDL(1,J))/2.)*(OXY(2,J)+OXY(1,J))
     4 *((HYD(2,J)+HYD(1,J))/2.)**2./(HHHH)
     6 -(3.*(OXY(2,J)-OXY(1,J))+(OXY(2,J+1)-OXY(1,J+1)))/(4.*DT)

      B(5,5)=DIRM(5)/HHHH**2.+3./(4.*DT)
     1 +FLUX2*EXP(-BO*(VDL(2,J)+VDL(1,J))/2.)
     2 *((HYD(2,J)+HYD(1,J))/2.)**2./HHHH
      D(5,5)=-DIRM(5)/HHHH**2.+1./(4.*DT)
      B(5,6)=-FLUX*EXP(BB*(VDL(2,J)+VDL(1,J))/2.)/HHHH
      B(5,16)=+FLUX2*EXP(-BO*(VDL(2,J)+VDL(1,J))/2.)*(OXY(2,J)+OXY(1,J))
     1 *(HYD(2,J)+HYD(1,J))/2./HHHH
      B(5,22)=-FLUX*EXP(BB*(VDL(2,J)+VDL(1,J))/2.)*(HPR(2,J)+HPR(1,J))
     1 *(BB/2.)/HHHH-FLUX2*EXP(-BO*(VDL(2,J)+VDL(1,J))/2.)*
     2 (OXY(2,J)+OXY(1,J))*((HYD(2,J)+HYD(1,J))/2.)**2.*(BO/2.)/HHHH

      BIG=ABS(DIRM(5)*OXY(2,J+1)/HHHH**2.)
      BIG2=ABS(DIRM(5)*OXY(2,J)/HHHH**2.)
      IF (BIG2.GT.BIG) BIG=BIG2
      BIG3=ABS(DIRM(5)*OXY(1,J+1)/HHHH**2.)
      IF (BIG3.GT.BIG) BIG=BIG3
      BIG4=ABS(DIRM(5)*OXY(1,J)/HHHH**2.)
      IF (BIG4.GT.BIG) BIG=BIG4
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C          BIG5=ABS(FLUX*EXP(BB*(VDL(2,J)+VDL(1,J))/2.)*(HPR(2,J))/(HHHH))
C          IF (BIG5.GT.BIG) BIG=BIG5
C          BIG6=ABS(FLUX*EXP(BB*(VDL(2,J)+VDL(1,J))/2.)*(HPR(1,J))/(HHHH))
C          IF (BIG6.GT.BIG) BIG=BIG6
        BIG11=ABS(3.*OXY(2,J)/(4.*DT))
        IF (BIG11.GT.BIG) BIG=BIG11
        BIG12=ABS(3.*OXY(1,J)/(4.*DT))
        IF (BIG12.GT.BIG) BIG=BIG12
        BIG13=ABS(OXY(2,J+1)/(4.*DT))
        IF (BIG13.GT.BIG) BIG=BIG13
        BIG14=ABS(OXY(1,J+1)/(4.*DT))
        IF (BIG14.GT.BIG) BIG=BIG14
C          BIG15=ABS(FLUX2*EXP(-BO*(VDL(2,J)+VDL(1,J))/2.)*(OXY(2,J))/(HHHH))
C          IF (BIG15.GT.BIG) BIG=BIG15
C          BIG16=ABS(FLUX2*EXP(-BO*(VDL(2,J)+VDL(1,J))/2.)*(OXY(1,J))/(HHHH))
C          IF (BIG16.GT.BIG) BIG=BIG16
        IF (ABS(G(5)).LT.BIG*EBIG) G(5)=0

C       For H2O2, reacting species *NOTES G 6 DIFF 6 CONC 6 (INCLUDING IN FLUX) RXN(4
        G(6)=DIRM(6)
       1 *(HPR(2,J+1)-HPR(2,J)+HPR(1,J+1)-HPR(1,J))/HHHH**2.
       2 -FLUX*EXP(BB*(VDL(2,J)+VDL(1,J))/2.)*(HPR(2,J)+HPR(1,J))/(HHHH)
       3 +FLUX2*EXP(-BO*(VDL(2,J)+VDL(1,J))/2.)*(OXY(2,J)+OXY(1,J))
       4 *((HYD(2,J)+HYD(1,J))/2.)**2./(HHHH)
       5 -FLUX3*EXP(-BR*(VDL(2,J)+VDL(1,J))/2.)*(HPR(2,J)+HPR(1,J))
       6 *((HYD(2,J)+HYD(1,J))/2.)**2./(HHHH)
       8  -(3.*(HPR(2,J)-HPR(1,J))+(HPR(2,J+1)-HPR(1,J+1)))/(4.*DT)

        B(6,6)=DIRM(6)/HHHH**2.+FLUX*EXP(BB*(VDL(2,J)+VDL(1,J))/2.)
       1 /HHHH+FLUX3*EXP(-BR*(VDL(2,J)+VDL(1,J))/2.)
       2 *((HYD(2,J)+HYD(1,J))/2.)**2./HHHH+3./(4.*DT)
        D(6,6)=-DIRM(6)/HHHH**2.+1./(4.*DT)
        B(6,5)=-FLUX2*EXP(-BO*(VDL(2,J)+VDL(1,J))/2.)
       1 *((HYD(2,J)+HYD(1,J))/2.)**2./HHHH
        B(6,16)=-FLUX2*EXP(-BO*(VDL(2,J)+VDL(1,J))/2.)*(OXY(2,J)+OXY(1,J))
       1 *((HYD(2,J)+HYD(1,J))/2.)/(HHHH)
       2 +FLUX3*EXP(-BR*(VDL(2,J)+VDL(1,J))/2.)*(HPR(2,J)+HPR(1,J))
       3 *((HYD(2,J)+HYD(1,J))/2.)/(HHHH)
        B(6,22)=FLUX*EXP(BB*(VDL(2,J)+VDL(1,J))/2.)*(HPR(2,J)+HPR(1,J))
       1 *(BB/2.)/HHHH+FLUX2*EXP(-BO*(VDL(2,J)+VDL(1,J))/2.)*
       2 (OXY(2,J)+OXY(1,J))*((HYD(2,J)+HYD(1,J))/2.)**2.*(BO/2)/HHHH
       3 -FLUX3*EXP(-BR*(VDL(2,J)+VDL(1,J))/2.)*(HPR(2,J)+HPR(1,J))
       4 *((HYD(2,J)+HYD(1,J))/2.)**2.*(BR/2)/HHHH

        BIG=ABS(DIRM(6)*HPR(2,J+1)/HHHH**2.)
        BIG2=ABS(DIRM(6)*HPR(2,J)/HHHH**2.)
        IF (BIG2.GT.BIG) BIG=BIG2
        BIG3=ABS(DIRM(6)*HPR(1,J+1)/HHHH**2.)
        IF (BIG3.GT.BIG) BIG=BIG3
        BIG4=ABS(DIRM(6)*HPR(1,J)/HHHH**2.)
        IF (BIG4.GT.BIG) BIG=BIG4
        BIG11=ABS(3.*HPR(2,J)/(4.*DT))
        IF (BIG11.GT.BIG) BIG=BIG11
        BIG12=ABS(3.*HPR(1,J)/(4.*DT))
        IF (BIG12.GT.BIG) BIG=BIG12
        BIG13=ABS(HPR(2,J+1)/(4.*DT))
        IF (BIG13.GT.BIG) BIG=BIG13
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       BIG14=ABS(HPR(1,J+1)/(4.*DT))
       IF (BIG14.GT.BIG) BIG=BIG14
       IF (ABS(G(6)).LT.BIG*EBIG) G(6)=0

C      For CX-GOx2, enzyme complex
      G(7)=(GOA(2,J)+GOA(1,J))/2.
      B(7,7)=-1./2.

C      For CX-GOx, enzyme complex
      G(8)=(GOP(2,J)+GOP(1,J))/2.
      B(8,8)=-1./2.

C      For Reaction 1 Enzymatic Catalysis
      G(9)=(EQ1(2,J)+EQ1(1,J))/2.
      B(9,9)=-1./2.


C      For Reaction 2
      G(10)=(RGA(2,J)+RGA(1,J))/2.
      B(10,10)=-1./2.

C      For Reaction 3 Meditation/regeneration
      G(11)=(EQ2(2,J)+EQ2(1,J))/2.
      B(11,11)=-1./2.

C      For Reaction 4
      G(12)=(RHP(2,J)+RHP(1,J))/2.
      B(12,12)=-1./2.

C     REACTION5
  218 G(13)=-(ANM(2,J)+ANM(1,J))/2.+ratef5*((GLUA(2,J)+GLUA(1,J))/2.
     1   -(GLU(2,J)+GLU(1,J))/2./equilib5)
      B(13,1)=ratef5/2./equilib5
      B(13,14)=-ratef5/2.
      B(13,13)=+1./2.

      BIG=ABS(ANM(2,J)/2.)
      BIG2=ABS(ANM(1,J)/2.)
      IF (BIG2.GT.BIG) BIG=BIG2
      BIG3=ABS(ratef5*GLUA(2,J)/2.)
      IF (BIG3.GT.BIG) BIG=BIG3
      BIG4=ABS(ratef5*GLUA(1,J)/2.)
      IF (BIG4.GT.BIG) BIG=BIG4
      BIG5=ABS(ratef5*GLU(2,J)/2./equilib5)
      IF (BIG5.GT.BIG) BIG=BIG5
      BIG6=ABS(ratef5*GLU(1,J)/2./equilib5)
      IF (BIG6.GT.BIG) BIG=BIG6
      IF (ABS(G(13)).LT.BIG*EBIG) G(13)=0
C For alpha glucose, being consumed only

      G(14)=DIRM(9)*(GLUA(2,J+1)-GLUA(2,J)+GLUA(1,J+1)-GLUA(1,J))
     1 /HHHH**2.-(3.*(ANM(2,J)+ANM(1,J))+(ANM(2,J+1)+ANM(1,J+1)))/8.
     2  -(3.*(GLUA(2,J)-GLUA(1,J))+(GLUA(2,J+1)-GLUA(1,J+1)))/(4.*DT)

      B(14,14)=DIRM(9)/HHHH**2.+3./(4.*DT)
      D(14,14)=-DIRM(9)/HHHH**2.+1./(4.*DT)
      B(14,13)=3./8.
      D(14,13)=1./8.
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      BIG=ABS(DIRM(9)*GLUA(2,J+1)/HHHH**2.)
      BIG2=ABS(DIRM(9)*GLUA(2,J)/HHHH**2.)
      IF (BIG2.GT.BIG) BIG=BIG2
      BIG3=ABS(DIRM(9)*GLUA(1,J+1)/HHHH**2.)
      IF (BIG3.GT.BIG) BIG=BIG3
      BIG4=ABS(DIRM(9)*GLUA(1,J)/HHHH**2.)
      IF (BIG4.GT.BIG) BIG=BIG4
      BIG5=ABS(3.*ANM(2,J)/8.)
      IF (BIG5.GT.BIG) BIG=BIG5
      BIG6=ABS(3.*ANM(1,J)/8.)
      IF (BIG6.GT.BIG) BIG=BIG6
      BIG7=ABS(ANM(2,J+1)/8.)
      IF (BIG7.GT.BIG) BIG=BIG7
      BIG8=ABS(ANM(1,J+1)/8.)
      IF (BIG8.GT.BIG) BIG=BIG8
      BIG9=ABS(3.*GLUA(2,J)/(4.*DT))
      IF (BIG9.GT.BIG) BIG=BIG9
      BIG10=ABS(3.*GLUA(1,J)/(4.*DT))
      IF (BIG10.GT.BIG) BIG=BIG10
      BIG11=ABS(GLUA(2,J+1)/(4.*DT))
      IF (BIG11.GT.BIG) BIG=BIG11
      BIG12=ABS(GLUA(2,J+1)/(4.*DT))
      IF (BIG12.GT.BIG) BIG=BIG12
      IF (ABS(G(14)).LT.BIG*EBIG) G(14)=0

C Gluconic acid dissociation

      G(15)=equilib6*(GLA(2,J)+GLA(1,J))/2.-(GLI(2,J)+GLI(1,J))*
     1   (HYD(2,J)+HYD(1,J))/4.
      B(15,3)=-equilib6/2.
      B(15,15)=(HYD(2,J)+HYD(1,J))/4.
      B(15,16)=(GLI(2,J)+GLI(1,J))/4.

      BIG=ABS(equilib6*GLA(2,J)/2.)
      BIG2=ABS(equilib6*GLA(1,J)/2.)
      IF (BIG2.GT.BIG) BIG=BIG2
      BIG3=ABS(GLI(2,J)*HYD(2,J)/4.)
      IF (BIG3.GT.BIG) BIG=BIG3
      BIG4=ABS(GLI(2,J)*HYD(1,J)/4)
      IF (BIG4.GT.BIG) BIG=BIG4
      BIG5=ABS(GLI(1,J)*HYD(2,J)/4)
      IF (BIG5.GT.BIG) BIG=BIG5
      BIG6=ABS(GLI(1,J)*HYD(1,J)/4)
      IF (BIG6.GT.BIG) BIG=BIG6
      IF (ABS(G(15)).LT.BIG*EBIG) G(15)=0

C Flux of Hydrogen ion, Hydroxide ion, gluconate ion, and bicarbonate ion
C *Note flux4 has a factor of 4 in nom and denominator which cancels out

      G(16)=DIRM(11)*(HYD(2,J+1)-HYD(2,J)+HYD(1,J+1)-HYD(1,J))
     1   /HHHH**2.-DIRM(15)*(OHI(2,J+1)-OHI(2,J)+OHI(1,J+1)-OHI(1,J))
     2 /HHHH**2.-DIRM(10)*(GLI(2,J+1)-GLI(2,J)+GLI(1,J+1)-GLI(1,J))
     3 /HHHH**2.-DIRM(14)*(CBI(2,J+1)-CBI(2,J)+CBI(1,J+1)-CBI(1,J))
     4 /HHHH**2.-(3.*(HYD(2,J)-HYD(1,J))+(HYD(2,J+1)-HYD(1,J+1)))
     4 /(4.*DT)
     5 +(3.*(OHI(2,J)-OHI(1,J))+(OHI(2,J+1)-OHI(1,J+1)))/(4.*DT)
     6 +(3.*(GLI(2,J)-GLI(1,J))+(GLI(2,J+1)-GLI(1,J+1)))/(4.*DT)
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     7 +(3.*(CBI(2,J)-CBI(1,J))+(CBI(2,J+1)-CBI(1,J+1)))/(4.*DT)
     8 +2.*FLUX*EXP(BB*(VDL(2,J)+VDL(1,J))/2.)*(HPR(2,J)+HPR(1,J))
     8 /(HHHH)
     9 -2.*FLUX2*EXP(-BO*(VDL(2,J)+VDL(1,J))/2.)*(OXY(2,J)+OXY(1,J))
     1 *((HYD(2,J)+HYD(1,J))/2.)**2./(HHHH)
     2 -2.*FLUX3*EXP(-BR*(VDL(2,J)+VDL(1,J))/2.)*(HPR(2,J)+HPR(1,J))
     3 *((HYD(2,J)+HYD(1,J))/2.)**2./(HHHH)
     4 -FLUX4*((HYD(2,J)+HYD(1,J)))**2.
     5 *EXP(-BH*(VDL(2,J)+VDL(1,J))/2.)/(HHHH)

      B(16,16)=DIRM(11)/HHHH**2.+3./(4.*DT)
     1 +FLUX2*EXP(-BO*(VDL(2,J)+VDL(1,J))/2.)*(OXY(2,J)+OXY(1,J))
     2 *(HYD(2,J)+HYD(1,J))/HHHH
     3 +FLUX3*EXP(-BR*(VDL(2,J)+VDL(1,J))/2.)*(HPR(2,J)+HPR(1,J))
     4 *((HYD(2,J)+HYD(1,J)))/(HHHH)
     5 +FLUX4*2.*(HYD(2,J)+HYD(1,J))
     6 *EXP(-BH*(VDL(2,J)+VDL(1,J))/2.)/(HHHH)

      D(16,16)=-DIRM(11)/HHHH**2.+1./(4.*DT)
      B(16,17)=-DIRM(15)/HHHH**2.-3./(4.*DT)
      D(16,17)=DIRM(15)/HHHH**2.-1./(4.*DT)
      B(16,15)=-DIRM(10)/HHHH**2.-3./(4.*DT)
      D(16,15)=DIRM(10)/HHHH**2.-1./(4.*DT)
      B(16,20)=-DIRM(14)/HHHH**2.-3./(4.*DT)
      D(16,20)=DIRM(14)/HHHH**2.-1./(4.*DT)

      B(16,5)=+2.*FLUX2*EXP(-BO*(VDL(2,J)+VDL(1,J))/2.)
     1 *((HYD(2,J)+HYD(1,J))/2.)**2./(HHHH)

      B(16,6)=-2.*FLUX*EXP(BB*(VDL(2,J)+VDL(1,J))/2.)/(HHHH)
     1 +2.*FLUX3*EXP(-BR*(VDL(2,J)+VDL(1,J))/2.)
     2 *((HYD(2,J)+HYD(1,J))/2.)**2./(HHHH)

      B(16,22)=-2.*FLUX*EXP(BB*(VDL(2,J)+VDL(1,J))/2.)
     1 *(HPR(2,J)+HPR(1,J))*(BB/2.)/HHHH
     2 -2.*FLUX2*EXP(-BO*(VDL(2,J)+VDL(1,J))/2.)
     3 *(OXY(2,J)+OXY(1,J))*((HYD(2,J)+HYD(1,J))/2.)**2.*(BO/2.)/HHHH
     4 -2.*FLUX3*EXP(-BR*(VDL(2,J)+VDL(1,J))/2.)*(HPR(2,J)+HPR(1,J))
     5 *((HYD(2,J)+HYD(1,J))/2.)**2.*(BR/2)/HHHH
     6 -FLUX4*((HYD(2,J)+HYD(1,J)))**2.
     5 *EXP(-BH*(VDL(2,J)+VDL(1,J))/2.)*(BH/2.)/(HHHH)

      BIG=ABS(DIRM(11)*HYD(2,J+1)/HHHH**2.)
      BIG2=ABS(DIRM(11)*HYD(2,J)/HHHH**2.)
      IF (BIG2.GT.BIG) BIG=BIG2
      BIG3=ABS(DIRM(11)*HYD(1,J+1)/HHHH**2.)
      IF (BIG3.GT.BIG) BIG=BIG3
      BIG4=ABS(DIRM(11)*HYD(1,J)/HHHH**2.)
      IF (BIG4.GT.BIG) BIG=BIG4
      BIG5=ABS(DIRM(15)*OHI(2,J+1)/HHHH**2.)
      IF (BIG5.GT.BIG) BIG=BIG5
      BIG6=ABS(DIRM(15)*OHI(2,J)/HHHH**2.)
      IF (BIG6.GT.BIG) BIG=BIG6
      BIG7=ABS(DIRM(15)*OHI(1,J+1)/HHHH**2.)
      IF (BIG7.GT.BIG) BIG=BIG7
      BIG8=ABS(DIRM(15)*OHI(1,J)/HHHH**2.)
      IF (BIG8.GT.BIG) BIG=BIG8
      BIG9=ABS(DIRM(10)*GLI(2,J+1)/HHHH**2.)
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      IF (BIG9.GT.BIG) BIG=BIG9
      BIG10=ABS(DIRM(10)*GLI(2,J)/HHHH**2.)
      IF (BIG10.GT.BIG) BIG=BIG10
      BIG11=ABS(DIRM(10)*GLI(1,J+1)/HHHH**2.)
      IF (BIG11.GT.BIG) BIG=BIG11
      BIG12=ABS(DIRM(10)*GLI(1,J)/HHHH**2.)
      IF (BIG12.GT.BIG) BIG=BIG12
      BIG13=ABS(DIRM(14)*CBI(2,J+1)/HHHH**2.)
      IF (BIG13.GT.BIG) BIG=BIG13
      BIG14=ABS(DIRM(14)*CBI(2,J)/HHHH**2.)
      IF (BIG14.GT.BIG) BIG=BIG14
      BIG15=ABS(DIRM(14)*CBI(1,J+1)/HHHH**2.)
      IF (BIG15.GT.BIG) BIG=BIG15
      BIG16=ABS(DIRM(14)*CBI(1,J)/HHHH**2.)
      IF (BIG16.GT.BIG) BIG=BIG16
      BIG17=ABS(3.*HYD(2,J)/(4.*DT))
      IF (BIG17.GT.BIG) BIG=BIG17
      BIG18=ABS(3.*HYD(1,J)/(4.*DT))
      IF (BIG18.GT.BIG) BIG=BIG18
      BIG19=ABS(HYD(2,J+1)/(4.*DT))
      IF (BIG19.GT.BIG) BIG=BIG19
      BIG20=ABS(HYD(1,J+1)/(4.*DT))
      IF (BIG20.GT.BIG) BIG=BIG20
      BIG21=ABS(3.*OHI(2,J)/(4.*DT))
      IF (BIG21.GT.BIG) BIG=BIG21
      BIG22=ABS(3.*OHI(1,J)/(4.*DT))
      IF (BIG22.GT.BIG) BIG=BIG22
      BIG23=ABS(OHI(2,J+1)/(4.*DT))
      IF (BIG23.GT.BIG) BIG=BIG23
      BIG24=ABS(OHI(1,J+1)/(4.*DT))
      IF (BIG24.GT.BIG) BIG=BIG24
      BIG25=ABS(3.*GLI(2,J)/(4.*DT))
      IF (BIG25.GT.BIG) BIG=BIG25
      BIG26=ABS(3.*GLI(1,J)/(4.*DT))
      IF (BIG26.GT.BIG) BIG=BIG26
      BIG27=ABS(GLI(2,J+1)/(4.*DT))
      IF (BIG27.GT.BIG) BIG=BIG27
      BIG28=ABS(GLI(1,J+1)/(4.*DT))
      IF (BIG28.GT.BIG) BIG=BIG28
      BIG29=ABS(3.*CBI(2,J)/(4.*DT))
      IF (BIG29.GT.BIG) BIG=BIG29
      BIG30=ABS(3.*CBI(1,J)/(4.*DT))
      IF (BIG30.GT.BIG) BIG=BIG30
      BIG31=ABS(CBI(2,J+1)/(4.*DT))
      IF (BIG31.GT.BIG) BIG=BIG31
      BIG32=ABS(CBI(1,J+1)/(4.*DT))
      IF (BIG32.GT.BIG) BIG=BIG32
      IF (ABS(G(16)).LT.BIG*EBIG) G(16)=0
C     Water dissociation

      G(17)=equilib9 -(HYD(2,J)+HYD(1,J))*(OHI(2,J)+OHI(1,J))/4.
      B(17,17)=(HYD(2,J)+HYD(1,J))/4.
      B(17,16)=(OHI(2,J)+OHI(1,J))/4.

      BIG=ABS(equilib9)
      BIG2=ABS(HYD(2,J)*OHI(2,J)/4.)
      IF (BIG2.GT.BIG) BIG=BIG2
      BIG3=ABS(HYD(2,J)*OHI(1,J)/4.)
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      IF (BIG3.GT.BIG) BIG=BIG3
      BIG4=ABS(HYD(1,J)*OHI(2,J)/4.)
      IF (BIG4.GT.BIG) BIG=BIG4
      BIG5=ABS(HYD(1,J)*OHI(1,J)/4.)
      IF (BIG5.GT.BIG) BIG=BIG5
      IF (ABS(G(17)).LT.BIG*EBIG) G(17)=0
C CO2 Hydration

      G(18)=equilib7*(CO2(2,J)+CO2(1,J))/2.-(CBA(2,J)+CBA(1,J))/2.
      B(18,18)=-equilib7/2.
      B(18,19)=1./2.

      BIG=ABS(equilib7*CO2(2,J)/2.)
      BIG2=ABS(equilib7*CO2(1,J)/2.)
      IF (BIG2.GT.BIG) BIG=BIG2
      BIG3=ABS(CBA(2,J)/2.)
      IF (BIG3.GT.BIG) BIG=BIG3
      BIG4=ABS(CBA(1,J)/2.)
      IF (BIG4.GT.BIG) BIG=BIG4
      IF (ABS(G(18)).LT.BIG*EBIG) G(18)=0

C Carbonic acid dissociation

      G(19)=equilib8*(CBA(2,J)+CBA(1,J))/2.-(CBI(2,J)+CBI(1,J))
     1 *(HYD(2,J)+HYD(1,J))/4.
      B(19,19)=-equilib8/2.
      B(19,20)=(HYD(2,J)+HYD(1,J))/4.
      B(19,16)=(CBI(2,J)+CBI(1,J))/4.

      BIG=ABS(equilib8*CBA(2,J)/2.)
      BIG2=ABS(equilib8*CBA(1,J)/2.)
      IF (BIG2.GT.BIG) BIG=BIG2
      BIG3=ABS(CBI(2,J)*HYD(2,J)/4.)
      IF (BIG3.GT.BIG) BIG=BIG3
      BIG4=ABS(CBI(2,J)*HYD(1,J)/4.)
      IF (BIG4.GT.BIG) BIG=BIG4
      BIG5=ABS(CBI(1,J)*HYD(2,J)/4.)
      IF (BIG5.GT.BIG) BIG=BIG5
      BIG6=ABS(CBI(1,J)*HYD(1,J)/4.)
      IF (BIG6.GT.BIG) BIG=BIG6
      IF (ABS(G(19)).LT.BIG*EBIG) G(19)=0

C FLUX OF CO2, CARBONIC ACID, BICARBONATE ION

      G(20)=DIRM(12)*(CO2(2,J+1)-CO2(2,J)+CO2(1,J+1)-CO2(1,J))
     1 /HHHH**2.+DIRM(13)*(CBA(2,J+1)-CBA(2,J)+CBA(1,J+1)-CBA(1,J))
     2 /HHHH**2.+DIRM(14)*(CBI(2,J+1)-CBI(2,J)+CBI(1,J+1)-CBI(1,J))
     3 /HHHH**2.-(3.*(CO2(2,J)-CO2(1,J))+(CO2(2,J+1)-CO2(1,J+1)))
     3 /(4.*DT)
     4 -(3.*(CBA(2,J)-CBA(1,J))+(CBA(2,J+1)-CBA(1,J+1)))/(4.*DT)
     5 -(3.*(CBI(2,J)-CBI(1,J))+(CBI(2,J+1)-CBI(1,J+1)))/(4.*DT)

      B(20,20)=DIRM(14)/HHHH**2.+3./(4.*DT)
      D(20,20)=-DIRM(14)/HHHH**2.+1./(4.*DT)
      B(20,18)=DIRM(12)/HHHH**2.+3./(4.*DT)
      D(20,18)=-DIRM(12)/HHHH**2.+1./(4.*DT)
      B(20,19)=DIRM(13)/HHHH**2.+3./(4.*DT)
      D(20,19)=-DIRM(13)/HHHH**2.+1./(4.*DT)
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      BIG=ABS(DIRM(12)*CO2(2,J+1)/HHHH**2.)
      BIG2=ABS(DIRM(12)*CO2(2,J)/HHHH**2.)
      IF (BIG2.GT.BIG) BIG=BIG2
      BIG3=ABS(DIRM(12)*CO2(1,J+1)/HHHH**2.)
      IF (BIG3.GT.BIG) BIG=BIG3
      BIG4=ABS(DIRM(12)*CO2(1,J)/HHHH**2.)
      IF (BIG4.GT.BIG) BIG=BIG4
      BIG5=ABS(DIRM(13)*CBA(2,J+1)/HHHH**2.)
      IF (BIG5.GT.BIG) BIG=BIG5
      BIG6=ABS(DIRM(13)*CBA(2,J)/HHHH**2.)
      IF (BIG6.GT.BIG) BIG=BIG6
      BIG7=ABS(DIRM(13)*CBA(1,J+1)/HHHH**2.)
      IF (BIG7.GT.BIG) BIG=BIG7
      BIG8=ABS(DIRM(13)*CBA(1,J)/HHHH**2.)
      IF (BIG8.GT.BIG) BIG=BIG8
      BIG9=ABS(DIRM(14)*CBI(2,J+1)/HHHH**2.)
      IF (BIG9.GT.BIG) BIG=BIG9
      BIG10=ABS(DIRM(14)*CBI(2,J)/HHHH**2.)
      IF (BIG10.GT.BIG) BIG=BIG10
      BIG11=ABS(DIRM(14)*CBI(1,J+1)/HHHH**2.)
      IF (BIG11.GT.BIG) BIG=BIG11
      BIG12=ABS(DIRM(14)*CBI(1,J)/HHHH**2.)
      IF (BIG12.GT.BIG) BIG=BIG12
      BIG13=ABS(3.*CO2(2,J)/(4.*DT))
      IF (BIG13.GT.BIG) BIG=BIG13
      BIG14=ABS(3.*CO2(1,J)/(4.*DT))
      IF (BIG14.GT.BIG) BIG=BIG14
      BIG15=ABS(CO2(2,J+1)/(4.*DT))
      IF (BIG15.GT.BIG) BIG=BIG15
      BIG16=ABS(CO2(1,J+1)/(4.*DT))
      IF (BIG16.GT.BIG) BIG=BIG16
      BIG17=ABS(3.*CBA(2,J)/(4.*DT))
      IF (BIG17.GT.BIG) BIG=BIG17
      BIG18=ABS(3.*CBA(1,J)/(4.*DT))
      IF (BIG18.GT.BIG) BIG=BIG18
      BIG19=ABS(CBA(2,J+1)/(4.*DT))
      IF (BIG19.GT.BIG) BIG=BIG19
      BIG20=ABS(CBA(1,J+1)/(4.*DT))
      IF (BIG20.GT.BIG) BIG=BIG20
      BIG21=ABS(3.*CBI(2,J)/(4.*DT))
      IF (BIG21.GT.BIG) BIG=BIG21
      BIG22=ABS(3.*CBI(1,J)/(4.*DT))
      IF (BIG22.GT.BIG) BIG=BIG22
      BIG23=ABS(CBI(2,J+1)/(4.*DT))
      IF (BIG23.GT.BIG) BIG=BIG23
      BIG24=ABS(CBI(1,J+1)/(4.*DT))
      IF (BIG24.GT.BIG) BIG=BIG24
      IF (ABS(G(20)).LT.BIG*EBIG) G(20)=0

C     flux OF Acetaminophen

      G(21)=DIRM(16)
     1  *(ACE(2,J+1)-ACE(2,J)+ACE(1,J+1)-ACE(1,J))/HHHH**2.
     2  -FLUX5*EXP(BA*(VDL(2,J)+VDL(1,J))/2.)*(ACE(2,J)+ACE(1,J))/(HHHH)
     8   -(3.*(ACE(2,J)-ACE(1,J))+(ACE(2,J+1)-ACE(1,J+1)))/(4.*DT)

      B(21,21)=DIRM(16)/HHHH**2.+FLUX5*EXP(BA*(VDL(2,J)+VDL(1,J))/2.)
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     1  /HHHH+3./(4.*DT)

      D(21,21)=-DIRM(16)/HHHH**2.+1./(4.*DT)

      B(21,22)=FLUX5*EXP(BA*(VDL(2,J)+VDL(1,J))/2.)*(ACE(2,J)+ACE(1,J))
     1  *(BA/2.)/HHHHH

      BIG=ABS(DIRM(16)*ACE(2,J+1)/HHHH**2.)
      BIG2=ABS(DIRM(16)*ACE(2,J)/HHHH**2.)
      IF  (BIG2.GT.BIG)  BIG=BIG2
      BIG3=ABS(DIRM(16)*ACE(1,J+1)/HHHH**2.)
      IF  (BIG3.GT.BIG)  BIG=BIG3
      BIG4=ABS(DIRM(16)*ACE(1,J)/HHHH**2.)
      IF  (BIG4.GT.BIG)  BIG=BIG4
      BIG11=ABS(3.*ACE(2,J)/(4.*DT))
      IF  (BIG11.GT.BIG)  BIG=BIG11
      BIG12=ABS(3.*ACE(1,J)/(4.*DT))
      IF  (BIG12.GT.BIG)  BIG=BIG12
      BIG13=ABS(ACE(2,J+1)/(4.*DT))
      IF  (BIG13.GT.BIG)  BIG=BIG13
      BIG14=ABS(ACE(1,J+1)/(4.*DT))
      IF  (BIG14.GT.BIG)  BIG=BIG14
      IF  (ABS(G(21)).LT.BIG*EBIG)  G(21)=0
C     For Voltage drop across double layer

      G(22)=  VAP-RE*(AKB*EXP(BB*(VDL(2,J)+VDL(1,J))/2.)
     1  *(HPR(2,J)+HPR(1,J))/2.-AKO*EXP(-BO*(VDL(2,J)+VDL(1,J))/2.)
     2  *(OXY(2,J)+OXY(1,J))/2.*((HYD(2,J)+HYD(1,J))/2.)**2.
     3  -AKR*EXP(-BR*(VDL(2,J)+VDL(1,J))/2.)*(HPR(2,J)+HPR(1,J))/2.
     4  *((HYD(2,J)+HYD(1,J))/2.)**2.
     5  -AKH*EXP(-BH*(VDL(2,J)+VDL(1,J))/2.)*((HYD(2,J)+HYD(1,J))/2.)**2.
     6  +AKA*EXP(BA*(VDL(2,J)+VDL(1,J))/2.)*(ACE(2,J)+ACE(1,J))/2.
     6  +CDL*(VDL(2,J)-VDL(1,J))/DT)-(VDL(2,J)+VDL(1,J))/2.

      B(22,22)=  RE*AKB*(BB/2.)*EXP(BB*(VDL(2,J)+VDL(1,J))/2.)
     1    *(HPR(2,J)+HPR(1,J))/2.+RE*AKO*(BO/2.)
     2  *EXP(-BO*(VDL(2,J)+VDL(1,J))/2.)*(OXY(2,J)+OXY(1,J))/2.
     3  *((HYD(2,J)+HYD(1,J))/2.)**2.
     4  +RE*AKR*(BR/2.)*EXP(-BR*(VDL(2,J)+VDL(1,J))/2.)
     5  *(HPR(2,J)+HPR(1,J))/2.*((HYD(2,J)+HYD(1,J))/2.)**2.
     6  +RE*AKH*(BH/2.)*EXP(-BH*(VDL(2,J)+VDL(1,J))/2.)
     7  *((HYD(2,J)+HYD(1,J))/2.)**2.
     8  +RE*AKA*(BA/2.)*EXP(BA*(VDL(2,J)+VDL(1,J))/2.)
     9  *(ACE(2,J)+ACE(1,J))/2.+RE*CDL/DT+1./2.


      B(22,5)=-RE*AKO*EXP(-BO*(VDL(2,J)+VDL(1,J))/2.)/2.
     1  *((HYD(2,J)+HYD(1,J))/2.)**2.
      B(22,6)=RE*AKB*EXP(BB*(VDL(2,J)+VDL(1,J))/2.)/2.
     1  -RE*AKR*EXP(-BR*(VDL(2,J)+VDL(1,J))/2.)/2.
     2  *((HYD(2,J)+HYD(1,J))/2.)**2.
      B(22,16)=-AKO*EXP(-BO*(VDL(2,J)+VDL(1,J))/2.)
     1  *(OXY(2,J)+OXY(1,J))/2.*(HYD(2,J)+HYD(1,J))/2.
     2  -AKR*EXP(-BR*(VDL(2,J)+VDL(1,J))/2.)*(HPR(2,J)+HPR(1,J))/2.
     3  *(HYD(2,J)+HYD(1,J))/2.
     4  -AKH*EXP(-BH*(VDL(2,J)+VDL(1,J))/2.)*(HYD(2,J)+HYD(1,J))/2.
      B(22,21)=RE*AKA*EXP(BA*(VDL(2,J)+VDL(1,J))/2.)/2.

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      RETURN
      END

      SUBROUTINE INSULATION(J)
      IMPLICIT DOUBLE PRECISION (A-H, O-Z)
      COMMON/BAB/ A(22,22),B(22,22),C(22,80001),D(22,45),G(22),X(22,22)
     1    ,Y(22,22)
      COMMON/NSN/ N, NJ
      COMMON/GLC/ NTIME,LL
      COMMON/VAR/ DIFF(16),H,EBIG,HH,IJ ,KJ,TT,VAP,HHH,DT,RE,AKB,BB,CDL
      COMMON/VARR/ HHHH,HHHHH,MJ,LJ
      COMMON/DIN/ DGOX(16),DGLM(16),DIRM(16),DBULK(16)
      COMMON/SPCI/ GLU(2,80001),GOX(2,80001),GLA(2,80001),GOR(2,80001)
      COMMON/SPCII/ OXY(2,80001),HPR(2,80001),GOA(2,80001),GOP(2,80001)
      COMMON/RXT/ EQ1(2,80001),RGA(2,80001),EQ2(2,80001),RHP(2,80001)
      COMMON/SPCIII/ ANM(2,80001),GLUA(2,80001),GLI(2,80001)
      COMMON/SPCIV/ HYD(2,80001),OHI(2,80001),CO2(2,80001),CBA(2,80001)
      COMMON/SPCV/ CBI(2,80001),ACE(2,800001)
      COMMON/VOL/ VDL(2,80001)
      COMMON/POR/ POR1,POR2,PORGLU,PARION,PARACE
      COMMON/RTE/ ratef1 ,equilib1 ,ratef2 ,ratef3 ,equilib3 ,ratef4
      COMMON/RTD/ ratef5 ,equilib5 ,equilib6 ,equilib7 ,equilib8 ,equilib9
      COMMON/BUL/ CBULK(16),PARH2O2,PAR02,PARGLUCOSE,JCOUNT

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

C       For Glucose, being consumed only
      G(1)=DIRM(1)*(GLU(2,J+1)-2.*GLU(2,J)+GLU(2,J-1)
     1        +GLU(1,J+1)-2.*GLU(1,J)+GLU(1,J-1))/(2.*HHHH**2.)
     2      +(ANM(2,J)+ANM(1,J))/2.-(GLU(2,J)-GLU(1,J))/DT

      B(1,1)=DIRM(1)/HHHH**2.+1./DT
      D(1,1)=-DIRM(1)/(2.*HHHH**2.)
      A(1,1)=-DIRM(1)/(2.*HHHH**2.)
      B(1,13)=-1./2.


      BIG=ABS(DIRM(1)*(GLU(2,J+1))/(2.*HHHH**2.))
      BIG2=ABS(DIRM(1)*(GLU(2,J))/(HHHH**2.))
      IF (BIG2.GT.BIG) BIG=BIG2
      BIG3=ABS(DIRM(1)*(GLU(2,J-1))/(2.*HHHH**2.))
      IF (BIG3.GT.BIG) BIG=BIG3
      BIG4=ABS(DIRM(1)*(GLU(1,J+1))/(2.*HHHH**2.))
      IF (BIG4.GT.BIG) BIG=BIG4
      BIG5=ABS(DIRM(1)*(GLU(1,J))/(HHHH**2.))
      IF (BIG5.GT.BIG) BIG=BIG5
      BIG6=ABS(DIRM(1)*(GLU(1,J-1))/(2.*HHHH**2.))
      IF (BIG6.GT.BIG) BIG=BIG6
      BIG7=ABS(GLU(2,J)/DT)
      IF (BIG7.GT.BIG) BIG=BIG7
      BIG8=ABS(GLU(1,J)/DT)
      IF (BIG8.GT.BIG) BIG=BIG8
      BIG9=ABS(ANM(2,J)/2.)
      IF (BIG9.GT.BIG) BIG=BIG9
      BIG10=ABS(ANM(1,J)/2.)
      IF (BIG10.GT.BIG) BIG=BIG10
      IF (ABS(G(1)).LT.BIG*EBIG) G(1)=0

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C       For GOx, enzyme
      G(2)=(GOX(2,J)+GOX(1,J))/2.
      B(2,2)=-1./2.


C       For Gluconic Acid, being produced only
      G(3)=DIRM(3)*(GLA(2,J+1)-2.*GLA(2,J)+GLA(2,J-1)
     1      +GLA(1,J+1)-2.*GLA(1,J)+GLA(1,J-1))/(2.*HHHH**2.)
     2      +DIRM(10)*(GLI(2,J+1)-2.*GLI(2,J)+GLI(2,J-1)
     3      +GLI(1,J+1)-2.*GLI(1,J)+GLI(1,J-1))/(2.*HHHH**2.)
     2     -(GLA(2,J)-GLA(1,J))/DT-(GLI(2,J)-GLI(1,J))/DT

      B(3,3)=DIRM(3)/HHHH**2.+1./DT
      D(3,3)=-DIRM(3)/(2.*HHHH**2.)
      A(3,3)=-DIRM(3)/(2.*HHHH**2.)
      B(3,15)=DIRM(10)/HHHH**2.+1./DT
      D(3,15)=-DIRM(10)/(2.*HHHH**2.)
      A(3,15)=-DIRM(10)/(2.*HHHH**2.)


      BIG=ABS(DIRM(3)*(GLA(2,J+1))/(2.*HHHH**2.))
      BIG2=ABS(DIRM(3)*(GLA(2,J))/(HHHH**2.))
      IF (BIG2.GT.BIG) BIG=BIG2
      BIG3=ABS(DIRM(3)*(GLA(2,J-1))/(2.*HHHH**2.))
      IF (BIG3.GT.BIG) BIG=BIG3
      BIG4=ABS(DIRM(3)*(GLA(1,J+1))/(2.*HHHH**2.))
      IF (BIG4.GT.BIG) BIG=BIG4
      BIG5=ABS(DIRM(3)*(GLA(1,J))/(HHHH**2.))
      IF (BIG5.GT.BIG) BIG=BIG5
      BIG6=ABS(DIRM(3)*(GLA(1,J-1))/(2.*HHHH**2.))
      IF (BIG6.GT.BIG) BIG=BIG6
      BIG7=ABS(GLA(2,J)/DT)
      IF (BIG7.GT.BIG) BIG=BIG7
      BIG8=ABS(GLA(1,J)/DT)
      IF (BIG8.GT.BIG) BIG=BIG8
      BIG9=ABS(DIRM(10)*(GLI(2,J+1))/(2.*HHHH**2.))
      IF (BIG9.GT.BIG) BIG=BIG9
      BIG10=ABS(DIRM(10)*(GLI(2,J))/(HHHH**2.))
      IF (BIG10.GT.BIG) BIG=BIG10
      BIG11=ABS(DIRM(10)*(GLI(2,J-1))/(2.*HHHH**2.))
      IF (BIG11.GT.BIG) BIG=BIG11
      BIG12=ABS(DIRM(10)*(GLI(1,J+1))/(2.*HHHH**2.))
      IF (BIG12.GT.BIG) BIG=BIG12
      BIG13=ABS(DIRM(10)*(GLI(1,J))/(HHHH**2.))
      IF (BIG13.GT.BIG) BIG=BIG13
      BIG14=ABS(DIRM(10)*(GLI(1,J-1))/(2.*HHHH**2.))
      IF (BIG14.GT.BIG) BIG=BIG14
      BIG15=ABS(GLI(2,J)/DT)
      IF (BIG15.GT.BIG) BIG=BIG15
      BIG16=ABS(GLI(1,J)/DT)
      IF (BIG16.GT.BIG) BIG=BIG16
      IF (ABS(G(3)).LT.BIG*EBIG) G(3)=0

C       For GOx2, enzyme
      G(4)=(GOR(2,J)+GOR(1,J))/2.
      B(4,4)=-1./2.
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C       For O2, being consumed only
        G(5)=DIRM(5)*(OXY(2,J+1)-2.*OXY(2,J)+OXY(2,J-1)
     1        +OXY(1,J+1)-2.*OXY(1,J)+OXY(1,J-1))/(2.*HHHH**2.)
     2      -(OXY(2,J)-OXY(1,J))/DT

        B(5,5)=DIRM(5)/HHHH**2.+1./DT
        D(5,5)=-DIRM(5)/(2.*HHHH**2.)
        A(5,5)=-DIRM(5)/(2.*HHHH**2.)


        BIG=ABS(DIRM(5)*(OXY(2,J+1))/(2.*HHHH**2.))
        BIG2=ABS(DIRM(5)*(OXY(2,J))/(HHHH**2.))
        IF (BIG2.GT.BIG) BIG=BIG2
        BIG3=ABS(DIRM(5)*(OXY(2,J-1))/(2.*HHHH**2.))
        IF (BIG3.GT.BIG) BIG=BIG3
        BIG4=ABS(DIRM(5)*(OXY(1,J+1))/(2.*HHHH**2.))
        IF (BIG4.GT.BIG) BIG=BIG4
        BIG5=ABS(DIRM(5)*(OXY(1,J))/(HHHH**2.))
        IF (BIG5.GT.BIG) BIG=BIG5
        BIG6=ABS(DIRM(5)*(OXY(1,J-1))/(2.*HHHH**2.))
        IF (BIG6.GT.BIG) BIG=BIG6
        BIG7=ABS(OXY(2,J)/DT)
        IF (BIG7.GT.BIG) BIG=BIG7
        BIG8=ABS(OXY(1,J)/DT)
        IF (BIG8.GT.BIG) BIG=BIG8
        IF (ABS(G(5)).LT.BIG*EBIG) G(5)=0

C       For H2O2, reacting species
        G(6)=DIRM(6)*(HPR(2,J+1)-2.*HPR(2,J)+HPR(2,J-1)
     1        +HPR(1,J+1)-2.*HPR(1,J)+HPR(1,J-1))/(2.*HHHH**2.)
     2      -(HPR(2,J)-HPR(1,J))/DT

        B(6,6)=DIRM(6)/HHHH**2.+1./DT
        D(6,6)=-DIRM(6)/(2.*HHHH**2.)
        A(6,6)=-DIRM(6)/(2.*HHHH**2.)


        BIG=ABS(DIRM(6)*(HPR(2,J+1))/(2.*HHHH**2.))
        BIG2=ABS(DIRM(6)*(HPR(2,J))/(HHHH**2.))
        IF (BIG2.GT.BIG) BIG=BIG2
        BIG3=ABS(DIRM(6)*(HPR(2,J-1))/(2.*HHHH**2.))
        IF (BIG3.GT.BIG) BIG=BIG3
        BIG4=ABS(DIRM(6)*(HPR(1,J+1))/(2.*HHHH**2.))
        IF (BIG4.GT.BIG) BIG=BIG4
        BIG5=ABS(DIRM(6)*(HPR(1,J))/(HHHH**2.))
        IF (BIG5.GT.BIG) BIG=BIG5
        BIG6=ABS(DIRM(6)*(HPR(1,J-1))/(2.*HHHH**2.))
        IF (BIG6.GT.BIG) BIG=BIG6
        BIG7=ABS(HPR(2,J)/DT)
        IF (BIG7.GT.BIG) BIG=BIG7
        BIG8=ABS(HPR(1,J)/DT)
        IF (BIG8.GT.BIG) BIG=BIG8
        IF (ABS(G(6)).LT.BIG*EBIG) G(6)=0

C       For CX-GOx2, enzyme complex
        G(7)=(GOA(2,J)+GOA(1,J))/2.
        B(7,7) = -1./2.
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C     For CX-GOx, enzyme complex
      G(8)=(GOP(2,J)+GOP(1,J))/2.
      B(8,8)=-1./2.

C     For Reaction 1 Enzymatic Catalysis
      G(9)=(EQ1(2,J)+EQ1(1,J))/2.
      B(9,9)=-1./2.

C     For Reaction 2
      G(10)=(RGA(2,J)+RGA(1,J))/2.
      B(10,10)=-1./2.

C     For Reaction 3 Meditation/regeneration
      G(11)=(EQ2(2,J)+EQ2(1,J))/2.
      B(11,11)=-1./2.

C     For Reaction 4
      G(12)=(RHP(2,J)+RHP(1,J))/2.
      B(12,12)=-1./2.

C     REACTION5
  218 G(13)=-(ANM(2,J)+ANM(1,J))/2.+ratef5*((GLUA(2,J)+GLUA(1,J))/2.
     1    -(GLU(2,J)+GLU(1,J))/2./equilib5)
      B(13,1)=ratef5/2./equilib5
      B(13,14)=-ratef5/2.
      B(13,13)=+1./2.

      BIG=ABS(ANM(2,J)/2.)
      BIG2=ABS(ANM(1,J)/2.)
      IF (BIG2.GT.BIG) BIG=BIG2
      BIG3=ABS(ratef5*GLUA(2,J)/2.)
      IF (BIG3.GT.BIG) BIG=BIG3
      BIG4=ABS(ratef5*GLUA(1,J)/2.)
      IF (BIG4.GT.BIG) BIG=BIG4
      BIG5=ABS(ratef5*GLU(2,J)/2./equilib5)
      IF (BIG5.GT.BIG) BIG=BIG5
      BIG6=ABS(ratef5*GLU(1,J)/2./equilib5)
      IF (BIG6.GT.BIG) BIG=BIG6
      IF (ABS(G(13)).LT.BIG*EBIG) G(13)=0.0

C     For alpha Glucose, being consumed only
      G(14)=DIRM(9)*(GLUA(2,J+1)-2.*GLUA(2,J)+GLUA(2,J-1)
     1       +GLUA(1,J+1)-2.*GLUA(1,J)+GLUA(1,J-1))/(2.*HHHH**2.)
     2        -(ANM(2,J)+ANM(1,J))/2.-(GLUA(2,J)-GLUA(1,J))/DT
      B(14,14)=DIRM(9)/HHHH**2.+1./DT
      D(14,14)=-DIRM(9)/(2.*HHHH**2.)
      A(14,14)=-DIRM(9)/(2.*HHHH**2.)
      B(14,13)=1./2.

      BIG=ABS(DIRM(9)*(GLUA(2,J+1))/(2.*HHHH**2.))
      BIG2=ABS(DIRM(9)*(GLUA(2,J))/(HHHH**2.))
      IF (BIG2.GT.BIG) BIG=BIG2
      BIG3=ABS(DIRM(9)*(GLUA(2,J-1))/(2.*HHHH**2.))
      IF (BIG3.GT.BIG) BIG=BIG3
      BIG4=ABS(DIRM(9)*(GLUA(1,J+1))/(2.*HHHH**2.))
      IF (BIG4.GT.BIG) BIG=BIG4
      BIG5=ABS(DIRM(9)*(GLUA(1,J))/(HHHH**2.))
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      IF (BIG5.GT.BIG) BIG=BIG5
      BIG6=ABS(DIRM(9)*(GLUA(1,J-1))/(2.*HHHH**2.))
      IF (BIG6.GT.BIG) BIG=BIG6
      BIG7=ABS(ANM(2,J)/2.)
      IF (BIG7.GT.BIG) BIG=BIG7
      BIG8=ABS(ANM(1,J)/2.)
      IF (BIG8.GT.BIG) BIG=BIG8
      BIG9=ABS(GLUA(2,J)/DT)
      IF (BIG9.GT.BIG) BIG=BIG9
      BIG10=ABS(GLUA(1,J)/DT)
      IF (BIG10.GT.BIG) BIG=BIG10
      IF (ABS(G(14)).LT.BIG*EBIG) G(14)=0.0

C Gluconic acid dissociation

      G(15)=equilib6*(GLA(2,J)+GLA(1,J))/2.-(GLI(2,J)+GLI(1,J))*
     1   (HYD(2,J)+HYD(1,J))/4.
      B(15,3)=-equilib6/2.
      B(15,15)=(HYD(2,J)+HYD(1,J))/4.
      B(15,16)=(GLI(2,J)+GLI(1,J))/4.

      BIG=ABS(equilib6*GLA(2,J)/2.)
      BIG2=ABS(equilib6*GLA(1,J)/2.)
      IF (BIG2.GT.BIG) BIG=BIG2
      BIG3=ABS(GLI(2,J)*HYD(2,J)/4.)
      IF (BIG3.GT.BIG) BIG=BIG3
      BIG4=ABS(GLI(2,J)*HYD(1,J)/4)
      IF (BIG4.GT.BIG) BIG=BIG4
      BIG5=ABS(GLI(1,J)*HYD(2,J)/4)
      IF (BIG5.GT.BIG) BIG=BIG5
      BIG6=ABS(GLI(1,J)*HYD(1,J)/4)
      IF (BIG6.GT.BIG) BIG=BIG6
      IF (ABS(G(15)).LT.BIG*EBIG) G(15)=0
C Hydrogen ion, hydroxide ion, gluconate ion, bicarbonate ion flux
      G(16)=DIRM(11)*(HYD(2,J+1)-2.*HYD(2,J)+HYD(2,J-1)
     1       +HYD(1,J+1)-2.*HYD(1,J)+HYD(1,J-1))/(2.*HHHH**2.)
     2   -DIRM(15)*(OHI(2,J+1)-2.*OHI(2,J)+OHI(2,J-1)
     3       +OHI(1,J+1)-2.*OHI(1,J)+OHI(1,J-1))/(2.*HHHH**2.)
     4   -DIRM(10)*(GLI(2,J+1)-2.*GLI(2,J)+GLI(2,J-1)
     5       +GLI(1,J+1)-2.*GLI(1,J)+GLI(1,J-1))/(2.*HHHH**2.)
     6   -DIRM(14)*(CBI(2,J+1)-2.*CBI(2,J)+CBI(2,J-1)
     7       +CBI(1,J+1)-2.*CBI(1,J)+CBI(1,J-1))/(2.*HHHH**2.)
     8   -(HYD(2,J)-HYD(1,J))/DT+(OHI(2,J)-OHI(1,J))/DT
     9   +(GLI(2,J)-GLI(1,J))/DT+(CBI(2,J)-CBI(1,J))/DT

      B(16,16)=DIRM(11)/HHHH**2.+1./DT
      D(16,16)=-DIRM(11)/(2.*HHHH**2.)
      A(16,16)=-DIRM(11)/(2.*HHHH**2.)
      B(16,17)=-DIRM(15)/HHHH**2.-1./DT
      D(16,17)=DIRM(15)/(2.*HHHH**2.)
      A(16,17)=DIRM(15)/(2.*HHHH**2.)
      B(16,15)=-DIRM(10)/HHHH**2.-1./DT
      D(16,15)=DIRM(10)/(2.*HHHH**2.)
      A(16,15)=DIRM(10)/(2.*HHHH**2.)
      B(16,20)=-DIRM(14)/HHHH**2.-1./DT
      D(16,20)=DIRM(14)/(2.*HHHH**2.)
      A(16,20)=DIRM(14)/(2.*HHHH**2.)

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      BIG=ABS(DIRM(11)*(HYD(2,J+1))/(2.*HHHH**2.))
      BIG2=ABS(DIRM(11)*(HYD(2,J))/(HHHH**2.))
      IF (BIG2.GT.BIG) BIG=BIG2
      BIG3=ABS(DIRM(11)*(HYD(2,J-1))/(2.*HHHH**2.))
      IF (BIG3.GT.BIG) BIG=BIG3
      BIG4=ABS(DIRM(11)*(HYD(1,J+1))/(2.*HHHH**2.))
      IF (BIG4.GT.BIG) BIG=BIG4
      BIG5=ABS(DIRM(11)*(HYD(1,J))/(HHHH**2.))
      IF (BIG5.GT.BIG) BIG=BIG5
      BIG6=ABS(DIRM(11)*(HYD(1,J-1))/(2.*HHHH**2.))
      IF (BIG6.GT.BIG) BIG=BIG6
      BIG7=ABS(DIRM(15)*OHI(2,J+1)/(2.*HHHH**2.))
      IF (BIG7.GT.BIG) BIG=BIG7
      BIG8=ABS(DIRM(15)*OHI(2,J)/(HHHH**2.))
      IF (BIG8.GT.BIG) BIG=BIG8
      BIG9=ABS(DIRM(15)*OHI(2,J-1)/(2.*HHHH**2.))
      IF (BIG9.GT.BIG) BIG=BIG9
      BIG10=ABS(DIRM(15)*OHI(1,J+1)/(2.*HHHH**2.))
      IF (BIG10.GT.BIG) BIG=BIG10
      BIG11=ABS(DIRM(15)*OHI(1,J)/(HHHH**2.))
      IF (BIG11.GT.BIG) BIG=BIG11
      BIG12=ABS(DIRM(15)*OHI(1,J-1)/(2.*HHHH**2.))
      IF (BIG12.GT.BIG) BIG=BIG12
      BIG13=ABS(DIRM(10)*GLI(2,J+1)/(2.*HHHH**2.))
      IF (BIG13.GT.BIG) BIG=BIG13
      BIG14=ABS(DIRM(10)*GLI(2,J)/(HHHH**2.))
      IF (BIG14.GT.BIG) BIG=BIG14
      BIG15=ABS(DIRM(10)*GLI(2,J-1)/(2.*HHHH**2.))
      IF (BIG15.GT.BIG) BIG=BIG15
      BIG16=ABS(DIRM(10)*GLI(1,J+1)/(2.*HHHH**2.))
      IF (BIG16.GT.BIG) BIG=BIG16
      BIG17=ABS(DIRM(10)*GLI(1,J)/(HHHH**2.))
      IF (BIG17.GT.BIG) BIG=BIG17
      BIG18=ABS(DIRM(10)*GLI(1,J-1)/(2.*HHHH**2.))
      IF (BIG18.GT.BIG) BIG=BIG18
      BIG19=ABS(DIRM(14)*CBI(2,J+1)/(2.*HHHH**2.))
      IF (BIG19.GT.BIG) BIG=BIG19
      BIG20=ABS(DIRM(14)*CBI(2,J)/(HHHH**2.))
      IF (BIG20.GT.BIG) BIG=BIG20
      BIG21=ABS(DIRM(14)*CBI(2,J-1)/(2.*HHHH**2.))
      IF (BIG21.GT.BIG) BIG=BIG21
      BIG22=ABS(DIRM(14)*CBI(1,J+1)/(2.*HHHH**2.))
      IF (BIG22.GT.BIG) BIG=BIG22
      BIG23=ABS(DIRM(14)*CBI(1,J)/(HHHH**2.))
      IF (BIG23.GT.BIG) BIG=BIG23
      BIG24=ABS(DIRM(14)*CBI(1,J-1)/(2.*HHHH**2.))
      IF (BIG24.GT.BIG) BIG=BIG24
      BIG25=ABS(HYD(2,J)/DT)
      IF (BIG25.GT.BIG) BIG=BIG25
      BIG26=ABS(HYD(1,J)/DT)
      IF (BIG26.GT.BIG) BIG=BIG26
      BIG27=ABS(OHI(2,J)/DT)
      IF (BIG27.GT.BIG) BIG=BIG27
      BIG28=ABS(OHI(1,J)/DT)
      IF (BIG28.GT.BIG) BIG=BIG28
      BIG29=ABS(GLI(2,J)/DT)
      IF (BIG29.GT.BIG) BIG=BIG29
      BIG30=ABS(GLI(1,J)/DT)
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      IF (BIG30.GT.BIG) BIG=BIG30
      BIG31=ABS(CBI(2,J)/DT)
      IF (BIG31.GT.BIG) BIG=BIG31
      BIG32=ABS(CBI(1,J)/DT)
      IF (BIG32.GT.BIG) BIG=BIG32
      IF (ABS(G(16)).LT.BIG*EBIG) G(16)=0

c Water Dissociation
      G(17)=equilib9 -(HYD(2,J)+HYD(1,J))*(OHI(2,J)+OHI(1,J))/4.
      B(17,17)=(HYD(2,J)+HYD(1,J))/4.
      B(17,16)=(OHI(2,J)+OHI(1,J))/4.

      BIG=ABS(equilib9)
      BIG2=ABS(HYD(2,J)*OHI(2,J)/4.)
      IF (BIG2.GT.BIG) BIG=BIG2
      BIG3=ABS(HYD(2,J)*OHI(1,J)/4.)
      IF (BIG3.GT.BIG) BIG=BIG3
      BIG4=ABS(HYD(1,J)*OHI(2,J)/4.)
      IF (BIG4.GT.BIG) BIG=BIG4
      BIG5=ABS(HYD(1,J)*OHI(1,J)/4.)
      IF (BIG5.GT.BIG) BIG=BIG5
      IF (ABS(G(17)).LT.BIG*EBIG) G(17)=0

C CO2 Hydration

      G(18)=equilib7*(CO2(2,J)+CO2(1,J))/2.-(CBA(2,J)+CBA(1,J))/2.
      B(18,18)=-equilib7/2.
      B(18,19)=1./2.

      BIG=ABS(equilib7*CO2(2,J)/2.)
      BIG2=ABS(equilib7*CO2(1,J)/2.)
      IF (BIG2.GT.BIG) BIG=BIG2
      BIG3=ABS(CBA(2,J)/2.)
      IF (BIG3.GT.BIG) BIG=BIG3
      BIG4=ABS(CBA(1,J)/2.)
      IF (BIG4.GT.BIG) BIG=BIG4
      IF (ABS(G(18)).LT.BIG*EBIG) G(18)=0

C Carbonic acid dissociation

      G(19)=equilib8*(CBA(2,J)+CBA(1,J))/2.-(CBI(2,J)+CBI(1,J))
     1  *(HYD(2,J)+HYD(1,J))/4.
      B(19,19)=-equilib8/2.
      B(19,20)=(HYD(2,J)+HYD(1,J))/4.
      B(19,16)=(CBI(2,J)+CBI(1,J))/4.

      BIG=ABS(equilib8*CBA(2,J)/2.)
      BIG2=ABS(equilib8*CBA(1,J)/2.)
      IF (BIG2.GT.BIG) BIG=BIG2
      BIG3=ABS(CBI(2,J)*HYD(2,J)/4.)
      IF (BIG3.GT.BIG) BIG=BIG3
      BIG4=ABS(CBI(2,J)*HYD(1,J)/4.)
      IF (BIG4.GT.BIG) BIG=BIG4
      BIG5=ABS(CBI(1,J)*HYD(2,J)/4.)
      IF (BIG5.GT.BIG) BIG=BIG5
      BIG6=ABS(CBI(1,J)*HYD(1,J)/4.)
      IF (BIG6.GT.BIG) BIG=BIG6
      IF (ABS(G(19)).LT.BIG*EBIG) G(19)=0
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C FLUX OF CO2, CARBONIC ACID, BICARBONATE ION
      G(20)=DIRM(12)*(CO2(2,J+1)-2.*CO2(2,J)+CO2(2,J-1)
     1       +CO2(1,J+1)-2.*CO2(1,J)+CO2(1,J-1))/(2.*HHHH**2.)
     2   +DIRM(13)*(CBA(2,J+1)-2.*CBA(2,J)+CBA(2,J-1)
     3       +CBA(1,J+1)-2.*CBA(1,J)+CBA(1,J-1))/(2.*HHHH**2.)
     4   +DIRM(14)*(CBI(2,J+1)-2.*CBI(2,J)+CBI(2,J-1)
     5       +CBI(1,J+1)-2.*CBI(1,J)+CBI(1,J-1))/(2.*HHHH**2.)
     8   -(CO2(2,J)-CO2(1,J))/DT-(CBA(2,J)-CBA(1,J))/DT
     9   -(CBI(2,J)-CBI(1,J))/DT

      B(20,20)=DIRM(14)/HHHH**2.+1./DT
      D(20,20)=-DIRM(14)/(2.*HHHH**2.)
      A(20,20)=-DIRM(14)/(2.*HHHH**2.)
      B(20,18)=DIRM(12)/HHHH**2.+1./DT
      D(20,18)=-DIRM(12)/(2.*HHHH**2.)
      A(20,18)=-DIRM(12)/(2.*HHHH**2.)
      B(20,19)=DIRM(13)/HHHH**2.+1./DT
      D(20,19)=-DIRM(13)/(2.*HHHH**2.)
      A(20,19)=-DIRM(13)/(2.*HHHH**2.)


      BIG=ABS(DIRM(12)*(CO2(2,J+1))/(2.*HHHH**2.))
      BIG2=ABS(DIRM(12)*(CO2(2,J))/(HHHH**2.))
      IF (BIG2.GT.BIG) BIG=BIG2
      BIG3=ABS(DIRM(12)*(CO2(2,J-1))/(2.*HHHH**2.))
      IF (BIG3.GT.BIG) BIG=BIG3
      BIG4=ABS(DIRM(12)*(CO2(1,J+1))/(2.*HHHH**2.))
      IF (BIG4.GT.BIG) BIG=BIG4
      BIG5=ABS(DIRM(12)*(CO2(1,J))/(HHHH**2.))
      IF (BIG5.GT.BIG) BIG=BIG5
      BIG6=ABS(DIRM(12)*(CO2(1,J-1))/(2.*HHHH**2.))
      IF (BIG6.GT.BIG) BIG=BIG6
      BIG7=ABS(DIRM(13)*CBA(2,J+1)/(2.*HHHH**2.))
      IF (BIG7.GT.BIG) BIG=BIG7
      BIG8=ABS(DIRM(13)*CBA(2,J)/(HHHH**2.))
      IF (BIG8.GT.BIG) BIG=BIG8
      BIG9=ABS(DIRM(13)*CBA(2,J-1)/(2.*HHHH**2.))
      IF (BIG9.GT.BIG) BIG=BIG9
      BIG10=ABS(DIRM(13)*CBA(1,J+1)/(2.*HHHH**2.))
      IF (BIG10.GT.BIG) BIG=BIG10
      BIG11=ABS(DIRM(13)*CBA(1,J)/(HHHH**2.))
      IF (BIG11.GT.BIG) BIG=BIG11
      BIG12=ABS(DIRM(13)*CBA(1,J-1)/(2.*HHHH**2.))
      IF (BIG12.GT.BIG) BIG=BIG12
      BIG13=ABS(DIRM(14)*CBI(2,J+1)/(2.*HHHH**2.))
      IF (BIG13.GT.BIG) BIG=BIG13
      BIG14=ABS(DIRM(14)*CBI(2,J)/(HHHH**2.))
      IF (BIG14.GT.BIG) BIG=BIG14
      BIG15=ABS(DIRM(14)*CBI(2,J-1)/(2.*HHHH**2.))
      IF (BIG15.GT.BIG) BIG=BIG15
      BIG16=ABS(DIRM(14)*CBI(1,J+1)/(2.*HHHH**2.))
      IF (BIG16.GT.BIG) BIG=BIG16
      BIG17=ABS(DIRM(14)*CBI(1,J)/(HHHH**2.))
      IF (BIG17.GT.BIG) BIG=BIG17
      BIG18=ABS(DIRM(14)*CBI(1,J-1)/(2.*HHHH**2.))
      IF (BIG18.GT.BIG) BIG=BIG18
      BIG19=ABS(CO2(2,J)/DT)
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       IF (BIG19.GT.BIG) BIG=BIG19
       BIG20=ABS(CO2(1,J)/DT)
       IF (BIG20.GT.BIG) BIG=BIG20
       BIG21=ABS(CBA(2,J)/DT)
       IF (BIG21.GT.BIG) BIG=BIG21
       BIG22=ABS(CBA(1,J)/DT)
       IF (BIG22.GT.BIG) BIG=BIG22
       BIG23=ABS(CBI(2,J)/DT)
       IF (BIG23.GT.BIG) BIG=BIG23
       BIG24=ABS(CBI(1,J)/DT)
       IF (BIG24.GT.BIG) BIG=BIG24
       IF (ABS(G(20)).LT.BIG*EBIG) G(20)=0

C      For Acetaminophen
      G(21)=DIRM(16)*(ACE(2,J+1)-2.*ACE(2,J)+ACE(2,J-1)
     1      +ACE(1,J+1)-2.*ACE(1,J)+ACE(1,J-1))/(2.*HHHH**2.)
     2     -(ACE(2,J)-ACE(1,J))/DT

      B(21,21)=DIRM(16)/HHHH**2.+1./DT
      D(21,21)=-DIRM(16)/(2.*HHHH**2.)
      A(21,21)=-DIRM(16)/(2.*HHHH**2.)


       BIG=ABS(DIRM(16)*(ACE(2,J+1))/(2.*HHHH**2.))
       BIG2=ABS(DIRM(16)*(ACE(2,J))/(HHHH**2.))
       IF (BIG2.GT.BIG) BIG=BIG2
       BIG3=ABS(DIRM(16)*(ACE(2,J-1))/(2.*HHHH**2.))
       IF (BIG3.GT.BIG) BIG=BIG3
       BIG4=ABS(DIRM(16)*(ACE(1,J+1))/(2.*HHHH**2.))
       IF (BIG4.GT.BIG) BIG=BIG4
       BIG5=ABS(DIRM(16)*(ACE(1,J))/(HHHH**2.))
       IF (BIG5.GT.BIG) BIG=BIG5
       BIG6=ABS(DIRM(16)*(ACE(1,J-1))/(2.*HHHH**2.))
       IF (BIG6.GT.BIG) BIG=BIG6
       BIG7=ABS(ACE(2,J)/DT)
       IF (BIG7.GT.BIG) BIG=BIG7
       BIG8=ABS(ACE(1,J)/DT)
       IF (BIG8.GT.BIG) BIG=BIG8
       IF (ABS(G(21)).LT.BIG*EBIG) G(21)=0

c     INTERFACE VOLTAGE - DUMMY
      G(22)=(VDL(2,J)+VDL(1,J))/2.

      B(22,22)=-1./2.

       BIG=ABS(VDL(2,J)/2.)
       BIG2=ABS(VDL(1,J)/2.)
       IF (BIG2.GT.BIG) BIG=BIG2
       IF (ABS(G(22)).LT.BIG*EBIG) G(22)=0

      RETURN
      END

      SUBROUTINE COUPLERINS(J)
      IMPLICIT DOUBLE PRECISION (A-H, O-Z)
      COMMON/BAB/ A(22,22),B(22,22),C(22,80001),D(22,45),G(22),X(22,22)
     1 ,Y(22,22)
      COMMON/NSN/ N, NJ
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```fortran
      COMMON/GLC/ NTIME,LL
      COMMON/VAR/ DIFF(16),H,EBIG,HH,IJ ,KJ,TT,VAP,HHH,DT,RE,AKB,BB,CDL
      COMMON/VARR/ HHHH,HHHHH,MJ,LJ
      COMMON/DIN/ DGOX(16),DGLM(16),DIRM(16),DBULK(16)
      COMMON/SPCI/ GLU(2,80001),GOX(2,80001),GLA(2,80001),GOR(2,80001)
      COMMON/SPCII/ OXY(2,80001),HPR(2,80001),GOA(2,80001),GOP(2,80001)
      COMMON/RXT/ EQ1(2,80001),RGA(2,80001),EQ2(2,80001),RHP(2,80001)
      COMMON/SPCIII/ ANM(2,80001),GLUA(2,80001),GLI(2,80001)
      COMMON/SPCIV/ HYD(2,80001),OHI(2,80001),CO2(2,80001),CBA(2,80001)
      COMMON/SPCV/ CBI(2,80001),ACE(2,800001)
      COMMON/VOL/ VDL(2,80001)
      COMMON/POR/ POR1,POR2,PORGLU,PARION,PARACE
      COMMON/RTE/ ratef1,equilib1 ,ratef2 ,ratef3 ,equilib3 ,ratef4
      COMMON/RTD/ ratef5,equilib5 ,equilib6 ,equilib7 ,equilib8 ,equilib9
      COMMON/BUL/ CBULK(16),PARH2O2,PAR02,PARGLUCOSE,JCOUNT


C          DIMENSION  COEFF1,  COEFF3,  COEFF5,  COEFF6

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

      COEFF1HHH=DGOX(1)/(HHH)
      COEFF1HHHH=DIRM(1)/(HHHH)
      COEFF3HHH=DGOX(3)/(HHH)
      COEFF3HHHH=DIRM(3)/(HHHH)
      COEFF5HHH=DGOX(5)/(HHH)
      COEFF5HHHH=DIRM(5)/(HHHH)
      COEFF6HHH=DGOX(6)/(HHH)
      COEFF6HHHH=DIRM(6)/(HHHH)
      COEFF9HHH=DGOX(9)/(HHH)
      COEFF9HHHH=DIRM(9)/(HHHH)
      COEFF10HHH=DGOX(10)/(HHH)
      COEFF10HHHH=DIRM(10)/(HHHH)
      COEFF11HHH=DGOX(11)/(HHH)
      COEFF11HHHH=DIRM(11)/(HHHH)
      COEFF12HHH=DGOX(12)/(HHH)
      COEFF12HHHH=DIRM(12)/(HHHH)
      COEFF13HHH=DGOX(13)/(HHH)
      COEFF13HHHH=DIRM(13)/(HHHH)
      COEFF14HHH=DGOX(14)/(HHH)
      COEFF14HHHH=DIRM(14)/(HHHH)
      COEFF15HHH=DGOX(15)/(HHH)
      COEFF15HHHH=DIRM(15)/(HHHH)
      COEFF16HHH=DGOX(16)/(HHH)
      COEFF16HHHH=DIRM(16)/(HHHH)

C       For Glucose, being consumed only
      G(1)=COEFF1HHH/2.*(GLU(2,J+1)+GLU(1,J+1)-GLU(2,J)-GLU(1,J))
     1        -COEFF1HHHH/2.*(GLU(2,J)+GLU(1,J)-GLU(2,J-1)-GLU(1,J-1))
     2        -(HHH/2.)*(3.*(EQ1(2,J)+EQ1(1,J))+(EQ1(2,J+1)+EQ1(1,J+1)))/8.
     2        +(HHH/2.)*(3.*(ANM(2,J)+ANM(1,J))+(ANM(2,J+1)+ANM(1,J+1)))/8.
     3        +(HHHH/2.)*(3.*(ANM(2,J)+ANM(1,J))+(ANM(2,J-1)+ANM(1,J-1)))/8.
     4    -HHH/2.*(3.*(GLU(2,J)-GLU(1,J))+(GLU(2,J+1)-GLU(1,J+1)))/(4.*DT)
     5  -HHHH/2.*(3.*(GLU(2,J)-GLU(1,J))+(GLU(2,J-1)-GLU(1,J-1)))/(4.*DT)

      B(1,1)=COEFF1HHH/2.+COEFF1HHHH/2.
     1    +HHH/2.*3./(4.*DT)+HHHH/2.*3./(4.*DT)
      D(1,1)=-COEFF1HHH/2.+HHH/2./(4.*DT)
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      A(1,1)=-COEFF1HHHH/2.+HHHH/2./(4.*DT)
      B(1,9)=+(HHH/2.)*(3./8.)
      D(1,9)=+(HHH/2.)*(1./8.)
      B(1,13)=-(HHH/2.)*(3./8.)-(HHHH/2.)*(3./8.)
      D(1,13)=-(HHH/2.)*(1./8.)
      A(1,13)=-(HHHH/2.)*(1./8.)

      BIG=ABS(COEFF1HHH/2.*GLU(2,J+1))
      BIG2=ABS(COEFF1HHH/2.*GLU(1,J+1))
      IF (BIG2.GT.BIG) BIG=BIG2
      BIG3=ABS(COEFF1HHH/2.*GLU(2,J))
      IF (BIG3.GT.BIG) BIG=BIG3
      BIG4=ABS(COEFF1HHH/2.*GLU(1,J))
      IF (BIG4.GT.BIG) BIG=BIG4
      BIG5=ABS(COEFF1HHHH/2.*GLU(2,J))
      IF (BIG5.GT.BIG) BIG=BIG5
      BIG6=ABS(COEFF1HHHH/2.*GLU(1,J))
      IF (BIG6.GT.BIG) BIG=BIG6
      BIG7=ABS(COEFF1HHHH/2.*GLU(2,J-1))
      IF (BIG7.GT.BIG) BIG=BIG7
      BIG8=ABS(COEFF1HHHH/2.*GLU(1,J-1))
      IF (BIG8.GT.BIG) BIG=BIG8
      BIG9=ABS(HHH/2.*3.*EQ1(2,J)/8.)
      IF (BIG9.GT.BIG) BIG=BIG9
      BIG10=ABS(HHH/2.*3.*EQ1(1,J)/8.)
      IF (BIG10.GT.BIG) BIG=BIG10
      BIG11=ABS(HHH/2.*EQ1(2,J+1)/8.)
      IF (BIG11.GT.BIG) BIG=BIG11
      BIG12=ABS(HHH/2.*EQ1(1,J+1)/8.)
      IF (BIG12.GT.BIG) BIG=BIG12
      BIG17=ABS(HHH/2.*3.*GLU(2,J)/(4.*DT))
      IF (BIG17.GT.BIG) BIG=BIG17
      BIG18=ABS(HHH/2.*3.*GLU(1,J)/(4.*DT))
      IF (BIG18.GT.BIG) BIG=BIG18
      BIG19=ABS(HHH/2.*GLU(2,J+1)/(4.*DT))
      IF (BIG19.GT.BIG) BIG=BIG19
      BIG20=ABS(HHH/2.*GLU(1,J+1)/(4.*DT))
      IF (BIG20.GT.BIG) BIG=BIG20
      BIG21=ABS(HHHH/2.*3.*GLU(2,J)/(4.*DT))
      IF (BIG21.GT.BIG) BIG=BIG21
      BIG22=ABS(HHHH/2.*3.*GLU(1,J)/(4.*DT))
      IF (BIG22.GT.BIG) BIG=BIG22
      BIG23=ABS(HHHH/2.*GLU(2,J-1)/(4.*DT))
      IF (BIG23.GT.BIG) BIG=BIG23
      BIG24=ABS(HHHH/2.*GLU(1,J-1)/(4.*DT))
      IF (BIG24.GT.BIG) BIG=BIG24
      BIG25=ABS(HHH/2.*3.*ANM(2,J)/8.)
      IF (BIG25.GT.BIG) BIG=BIG25
      BIG26=ABS(HHH/2.*3.*ANM(1,J)/8.)
      IF (BIG26.GT.BIG) BIG=BIG26
      BIG27=ABS(HHH/2.*ANM(2,J+1)/8.)
      IF (BIG27.GT.BIG) BIG=BIG27
      BIG28=ABS(HHH/2.*ANM(1,J+1)/8.)
      IF (BIG28.GT.BIG) BIG=BIG28
      BIG29=ABS(HHHH/2.*3.*ANM(2,J)/8.)
      IF (BIG29.GT.BIG) BIG=BIG29
      BIG30=ABS(HHHH/2.*3.*ANM(1,J)/8.)
      IF (BIG30.GT.BIG) BIG=BIG30
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      BIG31=ABS(HHHH/2.*ANM(2,J-1)/8.)
      IF (BIG31.GT.BIG) BIG=BIG31
      BIG32=ABS(HHHH/2.*ANM(1,J-1)/8.)
      IF (BIG32.GT.BIG) BIG=BIG32
      IF (ABS(G(1)).LT.BIG*EBIG) G(1)=0

C       For GOx, enzyme
      G(2)=-(EQ1(2,J)+EQ1(1,J))/2.+(RHP(2,J)+RHP(1,J))/2.
     1  -(GOX(2,J)-GOX(1,J))/DT
      B(2,2)=+1./DT
      B(2,9)=+1./2.
      B(2,12)=-1./2.


      IF (ABS(EQ1(2,J)).GT.BIG) BIG=ABS(EQ1(2,J))
      IF (ABS(EQ1(1,J)).GT.BIG) BIG=ABS(EQ1(1,J))
      IF (ABS(RHP(2,J)).GT.BIG) BIG=ABS(RHP(2,J))
      IF (ABS(RHP(1,J)).GT.BIG) BIG=ABS(RHP(1,J))
      IF (ABS(GOX(2,J)/DT).GT.BIG) BIG=ABS(GOX(2,J)/DT)
      IF (ABS(GOX(1,J)/DT).GT.BIG) BIG=ABS(GOX(1,J)/DT)
      IF (ABS(G(2)).LT.BIG*EBIG) G(2)=0

C       For Gluconic Acid, being produced only Balanced by Gluconate Ion
      G(3)=COEFF3HHH/2.*(GLA(2,J+1)+GLA(1,J+1)-GLA(2,J)-GLA(1,J))
     1       -COEFF3HHHH/2.*(GLA(2,J)+GLA(1,J)-GLA(2,J-1)-GLA(1,J-1))
     2       +COEFF10HHH/2.*(GLI(2,J+1)+GLI(1,J+1)-GLI(2,J)-GLI(1,J))
     3       -COEFF10HHHH/2.*(GLI(2,J)+GLI(1,J)-GLI(2,J-1)-GLI(1,J-1))
     4       +(HHH/2.)*(3.*(RGA(2,J)+RGA(1,J))+(RGA(2,J+1)+RGA(1,J+1)))/8.
     6   -HHH/2.*(3.*(GLA(2,J)-GLA(1,J))+(GLA(2,J+1)-GLA(1,J+1)))/(4.*DT)
     7 -HHHH/2.*(3.*(GLA(2,J)-GLA(1,J))+(GLA(2,J-1)-GLA(1,J-1)))/(4.*DT)
     8   -HHH/2.*(3.*(GLI(2,J)-GLI(1,J))+(GLI(2,J+1)-GLI(1,J+1)))/(4.*DT)
     9 -HHHH/2.*(3.*(GLI(2,J)-GLI(1,J))+(GLI(2,J-1)-GLI(1,J-1)))/(4.*DT)

      B(3,3)=COEFF3HHH/2.+COEFF3HHHH/2.
     1 +HHH/2.*3./(4.*DT)+HHHH/2.*3./(4.*DT)
      D(3,3)=-COEFF3HHH/2.+HHH/2./(4.*DT)
      A(3,3)=-COEFF3HHHH/2.+HHHH/2./(4.*DT)
      B(3,10)=-(HHH/2.)*(3./8.)
      D(3,10)=-(HHH/2.)*(1./8.)
      B(3,15)=COEFF10HHH/2.+COEFF10HHHH/2.+HHH/2.*3./(4.*DT)
     1 +HHHH/2.*3./(4.*DT)
      D(3,15)=-COEFF10HHH/2.+HHH/2./(4.*DT)
      A(3,15)=-COEFF10HHHH/2.+HHHH/2./(4.*DT)


      BIG=ABS(COEFF3HHH/2.*GLA(2,J+1))
      BIG2=ABS(COEFF3HHH/2.*GLA(1,J+1))
      IF (BIG2.GT.BIG) BIG=BIG2
      BIG3=ABS(COEFF3HHH/2.*GLA(2,J))
      IF (BIG3.GT.BIG) BIG=BIG3
      BIG4=ABS(COEFF3HHH/2.*GLA(1,J))
      IF (BIG4.GT.BIG) BIG=BIG4
      BIG5=ABS(COEFF3HHHH/2.*GLA(2,J))
      IF (BIG5.GT.BIG) BIG=BIG5
      BIG6=ABS(COEFF3HHHH/2.*GLA(1,J))
      IF (BIG6.GT.BIG) BIG=BIG6
      BIG7=ABS(COEFF3HHHH/2.*GLA(2,J-1))
      IF (BIG7.GT.BIG) BIG=BIG7
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      BIG8=ABS(COEFF3HHHH/2.*GLA(1,J-1))
      IF (BIG8.GT.BIG) BIG=BIG8
      BIG9=ABS(HHH/2.*3.*RGA(2,J)/8.)
      IF (BIG9.GT.BIG) BIG=BIG9
      BIG10=ABS(HHH/2.*3.*RGA(1,J)/8.)
      IF (BIG10.GT.BIG) BIG=BIG10
      BIG11=ABS(HHH/2.*RGA(2,J+1)/8.)
      IF (BIG11.GT.BIG) BIG=BIG11
      BIG12=ABS(HHH/2.*RGA(1,J+1)/8.)
      IF (BIG12.GT.BIG) BIG=BIG12
      BIG17=ABS(HHH/2.*3.*GLA(2,J)/(4.*DT))
      IF (BIG17.GT.BIG) BIG=BIG17
      BIG18=ABS(HHH/2.*3.*GLA(1,J)/(4.*DT))
      IF (BIG18.GT.BIG) BIG=BIG18
      BIG19=ABS(HHH/2.*GLA(2,J+1)/(4.*DT))
      IF (BIG19.GT.BIG) BIG=BIG19
      BIG20=ABS(HHH/2.*GLA(1,J+1)/(4.*DT))
      IF (BIG20.GT.BIG) BIG=BIG20
      BIG21=ABS(HHHH/2.*3.*GLA(2,J)/(4.*DT))
      IF (BIG21.GT.BIG) BIG=BIG21
      BIG22=ABS(HHHH/2.*3.*GLA(1,J)/(4.*DT))
      IF (BIG22.GT.BIG) BIG=BIG22
      BIG23=ABS(HHHH/2.*GLA(2,J-1)/(4.*DT))
      IF (BIG23.GT.BIG) BIG=BIG23
      BIG24=ABS(HHHH/2.*GLA(1,J-1)/(4.*DT))
      IF (BIG24.GT.BIG) BIG=BIG24
      BIG25=ABS(COEFF10HHH/2.*GLI(2,J+1))
      IF (BIG25.GT.BIG) BIG=BIG25
      BIG26=ABS(COEFF10HHH/2.*GLI(1,J+1))
      IF (BIG26.GT.BIG) BIG=BIG26
      BIG27=ABS(COEFF10HHH/2.*GLI(2,J))
      IF (BIG27.GT.BIG) BIG=BIG27
      BIG28=ABS(COEFF10HHH/2.*GLI(1,J))
      IF (BIG28.GT.BIG) BIG=BIG28
      BIG29=ABS(COEFF10HHHH/2.*GLI(2,J))
      IF (BIG29.GT.BIG) BIG=BIG29
      BIG30=ABS(COEFF10HHHH/2.*GLI(1,J))
      IF (BIG30.GT.BIG) BIG=BIG30
      BIG31=ABS(COEFF10HHHH/2.*GLI(2,J-1))
      IF (BIG31.GT.BIG) BIG=BIG31
      BIG32=ABS(COEFF10HHHH/2.*GLI(1,J-1))
      IF (BIG32.GT.BIG) BIG=BIG32
      BIG33=ABS(HHH/2.*3.*GLI(2,J)/(4.*DT))
      IF (BIG33.GT.BIG) BIG=BIG33
      BIG34=ABS(HHH/2.*3.*GLI(1,J)/(4.*DT))
      IF (BIG34.GT.BIG) BIG=BIG34
      BIG35=ABS(HHH/2.*GLI(2,J+1)/(4.*DT))
      IF (BIG35.GT.BIG) BIG=BIG35
      BIG36=ABS(HHH/2.*GLI(1,J+1)/(4.*DT))
      IF (BIG36.GT.BIG) BIG=BIG36
      BIG37=ABS(HHHH/2.*3.*GLI(2,J)/(4.*DT))
      IF (BIG37.GT.BIG) BIG=BIG37
      BIG38=ABS(HHHH/2.*3.*GLI(1,J)/(4.*DT))
      IF (BIG38.GT.BIG) BIG=BIG38
      BIG39=ABS(HHHH/2.*GLI(2,J-1)/(4.*DT))
      IF (BIG39.GT.BIG) BIG=BIG39
      BIG40=ABS(HHHH/2.*GLI(1,J-1)/(4.*DT))
      IF (BIG40.GT.BIG) BIG=BIG40
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       IF (ABS(G(3)).LT.BIG*EBIG) G(3)=0

C      For GOx2, enzyme
      G(4)=CBULK(2)+CBULK(4)+CBULK(7)+CBULK(8)-(GOX(2,J)+GOX(1,J))/2.
     1 -(GOR(2,J)+GOR(1,J))/2.-(GOA(2,J)+GOA(1,J))/2.
     2 -(GOP(2,J)+GOP(1,J))/2.
      B(4,4)=+1./2.
      B(4,2)=+1./2.
      B(4,7)=+1./2.
      B(4,8)=+1./2.

      BIG=ABS(CBULK(2))
      IF (ABS(CBULK(4)).GT.BIG) BIG=ABS(CBULK(4))
      IF (ABS(CBULK(7)).GT.BIG) BIG=ABS(CBULK(7))
      IF (ABS(CBULK(8)).GT.BIG) BIG=ABS(CBULK(8))
      IF (ABS(GOX(2,J)/2.).GT.BIG) BIG=ABS(GOX(2,J)/2.)
      IF (ABS(GOX(1,J)/2.).GT.BIG) BIG=ABS(GOX(1,J)/2.)
      IF (ABS(GOR(2,J)/2.).GT.BIG) BIG=ABS(GOR(2,J)/2.)
      IF (ABS(GOR(1,J)/2.).GT.BIG) BIG=ABS(GOR(1,J)/2.)
      IF (ABS(GOA(2,J)/2.).GT.BIG) BIG=ABS(GOA(2,J)/2.)
      IF (ABS(GOA(1,J)/2.).GT.BIG) BIG=ABS(GOA(1,J)/2.)
      IF (ABS(GOP(2,J)/2.).GT.BIG) BIG=ABS(GOP(2,J)/2.)
      IF (ABS(GOP(1,J)/2.).GT.BIG) BIG=ABS(GOP(1,J)/2.)
      IF (ABS(G(4)).LT.BIG*EBIG) G(4)=0

C      For O2, being consumed only
      G(5)=COEFF5HHH/2.*(OXY(2,J+1)+OXY(1,J+1)-OXY(2,J)-OXY(1,J))
     1     -COEFF5HHHH/2.*(OXY(2,J)+OXY(1,J)-OXY(2,J-1)-OXY(1,J-1))
     2     -(HHH/2.)*(3.*(EQ2(2,J)+EQ2(1,J))+(EQ2(2,J+1)+EQ2(1,J+1)))/8.
     4  -HHH/2.*(3.*(OXY(2,J)-OXY(1,J))+(OXY(2,J+1)-OXY(1,J+1)))/(4.*DT)
     5 -HHHH/2.*(3.*(OXY(2,J)-OXY(1,J))+(OXY(2,J-1)-OXY(1,J-1)))/(4.*DT)

      B(5,5)=COEFF5HHH/2.+COEFF5HHHH/2.
     1 +HHH/2.*3./(4.*DT)+HHHH/2.*3./(4.*DT)
      D(5,5)=-COEFF5HHH/2.+HHH/2./(4.*DT)
      A(5,5)=-COEFF5HHHH/2.+HHHH/2./(4.*DT)
      B(5,11)=+(HHH/2.)*(3./8.)
      D(5,11)=+(HHH/2.)*(1./8.)


      BIG=ABS(COEFF5HHH/2.*OXY(2,J+1))
      BIG2=ABS(COEFF5HHH/2.*OXY(1,J+1))
      IF (BIG2.GT.BIG) BIG=BIG2
      BIG3=ABS(COEFF5HHH/2.*OXY(2,J))
      IF (BIG3.GT.BIG) BIG=BIG3
      BIG4=ABS(COEFF5HHH/2.*OXY(1,J))
      IF (BIG4.GT.BIG) BIG=BIG4
      BIG5=ABS(COEFF5HHHH/2.*OXY(2,J))
      IF (BIG5.GT.BIG) BIG=BIG5
      BIG6=ABS(COEFF5HHHH/2.*OXY(1,J))
      IF (BIG6.GT.BIG) BIG=BIG6
      BIG7=ABS(COEFF5HHHH/2.*OXY(2,J-1))
      IF (BIG7.GT.BIG) BIG=BIG7
      BIG8=ABS(COEFF5HHHH/2.*OXY(1,J-1))
      IF (BIG8.GT.BIG) BIG=BIG8
      BIG9=ABS(HHH/2.*3.*EQ2(2,J)/8.)
      IF (BIG9.GT.BIG) BIG=BIG9
      BIG10=ABS(HHH/2.*3.*EQ2(1,J)/8.)
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      IF (BIG10.GT.BIG) BIG=BIG10
      BIG11=ABS(HHH/2.*EQ2(2,J+1)/8.)
      IF (BIG11.GT.BIG) BIG=BIG11
      BIG12=ABS(HHH/2.*EQ2(1,J+1)/8.)
      IF (BIG12.GT.BIG) BIG=BIG12
      BIG17=ABS(HHH/2.*3.*OXY(2,J)/(4.*DT))
      IF (BIG17.GT.BIG) BIG=BIG17
      BIG18=ABS(HHH/2.*3.*OXY(1,J)/(4.*DT))
      IF (BIG18.GT.BIG) BIG=BIG18
      BIG19=ABS(HHH/2.*OXY(2,J+1)/(4.*DT))
      IF (BIG19.GT.BIG) BIG=BIG19
      BIG20=ABS(HHH/2.*OXY(1,J+1)/(4.*DT))
      IF (BIG20.GT.BIG) BIG=BIG20
      BIG21=ABS(HHHH/2.*3.*OXY(2,J)/(4.*DT))
      IF (BIG21.GT.BIG) BIG=BIG21
      BIG22=ABS(HHHH/2.*3.*OXY(1,J)/(4.*DT))
      IF (BIG22.GT.BIG) BIG=BIG22
      BIG23=ABS(HHHH/2.*OXY(2,J-1)/(4.*DT))
      IF (BIG23.GT.BIG) BIG=BIG23
      BIG24=ABS(HHHH/2.*OXY(1,J-1)/(4.*DT))
      IF (BIG24.GT.BIG) BIG=BIG24
      IF (ABS(G(5)).LT.BIG*EBIG) G(5)=0

C     For H2O2, reacting species
      G(6)=COEFF6HHH/2.*(HPR(2,J+1)+HPR(1,J+1)-HPR(2,J)-HPR(1,J))
     1    -COEFF6HHHH/2.*(HPR(2,J)+HPR(1,J)-HPR(2,J-1)-HPR(1,J-1))
     2    +(HHH/2.)*(3.*(RHP(2,J)+RHP(1,J))+(RHP(2,J+1)+RHP(1,J+1)))/8.
     4  -HHH/2.*(3.*(HPR(2,J)-HPR(1,J))+(HPR(2,J+1)-HPR(1,J+1)))/(4.*DT)
     5 -HHHH/2.*(3.*(HPR(2,J)-HPR(1,J))+(HPR(2,J-1)-HPR(1,J-1)))/(4.*DT)

      B(6,6)=COEFF6HHH/2.+COEFF6HHHH/2.
     1 +HHH/2.*3./(4.*DT)+HHHH/2.*3./(4.*DT)
      D(6,6)=-COEFF6HHH/2.+HHH/2./(4.*DT)
      A(6,6)=-COEFF6HHHH/2.+HHHH/2./(4.*DT)
      B(6,12)=-(HHH/2.)*(3./8.)
      D(6,12)=-(HHH/2.)*(1./8.)

      BIG=ABS(COEFF6HHH/2.*HPR(2,J+1))
      BIG2=ABS(COEFF6HHH/2.*HPR(1,J+1))
      IF (BIG2.GT.BIG) BIG=BIG2
      BIG3=ABS(COEFF6HHH/2.*HPR(2,J))
      IF (BIG3.GT.BIG) BIG=BIG3
      BIG4=ABS(COEFF6HHH/2.*HPR(1,J))
      IF (BIG4.GT.BIG) BIG=BIG4
      BIG5=ABS(COEFF6HHHH/2.*HPR(2,J))
      IF (BIG5.GT.BIG) BIG=BIG5
      BIG6=ABS(COEFF6HHHH/2.*HPR(1,J))
      IF (BIG6.GT.BIG) BIG=BIG6
      BIG7=ABS(COEFF6HHHH/2.*HPR(2,J-1))
      IF (BIG7.GT.BIG) BIG=BIG7
      BIG8=ABS(COEFF6HHHH/2.*HPR(1,J-1))
      IF (BIG8.GT.BIG) BIG=BIG8
      BIG9=ABS(HHH/2.*3.*RHP(2,J)/8.)
      IF (BIG9.GT.BIG) BIG=BIG9
      BIG10=ABS(HHH/2.*3.*RHP(1,J)/8.)
      IF (BIG10.GT.BIG) BIG=BIG10
      BIG11=ABS(HHH/2.*RHP(2,J+1)/8.)
      IF (BIG11.GT.BIG) BIG=BIG11
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      BIG12=ABS(HHH/2.*RHP(1,J+1)/8.)
      IF (BIG12.GT.BIG) BIG=BIG12
      BIG17=ABS(HHH/2.*3.*HPR(2,J)/(4.*DT))
      IF (BIG17.GT.BIG) BIG=BIG17
      BIG18=ABS(HHH/2.*3.*HPR(1,J)/(4.*DT))
      IF (BIG18.GT.BIG) BIG=BIG18
      BIG19=ABS(HHH/2.*HPR(2,J+1)/(4.*DT))
      IF (BIG19.GT.BIG) BIG=BIG19
      BIG20=ABS(HHH/2.*HPR(1,J+1)/(4.*DT))
      IF (BIG20.GT.BIG) BIG=BIG20
      BIG21=ABS(HHHH/2.*3.*HPR(2,J)/(4.*DT))
      IF (BIG21.GT.BIG) BIG=BIG21
      BIG22=ABS(HHHH/2.*3.*HPR(1,J)/(4.*DT))
      IF (BIG22.GT.BIG) BIG=BIG22
      BIG23=ABS(HHHH/2.*HPR(2,J-1)/(4.*DT))
      IF (BIG23.GT.BIG) BIG=BIG23
      BIG24=ABS(HHHH/2.*HPR(1,J-1)/(4.*DT))
      IF (BIG24.GT.BIG) BIG=BIG24
      IF (ABS(G(6)).LT.BIG*EBIG) G(6)=0

C     For CX-GOx2, enzyme
      G(7)=(EQ1(2,J)+EQ1(1,J))/2.-(RGA(2,J)+RGA(1,J))/2.
     1  -(GOA(2,J)-GOA(1,J))/DT

      B(7,7)=+1./DT
      B(7,9)=-1./2.
      B(7,10)=1./2.

      IF (ABS(EQ1(2,J)).GT.BIG) BIG=ABS(EQ1(2,J))
      IF (ABS(EQ1(1,J)).GT.BIG) BIG=ABS(EQ1(1,J))
      IF (ABS(RGA(2,J)).GT.BIG) BIG=ABS(RGA(2,J))
      IF (ABS(RGA(1,J)).GT.BIG) BIG=ABS(RGA(1,J))
      IF (ABS(GOA(2,J)/DT).GT.BIG) BIG=ABS(GOA(2,J)/DT)
      IF (ABS(GOA(1,J)/DT).GT.BIG) BIG=ABS(GOA(1,J)/DT)
      IF (ABS(G(7)).LT.BIG*EBIG) G(7)=0


C     For CX-GOx, enzyme
      G(8)=(EQ2(2,J)+EQ2(1,J))/2.-(RHP(2,J)+RHP(1,J))/2.
     1  -(GOP(2,J)-GOP(1,J))/DT
      B(8,8)=+1./DT
      B(8,11)=-1./2.
      B(8,12)=1./2.

      IF (ABS(EQ2(2,J)).GT.BIG) BIG=ABS(EQ2(2,J))
      IF (ABS(EQ2(1,J)).GT.BIG) BIG=ABS(EQ2(1,J))
      IF (ABS(RHP(2,J)).GT.BIG) BIG=ABS(RHP(2,J))
      IF (ABS(RHP(1,J)).GT.BIG) BIG=ABS(RHP(1,J))
      IF (ABS(GOP(2,J)/DT).GT.BIG) BIG=ABS(GOP(2,J)/DT)
      IF (ABS(GOP(1,J)/DT).GT.BIG) BIG=ABS(GOP(1,J)/DT)
      IF (ABS(G(8)).LT.BIG*EBIG) G(8)=0


C     REACTION1
  214 G(9)=-(EQ1(2,J)+EQ1(1,J))/2.
     1  +ratef1*((GLU(2,J)+GLU(1,J))*(GOX(2,J)+GOX(1,J))/4.
     2  -(GOA(2,J)+GOA(1,J))/2./equilib1)
      B(9,1)=-ratef1*(GOX(2,J)+GOX(1,J))/4.
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      B(9,2)=-ratef1*(GLU(2,J)+GLU(1,J))/4.
      B(9,7)=ratef1/2./equilib1
      B(9,9)=+1./2.

      BIG=ABS(EQ1(2,J)/2.)
      BIG2=ABS(EQ1(1,J)/2.)
      IF (BIG2.GT.BIG) BIG=BIG2
      BIG3=ABS(ratef1*GLU(2,J)*GOX(2,J)/4.)
      IF (BIG3.GT.BIG) BIG=BIG3
      BIG4=ABS(ratef1*GLU(1,J)*GOX(2,J)/4)
      IF (BIG4.GT.BIG) BIG=BIG4
      BIG5=ABS(ratef1*GLU(2,J)*GOX(1,J)/4)
      IF (BIG5.GT.BIG) BIG=BIG5
      BIG6=ABS(ratef1*GLU(1,J)*GOX(1,J)/4)
      IF (BIG6.GT.BIG) BIG=BIG6
      BIG7=ABS(ratef1*GOA(2,J)/2./equilib1)
      IF (BIG7.GT.BIG) BIG=BIG7
      BIG8=ABS(ratef1*GOA(1,J)/2./equilib1)
      IF (BIG8.GT.BIG) BIG=BIG8
      IF (ABS(G(9)).LT.BIG*EBIG) G(9)=0

C     REACTION2
  215 G(10)=-(RGA(2,J)+RGA(1,J))/2.+ratef2*(GOA(2,J)+GOA(1,J))/2.
      B(10,7)=-ratef2/2.
      B(10,10)=+1./2.

      BIG=ABS(RGA(2,J)/2.)
      BIG2=ABS(RGA(1,J)/2.)
      IF (BIG2.GT.BIG) BIG=BIG2
      BIG3=ABS(ratef2*GOA(2,J)/2.)
      IF (BIG3.GT.BIG) BIG=BIG3
      BIG4=ABS(ratef2*GOA(1,J)/2.)
      IF (BIG4.GT.BIG) BIG=BIG4
      IF (ABS(G(10)).LT.BIG*EBIG) G(10)=0

C     REACTION3
  216 G(11)=-(EQ2(2,J)+EQ2(1,J))/2.
     1 +ratef3*((GOR(2,J)+GOR(1,J))*(OXY(2,J)+OXY(1,J))/4.
     2 -(GOP(2,J)+GOP(1,J))/2./equilib3)
      B(11,4)=-ratef3*(OXY(2,J)+OXY(1,J))/4.
      B(11,5)=-ratef3*(GOR(2,J)+GOR(1,J))/4.
      B(11,8)=ratef3/2./equilib3
      B(11,11)=+1./2.

      BIG=ABS(EQ2(2,J)/2.)
      BIG2=ABS(EQ2(1,J)/2.)
      IF (BIG2.GT.BIG) BIG=BIG2
      BIG3=ABS(ratef3*GOR(2,J)*OXY(2,J)/4.)
      IF (BIG3.GT.BIG) BIG=BIG3
      BIG4=ABS(ratef3*GOR(1,J)*OXY(2,J)/4)
      IF (BIG4.GT.BIG) BIG=BIG4
      BIG5=ABS(ratef3*GOR(2,J)*OXY(1,J)/4)
      IF (BIG5.GT.BIG) BIG=BIG5
      BIG6=ABS(ratef3*GOR(1,J)*OXY(1,J)/4)
      IF (BIG6.GT.BIG) BIG=BIG6
      BIG7=ABS(ratef3*GOP(2,J)/2./EQUILIB3)
      IF (BIG7.GT.BIG) BIG=BIG7
      BIG8=ABS(ratef3*GOP(1,J)/2./EQUILIB3)
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      IF (BIG8.GT.BIG) BIG=BIG8
      IF (ABS(G(11)).LT.BIG*EBIG) G(11)=0

C     REACTION4
  217 G(12)=-(RHP(2,J)+RHP(1,J))/2.+ratef4*(GOP(2,J)+GOP(1,J))/2.
      B(12,8)=-ratef4/2.
      B(12,12)=+1./2.

      BIG=ABS(RHP(2,J)/2.)
      BIG2=ABS(RHP(1,J)/2.)
      IF (BIG2.GT.BIG) BIG=BIG2
      BIG3=ABS(ratef4*GOP(2,J)/2.)
      IF (BIG3.GT.BIG) BIG=BIG3
      BIG4=ABS(ratef4*GOP(1,J)/2.)
      IF (BIG4.GT.BIG) BIG=BIG4
      IF (ABS(G(12)).LT.BIG*EBIG) G(12)=0

C     REACTION5
  218 G(13)=-(ANM(2,J)+ANM(1,J))/2.+ratef5*((GLUA(2,J)+GLUA(1,J))/2.
     1   -(GLU(2,J)+GLU(1,J))/2./equilib5)
      B(13,1)=ratef5/2./equilib5
      B(13,14)=-ratef5/2.
      B(13,13)=+1./2.

      BIG=ABS(ANM(2,J)/2.)
      BIG2=ABS(ANM(1,J)/2.)
      IF (BIG2.GT.BIG) BIG=BIG2
      BIG3=ABS(ratef5*GLUA(2,J)/2.)
      IF (BIG3.GT.BIG) BIG=BIG3
      BIG4=ABS(ratef5*GLUA(1,J)/2.)
      IF (BIG4.GT.BIG) BIG=BIG4
      BIG5=ABS(ratef5*GLU(2,J)/2./equilib5)
      IF (BIG5.GT.BIG) BIG=BIG5
      BIG6=ABS(ratef5*GLU(1,J)/2./equilib5)
      IF (BIG6.GT.BIG) BIG=BIG6
      IF (ABS(G(13)).LT.BIG*EBIG) G(13)=0.0

C      For alpha Glucose, being consumed only
      G(14)=COEFF9HHH/2.*(GLUA(2,J+1)+GLUA(1,J+1)-GLUA(2,J)-GLUA(1,J))
     1      -COEFF9HHHH/2.*(GLUA(2,J)+GLUA(1,J)-GLUA(2,J-1)-GLUA(1,J-1))
     2      -(HHH/2.) *(3.*(ANM(2,J)+ANM(1,J)) +(ANM(2,J+1)+ANM(1,J+1)))/8.
     3      -(HHHH/2.) *(3.*(ANM(2,J)+ANM(1,J)) +(ANM(2,J-1)+ANM(1,J-1)))/8.
     4      -HHH/2.
     5      *(3.*(GLUA(2,J)-GLUA(1,J)) +(GLUA(2,J+1)-GLUA(1,J+1)))/(4.*DT)
     6      -HHHH/2.
     7      *(3.*(GLUA(2,J)-GLUA(1,J)) +(GLUA(2,J-1)-GLUA(1,J-1)))/(4.*DT)

      B(14,14)=COEFF9HHH/2.+COEFF9HHHH/2.+HHH/2.*3./(4.*DT)
     1 +HHHH/2.*3./(4.*DT)
      D(14,14)=-COEFF9HHH/2.+HHH/2./(4.*DT)
      A(14,14)=-COEFF9HHHH/2.+HHHH/2./(4.*DT)
      B(14,13)=+(HHH/2.) *(3./8.) +(HHHH/2.) *(3./8.)
      D(14,13)=+(HHH/2.) *(1./8.)
      A(14,13)=+(HHHH/2.) *(1./8.)

      BIG=ABS(COEFF9HHH/2.*GLUA(2,J+1))
      BIG2=ABS(COEFF9HHH/2.*GLUA(1,J+1))
      IF (BIG2.GT.BIG) BIG=BIG2
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      BIG3=ABS(COEFF9HHH/2.*GLUA(2,J))
      IF (BIG3.GT.BIG) BIG=BIG3
      BIG4=ABS(COEFF9HHH/2.*GLUA(1,J))
      IF (BIG4.GT.BIG) BIG=BIG4
      BIG5=ABS(COEFF9HHHH/2.*GLUA(2,J))
      IF (BIG5.GT.BIG) BIG=BIG5
      BIG6=ABS(COEFF9HHHH/2.*GLUA(1,J))
      IF (BIG6.GT.BIG) BIG=BIG6
      BIG7=ABS(COEFF9HHHH/2.*GLUA(2,J-1))
      IF (BIG7.GT.BIG) BIG=BIG7
      BIG8=ABS(COEFF9HHHH/2.*GLUA(1,J-1))
      IF (BIG8.GT.BIG) BIG=BIG8
      BIG9=ABS(HHH/2.*3.*GLUA(2,J)/(4.*DT))
      IF (BIG9.GT.BIG) BIG=BIG9
      BIG10=ABS(HHH/2.*3.*GLUA(1,J)/(4.*DT))
      IF (BIG10.GT.BIG) BIG=BIG10
      BIG11=ABS(HHH/2.*GLUA(2,J+1)/(4.*DT))
      IF (BIG11.GT.BIG) BIG=BIG11
      BIG12=ABS(HHH/2.*GLUA(1,J+1)/(4.*DT))
      IF (BIG12.GT.BIG) BIG=BIG12
      BIG13=ABS(HHHH/2.*3.*GLUA(2,J)/(4.*DT))
      IF (BIG13.GT.BIG) BIG=BIG13
      BIG14=ABS(HHHH/2.*3.*GLUA(1,J)/(4.*DT))
      IF (BIG14.GT.BIG) BIG=BIG14
      BIG15=ABS(HHHH/2.*GLUA(2,J-1)/(4.*DT))
      IF (BIG15.GT.BIG) BIG=BIG15
      BIG16=ABS(HHHH/2.*GLUA(1,J-1)/(4.*DT))
      IF (BIG16.GT.BIG) BIG=BIG16
      BIG17=ABS(HHH/2.*3.*ANM(2,J)/8.)
      IF (BIG17.GT.BIG) BIG=BIG17
      BIG18=ABS(HHH/2.*3.*ANM(1,J)/8.)
      IF (BIG18.GT.BIG) BIG=BIG18
      BIG19=ABS(HHH/2.*ANM(2,J+1)/8.)
      IF (BIG19.GT.BIG) BIG=BIG19
      BIG20=ABS(HHH/2.*ANM(1,J+1)/8.)
      IF (BIG20.GT.BIG) BIG=BIG20
      BIG21=ABS(HHHH/2.*3.*ANM(2,J)/8.)
      IF (BIG21.GT.BIG) BIG=BIG21
      BIG22=ABS(HHHH/2.*3.*ANM(1,J)/8.)
      IF (BIG22.GT.BIG) BIG=BIG22
      BIG23=ABS(HHHH/2.*ANM(2,J-1)/8.)
      IF (BIG23.GT.BIG) BIG=BIG23
      BIG24=ABS(HHHH/2.*ANM(1,J-1)/8.)
      IF (BIG24.GT.BIG) BIG=BIG24
      IF (ABS(G(14)).LT.BIG*EBIG) G(14)=0

C Gluconic acid dissociation

      G(15)=equilib6*(GLA(2,J)+GLA(1,J))/2.-(GLI(2,J)+GLI(1,J))*
     1  (HYD(2,J)+HYD(1,J))/4.
      B(15,3)=-equilib6/2.
      B(15,15)=(HYD(2,J)+HYD(1,J))/4.
      B(15,16)=(GLI(2,J)+GLI(1,J))/4.

      BIG=ABS(equilib6*GLA(2,J)/2.)
      BIG2=ABS(equilib6*GLA(1,J)/2.)
      IF (BIG2.GT.BIG) BIG=BIG2
      BIG3=ABS(GLI(2,J)*HYD(2,J)/4.)
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       IF (BIG3.GT.BIG) BIG=BIG3
       BIG4=ABS(GLI(2,J)*HYD(1,J)/4)
       IF (BIG4.GT.BIG) BIG=BIG4
       BIG5=ABS(GLI(1,J)*HYD(2,J)/4)
       IF (BIG5.GT.BIG) BIG=BIG5
       BIG6=ABS(GLI(1,J)*HYD(1,J)/4)
       IF (BIG6.GT.BIG) BIG=BIG6
       IF (ABS(G(15)).LT.BIG*EBIG) G(15)=0

C Hydrogen ion, hydroxide ion, gluconate ion, bicarbonate ion flux
      G(16)=COEFF11HHH/2.*(HYD(2,J+1)+HYD(1,J+1)-HYD(2,J)-HYD(1,J))
     1        -COEFF11HHHH/2.*(HYD(2,J)+HYD(1,J)-HYD(2,J-1)-HYD(1,J-1))
     2        -COEFF15HHH/2.*(OHI(2,J+1)+OHI(1,J+1)-OHI(2,J)-OHI(1,J))
     3        +COEFF15HHHH/2.*(OHI(2,J)+OHI(1,J)-OHI(2,J-1)-OHI(1,J-1))
     4        -COEFF10HHH/2.*(GLI(2,J+1)+GLI(1,J+1)-GLI(2,J)-GLI(1,J))
     5        +COEFF10HHHH/2.*(GLI(2,J)+GLI(1,J)-GLI(2,J-1)-GLI(1,J-1))
     6        -COEFF14HHH/2.*(CBI(2,J+1)+CBI(1,J+1)-CBI(2,J)-CBI(1,J))
     7        +COEFF14HHHH/2.*(CBI(2,J)+CBI(1,J)-CBI(2,J-1)-CBI(1,J-1))
     8   -HHH/2.*(3.*(HYD(2,J)-HYD(1,J))+(HYD(2,J+1)-HYD(1,J+1)))/(4.*DT)
     9 -HHHH/2.*(3.*(HYD(2,J)-HYD(1,J))+(HYD(2,J-1)-HYD(1,J-1)))/(4.*DT)
     1   +HHH/2.*(3.*(OHI(2,J)-OHI(1,J))+(OHI(2,J+1)-OHI(1,J+1)))/(4.*DT)
     2 +HHHH/2.*(3.*(OHI(2,J)-OHI(1,J))+(OHI(2,J-1)-OHI(1,J-1)))/(4.*DT)
     3   +HHH/2.*(3.*(GLI(2,J)-GLI(1,J))+(GLI(2,J+1)-GLI(1,J+1)))/(4.*DT)
     4 +HHHH/2.*(3.*(GLI(2,J)-GLI(1,J))+(GLI(2,J-1)-GLI(1,J-1)))/(4.*DT)
     5   +HHH/2.*(3.*(CBI(2,J)-CBI(1,J))+(CBI(2,J+1)-CBI(1,J+1)))/(4.*DT)
     6 +HHHH/2.*(3.*(CBI(2,J)-CBI(1,J))+(CBI(2,J-1)-CBI(1,J-1)))/(4.*DT)

      B(16,16)=COEFF11HHH/2.+COEFF11HHHH/2.+HHH/2.*3./(4.*DT)
     1 +HHHH/2.*3./(4.*DT)
      D(16,16)=-COEFF11HHH/2.+HHH/2./(4.*DT)
      A(16,16)=-COEFF11HHHH/2.+HHHH/2./(4.*DT)

      B(16,17)=-COEFF15HHH/2.-COEFF15HHHH/2.-HHH/2.*3./(4.*DT)
     1 -HHHH/2.*3./(4.*DT)
      D(16,17)=+COEFF15HHH/2.-HHH/2./(4.*DT)
      A(16,17)=+COEFF15HHHH/2.-HHHH/2./(4.*DT)

      B(16,15)=-COEFF10HHH/2.-COEFF10HHHH/2.-HHH/2.*3./(4.*DT)
     1 -HHHH/2.*3./(4.*DT)
      D(16,15)=+COEFF10HHH/2.-HHH/2./(4.*DT)
      A(16,15)=+COEFF10HHHH/2.-HHHH/2./(4.*DT)

      B(16,20)=-COEFF14HHH/2.-COEFF14HHHH/2.-HHH/2.*3./(4.*DT)
     1 -HHHH/2.*3./(4.*DT)
      D(16,20)=+COEFF14HHH/2.-HHH/2./(4.*DT)
      A(16,20)=+COEFF14HHHH/2.-HHHH/2./(4.*DT)

       BIG=ABS(COEFF11HHH/2.*HYD(2,J+1))
       BIG2=ABS(COEFF11HHH/2.*HYD(1,J+1))
       IF (BIG2.GT.BIG) BIG=BIG2
       BIG3=ABS(COEFF11HHH/2.*HYD(2,J))
       IF (BIG3.GT.BIG) BIG=BIG3
       BIG4=ABS(COEFF11HHH/2.*HYD(1,J))
       IF (BIG4.GT.BIG) BIG=BIG4
       BIG5=ABS(COEFF11HHHH/2.*HYD(2,J))
       IF (BIG5.GT.BIG) BIG=BIG5
       BIG6=ABS(COEFF11HHHH/2.*HYD(1,J))
       IF (BIG6.GT.BIG) BIG=BIG6
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      BIG7=ABS(COEFF11HHHH/2.*HYD(2,J-1))
      IF  (BIG7.GT.BIG)  BIG=BIG7
      BIG8=ABS(COEFF11HHHH/2.*HYD(1,J-1))
      IF  (BIG8.GT.BIG)  BIG=BIG8
      BIG9=ABS(HHH/2.*3.*HYD(2,J)/(4.*DT))
      IF  (BIG9.GT.BIG)  BIG=BIG9
      BIG10=ABS(HHH/2.*3.*HYD(1,J)/(4.*DT))
      IF  (BIG10.GT.BIG)  BIG=BIG10
      BIG11=ABS(HHH/2.*HYD(2,J+1)/(4.*DT))
      IF  (BIG11.GT.BIG)  BIG=BIG11
      BIG12=ABS(HHH/2.*HYD(1,J+1)/(4.*DT))
      IF  (BIG12.GT.BIG)  BIG=BIG12
      BIG13=ABS(HHHH/2.*3.*HYD(2,J)/(4.*DT))
      IF  (BIG13.GT.BIG)  BIG=BIG13
      BIG14=ABS(HHHH/2.*3.*HYD(1,J)/(4.*DT))
      IF  (BIG14.GT.BIG)  BIG=BIG14
      BIG15=ABS(HHHH/2.*HYD(2,J-1)/(4.*DT))
      IF  (BIG15.GT.BIG)  BIG=BIG15
      BIG16=ABS(HHHH/2.*HYD(1,J-1)/(4.*DT))
      IF  (BIG16.GT.BIG)  BIG=BIG16
      BIG17=ABS(COEFF15HHH/2.*OHI(2,J+1))
      IF  (BIG17.GT.BIG)  BIG=BIG17
      BIG18=ABS(COEFF15HHH/2.*OHI(1,J+1))
      IF  (BIG18.GT.BIG)  BIG=BIG18
      BIG19=ABS(COEFF15HHH/2.*OHI(2,J))
      IF  (BIG19.GT.BIG)  BIG=BIG19
      BIG20=ABS(COEFF15HHH/2.*OHI(1,J))
      IF  (BIG20.GT.BIG)  BIG=BIG20
      BIG21=ABS(COEFF15HHHH/2.*OHI(2,J))
      IF  (BIG21.GT.BIG)  BIG=BIG21
      BIG22=ABS(COEFF15HHHH/2.*OHI(1,J))
      IF  (BIG22.GT.BIG)  BIG=BIG22
      BIG23=ABS(COEFF15HHHH/2.*OHI(2,J-1))
      IF  (BIG23.GT.BIG)  BIG=BIG23
      BIG24=ABS(COEFF15HHHH/2.*OHI(1,J-1))
      IF  (BIG24.GT.BIG)  BIG=BIG24
      BIG25=ABS(HHH/2.*3.*OHI(2,J)/(4.*DT))
      IF  (BIG25.GT.BIG)  BIG=BIG25
      BIG26=ABS(HHH/2.*3.*OHI(1,J)/(4.*DT))
      IF  (BIG26.GT.BIG)  BIG=BIG26
      BIG27=ABS(HHH/2.*OHI(2,J+1)/(4.*DT))
      IF  (BIG27.GT.BIG)  BIG=BIG27
      BIG28=ABS(HHH/2.*OHI(1,J+1)/(4.*DT))
      IF  (BIG28.GT.BIG)  BIG=BIG28
      BIG29=ABS(HHHH/2.*3.*OHI(2,J)/(4.*DT))
      IF  (BIG29.GT.BIG)  BIG=BIG29
      BIG30=ABS(HHHH/2.*3.*OHI(1,J)/(4.*DT))
      IF  (BIG30.GT.BIG)  BIG=BIG30
      BIG31=ABS(HHHH/2.*OHI(2,J-1)/(4.*DT))
      IF  (BIG31.GT.BIG)  BIG=BIG31
      BIG32=ABS(HHHH/2.*OHI(1,J-1)/(4.*DT))
      IF  (BIG32.GT.BIG)  BIG=BIG32
      BIG33=ABS(COEFF10HHH/2.*GLI(2,J+1))
      IF  (BIG33.GT.BIG)  BIG=BIG33
      BIG34=ABS(COEFF10HHH/2.*GLI(1,J+1))
      IF  (BIG34.GT.BIG)  BIG=BIG34
      BIG35=ABS(COEFF10HHH/2.*GLI(2,J))
      IF  (BIG35.GT.BIG)  BIG=BIG35
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      BIG36=ABS(COEFF10HHH/2.*GLI(1,J))
      IF (BIG36.GT.BIG) BIG=BIG36
      BIG37=ABS(COEFF10HHHH/2.*GLI(2,J))
      IF (BIG37.GT.BIG) BIG=BIG37
      BIG38=ABS(COEFF10HHHH/2.*GLI(1,J))
      IF (BIG38.GT.BIG) BIG=BIG38
      BIG39=ABS(COEFF10HHHH/2.*GLI(2,J-1))
      IF (BIG39.GT.BIG) BIG=BIG39
      BIG40=ABS(COEFF10HHHH/2.*GLI(1,J-1))
      IF (BIG40.GT.BIG) BIG=BIG40
      BIG41=ABS(HHH/2.*3.*GLI(2,J)/(4.*DT))
      IF (BIG41.GT.BIG) BIG=BIG41
      BIG42=ABS(HHH/2.*3.*GLI(1,J)/(4.*DT))
      IF (BIG42.GT.BIG) BIG=BIG42
      BIG43=ABS(HHH/2.*GLI(2,J+1)/(4.*DT))
      IF (BIG43.GT.BIG) BIG=BIG43
      BIG44=ABS(HHH/2.*GLI(1,J+1)/(4.*DT))
      IF (BIG44.GT.BIG) BIG=BIG44
      BIG45=ABS(HHHH/2.*3.*GLI(2,J)/(4.*DT))
      IF (BIG45.GT.BIG) BIG=BIG45
      BIG46=ABS(HHHH/2.*3.*GLI(1,J)/(4.*DT))
      IF (BIG46.GT.BIG) BIG=BIG46
      BIG47=ABS(HHHH/2.*GLI(2,J-1)/(4.*DT))
      IF (BIG47.GT.BIG) BIG=BIG47
      BIG48=ABS(HHHH/2.*GLI(1,J-1)/(4.*DT))
      IF (BIG48.GT.BIG) BIG=BIG48
      BIG49=ABS(COEFF14HHH/2.*CBI(2,J+1))
      IF (BIG49.GT.BIG) BIG=BIG49
      BIG50=ABS(COEFF14HHH/2.*CBI(1,J+1))
      IF (BIG50.GT.BIG) BIG=BIG50
      BIG51=ABS(COEFF14HHH/2.*CBI(2,J))
      IF (BIG51.GT.BIG) BIG=BIG51
      BIG52=ABS(COEFF14HHH/2.*CBI(1,J))
      IF (BIG52.GT.BIG) BIG=BIG52
      BIG53=ABS(COEFF14HHHH/2.*CBI(2,J))
      IF (BIG53.GT.BIG) BIG=BIG53
      BIG54=ABS(COEFF14HHHH/2.*CBI(1,J))
      IF (BIG54.GT.BIG) BIG=BIG54
      BIG55=ABS(COEFF14HHHH/2.*CBI(2,J-1))
      IF (BIG55.GT.BIG) BIG=BIG55
      BIG56=ABS(COEFF14HHHH/2.*CBI(1,J-1))
      IF (BIG56.GT.BIG) BIG=BIG56
      BIG57=ABS(HHH/2.*3.*CBI(2,J)/(4.*DT))
      IF (BIG57.GT.BIG) BIG=BIG57
      BIG58=ABS(HHH/2.*3.*CBI(1,J)/(4.*DT))
      IF (BIG58.GT.BIG) BIG=BIG58
      BIG59=ABS(HHH/2.*CBI(2,J+1)/(4.*DT))
      IF (BIG59.GT.BIG) BIG=BIG59
      BIG60=ABS(HHH/2.*CBI(1,J+1)/(4.*DT))
      IF (BIG60.GT.BIG) BIG=BIG60
      BIG61=ABS(HHHH/2.*3.*CBI(2,J)/(4.*DT))
      IF (BIG61.GT.BIG) BIG=BIG61
      BIG62=ABS(HHHH/2.*3.*CBI(1,J)/(4.*DT))
      IF (BIG62.GT.BIG) BIG=BIG62
      BIG63=ABS(HHHH/2.*CBI(2,J-1)/(4.*DT))
      IF (BIG63.GT.BIG) BIG=BIG63
      BIG64=ABS(HHHH/2.*CBI(1,J-1)/(4.*DT))
      IF (BIG64.GT.BIG) BIG=BIG64
```

```
      IF (ABS(G(16)).LT.BIG*EBIG) G(16)=0

c Water Dissociation
      G(17)=equilib9-(HYD(2,J)+HYD(1,J))*(OHI(2,J)+OHI(1,J))/4.
      B(17,17)=(HYD(2,J)+HYD(1,J))/4.
      B(17,16)=(OHI(2,J)+OHI(1,J))/4.

      BIG=ABS(equilib9)
      BIG2=ABS(HYD(2,J)*OHI(2,J)/4.)
      IF (BIG2.GT.BIG) BIG=BIG2
      BIG3=ABS(HYD(2,J)*OHI(1,J)/4.)
      IF (BIG3.GT.BIG) BIG=BIG3
      BIG4=ABS(HYD(1,J)*OHI(2,J)/4.)
      IF (BIG4.GT.BIG) BIG=BIG4
      BIG5=ABS(HYD(1,J)*OHI(1,J)/4.)
      IF (BIG5.GT.BIG) BIG=BIG5
      IF (ABS(G(17)).LT.BIG*EBIG) G(17)=0

C CO2 Hydration

      G(18)=equilib7*(CO2(2,J)+CO2(1,J))/2.-(CBA(2,J)+CBA(1,J))/2.
      B(18,18)=-equilib7/2.
      B(18,19)=1./2.

      BIG=ABS(equilib7*CO2(2,J)/2.)
      BIG2=ABS(equilib7*CO2(1,J)/2.)
      IF (BIG2.GT.BIG) BIG=BIG2
      BIG3=ABS(CBA(2,J)/2.)
      IF (BIG3.GT.BIG) BIG=BIG3
      BIG4=ABS(CBA(1,J)/2.)
      IF (BIG4.GT.BIG) BIG=BIG4
      IF (ABS(G(18)).LT.BIG*EBIG) G(18)=0

C Carbonic acid dissociation

      G(19)=equilib8*(CBA(2,J)+CBA(1,J))/2.-(CBI(2,J)+CBI(1,J))
     1 *(HYD(2,J)+HYD(1,J))/4.
      B(19,19)=-equilib8/2.
      B(19,20)=(HYD(2,J)+HYD(1,J))/4.
      B(19,16)=(CBI(2,J)+CBI(1,J))/4.

      BIG=ABS(equilib8*CBA(2,J)/2.)
      BIG2=ABS(equilib8*CBA(1,J)/2.)
      IF (BIG2.GT.BIG) BIG=BIG2
      BIG3=ABS(CBI(2,J)*HYD(2,J)/4.)
      IF (BIG3.GT.BIG) BIG=BIG3
      BIG4=ABS(CBI(2,J)*HYD(1,J)/4.)
      IF (BIG4.GT.BIG) BIG=BIG4
      BIG5=ABS(CBI(1,J)*HYD(2,J)/4.)
      IF (BIG5.GT.BIG) BIG=BIG5
      BIG6=ABS(CBI(1,J)*HYD(1,J)/4.)
      IF (BIG6.GT.BIG) BIG=BIG6
      IF (ABS(G(19)).LT.BIG*EBIG) G(19)=0

C FLUX OF CO2, CARBONIC ACID, BICARBONATE ION
      G(20)=COEFF12HHH/2.*(CO2(2,J+1)+CO2(1,J+1)-CO2(2,J)-CO2(1,J))
     1     -COEFF12HHHH/2.*(CO2(2,J)+CO2(1,J)-CO2(2,J-1)-CO2(1,J-1))
     2     +COEFF13HHH/2.*(CBA(2,J+1)+CBA(1,J+1)-CBA(2,J)-CBA(1,J))
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     3        -COEFF13HHHH/2.*(CBA(2,J)+CBA(1,J)-CBA(2,J-1)-CBA(1,J-1))
     4        +COEFF14HHH/2.*(CBI(2,J+1)+CBI(1,J+1)-CBI(2,J)-CBI(1,J))
     5        -COEFF14HHHH/2.*(CBI(2,J)+CBI(1,J)-CBI(2,J-1)-CBI(1,J-1))
     6   -HHH/2.*(3.*(CO2(2,J)-CO2(1,J))+(CO2(2,J+1)-CO2(1,J+1)))/(4.*DT)
     7 -HHHH/2.*(3.*(CO2(2,J)-CO2(1,J))+(CO2(2,J-1)-CO2(1,J-1)))/(4.*DT)
     8   -HHH/2.*(3.*(CBA(2,J)-CBA(1,J))+(CBA(2,J+1)-CBA(1,J+1)))/(4.*DT)
     9 -HHHH/2.*(3.*(CBA(2,J)-CBA(1,J))+(CBA(2,J-1)-CBA(1,J-1)))/(4.*DT)
     1   -HHH/2.*(3.*(CBI(2,J)-CBI(1,J))+(CBI(2,J+1)-CBI(1,J+1)))/(4.*DT)
     2 -HHHH/2.*(3.*(CBI(2,J)-CBI(1,J))+(CBI(2,J-1)-CBI(1,J-1)))/(4.*DT)

      B(20,20)=COEFF14HHH/2.+COEFF14HHHH/2.+HHH/2.*3./(4.*DT)
     1 +HHHH/2.*3./(4.*DT)
      D(20,20)=-COEFF14HHH/2.+HHH/2./(4.*DT)
      A(20,20)=-COEFF14HHHH/2.+HHHH/2./(4.*DT)
      B(20,18)=COEFF12HHH/2.+COEFF12HHHH/2.+HHH/2.*3./(4.*DT)
     1 +HHHH/2.*3./(4.*DT)
      D(20,18)=-COEFF12HHH/2.+HHH/2./(4.*DT)
      A(20,18)=-COEFF12HHHH/2.+HHHH/2./(4.*DT)
      B(20,19)=COEFF13HHH/2.+COEFF13HHHH/2.+HHH/2.*3./(4.*DT)
     1 +HHHH/2.*3./(4.*DT)
      D(20,19)=-COEFF13HHH/2.+HHH/2./(4.*DT)
      A(20,19)=-COEFF13HHHH/2.+HHHH/2./(4.*DT)

      BIG=ABS(COEFF12HHH/2.*CO2(2,J+1))
      BIG2=ABS(COEFF12HHH/2.*CO2(1,J+1))
      IF (BIG2.GT.BIG) BIG=BIG2
      BIG3=ABS(COEFF12HHH/2.*CO2(2,J))
      IF (BIG3.GT.BIG) BIG=BIG3
      BIG4=ABS(COEFF12HHH/2.*CO2(1,J))
      IF (BIG4.GT.BIG) BIG=BIG4
      BIG5=ABS(COEFF12HHHH/2.*CO2(2,J))
      IF (BIG5.GT.BIG) BIG=BIG5
      BIG6=ABS(COEFF12HHHH/2.*CO2(1,J))
      IF (BIG6.GT.BIG) BIG=BIG6
      BIG7=ABS(COEFF12HHHH/2.*CO2(2,J-1))
      IF (BIG7.GT.BIG) BIG=BIG7
      BIG8=ABS(COEFF12HHHH/2.*CO2(1,J-1))
      IF (BIG8.GT.BIG) BIG=BIG8
      BIG9=ABS(HHH/2.*3.*CO2(2,J)/(4.*DT))
      IF (BIG9.GT.BIG) BIG=BIG9
      BIG10=ABS(HHH/2.*3.*CO2(1,J)/(4.*DT))
      IF (BIG10.GT.BIG) BIG=BIG10
      BIG11=ABS(HHH/2.*CO2(2,J+1)/(4.*DT))
      IF (BIG11.GT.BIG) BIG=BIG11
      BIG12=ABS(HHH/2.*CO2(1,J+1)/(4.*DT))
      IF (BIG12.GT.BIG) BIG=BIG12
      BIG13=ABS(HHHH/2.*3.*CO2(2,J)/(4.*DT))
      IF (BIG13.GT.BIG) BIG=BIG13
      BIG14=ABS(HHHH/2.*3.*CO2(1,J)/(4.*DT))
      IF (BIG14.GT.BIG) BIG=BIG14
      BIG15=ABS(HHHH/2.*CO2(2,J-1)/(4.*DT))
      IF (BIG15.GT.BIG) BIG=BIG15
      BIG16=ABS(HHHH/2.*CO2(1,J-1)/(4.*DT))
      IF (BIG16.GT.BIG) BIG=BIG16
      BIG17=ABS(COEFF13HHH/2.*CBA(2,J+1))
      IF (BIG17.GT.BIG) BIG=BIG17
      BIG18=ABS(COEFF13HHH/2.*CBA(1,J+1))
      IF (BIG18.GT.BIG) BIG=BIG18
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      BIG19=ABS(COEFF13HHH/2.*CBA(2,J))
      IF (BIG19.GT.BIG) BIG=BIG19
      BIG20=ABS(COEFF13HHH/2.*CBA(1,J))
      IF (BIG20.GT.BIG) BIG=BIG20
      BIG21=ABS(COEFF13HHHH/2.*CBA(2,J))
      IF (BIG21.GT.BIG) BIG=BIG21
      BIG22=ABS(COEFF13HHHH/2.*CBA(1,J))
      IF (BIG22.GT.BIG) BIG=BIG22
      BIG23=ABS(COEFF13HHHH/2.*CBA(2,J-1))
      IF (BIG23.GT.BIG) BIG=BIG23
      BIG24=ABS(COEFF13HHHH/2.*CBA(1,J-1))
      IF (BIG24.GT.BIG) BIG=BIG24
      BIG25=ABS(HHH/2.*3.*CBA(2,J)/(4.*DT))
      IF (BIG25.GT.BIG) BIG=BIG25
      BIG26=ABS(HHH/2.*3.*CBA(1,J)/(4.*DT))
      IF (BIG26.GT.BIG) BIG=BIG26
      BIG27=ABS(HHH/2.*CBA(2,J+1)/(4.*DT))
      IF (BIG27.GT.BIG) BIG=BIG27
      BIG28=ABS(HHH/2.*CBA(1,J+1)/(4.*DT))
      IF (BIG28.GT.BIG) BIG=BIG28
      BIG29=ABS(HHHH/2.*3.*CBA(2,J)/(4.*DT))
      IF (BIG29.GT.BIG) BIG=BIG29
      BIG30=ABS(HHHH/2.*3.*CBA(1,J)/(4.*DT))
      IF (BIG30.GT.BIG) BIG=BIG30
      BIG31=ABS(HHHH/2.*CBA(2,J-1)/(4.*DT))
      IF (BIG31.GT.BIG) BIG=BIG31
      BIG32=ABS(HHHH/2.*CBA(1,J-1)/(4.*DT))
      IF (BIG32.GT.BIG) BIG=BIG32
      BIG33=ABS(COEFF14HHH/2.*CBI(2,J+1))
      IF (BIG33.GT.BIG) BIG=BIG33
      BIG34=ABS(COEFF14HHH/2.*CBI(1,J+1))
      IF (BIG34.GT.BIG) BIG=BIG34
      BIG35=ABS(COEFF14HHH/2.*CBI(2,J))
      IF (BIG35.GT.BIG) BIG=BIG35
      BIG36=ABS(COEFF14HHH/2.*CBI(1,J))
      IF (BIG36.GT.BIG) BIG=BIG36
      BIG37=ABS(COEFF14HHHH/2.*CBI(2,J))
      IF (BIG37.GT.BIG) BIG=BIG37
      BIG38=ABS(COEFF14HHHH/2.*CBI(1,J))
      IF (BIG38.GT.BIG) BIG=BIG38
      BIG39=ABS(COEFF14HHHH/2.*CBI(2,J-1))
      IF (BIG39.GT.BIG) BIG=BIG39
      BIG40=ABS(COEFF14HHHH/2.*CBI(1,J-1))
      IF (BIG40.GT.BIG) BIG=BIG40
      BIG41=ABS(HHH/2.*3.*CBI(2,J)/(4.*DT))
      IF (BIG41.GT.BIG) BIG=BIG41
      BIG42=ABS(HHH/2.*3.*CBI(1,J)/(4.*DT))
      IF (BIG42.GT.BIG) BIG=BIG42
      BIG43=ABS(HHH/2.*CBI(2,J+1)/(4.*DT))
      IF (BIG43.GT.BIG) BIG=BIG43
      BIG44=ABS(HHH/2.*CBI(1,J+1)/(4.*DT))
      IF (BIG44.GT.BIG) BIG=BIG44
      BIG45=ABS(HHHH/2.*3.*CBI(2,J)/(4.*DT))
      IF (BIG45.GT.BIG) BIG=BIG45
      BIG46=ABS(HHHH/2.*3.*CBI(1,J)/(4.*DT))
      IF (BIG46.GT.BIG) BIG=BIG46
      BIG47=ABS(HHHH/2.*CBI(2,J-1)/(4.*DT))
      IF (BIG47.GT.BIG) BIG=BIG47
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       BIG48=ABS(HHHH/2.*CBI(1,J-1)/(4.*DT))
       IF (BIG48.GT.BIG) BIG=BIG48
       IF (ABS(G(20)).LT.BIG*EBIG) G(20)=0

C FOR ACETAMINOPHEN

      G(21)=COEFF16HHH/2.*(ACE(2,J+1)+ACE(1,J+1)-ACE(2,J)-ACE(1,J))
     1      -COEFF16HHHH/2.*(ACE(2,J)+ACE(1,J)-ACE(2,J-1)-ACE(1,J-1))
     4   -HHH/2.*(3.*(ACE(2,J)-ACE(1,J))+(ACE(2,J+1)-ACE(1,J+1)))/(4.*DT)
     5  -HHHH/2.*(3.*(ACE(2,J)-ACE(1,J))+(ACE(2,J-1)-ACE(1,J-1)))/(4.*DT)

      B(21,21)=COEFF16HHH/2.+COEFF16HHHH/2.
     1 +HHH/2.*3./(4.*DT)+HHHH/2.*3./(4.*DT)
      D(21,21)=-COEFF16HHH/2.+HHH/2./(4.*DT)
      A(21,21)=-COEFF16HHHH/2.+HHHH/2./(4.*DT)



       BIG=ABS(COEFF16HHH/2.*ACE(2,J+1))
       BIG2=ABS(COEFF16HHH/2.*ACE(1,J+1))
       IF (BIG2.GT.BIG) BIG=BIG2
       BIG3=ABS(COEFF16HHH/2.*ACE(2,J))
       IF (BIG3.GT.BIG) BIG=BIG3
       BIG4=ABS(COEFF16HHH/2.*ACE(1,J))
       IF (BIG4.GT.BIG) BIG=BIG4
       BIG5=ABS(COEFF16HHHH/2.*ACE(2,J))
       IF (BIG5.GT.BIG) BIG=BIG5
       BIG6=ABS(COEFF16HHHH/2.*ACE(1,J))
       IF (BIG6.GT.BIG) BIG=BIG6
       BIG7=ABS(COEFF16HHHH/2.*ACE(2,J-1))
       IF (BIG7.GT.BIG) BIG=BIG7
       BIG8=ABS(COEFF16HHHH/2.*ACE(1,J-1))
       IF (BIG8.GT.BIG) BIG=BIG8
       BIG17=ABS(HHH/2.*3.*ACE(2,J)/(4.*DT))
       IF (BIG17.GT.BIG) BIG=BIG17
       BIG18=ABS(HHH/2.*3.*ACE(1,J)/(4.*DT))
       IF (BIG18.GT.BIG) BIG=BIG18
       BIG19=ABS(HHH/2.*ACE(2,J+1)/(4.*DT))
       IF (BIG19.GT.BIG) BIG=BIG19
       BIG20=ABS(HHH/2.*ACE(1,J+1)/(4.*DT))
       IF (BIG20.GT.BIG) BIG=BIG20
       BIG21=ABS(HHHH/2.*3.*ACE(2,J)/(4.*DT))
       IF (BIG21.GT.BIG) BIG=BIG21
       BIG22=ABS(HHHH/2.*3.*ACE(1,J)/(4.*DT))
       IF (BIG22.GT.BIG) BIG=BIG22
       BIG23=ABS(HHHH/2.*ACE(2,J-1)/(4.*DT))
       IF (BIG23.GT.BIG) BIG=BIG23
       BIG24=ABS(HHHH/2.*ACE(1,J-1)/(4.*DT))
       IF (BIG24.GT.BIG) BIG=BIG24
       IF (ABS(G(21)).LT.BIG*EBIG) G(21)=0

C      DOUBLE LAYER VOLTAGE DUMMY VARIABLE

      G(22)=(VDL(2,J)+VDL(1,J))/2.

      B(22,22)=-1./2.

       BIG=ABS(VDL(2,J)/2.)
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```
      BIG2=ABS(VDL(1,J)/2.)
      IF (BIG2.GT.BIG) BIG=BIG2
      IF (ABS(G(22)).LT.BIG*EBIG) G(22)=0


C     212 WRITE(12,301) J, (G(K),K=1,N)
      RETURN
      END


      SUBROUTINE REACTION(J)
      IMPLICIT DOUBLE PRECISION (A-H, O-Z)
      COMMON/BAB/ A(22,22),B(22,22),C(22,80001),D(22,45),G(22),X(22,22)
     1   ,Y(22,22)
      COMMON/NSN/ N, NJ
      COMMON/GLC/ NTIME,LL
      COMMON/VAR/ DIFF(16),H,EBIG,HH,IJ ,KJ,TT,VAP,HHH,DT,RE,AKB,BB,CDL
      COMMON/VARR/ HHHH,HHHHH,MJ,LJ
      COMMON/DIN/ DGOX(16),DGLM(16),DIRM(16),DBULK(16)
      COMMON/SPCI/ GLU(2,80001),GOX(2,80001),GLA(2,80001),GOR(2,80001)
      COMMON/SPCII/ OXY(2,80001),HPR(2,80001),GOA(2,80001),GOP(2,80001)
      COMMON/RXT/ EQ1(2,80001),RGA(2,80001),EQ2(2,80001),RHP(2,80001)
      COMMON/SPCIII/ ANM(2,80001),GLUA(2,80001),GLI(2,80001)
      COMMON/SPCIV/ HYD(2,80001),OHI(2,80001),CO2(2,80001),CBA(2,80001)
      COMMON/SPCV/ CBI(2,80001),ACE(2,800001)
      COMMON/VOL/ VDL(2,80001)
      COMMON/POR/ POR1,POR2,PORGLU,PARION,PARACE
      COMMON/RTE/ ratef1,equilib1,ratef2,ratef3,equilib3,ratef4
      COMMON/RTD/ ratef5,equilib5,equilib6,equilib7,equilib8,equilib9
      COMMON/BUL/ CBULK(16),PARH2O2,PAR02,PARGLUCOSE,JCOUNT

  301 FORMAT (5x,'J=' I5,   13E18.9)

C      For Glucose, being consumed only
      G(1)=DGOX(1)*(GLU(2,J+1)-2.*GLU(2,J)+GLU(2,J-1)
     1      +GLU(1,J+1)-2.*GLU(1,J)+GLU(1,J-1))/(2.*HHH**2.)
     2    +(ANM(2,J)+ANM(1,J))/2.
     3    -(EQ1(2,J)+EQ1(1,J))/2.-(GLU(2,J)-GLU(1,J))/DT

      B(1,1)=DGOX(1)/HHH**2.+1./DT
      D(1,1)=-DGOX(1)/(2.*HHH**2.)
      A(1,1)=-DGOX(1)/(2.*HHH**2.)
      B(1,9)=+1./2.
      B(1,13)=-1./2.

      BIG=ABS(DGOX(1)*(GLU(2,J+1))/(2.*HHH**2.))
      BIG2=ABS(DGOX(1)*(GLU(2,J))/(HHH**2.))
      IF (BIG2.GT.BIG) BIG=BIG2
      BIG3=ABS(DGOX(1)*(GLU(2,J-1))/(2.*HHH**2.))
      IF (BIG3.GT.BIG) BIG=BIG3
      BIG4=ABS(DGOX(1)*(GLU(1,J+1))/(2.*HHH**2.))
      IF (BIG4.GT.BIG) BIG=BIG4
      BIG5=ABS(DGOX(1)*(GLU(1,J))/(HHH**2.))
      IF (BIG5.GT.BIG) BIG=BIG5
      BIG6=ABS(DGOX(1)*(GLU(1,J-1))/(2.*HHH**2.))
      IF (BIG6.GT.BIG) BIG=BIG6
      BIG7=ABS(EQ1(2,J)/2.)
      IF (BIG7.GT.BIG) BIG=BIG7
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      BIG8=ABS(EQ1(1,J)/2.)
      IF (BIG8.GT.BIG) BIG=BIG8
      BIG9=ABS(GLU(2,J)/DT)
      IF (BIG9.GT.BIG) BIG=BIG9
      BIG10=ABS(GLU(1,J)/DT)
      IF (BIG10.GT.BIG) BIG=BIG10
      BIG11=ABS(ANM(2,J)/2.)
      IF (BIG11.GT.BIG) BIG=BIG11
      BIG12=ABS(ANM(1,J)/2.)
      IF (BIG12.GT.BIG) BIG=BIG12
      IF (ABS(G(1)).LT.BIG*EBIG) G(1)=0

C     For GOx, enzyme
      G(2)=-(EQ1(2,J)+EQ1(1,J))/2.+(RHP(2,J)+RHP(1,J))/2.
     1 -(GOX(2,J)-GOX(1,J))/DT
      B(2,2)=+1./DT
      B(2,9)=+1./2.
      B(2,12)=-1./2.


      IF (ABS(EQ1(2,J)).GT.BIG) BIG=ABS(EQ1(2,J))
      IF (ABS(EQ1(1,J)).GT.BIG) BIG=ABS(EQ1(1,J))
      IF (ABS(RHP(2,J)).GT.BIG) BIG=ABS(RHP(2,J))
      IF (ABS(RHP(1,J)).GT.BIG) BIG=ABS(RHP(1,J))
      IF (ABS(GOX(2,J)/DT).GT.BIG) BIG=ABS(GOX(2,J)/DT)
      IF (ABS(GOX(1,J)/DT).GT.BIG) BIG=ABS(GOX(1,J)/DT)
      IF (ABS(G(2)).LT.BIG*EBIG) G(2)=0

C     For Gluconic Acid, being produced only
      G(3)=DGOX(3)*(GLA(2,J+1)-2.*GLA(2,J)+GLA(2,J-1)
     1      +GLA(1,J+1)-2.*GLA(1,J)+GLA(1,J-1))/(2.*HHH**2.)
     2      +DGOX(10)*(GLI(2,J+1)-2.*GLI(2,J)+GLI(2,J-1)
     3      +GLI(1,J+1)-2.*GLI(1,J)+GLI(1,J-1))/(2.*HHH**2.)
     4      +(RGA(2,J)+RGA(1,J))/2.-(GLA(2,J)-GLA(1,J))/DT
     5      -(GLI(2,J)-GLI(1,J))/DT

      B(3,3)=DGOX(3)/HHH**2.+1./DT
      B(3,10)=-1./2.
      D(3,3)=-DGOX(3)/(2.*HHH**2.)
      A(3,3)=-DGOX(3)/(2.*HHH**2.)
      B(3,15)=DGOX(10)/HHH**2.+1./DT
      D(3,15)=-DGOX(10)/(2.*HHH**2.)
      A(3,15)=-DGOX(10)/(2.*HHH**2.)

      BIG=ABS(DGOX(3)*GLA(2,J+1)/(2.*HHH**2.))
      BIG2=ABS(DGOX(3)*GLA(2,J)/(HHH**2.))
      IF (BIG2.GT.BIG) BIG=BIG2
      BIG3=ABS(DGOX(3)*GLA(2,J-1)/(2.*HHH**2.))
      IF (BIG3.GT.BIG) BIG=BIG3
      BIG4=ABS(DGOX(3)*GLA(1,J+1)/(2.*HHH**2.))
      IF (BIG4.GT.BIG) BIG=BIG4
      BIG5=ABS(DGOX(3)*GLA(1,J)/(HHH**2.))
      IF (BIG5.GT.BIG) BIG=BIG5
      BIG6=ABS(DGOX(3)*GLA(1,J-1)/(2.*HHH**2.))
      IF (BIG6.GT.BIG) BIG=BIG6
      BIG7=ABS(DGOX(10)*GLI(2,J+1)/(2.*HHH**2.))
      IF (BIG7.GT.BIG) BIG=BIG7
      BIG8=ABS(DGOX(10)*GLI(2,J)/(HHH**2.))
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      IF (BIG8.GT.BIG)  BIG=BIG8
      BIG9=ABS(DGOX(10)*GLI(2,J-1)/(2.*HHH**2.))
      IF (BIG9.GT.BIG)  BIG=BIG9
      BIG10=ABS(DGOX(10)*GLI(1,J+1)/(2.*HHH**2.))
      IF (BIG10.GT.BIG)  BIG=BIG10
      BIG11=ABS(DGOX(10)*GLI(1,J)/(HHH**2.))
      IF (BIG11.GT.BIG)  BIG=BIG11
      BIG12=ABS(DGOX(10)*GLI(1,J-1)/(2.*HHH**2.))
      IF (BIG12.GT.BIG)  BIG=BIG12
      BIG13=ABS(RGA(2,J)/2.)
      IF (BIG13.GT.BIG)  BIG=BIG13
      BIG14=ABS(RGA(1,J)/2)
      IF (BIG14.GT.BIG)  BIG=BIG14
      BIG15=ABS(GLA(2,J)/DT)
      IF (BIG15.GT.BIG)  BIG=BIG15
      BIG16=ABS(GLA(1,J)/DT)
      IF (BIG16.GT.BIG)  BIG=BIG16
      BIG17=ABS(GLI(2,J)/DT)
      IF (BIG17.GT.BIG)  BIG=BIG17
      BIG18=ABS(GLI(1,J)/DT)
      IF (BIG18.GT.BIG)  BIG=BIG18
      IF (ABS(G(3)).LT.BIG*EBIG)  G(3)=0

      G(4)=CBULK(2)+CBULK(4)+CBULK(7)+CBULK(8)-(GOX(2,J)+GOX(1,J))/2.
     1  -(GOR(2,J)+GOR(1,J))/2.-(GOA(2,J)+GOA(1,J))/2.
     2  -(GOP(2,J)+GOP(1,J))/2.
      B(4,4)=+1./2.
      B(4,2)=+1./2.
      B(4,7)=+1./2.
      B(4,8)=+1./2.

      BIG=ABS(CBULK(2))
      IF (ABS(CBULK(4)).GT.BIG)  BIG=ABS(CBULK(4))
      IF (ABS(CBULK(7)).GT.BIG)  BIG=ABS(CBULK(7))
      IF (ABS(CBULK(8)).GT.BIG)  BIG=ABS(CBULK(8))
      IF (ABS(GOX(2,J)/2.).GT.BIG)  BIG=ABS(GOX(2,J)/2.)
      IF (ABS(GOX(1,J)/2.).GT.BIG)  BIG=ABS(GOX(1,J)/2.)
      IF (ABS(GOR(2,J)/2.).GT.BIG)  BIG=ABS(GOR(2,J)/2.)
      IF (ABS(GOR(1,J)/2.).GT.BIG)  BIG=ABS(GOR(1,J)/2.)
      IF (ABS(GOA(2,J)/2.).GT.BIG)  BIG=ABS(GOA(2,J)/2.)
      IF (ABS(GOA(1,J)/2.).GT.BIG)  BIG=ABS(GOA(1,J)/2.)
      IF (ABS(GOP(2,J)/2.).GT.BIG)  BIG=ABS(GOP(2,J)/2.)
      IF (ABS(GOP(1,J)/2.).GT.BIG)  BIG=ABS(GOP(1,J)/2.)
      IF (ABS(G(4)).LT.BIG*EBIG)  G(4)=0


C     For O2,  being  consumed  only,  Diff(5), OXY,G5,EQ2
      G(5)=DGOX(5)*(OXY(2,J+1)-2.*OXY(2,J)+OXY(2,J-1)
     1       +OXY(1,J+1)-2.*OXY(1,J)+OXY(1,J-1))/(2.*HHH**2.)
     2        -(EQ2(2,J)+EQ2(1,J))/2.-(OXY(2,J)-OXY(1,J))/DT


      B(5,5)=DGOX(5)/HHH**2.+1./DT
      B(5,11)=1./2.
      D(5,5)=-DGOX(5)/(2.*HHH**2.)
      A(5,5)=-DGOX(5)/(2.*HHH**2.)


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      BIG=ABS(DGOX(5)*OXY(2,J+1)/(2.*HHH**2.))
      BIG2=ABS(DGOX(5)*OXY(2,J)/(HHH**2.))
      IF (BIG2.GT.BIG) BIG=BIG2
      BIG3=ABS(DGOX(5)*OXY(2,J-1)/(2.*HHH**2.))
      IF (BIG3.GT.BIG) BIG=BIG3
      BIG4=ABS(DGOX(5)*OXY(1,J+1)/(2.*HHH**2.))
      IF (BIG4.GT.BIG) BIG=BIG4
      BIG5=ABS(DGOX(5)*OXY(1,J)/(HHH**2.))
      IF (BIG5.GT.BIG) BIG=BIG5
      BIG6=ABS(DGOX(5)*OXY(1,J-1)/(2.*HHH**2.))
      IF (BIG6.GT.BIG) BIG=BIG6
      BIG7=ABS(EQ2(2,J)/2.)
      IF (BIG7.GT.BIG) BIG=BIG7
      BIG8=ABS(EQ2(1,J)/2)
      IF (BIG8.GT.BIG) BIG=BIG8
      BIG9=ABS(OXY(2,J)/DT)
      IF (BIG9.GT.BIG) BIG=BIG9
      BIG10=ABS(OXY(1,J)/DT)
      IF (BIG10.GT.BIG) BIG=BIG10
      IF (ABS(G(5)).LT.BIG*EBIG) G(5)=0

C     For H2O2, reacting species,DIFF(6),H202,RHP,G6
      G(6)=DGOX(6)*(HPR(2,J+1)-2.*HPR(2,J)+HPR(2,J-1)
     1     +HPR(1,J+1)-2.*HPR(1,J)+HPR(1,J-1))/(2.*HHH**2.)
     2     +(RHP(2,J)+RHP(1,J))/2.-(HPR(2,J)-HPR(1,J))/DT


      B(6,6)=DGOX(6)/HHH**2.+1./DT
      B(6,12)=-1./2.
      D(6,6)=-DGOX(6)/(2.*HHH**2.)
      A(6,6)=-DGOX(6)/(2.*HHH**2.)


      BIG=ABS(DGOX(6)*HPR(2,J+1)/(2.*HHH**2.))
      BIG2=ABS(DGOX(6)*HPR(2,J)/(HHH**2.))
      IF (BIG2.GT.BIG) BIG=BIG2
      BIG3=ABS(DGOX(6)*HPR(2,J-1)/(2.*HHH**2.))
      IF (BIG3.GT.BIG) BIG=BIG3
      BIG4=ABS(DGOX(6)*HPR(1,J+1)/(2.*HHH**2.))
      IF (BIG4.GT.BIG) BIG=BIG4
      BIG5=ABS(DGOX(6)*HPR(1,J)/(HHH**2.))
      IF (BIG5.GT.BIG) BIG=BIG5
      BIG6=ABS(DGOX(6)*HPR(1,J-1)/(2.*HHH**2.))
      IF (BIG6.GT.BIG) BIG=BIG6
      BIG7=ABS(RHP(2,J)/2.)
      IF (BIG7.GT.BIG) BIG=BIG7
      BIG8=ABS(RHP(1,J)/2)
      IF (BIG8.GT.BIG) BIG=BIG8
      BIG9=ABS(HPR(2,J)/DT)
      IF (BIG9.GT.BIG) BIG=BIG9
      BIG10=ABS(HPR(1,J)/DT)
      IF (BIG10.GT.BIG) BIG=BIG10
      IF (ABS(G(6)).LT.BIG*EBIG) G(6)=0

C     For CX-GOx2, enzyme
      G(7)=(EQ1(2,J)+EQ1(1,J))/2.-(RGA(2,J)+RGA(1,J))/2.
     1 -(GOA(2,J)-GOA(1,J))/DT

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      B(7,7)=+1./DT
      B(7,9)=-1./2.
      B(7,10)=1./2.

      IF (ABS(EQ1(2,J)).GT.BIG) BIG=ABS(EQ1(2,J))
      IF (ABS(EQ1(1,J)).GT.BIG) BIG=ABS(EQ1(1,J))
      IF (ABS(RGA(2,J)).GT.BIG) BIG=ABS(RGA(2,J))
      IF (ABS(RGA(1,J)).GT.BIG) BIG=ABS(RGA(1,J))
      IF (ABS(GOA(2,J)/DT).GT.BIG) BIG=ABS(GOA(2,J)/DT)
      IF (ABS(GOA(1,J)/DT).GT.BIG) BIG=ABS(GOA(1,J)/DT)
      IF (ABS(G(7)).LT.BIG*EBIG) G(7)=0

C     For CX-GOx, enzyme
      G(8)=(EQ2(2,J)+EQ2(1,J))/2.-(RHP(2,J)+RHP(1,J))/2.
     1 -(GOP(2,J)-GOP(1,J))/DT
      B(8,8)=+1./DT
      B(8,11)=-1./2.
      B(8,12)=1./2.

      IF (ABS(EQ2(2,J)).GT.BIG) BIG=ABS(EQ2(2,J))
      IF (ABS(EQ2(1,J)).GT.BIG) BIG=ABS(EQ2(1,J))
      IF (ABS(RHP(2,J)).GT.BIG) BIG=ABS(RHP(2,J))
      IF (ABS(RHP(1,J)).GT.BIG) BIG=ABS(RHP(1,J))
      IF (ABS(GOP(2,J)/DT).GT.BIG) BIG=ABS(GOP(2,J)/DT)
      IF (ABS(GOP(1,J)/DT).GT.BIG) BIG=ABS(GOP(1,J)/DT)
      IF (ABS(G(8)).LT.BIG*EBIG) G(8)=0


C     REACTION1
  214 G(9)=-(EQ1(2,J)+EQ1(1,J))/2.
     1 +ratef1*((GLU(2,J)+GLU(1,J))*(GOX(2,J)+GOX(1,J))/4.
     2 -(GOA(2,J)+GOA(1,J))/2./equilib1)
      B(9,1)=-ratef1*(GOX(2,J)+GOX(1,J))/4.
      B(9,2)=-ratef1*(GLU(2,J)+GLU(1,J))/4.
      B(9,7)=ratef1/2./equilib1
      B(9,9)=+1./2.

      BIG=ABS(EQ1(2,J)/2.)
      BIG2=ABS(EQ1(1,J)/2.)
      IF (BIG2.GT.BIG) BIG=BIG2
      BIG3=ABS(ratef1*GLU(2,J)*GOX(2,J)/4.)
      IF (BIG3.GT.BIG) BIG=BIG3
      BIG4=ABS(ratef1*GLU(1,J)*GOX(2,J)/4)
      IF (BIG4.GT.BIG) BIG=BIG4
      BIG5=ABS(ratef1*GLU(2,J)*GOX(1,J)/4)
      IF (BIG5.GT.BIG) BIG=BIG5
      BIG6=ABS(ratef1*GLU(1,J)*GOX(1,J)/4)
      IF (BIG6.GT.BIG) BIG=BIG6
      BIG7=ABS(ratef1*GOA(2,J)/2./equilib1)
      IF (BIG7.GT.BIG) BIG=BIG7
      BIG8=ABS(ratef1*GOA(1,J)/2./equilib1)
      IF (BIG8.GT.BIG) BIG=BIG8
      IF (ABS(G(9)).LT.BIG*EBIG) G(9)=0


C     REACTION2
  215 G(10)=-(RGA(2,J)+RGA(1,J))/2.+ratef2*(GOA(2,J)+GOA(1,J))/2.
      B(10,7)=-ratef2/2.
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      B(10,10)=+1./2.

      BIG=ABS(RGA(2,J)/2.)
      BIG2=ABS(RGA(1,J)/2.)
      IF (BIG2.GT.BIG) BIG=BIG2
      BIG3=ABS(ratef2*GOA(2,J)/2.)
      IF (BIG3.GT.BIG) BIG=BIG3
      BIG4=ABS(ratef2*GOA(1,J)/2.)
      IF (BIG4.GT.BIG) BIG=BIG4
      IF (ABS(G(10)).LT.BIG*EBIG) G(10)=0

C     REACTION3
 216  G(11)=-(EQ2(2,J)+EQ2(1,J))/2.
     1 +ratef3*((GOR(2,J)+GOR(1,J))*(OXY(2,J)+OXY(1,J))/4.
     2 -(GOP(2,J)+GOP(1,J))/2./equilib3)
      B(11,4)=-ratef3*(OXY(2,J)+OXY(1,J))/4.
      B(11,5)=-ratef3*(GOR(2,J)+GOR(1,J))/4.
      B(11,8)=ratef3/2./equilib3
      B(11,11)=+1./2.

      BIG=ABS(EQ2(2,J)/2.)
      BIG2=ABS(EQ2(1,J)/2.)
      IF (BIG2.GT.BIG) BIG=BIG2
      BIG3=ABS(ratef3*GOR(2,J)*OXY(2,J)/4.)
      IF (BIG3.GT.BIG) BIG=BIG3
      BIG4=ABS(ratef3*GOR(1,J)*OXY(2,J)/4)
      IF (BIG4.GT.BIG) BIG=BIG4
      BIG5=ABS(ratef3*GOR(2,J)*OXY(1,J)/4)
      IF (BIG5.GT.BIG) BIG=BIG5
      BIG6=ABS(ratef3*GOR(1,J)*OXY(1,J)/4)
      IF (BIG6.GT.BIG) BIG=BIG6
      BIG7=ABS(ratef3*GOP(2,J)/2./EQUILIB3)
      IF (BIG7.GT.BIG) BIG=BIG7
      BIG8=ABS(ratef3*GOP(1,J)/2./EQUILIB3)
      IF (BIG8.GT.BIG) BIG=BIG8
      IF (ABS(G(11)).LT.BIG*EBIG) G(11)=0.0

C     REACTION4
 217  G(12)=-(RHP(2,J)+RHP(1,J))/2.+ratef4*(GOP(2,J)+GOP(1,J))/2.
      B(12,8)=-ratef4/2.
      B(12,12)=+1./2.

      BIG=ABS(RHP(2,J)/2.)
      BIG2=ABS(RHP(1,J)/2.)
      IF (BIG2.GT.BIG) BIG=BIG2
      BIG3=ABS(ratef4*GOP(2,J)/2.)
      IF (BIG3.GT.BIG) BIG=BIG3
      BIG4=ABS(ratef4*GOP(1,J)/2.)
      IF (BIG4.GT.BIG) BIG=BIG4
      IF (ABS(G(12)).LT.BIG*EBIG) G(12)=0.0

C     REACTION5
 218  G(13)=-(ANM(2,J)+ANM(1,J))/2.+ratef5*((GLUA(2,J)+GLUA(1,J))/2.
     1  -(GLU(2,J)+GLU(1,J))/2./equilib5)
      B(13,1)=ratef5/2./equilib5
      B(13,14)=-ratef5/2.
      B(13,13)=+1./2.

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      BIG=ABS(ANM(2,J)/2.)
      BIG2=ABS(ANM(1,J)/2.)
      IF (BIG2.GT.BIG) BIG=BIG2
      BIG3=ABS(ratef5*GLUA(2,J)/2.)
      IF (BIG3.GT.BIG) BIG=BIG3
      BIG4=ABS(ratef5*GLUA(1,J)/2.)
      IF (BIG4.GT.BIG) BIG=BIG4
      BIG5=ABS(ratef5*GLU(2,J)/2./equilib5)
      IF (BIG5.GT.BIG) BIG=BIG5
      BIG6=ABS(ratef5*GLU(1,J)/2./equilib5)
      IF (BIG6.GT.BIG) BIG=BIG6
      IF (ABS(G(13)).LT.BIG*EBIG) G(13)=0.0

C       For alpha Glucose, being consumed only
      G(14)=DGOX(9)*(GLUA(2,J+1)-2.*GLUA(2,J)+GLUA(2,J-1)
     1       +GLUA(1,J+1)-2.*GLUA(1,J)+GLUA(1,J-1))/(2.*HHH**2.)
     2       -(ANM(2,J)+ANM(1,J))/2.-(GLUA(2,J)-GLUA(1,J))/DT
      B(14,14)=DGOX(9)/HHH**2.+1./DT
      D(14,14)=-DGOX(9)/(2.*HHH**2.)
      A(14,14)=-DGOX(9)/(2.*HHH**2.)
      B(14,13)=1./2.

      BIG=ABS(DGOX(9)*(GLUA(2,J+1))/(2.*HHH**2.))
      BIG2=ABS(DGOX(9)*(GLUA(2,J))/(HHH**2.))
      IF (BIG2.GT.BIG) BIG=BIG2
      BIG3=ABS(DGOX(9)*(GLUA(2,J-1))/(2.*HHH**2.))
      IF (BIG3.GT.BIG) BIG=BIG3
      BIG4=ABS(DGOX(9)*(GLUA(1,J+1))/(2.*HHH**2.))
      IF (BIG4.GT.BIG) BIG=BIG4
      BIG5=ABS(DGOX(9)*(GLUA(1,J))/(HHH**2.))
      IF (BIG5.GT.BIG) BIG=BIG5
      BIG6=ABS(DGOX(9)*(GLUA(1,J-1))/(2.*HHH**2.))
      IF (BIG6.GT.BIG) BIG=BIG6
      BIG7=ABS(ANM(2,J)/2.)
      IF (BIG7.GT.BIG) BIG=BIG7
      BIG8=ABS(ANM(1,J)/2.)
      IF (BIG8.GT.BIG) BIG=BIG8
      BIG9=ABS(GLUA(2,J)/DT)
      IF (BIG9.GT.BIG) BIG=BIG9
      BIG10=ABS(GLUA(1,J)/DT)
      IF (BIG10.GT.BIG) BIG=BIG10
      IF (ABS(G(14)).LT.BIG*EBIG) G(14)=0.0

C Gluconic acid dissociation

      G(15)=equilib6*(GLA(2,J)+GLA(1,J))/2.-(GLI(2,J)+GLI(1,J))*
     1   (HYD(2,J)+HYD(1,J))/4.
      B(15,3)=-equilib6/2.
      B(15,15)=(HYD(2,J)+HYD(1,J))/4.
      B(15,16)=(GLI(2,J)+GLI(1,J))/4.

      BIG=ABS(equilib6*GLA(2,J)/2.)
      BIG2=ABS(equilib6*GLA(1,J)/2.)
      IF (BIG2.GT.BIG) BIG=BIG2
      BIG3=ABS(GLI(2,J)*HYD(2,J)/4.)
      IF (BIG3.GT.BIG) BIG=BIG3
      BIG4=ABS(GLI(2,J)*HYD(1,J)/4)
      IF (BIG4.GT.BIG) BIG=BIG4
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      BIG5=ABS(GLI(1,J)*HYD(2,J)/4)
      IF (BIG5.GT.BIG) BIG=BIG5
      BIG6=ABS(GLI(1,J)*HYD(1,J)/4)
      IF (BIG6.GT.BIG) BIG=BIG6
      IF (ABS(G(15)).LT.BIG*EBIG) G(15)=0

C Hydrogen ion, hydroxide ion, gluconate ion, bicarbonate ion flux
      G(16)=DGOX(11)*(HYD(2,J+1)-2.*HYD(2,J)+HYD(2,J-1)
     1       +HYD(1,J+1)-2.*HYD(1,J)+HYD(1,J-1))/(2.*HHH**2.)
     2   -DGOX(15)*(OHI(2,J+1)-2.*OHI(2,J)+OHI(2,J-1)
     3       +OHI(1,J+1)-2.*OHI(1,J)+OHI(1,J-1))/(2.*HHH**2.)
     4   -DGOX(10)*(GLI(2,J+1)-2.*GLI(2,J)+GLI(2,J-1)
     5       +GLI(1,J+1)-2.*GLI(1,J)+GLI(1,J-1))/(2.*HHH**2.)
     6   -DGOX(14)*(CBI(2,J+1)-2.*CBI(2,J)+CBI(2,J-1)
     7       +CBI(1,J+1)-2.*CBI(1,J)+CBI(1,J-1))/(2.*HHH**2.)
     8    -(HYD(2,J)-HYD(1,J))/DT+(OHI(2,J)-OHI(1,J))/DT
     9   +(GLI(2,J)-GLI(1,J))/DT+(CBI(2,J)-CBI(1,J))/DT

      B(16,16)=DGOX(11)/HHH**2.+1./DT
      D(16,16)=-DGOX(11)/(2.*HHH**2.)
      A(16,16)=-DGOX(11)/(2.*HHH**2.)
      B(16,17)=-DGOX(15)/HHH**2.-1./DT
      D(16,17)=DGOX(15)/(2.*HHH**2.)
      A(16,17)=DGOX(15)/(2.*HHH**2.)
      B(16,15)=-DGOX(10)/HHH**2.-1./DT
      D(16,15)=DGOX(10)/(2.*HHH**2.)
      A(16,15)=DGOX(10)/(2.*HHH**2.)
      B(16,20)=-DGOX(14)/HHH**2.-1./DT
      D(16,20)=DGOX(14)/(2.*HHH**2.)
      A(16,20)=DGOX(14)/(2.*HHH**2.)

      BIG=ABS(DGOX(11)*(HYD(2,J+1))/(2.*HHH**2.))
      BIG2=ABS(DGOX(11)*(HYD(2,J))/(HHH**2.))
      IF (BIG2.GT.BIG) BIG=BIG2
      BIG3=ABS(DGOX(11)*(HYD(2,J-1))/(2.*HHH**2.))
      IF (BIG3.GT.BIG) BIG=BIG3
      BIG4=ABS(DGOX(11)*(HYD(1,J+1))/(2.*HHH**2.))
      IF (BIG4.GT.BIG) BIG=BIG4
      BIG5=ABS(DGOX(11)*(HYD(1,J))/(HHH**2.))
      IF (BIG5.GT.BIG) BIG=BIG5
      BIG6=ABS(DGOX(11)*(HYD(1,J-1))/(2.*HHH**2.))
      IF (BIG6.GT.BIG) BIG=BIG6
      BIG7=ABS(DGOX(15)*OHI(2,J+1)/(2.*HHH**2.))
      IF (BIG7.GT.BIG) BIG=BIG7
      BIG8=ABS(DGOX(15)*OHI(2,J)/(HHH**2.))
      IF (BIG8.GT.BIG) BIG=BIG8
      BIG9=ABS(DGOX(15)*OHI(2,J-1)/(2.*HHH**2.))
      IF (BIG9.GT.BIG) BIG=BIG9
      BIG10=ABS(DGOX(15)*OHI(1,J+1)/(2.*HHH**2.))
      IF (BIG10.GT.BIG) BIG=BIG10
      BIG11=ABS(DGOX(15)*OHI(1,J)/(HHH**2.))
      IF (BIG11.GT.BIG) BIG=BIG11
      BIG12=ABS(DGOX(15)*OHI(1,J-1)/(2.*HHH**2.))
      IF (BIG12.GT.BIG) BIG=BIG12
      BIG13=ABS(DGOX(10)*GLI(2,J+1)/(2.*HHH**2.))
      IF (BIG13.GT.BIG) BIG=BIG13
      BIG14=ABS(DGOX(10)*GLI(2,J)/(HHH**2.))
      IF (BIG14.GT.BIG) BIG=BIG14
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      BIG15=ABS(DGOX(10)*GLI(2,J-1)/(2.*HHH**2.))
      IF (BIG15.GT.BIG) BIG=BIG15
      BIG16=ABS(DGOX(10)*GLI(1,J+1)/(2.*HHH**2.))
      IF (BIG16.GT.BIG) BIG=BIG16
      BIG17=ABS(DGOX(10)*GLI(1,J)/(HHH**2.))
      IF (BIG17.GT.BIG) BIG=BIG17
      BIG18=ABS(DGOX(10)*GLI(1,J-1)/(2.*HHH**2.))
      IF (BIG18.GT.BIG) BIG=BIG18
      BIG19=ABS(DGOX(14)*CBI(2,J+1)/(2.*HHH**2.))
      IF (BIG19.GT.BIG) BIG=BIG19
      BIG20=ABS(DGOX(14)*CBI(2,J)/(HHH**2.))
      IF (BIG20.GT.BIG) BIG=BIG20
      BIG21=ABS(DGOX(14)*CBI(2,J-1)/(2.*HHH**2.))
      IF (BIG21.GT.BIG) BIG=BIG21
      BIG22=ABS(DGOX(14)*CBI(1,J+1)/(2.*HHH**2.))
      IF (BIG22.GT.BIG) BIG=BIG22
      BIG23=ABS(DGOX(14)*CBI(1,J)/(HHH**2.))
      IF (BIG23.GT.BIG) BIG=BIG23
      BIG24=ABS(DGOX(14)*CBI(1,J-1)/(2.*HHH**2.))
      IF (BIG24.GT.BIG) BIG=BIG24
      BIG25=ABS(HYD(2,J)/DT)
      IF (BIG25.GT.BIG) BIG=BIG25
      BIG26=ABS(HYD(1,J)/DT)
      IF (BIG26.GT.BIG) BIG=BIG26
      BIG27=ABS(OHI(2,J)/DT)
      IF (BIG27.GT.BIG) BIG=BIG27
      BIG28=ABS(OHI(1,J)/DT)
      IF (BIG28.GT.BIG) BIG=BIG28
      BIG29=ABS(GLI(2,J)/DT)
      IF (BIG29.GT.BIG) BIG=BIG29
      BIG30=ABS(GLI(1,J)/DT)
      IF (BIG30.GT.BIG) BIG=BIG30
      BIG31=ABS(CBI(2,J)/DT)
      IF (BIG31.GT.BIG) BIG=BIG31
      BIG32=ABS(CBI(1,J)/DT)
      IF (BIG32.GT.BIG) BIG=BIG32
      IF (ABS(G(16)).LT.BIG*EBIG) G(16)=0

c Water Dissociation
      G(17)=equilib9-(HYD(2,J)+HYD(1,J))*(OHI(2,J)+OHI(1,J))/4.
      B(17,17)=(HYD(2,J)+HYD(1,J))/4.
      B(17,16)=(OHI(2,J)+OHI(1,J))/4.

      BIG=ABS(equilib9)
      BIG2=ABS(HYD(2,J)*OHI(2,J)/4.)
      IF (BIG2.GT.BIG) BIG=BIG2
      BIG3=ABS(HYD(2,J)*OHI(1,J)/4.)
      IF (BIG3.GT.BIG) BIG=BIG3
      BIG4=ABS(HYD(1,J)*OHI(2,J)/4.)
      IF (BIG4.GT.BIG) BIG=BIG4
      BIG5=ABS(HYD(1,J)*OHI(1,J)/4.)
      IF (BIG5.GT.BIG) BIG=BIG5
      IF (ABS(G(17)).LT.BIG*EBIG) G(17)=0

C CO2 Hydration

      G(18)=equilib7*(CO2(2,J)+CO2(1,J))/2.-(CBA(2,J)+CBA(1,J))/2.
      B(18,18)=-equilib7/2.
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      B(18,19)=1./2.

      BIG=ABS(equilib7*CO2(2,J)/2.)
      BIG2=ABS(equilib7*CO2(1,J)/2.)
      IF (BIG2.GT.BIG) BIG=BIG2
      BIG3=ABS(CBA(2,J)/2.)
      IF (BIG3.GT.BIG) BIG=BIG3
      BIG4=ABS(CBA(1,J)/2.)
      IF (BIG4.GT.BIG) BIG=BIG4
      IF (ABS(G(18)).LT.BIG*EBIG) G(18)=0

C Carbonic acid dissociation

      G(19)=equilib8*(CBA(2,J)+CBA(1,J))/2.-(CBI(2,J)+CBI(1,J))
     1  *(HYD(2,J)+HYD(1,J))/4.
      B(19,19)=-equilib8/2.
      B(19,20)=(HYD(2,J)+HYD(1,J))/4.
      B(19,16)=(CBI(2,J)+CBI(1,J))/4.

      BIG=ABS(equilib8*CBA(2,J)/2.)
      BIG2=ABS(equilib8*CBA(1,J)/2.)
      IF (BIG2.GT.BIG) BIG=BIG2
      BIG3=ABS(CBI(2,J)*HYD(2,J)/4.)
      IF (BIG3.GT.BIG) BIG=BIG3
      BIG4=ABS(CBI(2,J)*HYD(1,J)/4.)
      IF (BIG4.GT.BIG) BIG=BIG4
      BIG5=ABS(CBI(1,J)*HYD(2,J)/4.)
      IF (BIG5.GT.BIG) BIG=BIG5
      BIG6=ABS(CBI(1,J)*HYD(1,J)/4.)
      IF (BIG6.GT.BIG) BIG=BIG6
      IF (ABS(G(19)).LT.BIG*EBIG) G(19)=0

C FLUX OF CO2, CARBONIC ACID, BICARBONATE ION
      G(20)=DGOX(12)*(CO2(2,J+1)-2.*CO2(2,J)+CO2(2,J-1)
     1        +CO2(1,J+1)-2.*CO2(1,J)+CO2(1,J-1))/(2.*HHH**2.)
     2    +DGOX(13)*(CBA(2,J+1)-2.*CBA(2,J)+CBA(2,J-1)
     3        +CBA(1,J+1)-2.*CBA(1,J)+CBA(1,J-1))/(2.*HHH**2.)
     4    +DGOX(14)*(CBI(2,J+1)-2.*CBI(2,J)+CBI(2,J-1)
     5        +CBI(1,J+1)-2.*CBI(1,J)+CBI(1,J-1))/(2.*HHH**2.)
     8    -(CO2(2,J)-CO2(1,J))/DT-(CBA(2,J)-CBA(1,J))/DT
     9    -(CBI(2,J)-CBI(1,J))/DT

      B(20,20)=DGOX(14)/HHH**2.+1./DT
      D(20,20)=-DGOX(14)/(2.*HHH**2.)
      A(20,20)=-DGOX(14)/(2.*HHH**2.)
      B(20,18)=DGOX(12)/HHH**2.+1./DT
      D(20,18)=-DGOX(12)/(2.*HHH**2.)
      A(20,18)=-DGOX(12)/(2.*HHH**2.)
      B(20,19)=DGOX(13)/HHH**2.+1./DT
      D(20,19)=-DGOX(13)/(2.*HHH**2.)
      A(20,19)=-DGOX(13)/(2.*HHH**2.)


      BIG=ABS(DGOX(12)*(CO2(2,J+1))/(2.*HHH**2.))
      BIG2=ABS(DGOX(12)*(CO2(2,J))/(HHH**2.))
      IF (BIG2.GT.BIG) BIG=BIG2
      BIG3=ABS(DGOX(12)*(CO2(2,J-1))/(2.*HHH**2.))
      IF (BIG3.GT.BIG) BIG=BIG3
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      BIG4=ABS(DGOX(12)*(CO2(1,J+1))/(2.*HHH**2.))
      IF (BIG4.GT.BIG) BIG=BIG4
      BIG5=ABS(DGOX(12)*(CO2(1,J))/(HHH**2.))
      IF (BIG5.GT.BIG) BIG=BIG5
      BIG6=ABS(DGOX(12)*(CO2(1,J-1))/(2.*HHH**2.))
      IF (BIG6.GT.BIG) BIG=BIG6
      BIG7=ABS(DGOX(13)*CBA(2,J+1)/(2.*HHH**2.))
      IF (BIG7.GT.BIG) BIG=BIG7
      BIG8=ABS(DGOX(13)*CBA(2,J)/(HHH**2.))
      IF (BIG8.GT.BIG) BIG=BIG8
      BIG9=ABS(DGOX(13)*CBA(2,J-1)/(2.*HHH**2.))
      IF (BIG9.GT.BIG) BIG=BIG9
      BIG10=ABS(DGOX(13)*CBA(1,J+1)/(2.*HHH**2.))
      IF (BIG10.GT.BIG) BIG=BIG10
      BIG11=ABS(DGOX(13)*CBA(1,J)/(HHH**2.))
      IF (BIG11.GT.BIG) BIG=BIG11
      BIG12=ABS(DGOX(13)*CBA(1,J-1)/(2.*HHH**2.))
      IF (BIG12.GT.BIG) BIG=BIG12
      BIG13=ABS(DGOX(14)*CBI(2,J+1)/(2.*HHH**2.))
      IF (BIG13.GT.BIG) BIG=BIG13
      BIG14=ABS(DGOX(14)*CBI(2,J)/(HHH**2.))
      IF (BIG14.GT.BIG) BIG=BIG14
      BIG15=ABS(DGOX(14)*CBI(2,J-1)/(2.*HHH**2.))
      IF (BIG15.GT.BIG) BIG=BIG15
      BIG16=ABS(DGOX(14)*CBI(1,J+1)/(2.*HHH**2.))
      IF (BIG16.GT.BIG) BIG=BIG16
      BIG17=ABS(DGOX(14)*CBI(1,J)/(HHH**2.))
      IF (BIG17.GT.BIG) BIG=BIG17
      BIG18=ABS(DGOX(14)*CBI(1,J-1)/(2.*HHH**2.))
      IF (BIG18.GT.BIG) BIG=BIG18
      BIG19=ABS(CO2(2,J)/DT)
      IF (BIG19.GT.BIG) BIG=BIG19
      BIG20=ABS(CO2(1,J)/DT)
      IF (BIG20.GT.BIG) BIG=BIG20
      BIG21=ABS(CBA(2,J)/DT)
      IF (BIG21.GT.BIG) BIG=BIG21
      BIG22=ABS(CBA(1,J)/DT)
      IF (BIG22.GT.BIG) BIG=BIG22
      BIG23=ABS(CBI(2,J)/DT)
      IF (BIG23.GT.BIG) BIG=BIG23
      BIG24=ABS(CBI(1,J)/DT)
      IF (BIG24.GT.BIG) BIG=BIG24
      IF (ABS(G(20)).LT.BIG*EBIG) G(20)=0

C     For Acetaminophen
      G(21)=DGOX(16)*(ACE(2,J+1)-2.*ACE(2,J)+ACE(2,J-1)
     1        +ACE(1,J+1)-2.*ACE(1,J)+ACE(1,J-1))/(2.*HHH**2.)
     2      -(ACE(2,J)-ACE(1,J))/DT

      B(21,21)=DGOX(16)/HHH**2.+1./DT
      D(21,21)=-DGOX(16)/(2.*HHH**2.)
      A(21,21)=-DGOX(16)/(2.*HHH**2.)


      BIG=ABS(DGOX(16)*(ACE(2,J+1))/(2.*HHH**2.))
      BIG2=ABS(DGOX(16)*(ACE(2,J))/(HHH**2.))
      IF (BIG2.GT.BIG) BIG=BIG2
      BIG3=ABS(DGOX(16)*(ACE(2,J-1))/(2.*HHH**2.))
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      IF (BIG3.GT.BIG) BIG=BIG3
      BIG4=ABS(DGOX(16)*(ACE(1,J+1))/(2.*HHH**2.))
      IF (BIG4.GT.BIG) BIG=BIG4
      BIG5=ABS(DGOX(16)*(ACE(1,J))/(HHH**2.))
      IF (BIG5.GT.BIG) BIG=BIG5
      BIG6=ABS(DGOX(16)*(ACE(1,J-1))/(2.*HHH**2.))
      IF (BIG6.GT.BIG) BIG=BIG6
      BIG7=ABS(ACE(2,J)/DT)
      IF (BIG7.GT.BIG) BIG=BIG7
      BIG8=ABS(ACE(1,J)/DT)
      IF (BIG8.GT.BIG) BIG=BIG8
      IF (ABS(G(21)).LT.BIG*EBIG) G(21)=0

C     DOUBLE lAYER voLTAGE - DUMMY

      G(22)=(VDL(2,J)+VDL(1,J))/2.

      B(22,22)=-1./2.

      BIG=ABS(VDL(2,J)/2.)
      BIG2=ABS(VDL(1,J)/2.)
      IF (BIG2.GT.BIG) BIG=BIG2
      IF (ABS(G(22)).LT.BIG*EBIG) G(22)=0

      RETURN
      END

        SUBROUTINE COUPLER1(J)
      IMPLICIT DOUBLE PRECISION (A-H, O-Z)
      COMMON/BAB/ A(22,22),B(22,22),C(22,80001),D(22,45),G(22),X(22,22)
     1    ,Y(22,22)
      COMMON/NSN/ N, NJ
      COMMON/GLC/ NTIME,LL
      COMMON/VAR/ DIFF(16),H,EBIG,HH,IJ,KJ,TT,VAP,HHH,DT,RE,AKB,BB,CDL
      COMMON/VARR/ HHHH,HHHHH,MJ,LJ
      COMMON/DIN/ DGOX(16),DGLM(16),DIRM(16),DBULK(16)
      COMMON/SPCI/ GLU(2,80001),GOX(2,80001),GLA(2,80001),GOR(2,80001)
      COMMON/SPCII/ OXY(2,80001),HPR(2,80001),GOA(2,80001),GOP(2,80001)
      COMMON/RXT/ EQ1(2,80001),RGA(2,80001),EQ2(2,80001),RHP(2,80001)
      COMMON/SPCIII/ ANM(2,80001),GLUA(2,80001),GLI(2,80001)
      COMMON/SPCIV/ HYD(2,80001),OHI(2,80001),CO2(2,80001),CBA(2,80001)
      COMMON/SPCV/ CBI(2,80001),ACE(2,800001)
      COMMON/VOL/ VDL(2,80001)
      COMMON/POR/ POR1,POR2,PORGLU,PARION,PARACE
      COMMON/RTE/ ratef1,equilib1,ratef2,ratef3,equilib3,ratef4
      COMMON/RTD/ ratef5,equilib5,equilib6,equilib7,equilib8,equilib9
      COMMON/BUL/ CBULK(16),PARH2O2,PAR02,PARGLUCOSE,JCOUNT


C       DIMENSION COEFF1, COEFF3, COEFF5, COEFF6

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

      COEFF1HH=DGOX(1)/(HH)
      COEFF1HHH=DGOX(1)/(HHH)
      COEFF3HH=DGOX(3)/(HH)
      COEFF3HHH=DGOX(3)/(HHH)
      COEFF5HH=DGOX(5)/(HH)
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      COEFF5HHH=DGOX(5)/(HHH)
      COEFF6HH=DGOX(6)/(HH)
      COEFF6HHH=DGOX(6)/(HHH)
      COEFF9HH=DGOX(9)/(HH)
      COEFF9HHH=DGOX(9)/(HHH)
      COEFF10HH=DGOX(10)/(HH)
      COEFF10HHH=DGOX(10)/(HHH)
      COEFF11HH=DGOX(11)/(HH)
      COEFF11HHH=DGOX(11)/(HHH)
      COEFF12HH=DGOX(12)/(HH)
      COEFF12HHH=DGOX(12)/(HHH)
      COEFF13HH=DGOX(13)/(HH)
      COEFF13HHH=DGOX(13)/(HHH)
      COEFF14HH=DGOX(14)/(HH)
      COEFF14HHH=DGOX(14)/(HHH)
      COEFF15HH=DGOX(15)/(HH)
      COEFF15HHH=DGOX(15)/(HHH)
      COEFF16HH=DGOX(16)/(HH)
      COEFF16HHH=DGOX(16)/(HHH)

C     For Glucose, being consumed only
      G(1)=COEFF1HH/2.*(GLU(2,J+1)+GLU(1,J+1)-GLU(2,J)-GLU(1,J))
     1        -COEFF1HHH/2.*(GLU(2,J)+GLU(1,J)-GLU(2,J-1)-GLU(1,J-1))
     2        -(HH/2.)*(3.*(EQ1(2,J)+EQ1(1,J))+(EQ1(2,J+1)+EQ1(1,J+1)))/8.
     3        -(HHH/2.)*(3.*(EQ1(2,J)+EQ1(1,J))+(EQ1(2,J-1)+EQ1(1,J-1)))/8.
     2        +(HH/2.)*(3.*(ANM(2,J)+ANM(1,J))+(ANM(2,J+1)+ANM(1,J+1)))/8.
     3        +(HHH/2.)*(3.*(ANM(2,J)+ANM(1,J))+(ANM(2,J-1)+ANM(1,J-1)))/8.
     4      -HH/2.*(3.*(GLU(2,J)-GLU(1,J))+(GLU(2,J+1)-GLU(1,J+1)))/(4.*DT)
     5    -HHH/2.*(3.*(GLU(2,J)-GLU(1,J))+(GLU(2,J-1)-GLU(1,J-1)))/(4.*DT)

      B(1,1)=COEFF1HH/2.+COEFF1HHH/2.+HH/2.*3./(4.*DT)+HHH/2.*3./(4.*DT)
      D(1,1)=-COEFF1HH/2.+HH/2./(4.*DT)
      A(1,1)=-COEFF1HHH/2.+HHH/2./(4.*DT)
      B(1,9)=+(HH/2.)*(3./8.)+(HHH/2.)*(3./8.)
      D(1,9)=+(HH/2.)*(1./8.)
      A(1,9)=+(HHH/2.)*(1./8.)
      B(1,13)=-(HH/2.)*(3./8.)-(HHH/2.)*(3./8.)
      D(1,13)=-(HH/2.)*(1./8.)
      A(1,13)=-(HHH/2.)*(1./8.)

      BIG=ABS(COEFF1HH/2.*GLU(2,J+1))
      BIG2=ABS(COEFF1HH/2.*GLU(1,J+1))
      IF (BIG2.GT.BIG) BIG=BIG2
      BIG3=ABS(COEFF1HH/2.*GLU(2,J))
      IF (BIG3.GT.BIG) BIG=BIG3
      BIG4=ABS(COEFF1HH/2.*GLU(1,J))
      IF (BIG4.GT.BIG) BIG=BIG4
      BIG5=ABS(COEFF1HHH/2.*GLU(2,J))
      IF (BIG5.GT.BIG) BIG=BIG5
      BIG6=ABS(COEFF1HHH/2.*GLU(1,J))
      IF (BIG6.GT.BIG) BIG=BIG6
      BIG7=ABS(COEFF1HHH/2.*GLU(2,J-1))
      IF (BIG7.GT.BIG) BIG=BIG7
      BIG8=ABS(COEFF1HHH/2.*GLU(1,J-1))
      IF (BIG8.GT.BIG) BIG=BIG8
      BIG9=ABS(HH/2.*3.*EQ1(2,J)/8.)
      IF (BIG9.GT.BIG) BIG=BIG9
      BIG10=ABS(HH/2.*3.*EQ1(1,J)/8.)
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      IF (BIG10.GT.BIG) BIG=BIG10
      BIG11=ABS(HH/2.*EQ1(2,J+1)/8.)
      IF (BIG11.GT.BIG) BIG=BIG11
      BIG12=ABS(HH/2.*EQ1(1,J+1)/8.)
      IF (BIG12.GT.BIG) BIG=BIG12
      BIG13=ABS(HHH/2.*3.*EQ1(2,J)/8.)
      IF (BIG13.GT.BIG) BIG=BIG13
      BIG14=ABS(HHH/2.*3.*EQ1(1,J)/8.)
      IF (BIG14.GT.BIG) BIG=BIG14
      BIG15=ABS(HHH/2.*EQ1(2,J-1)/8.)
      IF (BIG15.GT.BIG) BIG=BIG15
      BIG16=ABS(HHH/2.*EQ1(1,J-1)/8.)
      IF (BIG16.GT.BIG) BIG=BIG16
      BIG17=ABS(HH/2.*3.*GLU(2,J)/(4.*DT))
      IF (BIG17.GT.BIG) BIG=BIG17
      BIG18=ABS(HH/2.*3.*GLU(1,J)/(4.*DT))
      IF (BIG18.GT.BIG) BIG=BIG18
      BIG19=ABS(HH/2.*GLU(2,J+1)/(4.*DT))
      IF (BIG19.GT.BIG) BIG=BIG19
      BIG20=ABS(HH/2.*GLU(1,J+1)/(4.*DT))
      IF (BIG20.GT.BIG) BIG=BIG20
      BIG21=ABS(HHH/2.*3.*GLU(2,J)/(4.*DT))
      IF (BIG21.GT.BIG) BIG=BIG21
      BIG22=ABS(HHH/2.*3.*GLU(1,J)/(4.*DT))
      IF (BIG22.GT.BIG) BIG=BIG22
      BIG23=ABS(HHH/2.*GLU(2,J-1)/(4.*DT))
      IF (BIG23.GT.BIG) BIG=BIG23
      BIG24=ABS(HHH/2.*GLU(1,J-1)/(4.*DT))
      IF (BIG24.GT.BIG) BIG=BIG24
      BIG25=ABS(HH/2.*3.*ANM(2,J)/8.)
      IF (BIG25.GT.BIG) BIG=BIG25
      BIG26=ABS(HH/2.*3.*ANM(1,J)/8.)
      IF (BIG26.GT.BIG) BIG=BIG26
      BIG27=ABS(HH/2.*ANM(2,J+1)/8.)
      IF (BIG27.GT.BIG) BIG=BIG27
      BIG28=ABS(HH/2.*ANM(1,J+1)/8.)
      IF (BIG28.GT.BIG) BIG=BIG28
      BIG29=ABS(HHH/2.*3.*ANM(2,J)/8.)
      IF (BIG29.GT.BIG) BIG=BIG29
      BIG30=ABS(HHH/2.*3.*ANM(1,J)/8.)
      IF (BIG30.GT.BIG) BIG=BIG30
      BIG31=ABS(HHH/2.*ANM(2,J-1)/8.)
      IF (BIG31.GT.BIG) BIG=BIG31
      BIG32=ABS(HHH/2.*ANM(1,J-1)/8.)
      IF (BIG32.GT.BIG) BIG=BIG32
      IF (ABS(G(1)).LT.BIG*EBIG) G(1)=0

C       For GOx, enzyme
      G(2)=-(EQ1(2,J)+EQ1(1,J))/2.+(RHP(2,J)+RHP(1,J))/2.
     1  -(GOX(2,J)-GOX(1,J))/DT
      B(2,2)=+1./DT
      B(2,9)=+1./2.
      B(2,12)=-1./2.


      IF (ABS(EQ1(2,J)).GT.BIG) BIG=ABS(EQ1(2,J))
      IF (ABS(EQ1(1,J)).GT.BIG) BIG=ABS(EQ1(1,J))
      IF (ABS(RHP(2,J)).GT.BIG) BIG=ABS(RHP(2,J))
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      IF (ABS(RHP(1,J)).GT.BIG) BIG=ABS(RHP(1,J))
      IF (ABS(GOX(2,J)/DT).GT.BIG) BIG=ABS(GOX(2,J)/DT)
      IF (ABS(GOX(1,J)/DT).GT.BIG) BIG=ABS(GOX(1,J)/DT)
      IF (ABS(G(2)).LT.BIG*EBIG) G(2)=0

C     For Gluconic Acid, being produced only Balanced by Gluconate Ion
      G(3)=COEFF3HH/2.*(GLA(2,J+1)+GLA(1,J+1)-GLA(2,J)-GLA(1,J))
     1       -COEFF3HHH/2.*(GLA(2,J)+GLA(1,J)-GLA(2,J-1)-GLA(1,J-1))
     2       +COEFF10HH/2.*(GLI(2,J+1)+GLI(1,J+1)-GLI(2,J)-GLI(1,J))
     3       -COEFF10HHH/2.*(GLI(2,J)+GLI(1,J)-GLI(2,J-1)-GLI(1,J-1))
     4       +(HH/2.)*(3.*(RGA(2,J)+RGA(1,J))+(RGA(2,J+1)+RGA(1,J+1)))/8.
     5       +(HHH/2.)*(3.*(RGA(2,J)+RGA(1,J))+(RGA(2,J-1)+RGA(1,J-1)))/8.
     6     -HH/2.*(3.*(GLA(2,J)-GLA(1,J))+(GLA(2,J+1)-GLA(1,J+1)))/(4.*DT)
     7   -HHH/2.*(3.*(GLA(2,J)-GLA(1,J))+(GLA(2,J-1)-GLA(1,J-1)))/(4.*DT)
     8     -HH/2.*(3.*(GLI(2,J)-GLI(1,J))+(GLI(2,J+1)-GLI(1,J+1)))/(4.*DT)
     9   -HHH/2.*(3.*(GLI(2,J)-GLI(1,J))+(GLI(2,J-1)-GLI(1,J-1)))/(4.*DT)

      B(3,3)=COEFF3HH/2.+COEFF3HHH/2.+HH/2.*3./(4.*DT)+HHH/2.*3./(4.*DT)
      D(3,3)=-COEFF3HH/2.+HH/2./(4.*DT)
      A(3,3)=-COEFF3HHH/2.+HHH/2./(4.*DT)
      B(3,10)=-(HH/2.)*(3./8.)-(HHH/2.)*(3./8.)
      D(3,10)=-(HH/2.)*(1./8.)
      A(3,10)=-(HHH/2.)*(1./8.)
      B(3,15)=COEFF10HH/2.+COEFF10HHH/2.+HH/2.*3./(4.*DT)
     1 +HHH/2.*3./(4.*DT)
      D(3,15)=-COEFF10HH/2.+HH/2./(4.*DT)
      A(3,15)=-COEFF10HHH/2.+HHH/2./(4.*DT)


      BIG=ABS(COEFF3HH/2.*GLA(2,J+1))
      BIG2=ABS(COEFF3HH/2.*GLA(1,J+1))
      IF (BIG2.GT.BIG) BIG=BIG2
      BIG3=ABS(COEFF3HH/2.*GLA(2,J))
      IF (BIG3.GT.BIG) BIG=BIG3
      BIG4=ABS(COEFF3HH/2.*GLA(1,J))
      IF (BIG4.GT.BIG) BIG=BIG4
      BIG5=ABS(COEFF3HHH/2.*GLA(2,J))
      IF (BIG5.GT.BIG) BIG=BIG5
      BIG6=ABS(COEFF3HHH/2.*GLA(1,J))
      IF (BIG6.GT.BIG) BIG=BIG6
      BIG7=ABS(COEFF3HHH/2.*GLA(2,J-1))
      IF (BIG7.GT.BIG) BIG=BIG7
      BIG8=ABS(COEFF3HHH/2.*GLA(1,J-1))
      IF (BIG8.GT.BIG) BIG=BIG8
      BIG9=ABS(HH/2.*3.*RGA(2,J)/8.)
      IF (BIG9.GT.BIG) BIG=BIG9
      BIG10=ABS(HH/2.*3.*RGA(1,J)/8.)
      IF (BIG10.GT.BIG) BIG=BIG10
      BIG11=ABS(HH/2.*RGA(2,J+1)/8.)
      IF (BIG11.GT.BIG) BIG=BIG11
      BIG12=ABS(HH/2.*RGA(1,J+1)/8.)
      IF (BIG12.GT.BIG) BIG=BIG12
      BIG13=ABS(HHH/2.*3.*RGA(2,J)/8.)
      IF (BIG13.GT.BIG) BIG=BIG13
      BIG14=ABS(HHH/2.*3.*RGA(1,J)/8.)
      IF (BIG14.GT.BIG) BIG=BIG14
      BIG15=ABS(HHH/2.*RGA(2,J-1)/8.)
      IF (BIG15.GT.BIG) BIG=BIG15
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      BIG16=ABS(HHH/2.*RGA(1,J-1)/8.)
      IF (BIG16.GT.BIG) BIG=BIG16
      BIG17=ABS(HH/2.*3.*GLA(2,J)/(4.*DT))
      IF (BIG17.GT.BIG) BIG=BIG17
      BIG18=ABS(HH/2.*3.*GLA(1,J)/(4.*DT))
      IF (BIG18.GT.BIG) BIG=BIG18
      BIG19=ABS(HH/2.*GLA(2,J+1)/(4.*DT))
      IF (BIG19.GT.BIG) BIG=BIG19
      BIG20=ABS(HH/2.*GLA(1,J+1)/(4.*DT))
      IF (BIG20.GT.BIG) BIG=BIG20
      BIG21=ABS(HHH/2.*3.*GLA(2,J)/(4.*DT))
      IF (BIG21.GT.BIG) BIG=BIG21
      BIG22=ABS(HHH/2.*3.*GLA(1,J)/(4.*DT))
      IF (BIG22.GT.BIG) BIG=BIG22
      BIG23=ABS(HHH/2.*GLA(2,J-1)/(4.*DT))
      IF (BIG23.GT.BIG) BIG=BIG23
      BIG24=ABS(HHH/2.*GLA(1,J-1)/(4.*DT))
      IF (BIG24.GT.BIG) BIG=BIG24
      BIG25=ABS(COEFF10HH/2.*GLI(2,J+1))
      IF (BIG25.GT.BIG) BIG=BIG25
      BIG26=ABS(COEFF10HH/2.*GLI(1,J+1))
      IF (BIG26.GT.BIG) BIG=BIG26
      BIG27=ABS(COEFF10HH/2.*GLI(2,J))
      IF (BIG27.GT.BIG) BIG=BIG27
      BIG28=ABS(COEFF10HH/2.*GLI(1,J))
      IF (BIG28.GT.BIG) BIG=BIG28
      BIG29=ABS(COEFF10HHH/2.*GLI(2,J))
      IF (BIG29.GT.BIG) BIG=BIG29
      BIG30=ABS(COEFF10HHH/2.*GLI(1,J))
      IF (BIG30.GT.BIG) BIG=BIG30
      BIG31=ABS(COEFF10HHH/2.*GLI(2,J-1))
      IF (BIG31.GT.BIG) BIG=BIG31
      BIG32=ABS(COEFF10HHH/2.*GLI(1,J-1))
      IF (BIG32.GT.BIG) BIG=BIG32
      BIG33=ABS(HH/2.*3.*GLI(2,J)/(4.*DT))
      IF (BIG33.GT.BIG) BIG=BIG33
      BIG34=ABS(HH/2.*3.*GLI(1,J)/(4.*DT))
      IF (BIG34.GT.BIG) BIG=BIG34
      BIG35=ABS(HH/2.*GLI(2,J+1)/(4.*DT))
      IF (BIG35.GT.BIG) BIG=BIG35
      BIG36=ABS(HH/2.*GLI(1,J+1)/(4.*DT))
      IF (BIG36.GT.BIG) BIG=BIG36
      BIG37=ABS(HHH/2.*3.*GLI(2,J)/(4.*DT))
      IF (BIG37.GT.BIG) BIG=BIG37
      BIG38=ABS(HHH/2.*3.*GLI(1,J)/(4.*DT))
      IF (BIG38.GT.BIG) BIG=BIG38
      BIG39=ABS(HHH/2.*GLI(2,J-1)/(4.*DT))
      IF (BIG39.GT.BIG) BIG=BIG39
      BIG40=ABS(HHH/2.*GLI(1,J-1)/(4.*DT))
      IF (BIG40.GT.BIG) BIG=BIG40
      IF (ABS(G(3)).LT.BIG*EBIG) G(3)=0

C     For GOx2, enzyme
      G(4)=CBULK(2)+CBULK(4)+CBULK(7)+CBULK(8)-(GOX(2,J)+GOX(1,J))/2.
     1 -(GOR(2,J)+GOR(1,J))/2.-(GOA(2,J)+GOA(1,J))/2.
     2 -(GOP(2,J)+GOP(1,J))/2.
      B(4,4)=+1./2.
      B(4,2)=+1./2.
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      B(4,7)=+1./2.
      B(4,8)=+1./2.

      BIG=ABS(CBULK(2))
      IF (ABS(CBULK(4)).GT.BIG) BIG=ABS(CBULK(4))
      IF (ABS(CBULK(7)).GT.BIG) BIG=ABS(CBULK(7))
      IF (ABS(CBULK(8)).GT.BIG) BIG=ABS(CBULK(8))
      IF (ABS(GOX(2,J)/2.).GT.BIG) BIG=ABS(GOX(2,J)/2.)
      IF (ABS(GOX(1,J)/2.).GT.BIG) BIG=ABS(GOX(1,J)/2.)
      IF (ABS(GOR(2,J)/2.).GT.BIG) BIG=ABS(GOR(2,J)/2.)
      IF (ABS(GOR(1,J)/2.).GT.BIG) BIG=ABS(GOR(1,J)/2.)
      IF (ABS(GOA(2,J)/2.).GT.BIG) BIG=ABS(GOA(2,J)/2.)
      IF (ABS(GOA(1,J)/2.).GT.BIG) BIG=ABS(GOA(1,J)/2.)
      IF (ABS(GOP(2,J)/2.).GT.BIG) BIG=ABS(GOP(2,J)/2.)
      IF (ABS(GOP(1,J)/2.).GT.BIG) BIG=ABS(GOP(1,J)/2.)
      IF (ABS(G(4)).LT.BIG*EBIG) G(4)=0

C     For O2, being consumed only
      G(5)=COEFF5HH/2.*(OXY(2,J+1)+OXY(1,J+1)-OXY(2,J)-OXY(1,J))
     1        -COEFF5HHH/2.*(OXY(2,J)+OXY(1,J)-OXY(2,J-1)-OXY(1,J-1))
     2        -(HH/2.)*(3.*(EQ2(2,J)+EQ2(1,J))+(EQ2(2,J+1)+EQ2(1,J+1)))/8.
     3        -(HHH/2.)*(3.*(EQ2(2,J)+EQ2(1,J))+(EQ2(2,J-1)+EQ2(1,J-1)))/8.
     4      -HH/2.*(3.*(OXY(2,J)-OXY(1,J))+(OXY(2,J+1)-OXY(1,J+1)))/(4.*DT)
     5    -HHH/2.*(3.*(OXY(2,J)-OXY(1,J))+(OXY(2,J-1)-OXY(1,J-1)))/(4.*DT)

      B(5,5)=COEFF5HH/2.+COEFF5HHH/2.+HH/2.*3./(4.*DT)+HHH/2.*3./(4.*DT)
      D(5,5)=-COEFF5HH/2.+HH/2./(4.*DT)
      A(5,5)=-COEFF5HHH/2.+HHH/2./(4.*DT)
      B(5,11)=+(HH/2.)*(3./8.)+(HHH/2.)*(3./8.)
      D(5,11)=+(HH/2.)*(1./8.)
      A(5,11)=+(HHH/2.)*(1./8.)

      BIG=ABS(COEFF5HH/2.*OXY(2,J+1))
      BIG2=ABS(COEFF5HH/2.*OXY(1,J+1))
      IF (BIG2.GT.BIG) BIG=BIG2
      BIG3=ABS(COEFF5HH/2.*OXY(2,J))
      IF (BIG3.GT.BIG) BIG=BIG3
      BIG4=ABS(COEFF5HH/2.*OXY(1,J))
      IF (BIG4.GT.BIG) BIG=BIG4
      BIG5=ABS(COEFF5HHH/2.*OXY(2,J))
      IF (BIG5.GT.BIG) BIG=BIG5
      BIG6=ABS(COEFF5HHH/2.*OXY(1,J))
      IF (BIG6.GT.BIG) BIG=BIG6
      BIG7=ABS(COEFF5HHH/2.*OXY(2,J-1))
      IF (BIG7.GT.BIG) BIG=BIG7
      BIG8=ABS(COEFF5HHH/2.*OXY(1,J-1))
      IF (BIG8.GT.BIG) BIG=BIG8
      BIG9=ABS(HH/2.*3.*EQ2(2,J)/8.)
      IF (BIG9.GT.BIG) BIG=BIG9
      BIG10=ABS(HH/2.*3.*EQ2(1,J)/8.)
      IF (BIG10.GT.BIG) BIG=BIG10
      BIG11=ABS(HH/2.*EQ2(2,J+1)/8.)
      IF (BIG11.GT.BIG) BIG=BIG11
      BIG12=ABS(HH/2.*EQ2(1,J+1)/8.)
      IF (BIG12.GT.BIG) BIG=BIG12
      BIG13=ABS(HHH/2.*3.*EQ2(2,J)/8.)
      IF (BIG13.GT.BIG) BIG=BIG13
      BIG14=ABS(HHH/2.*3.*EQ2(1,J)/8.)
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      IF (BIG14.GT.BIG) BIG=BIG14
      BIG15=ABS(HHH/2.*EQ2(2,J-1)/8.)
      IF (BIG15.GT.BIG) BIG=BIG15
      BIG16=ABS(HHH/2.*EQ2(1,J-1)/8.)
      IF (BIG16.GT.BIG) BIG=BIG16
      BIG17=ABS(HH/2.*3.*OXY(2,J)/(4.*DT))
      IF (BIG17.GT.BIG) BIG=BIG17
      BIG18=ABS(HH/2.*3.*OXY(1,J)/(4.*DT))
      IF (BIG18.GT.BIG) BIG=BIG18
      BIG19=ABS(HH/2.*OXY(2,J+1)/(4.*DT))
      IF (BIG19.GT.BIG) BIG=BIG19
      BIG20=ABS(HH/2.*OXY(1,J+1)/(4.*DT))
      IF (BIG20.GT.BIG) BIG=BIG20
      BIG21=ABS(HHH/2.*3.*OXY(2,J)/(4.*DT))
      IF (BIG21.GT.BIG) BIG=BIG21
      BIG22=ABS(HHH/2.*3.*OXY(1,J)/(4.*DT))
      IF (BIG22.GT.BIG) BIG=BIG22
      BIG23=ABS(HHH/2.*OXY(2,J-1)/(4.*DT))
      IF (BIG23.GT.BIG) BIG=BIG23
      BIG24=ABS(HHH/2.*OXY(1,J-1)/(4.*DT))
      IF (BIG24.GT.BIG) BIG=BIG24
      IF (ABS(G(5)).LT.BIG*EBIG) G(5)=0


C     For H2O2, reacting species
      G(6)=COEFF6HH/2.*(HPR(2,J+1)+HPR(1,J+1)-HPR(2,J)-HPR(1,J))
     1     -COEFF6HHH/2.*(HPR(2,J)+HPR(1,J)-HPR(2,J-1)-HPR(1,J-1))
     2     +(HH/2.)*(3.*(RHP(2,J)+RHP(1,J))+(RHP(2,J+1)+RHP(1,J+1)))/8.
     3     +(HHH/2.)*(3.*(RHP(2,J)+RHP(1,J))+(RHP(2,J-1)+RHP(1,J-1)))/8.
     4    -HH/2.*(3.*(HPR(2,J)-HPR(1,J))+(HPR(2,J+1)-HPR(1,J+1)))/(4.*DT)
     5  -HHH/2.*(3.*(HPR(2,J)-HPR(1,J))+(HPR(2,J-1)-HPR(1,J-1)))/(4.*DT)

      B(6,6)=COEFF6HH/2.+COEFF6HHH/2.+HH/2.*3./(4.*DT)+HHH/2.*3./(4.*DT)
      D(6,6)=-COEFF6HH/2.+HH/2./(4.*DT)
      A(6,6)=-COEFF6HHH/2.+HHH/2./(4.*DT)
      B(6,12)=-(HH/2.)*(3./8.)-(HHH/2.)*(3./8.)
      D(6,12)=-(HH/2.)*(1./8.)
      A(6,12)=-(HHH/2.)*(1./8.)

      BIG=ABS(COEFF6HH/2.*HPR(2,J+1))
      BIG2=ABS(COEFF6HH/2.*HPR(1,J+1))
      IF (BIG2.GT.BIG) BIG=BIG2
      BIG3=ABS(COEFF6HH/2.*HPR(2,J))
      IF (BIG3.GT.BIG) BIG=BIG3
      BIG4=ABS(COEFF6HH/2.*HPR(1,J))
      IF (BIG4.GT.BIG) BIG=BIG4
      BIG5=ABS(COEFF6HHH/2.*HPR(2,J))
      IF (BIG5.GT.BIG) BIG=BIG5
      BIG6=ABS(COEFF6HHH/2.*HPR(1,J))
      IF (BIG6.GT.BIG) BIG=BIG6
      BIG7=ABS(COEFF6HHH/2.*HPR(2,J-1))
      IF (BIG7.GT.BIG) BIG=BIG7
      BIG8=ABS(COEFF6HHH/2.*HPR(1,J-1))
      IF (BIG8.GT.BIG) BIG=BIG8
      BIG9=ABS(HH/2.*3.*RHP(2,J)/8.)
      IF (BIG9.GT.BIG) BIG=BIG9
      BIG10=ABS(HH/2.*3.*RHP(1,J)/8.)
      IF (BIG10.GT.BIG) BIG=BIG10
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      BIG11=ABS(HH/2.*RHP(2,J+1)/8.)
      IF (BIG11.GT.BIG) BIG=BIG11
      BIG12=ABS(HH/2.*RHP(1,J+1)/8.)
      IF (BIG12.GT.BIG) BIG=BIG12
      BIG13=ABS(HHH/2.*3.*RHP(2,J)/8.)
      IF (BIG13.GT.BIG) BIG=BIG13
      BIG14=ABS(HHH/2.*3.*RHP(1,J)/8.)
      IF (BIG14.GT.BIG) BIG=BIG14
      BIG15=ABS(HHH/2.*RHP(2,J-1)/8.)
      IF (BIG15.GT.BIG) BIG=BIG15
      BIG16=ABS(HHH/2.*RHP(1,J-1)/8.)
      IF (BIG16.GT.BIG) BIG=BIG16
      BIG17=ABS(HH/2.*3.*HPR(2,J)/(4.*DT))
      IF (BIG17.GT.BIG) BIG=BIG17
      BIG18=ABS(HH/2.*3.*HPR(1,J)/(4.*DT))
      IF (BIG18.GT.BIG) BIG=BIG18
      BIG19=ABS(HH/2.*HPR(2,J+1)/(4.*DT))
      IF (BIG19.GT.BIG) BIG=BIG19
      BIG20=ABS(HH/2.*HPR(1,J+1)/(4.*DT))
      IF (BIG20.GT.BIG) BIG=BIG20
      BIG21=ABS(HHH/2.*3.*HPR(2,J)/(4.*DT))
      IF (BIG21.GT.BIG) BIG=BIG21
      BIG22=ABS(HHH/2.*3.*HPR(1,J)/(4.*DT))
      IF (BIG22.GT.BIG) BIG=BIG22
      BIG23=ABS(HHH/2.*HPR(2,J-1)/(4.*DT))
      IF (BIG23.GT.BIG) BIG=BIG23
      BIG24=ABS(HHH/2.*HPR(1,J-1)/(4.*DT))
      IF (BIG24.GT.BIG) BIG=BIG24
      IF (ABS(G(6)).LT.BIG*EBIG) G(6)=0

C     For CX-GOx2, enzyme
      G(7)=(EQ1(2,J)+EQ1(1,J))/2.-(RGA(2,J)+RGA(1,J))/2.
     1  -(GOA(2,J)-GOA(1,J))/DT

      B(7,7)=+1./DT
      B(7,9)=-1./2.
      B(7,10)=1./2.

      IF (ABS(EQ1(2,J)).GT.BIG) BIG=ABS(EQ1(2,J))
      IF (ABS(EQ1(1,J)).GT.BIG) BIG=ABS(EQ1(1,J))
      IF (ABS(RGA(2,J)).GT.BIG) BIG=ABS(RGA(2,J))
      IF (ABS(RGA(1,J)).GT.BIG) BIG=ABS(RGA(1,J))
      IF (ABS(GOA(2,J)/DT).GT.BIG) BIG=ABS(GOA(2,J)/DT)
      IF (ABS(GOA(1,J)/DT).GT.BIG) BIG=ABS(GOA(1,J)/DT)
      IF (ABS(G(7)).LT.BIG*EBIG) G(7)=0


C     For CX-GOx, enzyme
      G(8)=(EQ2(2,J)+EQ2(1,J))/2.-(RHP(2,J)+RHP(1,J))/2.
     1  -(GOP(2,J)-GOP(1,J))/DT
      B(8,8)=+1./DT
      B(8,11)=-1./2.
      B(8,12)=1./2.

      IF (ABS(EQ2(2,J)).GT.BIG) BIG=ABS(EQ2(2,J))
      IF (ABS(EQ2(1,J)).GT.BIG) BIG=ABS(EQ2(1,J))
      IF (ABS(RHP(2,J)).GT.BIG) BIG=ABS(RHP(2,J))
      IF (ABS(RHP(1,J)).GT.BIG) BIG=ABS(RHP(1,J))
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      IF (ABS(GOP(2,J)/DT).GT.BIG) BIG=ABS(GOP(2,J)/DT)
      IF (ABS(GOP(1,J)/DT).GT.BIG) BIG=ABS(GOP(1,J)/DT)
      IF (ABS(G(8)).LT.BIG*EBIG) G(8)=0


C     REACTION1
  214 G(9)=-(EQ1(2,J)+EQ1(1,J))/2.
     1 +ratef1*((GLU(2,J)+GLU(1,J))*(GOX(2,J)+GOX(1,J))/4.
     2 -(GOA(2,J)+GOA(1,J))/2./equilib1)
      B(9,1)=-ratef1*(GOX(2,J)+GOX(1,J))/4.
      B(9,2)=-ratef1*(GLU(2,J)+GLU(1,J))/4.
      B(9,7)=ratef1/2./equilib1
      B(9,9)=+1./2.

      BIG=ABS(EQ1(2,J)/2.)
      BIG2=ABS(EQ1(1,J)/2.)
      IF (BIG2.GT.BIG) BIG=BIG2
      BIG3=ABS(ratef1*GLU(2,J)*GOX(2,J)/4.)
      IF (BIG3.GT.BIG) BIG=BIG3
      BIG4=ABS(ratef1*GLU(1,J)*GOX(2,J)/4)
      IF (BIG4.GT.BIG) BIG=BIG4
      BIG5=ABS(ratef1*GLU(2,J)*GOX(1,J)/4)
      IF (BIG5.GT.BIG) BIG=BIG5
      BIG6=ABS(ratef1*GLU(1,J)*GOX(1,J)/4)
      IF (BIG6.GT.BIG) BIG=BIG6
      BIG7=ABS(ratef1*GOA(2,J)/2./equilib1)
      IF (BIG7.GT.BIG) BIG=BIG7
      BIG8=ABS(ratef1*GOA(1,J)/2./equilib1)
      IF (BIG8.GT.BIG) BIG=BIG8
      IF (ABS(G(9)).LT.BIG*EBIG) G(9)=0


C     REACTION2
  215 G(10)=-(RGA(2,J)+RGA(1,J))/2.+ratef2*(GOA(2,J)+GOA(1,J))/2.
      B(10,7)=-ratef2/2.
      B(10,10)=+1./2.

      BIG=ABS(RGA(2,J)/2.)
      BIG2=ABS(RGA(1,J)/2.)
      IF (BIG2.GT.BIG) BIG=BIG2
      BIG3=ABS(ratef2*GOA(2,J)/2.)
      IF (BIG3.GT.BIG) BIG=BIG3
      BIG4=ABS(ratef2*GOA(1,J)/2.)
      IF (BIG4.GT.BIG) BIG=BIG4
      IF (ABS(G(10)).LT.BIG*EBIG) G(10)=0

C     REACTION3
  216 G(11)=-(EQ2(2,J)+EQ2(1,J))/2.
     1 +ratef3*((GOR(2,J)+GOR(1,J))*(OXY(2,J)+OXY(1,J))/4.
     2 -(GOP(2,J)+GOP(1,J))/2./equilib3)
      B(11,4)=-ratef3*(OXY(2,J)+OXY(1,J))/4.
      B(11,5)=-ratef3*(GOR(2,J)+GOR(1,J))/4.
      B(11,8)=ratef3/2./equilib3
      B(11,11)=+1./2.

      BIG=ABS(EQ2(2,J)/2.)
      BIG2=ABS(EQ2(1,J)/2.)
      IF (BIG2.GT.BIG) BIG=BIG2
```

```
      BIG3=ABS(ratef3*GOR(2,J)*OXY(2,J)/4.)
      IF (BIG3.GT.BIG) BIG=BIG3
      BIG4=ABS(ratef3*GOR(1,J)*OXY(2,J)/4)
      IF (BIG4.GT.BIG) BIG=BIG4
      BIG5=ABS(ratef3*GOR(2,J)*OXY(1,J)/4)
      IF (BIG5.GT.BIG) BIG=BIG5
      BIG6=ABS(ratef3*GOR(1,J)*OXY(1,J)/4)
      IF (BIG6.GT.BIG) BIG=BIG6
      BIG7=ABS(ratef3*GOP(2,J)/2./EQUILIB3)
      IF (BIG7.GT.BIG) BIG=BIG7
      BIG8=ABS(ratef3*GOP(1,J)/2./EQUILIB3)
      IF (BIG8.GT.BIG) BIG=BIG8
      IF (ABS(G(11)).LT.BIG*EBIG) G(11)=0

C     REACTION4
  217 G(12)=-(RHP(2,J)+RHP(1,J))/2.+ratef4*(GOP(2,J)+GOP(1,J))/2.
      B(12,8)=-ratef4/2.
      B(12,12)=+1./2.

      BIG=ABS(RHP(2,J)/2.)
      BIG2=ABS(RHP(1,J)/2.)
      IF (BIG2.GT.BIG) BIG=BIG2
      BIG3=ABS(ratef4*GOP(2,J)/2.)
      IF (BIG3.GT.BIG) BIG=BIG3
      BIG4=ABS(ratef4*GOP(1,J)/2.)
      IF (BIG4.GT.BIG) BIG=BIG4
      IF (ABS(G(12)).LT.BIG*EBIG) G(12)=0

C     REACTION5
  218 G(13)=-(ANM(2,J)+ANM(1,J))/2.+ratef5*((GLUA(2,J)+GLUA(1,J))/2.
     1   -(GLU(2,J)+GLU(1,J))/2./equilib5)
      B(13,1)=ratef5/2./equilib5
      B(13,14)=-ratef5/2.
      B(13,13)=+1./2.

      BIG=ABS(ANM(2,J)/2.)
      BIG2=ABS(ANM(1,J)/2.)
      IF (BIG2.GT.BIG) BIG=BIG2
      BIG3=ABS(ratef5*GLUA(2,J)/2.)
      IF (BIG3.GT.BIG) BIG=BIG3
      BIG4=ABS(ratef5*GLUA(1,J)/2.)
      IF (BIG4.GT.BIG) BIG=BIG4
      BIG5=ABS(ratef5*GLU(2,J)/2./equilib5)
      IF (BIG5.GT.BIG) BIG=BIG5
      BIG6=ABS(ratef5*GLU(1,J)/2./equilib5)
      IF (BIG6.GT.BIG) BIG=BIG6
      IF (ABS(G(13)).LT.BIG*EBIG) G(13)=0.0

C     For alpha Glucose, being consumed only
      G(14)=COEFF9HH/2.*(GLUA(2,J+1)+GLUA(1,J+1)-GLUA(2,J)-GLUA(1,J))
     1      -COEFF9HHH/2.*(GLUA(2,J)+GLUA(1,J)-GLUA(2,J-1)-GLUA(1,J-1))
     2      -(HH/2.)*(3.*(ANM(2,J)+ANM(1,J))+(ANM(2,J+1)+ANM(1,J+1)))/8.
     3      -(HHH/2.)*(3.*(ANM(2,J)+ANM(1,J))+(ANM(2,J-1)+ANM(1,J-1)))/8.
     4      -HH/2.
     5      *(3.*(GLUA(2,J)-GLUA(1,J))+(GLUA(2,J+1)-GLUA(1,J+1)))/(4.*DT)
     6      -HHH/2.
     7      *(3.*(GLUA(2,J)-GLUA(1,J))+(GLUA(2,J-1)-GLUA(1,J-1)))/(4.*DT)

```

```
      B(14,14)=COEFF9HH/2.+COEFF9HHH/2.+HH/2.*3./(4.*DT)
     1  +HHH/2.*3./(4.*DT)
      D(14,14)=-COEFF9HH/2.+HH/2./(4.*DT)
      A(14,14)=-COEFF9HHH/2.+HHH/2./(4.*DT)
      B(14,13)=+(HH/2.)*(3./8.)+(HHH/2.)*(3./8.)
      D(14,13)=+(HH/2.)*(1./8.)
      A(14,13)=+(HHH/2.)*(1./8.)

      BIG=ABS(COEFF9HH/2.*GLUA(2,J+1))
      BIG2=ABS(COEFF9HH/2.*GLUA(1,J+1))
      IF (BIG2.GT.BIG) BIG=BIG2
      BIG3=ABS(COEFF9HH/2.*GLUA(2,J))
      IF (BIG3.GT.BIG) BIG=BIG3
      BIG4=ABS(COEFF9HH/2.*GLUA(1,J))
      IF (BIG4.GT.BIG) BIG=BIG4
      BIG5=ABS(COEFF9HHH/2.*GLUA(2,J))
      IF (BIG5.GT.BIG) BIG=BIG5
      BIG6=ABS(COEFF9HHH/2.*GLUA(1,J))
      IF (BIG6.GT.BIG) BIG=BIG6
      BIG7=ABS(COEFF9HHH/2.*GLUA(2,J-1))
      IF (BIG7.GT.BIG) BIG=BIG7
      BIG8=ABS(COEFF9HHH/2.*GLUA(1,J-1))
      IF (BIG8.GT.BIG) BIG=BIG8
      BIG9=ABS(HH/2.*3.*GLUA(2,J)/(4.*DT))
      IF (BIG9.GT.BIG) BIG=BIG9
      BIG10=ABS(HH/2.*3.*GLUA(1,J)/(4.*DT))
      IF (BIG10.GT.BIG) BIG=BIG10
      BIG11=ABS(HH/2.*GLUA(2,J+1)/(4.*DT))
      IF (BIG11.GT.BIG) BIG=BIG11
      BIG12=ABS(HH/2.*GLUA(1,J+1)/(4.*DT))
      IF (BIG12.GT.BIG) BIG=BIG12
      BIG13=ABS(HHH/2.*3.*GLUA(2,J)/(4.*DT))
      IF (BIG13.GT.BIG) BIG=BIG13
      BIG14=ABS(HHH/2.*3.*GLUA(1,J)/(4.*DT))
      IF (BIG14.GT.BIG) BIG=BIG14
      BIG15=ABS(HHH/2.*GLUA(2,J-1)/(4.*DT))
      IF (BIG15.GT.BIG) BIG=BIG15
      BIG16=ABS(HHH/2.*GLUA(1,J-1)/(4.*DT))
      IF (BIG16.GT.BIG) BIG=BIG16
      BIG17=ABS(HH/2.*3.*ANM(2,J)/8.)
      IF (BIG17.GT.BIG) BIG=BIG17
      BIG18=ABS(HH/2.*3.*ANM(1,J)/8.)
      IF (BIG18.GT.BIG) BIG=BIG18
      BIG19=ABS(HH/2.*ANM(2,J+1)/8.)
      IF (BIG19.GT.BIG) BIG=BIG19
      BIG20=ABS(HH/2.*ANM(1,J+1)/8.)
      IF (BIG20.GT.BIG) BIG=BIG20
      BIG21=ABS(HHH/2.*3.*ANM(2,J)/8.)
      IF (BIG21.GT.BIG) BIG=BIG21
      BIG22=ABS(HHH/2.*3.*ANM(1,J)/8.)
      IF (BIG22.GT.BIG) BIG=BIG22
      BIG23=ABS(HHH/2.*ANM(2,J-1)/8.)
      IF (BIG23.GT.BIG) BIG=BIG23
      BIG24=ABS(HHH/2.*ANM(1,J-1)/8.)
      IF (BIG24.GT.BIG) BIG=BIG24
      IF (ABS(G(14)).LT.BIG*EBIG) G(14)=0
```

```
C Gluconic acid dissociation

      G(15)=equilib6*(GLA(2,J)+GLA(1,J))/2.-(GLI(2,J)+GLI(1,J))*
     1   (HYD(2,J)+HYD(1,J))/4.
      B(15,3)=-equilib6/2.
      B(15,15)=(HYD(2,J)+HYD(1,J))/4.
      B(15,16)=(GLI(2,J)+GLI(1,J))/4.

      BIG=ABS(equilib6*GLA(2,J)/2.)
      BIG2=ABS(equilib6*GLA(1,J)/2.)
      IF (BIG2.GT.BIG) BIG=BIG2
      BIG3=ABS(GLI(2,J)*HYD(2,J)/4.)
      IF (BIG3.GT.BIG) BIG=BIG3
      BIG4=ABS(GLI(2,J)*HYD(1,J)/4)
      IF (BIG4.GT.BIG) BIG=BIG4
      BIG5=ABS(GLI(1,J)*HYD(2,J)/4)
      IF (BIG5.GT.BIG) BIG=BIG5
      BIG6=ABS(GLI(1,J)*HYD(1,J)/4)
      IF (BIG6.GT.BIG) BIG=BIG6
      IF (ABS(G(15)).LT.BIG*EBIG) G(15)=0

C Hydrogen ion, hydroxide ion, gluconate ion, bicarbonate ion flux
      G(16)=COEFF11HH/2.*(HYD(2,J+1)+HYD(1,J+1)-HYD(2,J)-HYD(1,J))
     1     -COEFF11HHH/2.*(HYD(2,J)+HYD(1,J)-HYD(2,J-1)-HYD(1,J-1))
     2     -COEFF15HH/2.*(OHI(2,J+1)+OHI(1,J+1)-OHI(2,J)-OHI(1,J))
     3     +COEFF15HHH/2.*(OHI(2,J)+OHI(1,J)-OHI(2,J-1)-OHI(1,J-1))
     4     -COEFF10HH/2.*(GLI(2,J+1)+GLI(1,J+1)-GLI(2,J)-GLI(1,J))
     5     +COEFF10HHH/2.*(GLI(2,J)+GLI(1,J)-GLI(2,J-1)-GLI(1,J-1))
     6     -COEFF14HH/2.*(CBI(2,J+1)+CBI(1,J+1)-CBI(2,J)-CBI(1,J))
     7     +COEFF14HHH/2.*(CBI(2,J)+CBI(1,J)-CBI(2,J-1)-CBI(1,J-1))
     8    -HH/2.*(3.*(HYD(2,J)-HYD(1,J))+(HYD(2,J+1)-HYD(1,J+1)))/(4.*DT)
     9   -HHH/2.*(3.*(HYD(2,J)-HYD(1,J))+(HYD(2,J-1)-HYD(1,J-1)))/(4.*DT)
     1    +HH/2.*(3.*(OHI(2,J)-OHI(1,J))+(OHI(2,J+1)-OHI(1,J+1)))/(4.*DT)
     2   +HHH/2.*(3.*(OHI(2,J)-OHI(1,J))+(OHI(2,J-1)-OHI(1,J-1)))/(4.*DT)
     3    +HH/2.*(3.*(GLI(2,J)-GLI(1,J))+(GLI(2,J+1)-GLI(1,J+1)))/(4.*DT)
     4   +HHH/2.*(3.*(GLI(2,J)-GLI(1,J))+(GLI(2,J-1)-GLI(1,J-1)))/(4.*DT)
     5    +HH/2.*(3.*(CBI(2,J)-CBI(1,J))+(CBI(2,J+1)-CBI(1,J+1)))/(4.*DT)
     6   +HHH/2.*(3.*(CBI(2,J)-CBI(1,J))+(CBI(2,J-1)-CBI(1,J-1)))/(4.*DT)

      B(16,16)=COEFF11HH/2.+COEFF11HHH/2.+HH/2.*3./(4.*DT)
     1 +HHH/2.*3./(4.*DT)
      D(16,16)=-COEFF11HH/2.+HH/2./(4.*DT)
      A(16,16)=-COEFF11HHH/2.+HHH/2./(4.*DT)

      B(16,17)=-COEFF15HH/2.-COEFF15HHH/2.-HH/2.*3./(4.*DT)
     1 -HHH/2.*3./(4.*DT)
      D(16,17)=+COEFF15HH/2.-HH/2./(4.*DT)
      A(16,17)=+COEFF15HHH/2.-HHH/2./(4.*DT)

      B(16,15)=-COEFF10HH/2.-COEFF10HHH/2.-HH/2.*3./(4.*DT)
     1 -HHH/2.*3./(4.*DT)
      D(16,15)=+COEFF10HH/2.-HH/2./(4.*DT)
      A(16,15)=+COEFF10HHH/2.-HHH/2./(4.*DT)

      B(16,20)=-COEFF14HH/2.-COEFF14HHH/2.-HH/2.*3./(4.*DT)
     1 -HHH/2.*3./(4.*DT)
      D(16,20)=+COEFF14HH/2.-HH/2./(4.*DT)
      A(16,20)=+COEFF14HHH/2.-HHH/2./(4.*DT)
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      BIG=ABS(COEFF11HH/2.*HYD(2,J+1))
      BIG2=ABS(COEFF11HH/2.*HYD(1,J+1))
      IF (BIG2.GT.BIG) BIG=BIG2
      BIG3=ABS(COEFF11HH/2.*HYD(2,J))
      IF (BIG3.GT.BIG) BIG=BIG3
      BIG4=ABS(COEFF11HH/2.*HYD(1,J))
      IF (BIG4.GT.BIG) BIG=BIG4
      BIG5=ABS(COEFF11HHH/2.*HYD(2,J))
      IF (BIG5.GT.BIG) BIG=BIG5
      BIG6=ABS(COEFF11HHH/2.*HYD(1,J))
      IF (BIG6.GT.BIG) BIG=BIG6
      BIG7=ABS(COEFF11HHH/2.*HYD(2,J-1))
      IF (BIG7.GT.BIG) BIG=BIG7
      BIG8=ABS(COEFF11HHH/2.*HYD(1,J-1))
      IF (BIG8.GT.BIG) BIG=BIG8
      BIG9=ABS(HH/2.*3.*HYD(2,J)/(4.*DT))
      IF (BIG9.GT.BIG) BIG=BIG9
      BIG10=ABS(HH/2.*3.*HYD(1,J)/(4.*DT))
      IF (BIG10.GT.BIG) BIG=BIG10
      BIG11=ABS(HH/2.*HYD(2,J+1)/(4.*DT))
      IF (BIG11.GT.BIG) BIG=BIG11
      BIG12=ABS(HH/2.*HYD(1,J+1)/(4.*DT))
      IF (BIG12.GT.BIG) BIG=BIG12
      BIG13=ABS(HHH/2.*3.*HYD(2,J)/(4.*DT))
      IF (BIG13.GT.BIG) BIG=BIG13
      BIG14=ABS(HHH/2.*3.*HYD(1,J)/(4.*DT))
      IF (BIG14.GT.BIG) BIG=BIG14
      BIG15=ABS(HHH/2.*HYD(2,J-1)/(4.*DT))
      IF (BIG15.GT.BIG) BIG=BIG15
      BIG16=ABS(HHH/2.*HYD(1,J-1)/(4.*DT))
      IF (BIG16.GT.BIG) BIG=BIG16
      BIG17=ABS(COEFF15HH/2.*OHI(2,J+1))
      IF (BIG17.GT.BIG) BIG=BIG17
      BIG18=ABS(COEFF15HH/2.*OHI(1,J+1))
      IF (BIG18.GT.BIG) BIG=BIG18
      BIG19=ABS(COEFF15HH/2.*OHI(2,J))
      IF (BIG19.GT.BIG) BIG=BIG19
      BIG20=ABS(COEFF15HH/2.*OHI(1,J))
      IF (BIG20.GT.BIG) BIG=BIG20
      BIG21=ABS(COEFF15HHH/2.*OHI(2,J))
      IF (BIG21.GT.BIG) BIG=BIG21
      BIG22=ABS(COEFF15HHH/2.*OHI(1,J))
      IF (BIG22.GT.BIG) BIG=BIG22
      BIG23=ABS(COEFF15HHH/2.*OHI(2,J-1))
      IF (BIG23.GT.BIG) BIG=BIG23
      BIG24=ABS(COEFF15HHH/2.*OHI(1,J-1))
      IF (BIG24.GT.BIG) BIG=BIG24
      BIG25=ABS(HH/2.*3.*OHI(2,J)/(4.*DT))
      IF (BIG25.GT.BIG) BIG=BIG25
      BIG26=ABS(HH/2.*3.*OHI(1,J)/(4.*DT))
      IF (BIG26.GT.BIG) BIG=BIG26
      BIG27=ABS(HH/2.*OHI(2,J+1)/(4.*DT))
      IF (BIG27.GT.BIG) BIG=BIG27
      BIG28=ABS(HH/2.*OHI(1,J+1)/(4.*DT))
      IF (BIG28.GT.BIG) BIG=BIG28
      BIG29=ABS(HHH/2.*3.*OHI(2,J)/(4.*DT))
      IF (BIG29.GT.BIG) BIG=BIG29
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      BIG30=ABS(HHH/2.*3.*OHI(1,J)/(4.*DT))
      IF (BIG30.GT.BIG) BIG=BIG30
      BIG31=ABS(HHH/2.*OHI(2,J-1)/(4.*DT))
      IF (BIG31.GT.BIG) BIG=BIG31
      BIG32=ABS(HHH/2.*OHI(1,J-1)/(4.*DT))
      IF (BIG32.GT.BIG) BIG=BIG32
      BIG33=ABS(COEFF10HH/2.*GLI(2,J+1))
      IF (BIG33.GT.BIG) BIG=BIG33
      BIG34=ABS(COEFF10HH/2.*GLI(1,J+1))
      IF (BIG34.GT.BIG) BIG=BIG34
      BIG35=ABS(COEFF10HH/2.*GLI(2,J))
      IF (BIG35.GT.BIG) BIG=BIG35
      BIG36=ABS(COEFF10HH/2.*GLI(1,J))
      IF (BIG36.GT.BIG) BIG=BIG36
      BIG37=ABS(COEFF10HHH/2.*GLI(2,J))
      IF (BIG37.GT.BIG) BIG=BIG37
      BIG38=ABS(COEFF10HHH/2.*GLI(1,J))
      IF (BIG38.GT.BIG) BIG=BIG38
      BIG39=ABS(COEFF10HHH/2.*GLI(2,J-1))
      IF (BIG39.GT.BIG) BIG=BIG39
      BIG40=ABS(COEFF10HHH/2.*GLI(1,J-1))
      IF (BIG40.GT.BIG) BIG=BIG40
      BIG41=ABS(HH/2.*3.*GLI(2,J)/(4.*DT))
      IF (BIG41.GT.BIG) BIG=BIG41
      BIG42=ABS(HH/2.*3.*GLI(1,J)/(4.*DT))
      IF (BIG42.GT.BIG) BIG=BIG42
      BIG43=ABS(HH/2.*GLI(2,J+1)/(4.*DT))
      IF (BIG43.GT.BIG) BIG=BIG43
      BIG44=ABS(HH/2.*GLI(1,J+1)/(4.*DT))
      IF (BIG44.GT.BIG) BIG=BIG44
      BIG45=ABS(HHH/2.*3.*GLI(2,J)/(4.*DT))
      IF (BIG45.GT.BIG) BIG=BIG45
      BIG46=ABS(HHH/2.*3.*GLI(1,J)/(4.*DT))
      IF (BIG46.GT.BIG) BIG=BIG46
      BIG47=ABS(HHH/2.*GLI(2,J-1)/(4.*DT))
      IF (BIG47.GT.BIG) BIG=BIG47
      BIG48=ABS(HHH/2.*GLI(1,J-1)/(4.*DT))
      IF (BIG48.GT.BIG) BIG=BIG48
      BIG49=ABS(COEFF14HH/2.*CBI(2,J+1))
      IF (BIG49.GT.BIG) BIG=BIG49
      BIG50=ABS(COEFF14HH/2.*CBI(1,J+1))
      IF (BIG50.GT.BIG) BIG=BIG50
      BIG51=ABS(COEFF14HH/2.*CBI(2,J))
      IF (BIG51.GT.BIG) BIG=BIG51
      BIG52=ABS(COEFF14HH/2.*CBI(1,J))
      IF (BIG52.GT.BIG) BIG=BIG52
      BIG53=ABS(COEFF14HHH/2.*CBI(2,J))
      IF (BIG53.GT.BIG) BIG=BIG53
      BIG54=ABS(COEFF14HHH/2.*CBI(1,J))
      IF (BIG54.GT.BIG) BIG=BIG54
      BIG55=ABS(COEFF14HHH/2.*CBI(2,J-1))
      IF (BIG55.GT.BIG) BIG=BIG55
      BIG56=ABS(COEFF14HHH/2.*CBI(1,J-1))
      IF (BIG56.GT.BIG) BIG=BIG56
      BIG57=ABS(HH/2.*3.*CBI(2,J)/(4.*DT))
      IF (BIG57.GT.BIG) BIG=BIG57
      BIG58=ABS(HH/2.*3.*CBI(1,J)/(4.*DT))
      IF (BIG58.GT.BIG) BIG=BIG58
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      BIG59=ABS(HH/2.*CBI(2,J+1)/(4.*DT))
      IF (BIG59.GT.BIG) BIG=BIG59
      BIG60=ABS(HH/2.*CBI(1,J+1)/(4.*DT))
      IF (BIG60.GT.BIG) BIG=BIG60
      BIG61=ABS(HHH/2.*3.*CBI(2,J)/(4.*DT))
      IF (BIG61.GT.BIG) BIG=BIG61
      BIG62=ABS(HHH/2.*3.*CBI(1,J)/(4.*DT))
      IF (BIG62.GT.BIG) BIG=BIG62
      BIG63=ABS(HHH/2.*CBI(2,J-1)/(4.*DT))
      IF (BIG63.GT.BIG) BIG=BIG63
      BIG64=ABS(HHH/2.*CBI(1,J-1)/(4.*DT))
      IF (BIG64.GT.BIG) BIG=BIG64
      IF (ABS(G(16)).LT.BIG*EBIG) G(16)=0

c Water Dissociation
      G(17)=equilib9 -(HYD(2,J)+HYD(1,J))*(OHI(2,J)+OHI(1,J))/4.
      B(17,17)=(HYD(2,J)+HYD(1,J))/4.
      B(17,16)=(OHI(2,J)+OHI(1,J))/4.

      BIG=ABS(equilib9)
      BIG2=ABS(HYD(2,J)*OHI(2,J)/4.)
      IF (BIG2.GT.BIG) BIG=BIG2
      BIG3=ABS(HYD(2,J)*OHI(1,J)/4.)
      IF (BIG3.GT.BIG) BIG=BIG3
      BIG4=ABS(HYD(1,J)*OHI(2,J)/4.)
      IF (BIG4.GT.BIG) BIG=BIG4
      BIG5=ABS(HYD(1,J)*OHI(1,J)/4.)
      IF (BIG5.GT.BIG) BIG=BIG5
      IF (ABS(G(17)).LT.BIG*EBIG) G(17)=0

C CO2 Hydration

      G(18)=equilib7*(CO2(2,J)+CO2(1,J))/2.-(CBA(2,J)+CBA(1,J))/2.
      B(18,18)=-equilib7/2.
      B(18,19)=1./2.

      BIG=ABS(equilib7*CO2(2,J)/2.)
      BIG2=ABS(equilib7*CO2(1,J)/2.)
      IF (BIG2.GT.BIG) BIG=BIG2
      BIG3=ABS(CBA(2,J)/2.)
      IF (BIG3.GT.BIG) BIG=BIG3
      BIG4=ABS(CBA(1,J)/2.)
      IF (BIG4.GT.BIG) BIG=BIG4
      IF (ABS(G(18)).LT.BIG*EBIG) G(18)=0

C Carbonic acid dissociation

      G(19)=equilib8*(CBA(2,J)+CBA(1,J))/2.-(CBI(2,J)+CBI(1,J))
     1 *(HYD(2,J)+HYD(1,J))/4.
      B(19,19)=-equilib8/2.
      B(19,20)=(HYD(2,J)+HYD(1,J))/4.
      B(19,16)=(CBI(2,J)+CBI(1,J))/4.

      BIG=ABS(equilib8*CBA(2,J)/2.)
      BIG2=ABS(equilib8*CBA(1,J)/2.)
      IF (BIG2.GT.BIG) BIG=BIG2
      BIG3=ABS(CBI(2,J)*HYD(2,J)/4.)
      IF (BIG3.GT.BIG) BIG=BIG3
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      BIG4=ABS(CBI(2,J)*HYD(1,J)/4.)
      IF (BIG4.GT.BIG) BIG=BIG4
      BIG5=ABS(CBI(1,J)*HYD(2,J)/4.)
      IF (BIG5.GT.BIG) BIG=BIG5
      BIG6=ABS(CBI(1,J)*HYD(1,J)/4.)
      IF (BIG6.GT.BIG) BIG=BIG6
      IF (ABS(G(19)).LT.BIG*EBIG) G(19)=0

C FLUX OF CO2, CARBONIC ACID, BICARBONATE ION
      G(20)=COEFF12HH/2.*(CO2(2,J+1)+CO2(1,J+1)-CO2(2,J)-CO2(1,J))
     1     -COEFF12HHH/2.*(CO2(2,J)+CO2(1,J)-CO2(2,J-1)-CO2(1,J-1))
     2     +COEFF13HH/2.*(CBA(2,J+1)+CBA(1,J+1)-CBA(2,J)-CBA(1,J))
     3     -COEFF13HHH/2.*(CBA(2,J)+CBA(1,J)-CBA(2,J-1)-CBA(1,J-1))
     4     +COEFF14HH/2.*(CBI(2,J+1)+CBI(1,J+1)-CBI(2,J)-CBI(1,J))
     5     -COEFF14HHH/2.*(CBI(2,J)+CBI(1,J)-CBI(2,J-1)-CBI(1,J-1))
     6    -HH/2.*(3.*(CO2(2,J)-CO2(1,J))+(CO2(2,J+1)-CO2(1,J+1)))/(4.*DT)
     7   -HHH/2.*(3.*(CO2(2,J)-CO2(1,J))+(CO2(2,J-1)-CO2(1,J-1)))/(4.*DT)
     8    -HH/2.*(3.*(CBA(2,J)-CBA(1,J))+(CBA(2,J+1)-CBA(1,J+1)))/(4.*DT)
     9   -HHH/2.*(3.*(CBA(2,J)-CBA(1,J))+(CBA(2,J-1)-CBA(1,J-1)))/(4.*DT)
     1    -HH/2.*(3.*(CBI(2,J)-CBI(1,J))+(CBI(2,J+1)-CBI(1,J+1)))/(4.*DT)
     2   -HHH/2.*(3.*(CBI(2,J)-CBI(1,J))+(CBI(2,J-1)-CBI(1,J-1)))/(4.*DT)

      B(20,20)=COEFF14HH/2.+COEFF14HHH/2.+HH/2.*3./(4.*DT)
     1 +HHH/2.*3./(4.*DT)
      D(20,20)=-COEFF14HH/2.+HH/2./(4.*DT)
      A(20,20)=-COEFF14HHH/2.+HHH/2./(4.*DT)
      B(20,18)=COEFF12HH/2.+COEFF12HHH/2.+HH/2.*3./(4.*DT)
     1 +HHH/2.*3./(4.*DT)
      D(20,18)=-COEFF12HH/2.+HH/2./(4.*DT)
      A(20,18)=-COEFF12HHH/2.+HHH/2./(4.*DT)
      B(20,19)=COEFF13HH/2.+COEFF13HHH/2.+HH/2.*3./(4.*DT)
     1 +HHH/2.*3./(4.*DT)
      D(20,19)=-COEFF13HH/2.+HH/2./(4.*DT)
      A(20,19)=-COEFF13HHH/2.+HHH/2./(4.*DT)

      BIG=ABS(COEFF12HH/2.*CO2(2,J+1))
      BIG2=ABS(COEFF12HH/2.*CO2(1,J+1))
      IF (BIG2.GT.BIG) BIG=BIG2
      BIG3=ABS(COEFF12HH/2.*CO2(2,J))
      IF (BIG3.GT.BIG) BIG=BIG3
      BIG4=ABS(COEFF12HH/2.*CO2(1,J))
      IF (BIG4.GT.BIG) BIG=BIG4
      BIG5=ABS(COEFF12HHH/2.*CO2(2,J))
      IF (BIG5.GT.BIG) BIG=BIG5
      BIG6=ABS(COEFF12HHH/2.*CO2(1,J))
      IF (BIG6.GT.BIG) BIG=BIG6
      BIG7=ABS(COEFF12HHH/2.*CO2(2,J-1))
      IF (BIG7.GT.BIG) BIG=BIG7
      BIG8=ABS(COEFF12HHH/2.*CO2(1,J-1))
      IF (BIG8.GT.BIG) BIG=BIG8
      BIG9=ABS(HH/2.*3.*CO2(2,J)/(4.*DT))
      IF (BIG9.GT.BIG) BIG=BIG9
      BIG10=ABS(HH/2.*3.*CO2(1,J)/(4.*DT))
      IF (BIG10.GT.BIG) BIG=BIG10
      BIG11=ABS(HH/2.*CO2(2,J+1)/(4.*DT))
      IF (BIG11.GT.BIG) BIG=BIG11
      BIG12=ABS(HH/2.*CO2(1,J+1)/(4.*DT))
      IF (BIG12.GT.BIG) BIG=BIG12
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      BIG13=ABS(HHH/2.*3.*CO2(2,J)/(4.*DT))
      IF (BIG13.GT.BIG) BIG=BIG13
      BIG14=ABS(HHH/2.*3.*CO2(1,J)/(4.*DT))
      IF (BIG14.GT.BIG) BIG=BIG14
      BIG15=ABS(HHH/2.*CO2(2,J-1)/(4.*DT))
      IF (BIG15.GT.BIG) BIG=BIG15
      BIG16=ABS(HHH/2.*CO2(1,J-1)/(4.*DT))
      IF (BIG16.GT.BIG) BIG=BIG16
      BIG17=ABS(COEFF13HH/2.*CBA(2,J+1))
      IF (BIG17.GT.BIG) BIG=BIG17
      BIG18=ABS(COEFF13HH/2.*CBA(1,J+1))
      IF (BIG18.GT.BIG) BIG=BIG18
      BIG19=ABS(COEFF13HH/2.*CBA(2,J))
      IF (BIG19.GT.BIG) BIG=BIG19
      BIG20=ABS(COEFF13HH/2.*CBA(1,J))
      IF (BIG20.GT.BIG) BIG=BIG20
      BIG21=ABS(COEFF13HHH/2.*CBA(2,J))
      IF (BIG21.GT.BIG) BIG=BIG21
      BIG22=ABS(COEFF13HHH/2.*CBA(1,J))
      IF (BIG22.GT.BIG) BIG=BIG22
      BIG23=ABS(COEFF13HHH/2.*CBA(2,J-1))
      IF (BIG23.GT.BIG) BIG=BIG23
      BIG24=ABS(COEFF13HHH/2.*CBA(1,J-1))
      IF (BIG24.GT.BIG) BIG=BIG24
      BIG25=ABS(HH/2.*3.*CBA(2,J)/(4.*DT))
      IF (BIG25.GT.BIG) BIG=BIG25
      BIG26=ABS(HH/2.*3.*CBA(1,J)/(4.*DT))
      IF (BIG26.GT.BIG) BIG=BIG26
      BIG27=ABS(HH/2.*CBA(2,J+1)/(4.*DT))
      IF (BIG27.GT.BIG) BIG=BIG27
      BIG28=ABS(HH/2.*CBA(1,J+1)/(4.*DT))
      IF (BIG28.GT.BIG) BIG=BIG28
      BIG29=ABS(HHH/2.*3.*CBA(2,J)/(4.*DT))
      IF (BIG29.GT.BIG) BIG=BIG29
      BIG30=ABS(HHH/2.*3.*CBA(1,J)/(4.*DT))
      IF (BIG30.GT.BIG) BIG=BIG30
      BIG31=ABS(HHH/2.*CBA(2,J-1)/(4.*DT))
      IF (BIG31.GT.BIG) BIG=BIG31
      BIG32=ABS(HHH/2.*CBA(1,J-1)/(4.*DT))
      IF (BIG32.GT.BIG) BIG=BIG32
      BIG33=ABS(COEFF14HH/2.*CBI(2,J+1))
      IF (BIG33.GT.BIG) BIG=BIG33
      BIG34=ABS(COEFF14HH/2.*CBI(1,J+1))
      IF (BIG34.GT.BIG) BIG=BIG34
      BIG35=ABS(COEFF14HH/2.*CBI(2,J))
      IF (BIG35.GT.BIG) BIG=BIG35
      BIG36=ABS(COEFF14HH/2.*CBI(1,J))
      IF (BIG36.GT.BIG) BIG=BIG36
      BIG37=ABS(COEFF14HHH/2.*CBI(2,J))
      IF (BIG37.GT.BIG) BIG=BIG37
      BIG38=ABS(COEFF14HHH/2.*CBI(1,J))
      IF (BIG38.GT.BIG) BIG=BIG38
      BIG39=ABS(COEFF14HHH/2.*CBI(2,J-1))
      IF (BIG39.GT.BIG) BIG=BIG39
      BIG40=ABS(COEFF14HHH/2.*CBI(1,J-1))
      IF (BIG40.GT.BIG) BIG=BIG40
      BIG41=ABS(HH/2.*3.*CBI(2,J)/(4.*DT))
      IF (BIG41.GT.BIG) BIG=BIG41
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      BIG42=ABS(HH/2.*3.*CBI(1,J)/(4.*DT))
      IF (BIG42.GT.BIG) BIG=BIG42
      BIG43=ABS(HH/2.*CBI(2,J+1)/(4.*DT))
      IF (BIG43.GT.BIG) BIG=BIG43
      BIG44=ABS(HH/2.*CBI(1,J+1)/(4.*DT))
      IF (BIG44.GT.BIG) BIG=BIG44
      BIG45=ABS(HHH/2.*3.*CBI(2,J)/(4.*DT))
      IF (BIG45.GT.BIG) BIG=BIG45
      BIG46=ABS(HHH/2.*3.*CBI(1,J)/(4.*DT))
      IF (BIG46.GT.BIG) BIG=BIG46
      BIG47=ABS(HHH/2.*CBI(2,J-1)/(4.*DT))
      IF (BIG47.GT.BIG) BIG=BIG47
      BIG48=ABS(HHH/2.*CBI(1,J-1)/(4.*DT))
      IF (BIG48.GT.BIG) BIG=BIG48
      IF (ABS(G(20)).LT.BIG*EBIG) G(20)=0


C     For Acetaminophen, reacting species
      G(21)=COEFF16HH/2.*(ACE(2,J+1)+ACE(1,J+1)-ACE(2,J)-ACE(1,J))
     1    -COEFF16HHH/2.*(ACE(2,J)+ACE(1,J)-ACE(2,J-1)-ACE(1,J-1))
     4   -HH/2.*(3.*(ACE(2,J)-ACE(1,J))+(ACE(2,J+1)-ACE(1,J+1)))/(4.*DT)
     5  -HHH/2.*(3.*(ACE(2,J)-ACE(1,J))+(ACE(2,J-1)-ACE(1,J-1)))/(4.*DT)

      B(21,21)=COEFF16HH/2.+COEFF16HHH/2.
     1 +HH/2.*3./(4.*DT)+HHH/2.*3./(4.*DT)
      D(21,21)=-COEFF16HH/2.+HH/2./(4.*DT)
      A(21,21)=-COEFF16HHH/2.+HHH/2./(4.*DT)


      BIG=ABS(COEFF16HH/2.*ACE(2,J+1))
      BIG2=ABS(COEFF16HH/2.*ACE(1,J+1))
      IF (BIG2.GT.BIG) BIG=BIG2
      BIG3=ABS(COEFF16HH/2.*ACE(2,J))
      IF (BIG3.GT.BIG) BIG=BIG3
      BIG4=ABS(COEFF16HH/2.*ACE(1,J))
      IF (BIG4.GT.BIG) BIG=BIG4
      BIG5=ABS(COEFF16HHH/2.*ACE(2,J))
      IF (BIG5.GT.BIG) BIG=BIG5
      BIG6=ABS(COEFF16HHH/2.*ACE(1,J))
      IF (BIG6.GT.BIG) BIG=BIG6
      BIG7=ABS(COEFF16HHH/2.*ACE(2,J-1))
      IF (BIG7.GT.BIG) BIG=BIG7
      BIG8=ABS(COEFF16HHH/2.*ACE(1,J-1))
      IF (BIG8.GT.BIG) BIG=BIG8
      BIG17=ABS(HH/2.*3.*ACE(2,J)/(4.*DT))
      IF (BIG17.GT.BIG) BIG=BIG17
      BIG18=ABS(HH/2.*3.*ACE(1,J)/(4.*DT))
      IF (BIG18.GT.BIG) BIG=BIG18
      BIG19=ABS(HH/2.*ACE(2,J+1)/(4.*DT))
      IF (BIG19.GT.BIG) BIG=BIG19
      BIG20=ABS(HH/2.*ACE(1,J+1)/(4.*DT))
      IF (BIG20.GT.BIG) BIG=BIG20
      BIG21=ABS(HHH/2.*3.*ACE(2,J)/(4.*DT))
      IF (BIG21.GT.BIG) BIG=BIG21
      BIG22=ABS(HHH/2.*3.*ACE(1,J)/(4.*DT))
      IF (BIG22.GT.BIG) BIG=BIG22
      BIG23=ABS(HHH/2.*ACE(2,J-1)/(4.*DT))
      IF (BIG23.GT.BIG) BIG=BIG23
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      BIG24=ABS(HHH/2.*ACE(1,J-1)/(4.*DT))
      IF (BIG24.GT.BIG) BIG=BIG24
      IF (ABS(G(21)).LT.BIG*EBIG) G(21)=0


C     DOUBLE LAYER VOLTAGE DUMMY VARIABLE

      G(22)=(VDL(2,J)+VDL(1,J))/2.

      B(22,22)=-1./2.

      BIG=ABS(VDL(2,J)/2.)
      BIG2=ABS(VDL(1,J)/2.)
      IF (BIG2.GT.BIG) BIG=BIG2
      IF (ABS(G(22)).LT.BIG*EBIG) G(22)=0


C   212 WRITE(12,301) J, (G(K),K=1,N)
      RETURN
      END

C     INNER GOX REACTION LAYER

      SUBROUTINE INNER(J)
      IMPLICIT DOUBLE PRECISION (A-H, O-Z)
      COMMON/BAB/ A(22,22),B(22,22),C(22,80001),D(22,45),G(22),X(22,22)
     1   ,Y(22,22)
      COMMON/NSN/ N, NJ
      COMMON/GLC/ NTIME,LL
      COMMON/VAR/ DIFF(16),H,EBIG,HH,IJ,KJ,TT,VAP,HHH,DT,RE,AKB,BB,CDL
      COMMON/VARR/ HHHH,HHHHH,MJ,LJ
      COMMON/DIN/ DGOX(16),DGLM(16),DIRM(16),DBULK(16)
      COMMON/SPCI/ GLU(2,80001),GOX(2,80001),GLA(2,80001),GOR(2,80001)
      COMMON/SPCII/ OXY(2,80001),HPR(2,80001),GOA(2,80001),GOP(2,80001)
      COMMON/RXT/ EQ1(2,80001),RGA(2,80001),EQ2(2,80001),RHP(2,80001)
      COMMON/SPCIII/ ANM(2,80001),GLUA(2,80001),GLI(2,80001)
      COMMON/SPCIV/ HYD(2,80001),OHI(2,80001),CO2(2,80001),CBA(2,80001)
      COMMON/SPCV/ CBI(2,80001),ACE(2,800001)
      COMMON/VOL/ VDL(2,80001)
      COMMON/POR/ POR1,POR2,PORGLU,PARION,PARACE
      COMMON/RTE/ ratef1,equilib1,ratef2,ratef3,equilib3,ratef4
      COMMON/RTD/ ratef5,equilib5,equilib6,equilib7,equilib8,equilib9
      COMMON/BUL/ CBULK(16),PARH2O2,PAR02,PARGLUCOSE,JCOUNT


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


C     For Glucose, being consumed only
      G(1)=DGOX(1)*(GLU(2,J+1)-2.*GLU(2,J)+GLU(2,J-1)
     1    +GLU(1,J+1)-2.*GLU(1,J)+GLU(1,J-1))/(2.*HH**2.)
     2    +(ANM(2,J)+ANM(1,J))/2.
     3    -(EQ1(2,J)+EQ1(1,J))/2.-(GLU(2,J)-GLU(1,J))/DT

      B(1,1)=DGOX(1)/HH**2.+1./DT
      D(1,1)=-DGOX(1)/(2.*HH**2.)
      A(1,1)=-DGOX(1)/(2.*HH**2.)
      B(1,9)=+1./2.
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```fortran
      B(1,13)=-1./2.

      BIG=ABS(DGOX(1)*(GLU(2,J+1))/(2.*HH**2.))
      BIG2=ABS(DGOX(1)*(GLU(2,J))/(HH**2.))
      IF (BIG2.GT.BIG) BIG=BIG2
      BIG3=ABS(DGOX(1)*(GLU(2,J-1))/(2.*HH**2.))
      IF (BIG3.GT.BIG) BIG=BIG3
      BIG4=ABS(DGOX(1)*(GLU(1,J+1))/(2.*HH**2.))
      IF (BIG4.GT.BIG) BIG=BIG4
      BIG5=ABS(DGOX(1)*(GLU(1,J))/(HH**2.))
      IF (BIG5.GT.BIG) BIG=BIG5
      BIG6=ABS(DGOX(1)*(GLU(1,J-1))/(2.*HH**2.))
      IF (BIG6.GT.BIG) BIG=BIG6
      BIG7=ABS(EQ1(2,J)/2.)
      IF (BIG7.GT.BIG) BIG=BIG7
      BIG8=ABS(EQ1(1,J)/2.)
      IF (BIG8.GT.BIG) BIG=BIG8
      BIG9=ABS(ANM(2,J)/2.)
      IF (BIG9.GT.BIG) BIG=BIG9
      BIG10=ABS(ANM(1,J)/2.)
      IF (BIG10.GT.BIG) BIG=BIG10
      BIG11=ABS(GLU(2,J)/DT)
      IF (BIG11.GT.BIG) BIG=BIG11
      BIG12=ABS(GLU(1,J)/DT)
      IF (BIG12.GT.BIG) BIG=BIG12
      IF (ABS(G(1)).LT.BIG*EBIG) G(1)=0

C       For GOx, enzyme
      G(2)=-(EQ1(2,J)+EQ1(1,J))/2.+(RHP(2,J)+RHP(1,J))/2.
     1  -(GOX(2,J)-GOX(1,J))/DT
      B(2,2)=+1./DT
      B(2,9)=+1./2.
      B(2,12)=-1./2.


      IF (ABS(EQ1(2,J)).GT.BIG) BIG=ABS(EQ1(2,J))
      IF (ABS(EQ1(1,J)).GT.BIG) BIG=ABS(EQ1(1,J))
      IF (ABS(RHP(2,J)).GT.BIG) BIG=ABS(RHP(2,J))
      IF (ABS(RHP(1,J)).GT.BIG) BIG=ABS(RHP(1,J))
      IF (ABS(GOX(2,J)/DT).GT.BIG) BIG=ABS(GOX(2,J)/DT)
      IF (ABS(GOX(1,J)/DT).GT.BIG) BIG=ABS(GOX(1,J)/DT)
      IF (ABS(G(2)).LT.BIG*EBIG) G(2)=0



C       For Gluconic Acid, being produced only
      G(3)=DGOX(3)*(GLA(2,J+1)-2.*GLA(2,J)+GLA(2,J-1)
     1       +GLA(1,J+1)-2.*GLA(1,J)+GLA(1,J-1))/(2.*HH**2.)
     2       +DGOX(10)*(GLI(2,J+1)-2.*GLI(2,J)+GLI(2,J-1)
     3       +GLI(1,J+1)-2.*GLI(1,J)+GLI(1,J-1))/(2.*HH**2.)
     4       +(RGA(2,J)+RGA(1,J))/2.-(GLA(2,J)-GLA(1,J))/DT
     5       -(GLI(2,J)-GLI(1,J))/DT


      B(3,3)=DGOX(3)/HH**2.+1./DT
      B(3,10)=-1./2.
      D(3,3)=-DGOX(3)/(2.*HH**2.)
      A(3,3)=-DGOX(3)/(2.*HH**2.)
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      B(3,15)=DGOX(10)/HH**2.+1./DT
      D(3,15)=-DGOX(10)/(2.*HH**2.)
      A(3,15)=-DGOX(10)/(2.*HH**2.)


      BIG=ABS(DGOX(3)*GLA(2,J+1)/(2.*HH**2.))
      BIG2=ABS(DGOX(3)*GLA(2,J)/(HH**2.))
      IF (BIG2.GT.BIG) BIG=BIG2
      BIG3=ABS(DGOX(3)*GLA(2,J-1)/(2.*HH**2.))
      IF (BIG3.GT.BIG) BIG=BIG3
      BIG4=ABS(DGOX(3)*GLA(1,J+1)/(2.*HH**2.))
      IF (BIG4.GT.BIG) BIG=BIG4
      BIG5=ABS(DGOX(3)*GLA(1,J)/(HH**2.))
      IF (BIG5.GT.BIG) BIG=BIG5
      BIG6=ABS(DGOX(3)*GLA(1,J-1)/(2.*HH**2.))
      IF (BIG6.GT.BIG) BIG=BIG6
      BIG7=ABS(DGOX(10)*GLI(2,J+1)/(2.*HH**2.))
      IF (BIG7.GT.BIG) BIG=BIG7
      BIG8=ABS(DGOX(10)*GLI(2,J)/(HH**2.))
      IF (BIG8.GT.BIG) BIG=BIG8
      BIG9=ABS(DGOX(10)*GLI(2,J-1)/(2.*HH**2.))
      IF (BIG9.GT.BIG) BIG=BIG9
      BIG10=ABS(DGOX(10)*GLI(1,J+1)/(2.*HH**2.))
      IF (BIG10.GT.BIG) BIG=BIG1
      BIG11=ABS(DGOX(10)*GLI(1,J)/(HH**2.))
      IF (BIG11.GT.BIG) BIG=BIG11
      BIG12=ABS(DGOX(10)*GLI(1,J-1)/(2.*HH**2.))
      IF (BIG12.GT.BIG) BIG=BIG12
      BIG13=ABS(RGA(2,J)/2.)
      IF (BIG13.GT.BIG) BIG=BIG13
      BIG14=ABS(RGA(1,J)/2)
      IF (BIG14.GT.BIG) BIG=BIG14
      BIG15=ABS(GLA(2,J)/DT)
      IF (BIG15.GT.BIG) BIG=BIG15
      BIG16=ABS(GLA(1,J)/DT)
      IF (BIG16.GT.BIG) BIG=BIG16
      BIG17=ABS(GLI(2,J)/DT)
      IF (BIG17.GT.BIG) BIG=BIG17
      BIG18=ABS(GLI(1,J)/DT)
      IF (BIG18.GT.BIG) BIG=BIG18
      IF (ABS(G(3)).LT.BIG*EBIG) G(3)=0



C     For GOx2, enzyme

      G(4)=CBULK(2)+CBULK(4)+CBULK(7)+CBULK(8)-(GOX(2,J)+GOX(1,J))/2.
     1 -(GOR(2,J)+GOR(1,J))/2.-(GOA(2,J)+GOA(1,J))/2.
     2 -(GOP(2,J)+GOP(1,J))/2.
      B(4,4)=+1./2.
      B(4,2)=+1./2.
      B(4,7)=+1./2.
      B(4,8)=+1./2.

      BIG=ABS(CBULK(2))
      IF (ABS(CBULK(4)).GT.BIG) BIG=ABS(CBULK(4))
      IF (ABS(CBULK(7)).GT.BIG) BIG=ABS(CBULK(7))
      IF (ABS(CBULK(8)).GT.BIG) BIG=ABS(CBULK(8))
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      IF (ABS(GOX(2,J)/2.).GT.BIG) BIG=ABS(GOX(2,J)/2.)
      IF (ABS(GOX(1,J)/2.).GT.BIG) BIG=ABS(GOX(1,J)/2.)
      IF (ABS(GOR(2,J)/2.).GT.BIG) BIG=ABS(GOR(2,J)/2.)
      IF (ABS(GOR(1,J)/2.).GT.BIG) BIG=ABS(GOR(1,J)/2.)
      IF (ABS(GOA(2,J)/2.).GT.BIG) BIG=ABS(GOA(2,J)/2.)
      IF (ABS(GOA(1,J)/2.).GT.BIG) BIG=ABS(GOA(1,J)/2.)
      IF (ABS(GOP(2,J)/2.).GT.BIG) BIG=ABS(GOP(2,J)/2.)
      IF (ABS(GOP(1,J)/2.).GT.BIG) BIG=ABS(GOP(1,J)/2.)
      IF (ABS(G(4)).LT.BIG*EBIG) G(4)=0


C     For O2, being consumed only, Diff(5), OXY,G5,EQ2
      G(5)=DGOX(5)*(OXY(2,J+1)-2.*OXY(2,J)+OXY(2,J-1)
     1      +OXY(1,J+1)-2.*OXY(1,J)+OXY(1,J-1))/(2.*HH**2.)
     2      -(EQ2(2,J)+EQ2(1,J))/2.-(OXY(2,J)-OXY(1,J))/DT


      B(5,5)=DGOX(5)/HH**2.+1./DT
      B(5,11)=1./2.
      D(5,5)=-DGOX(5)/(2.*HH**2.)
      A(5,5)=-DGOX(5)/(2.*HH**2.)


      BIG=ABS(DGOX(5)*OXY(2,J+1)/(2.*HH**2.))
      BIG2=ABS(DGOX(5)*OXY(2,J)/(HH**2.))
      IF (BIG2.GT.BIG) BIG=BIG2
      BIG3=ABS(DGOX(5)*OXY(2,J-1)/(2.*HH**2.))
      IF (BIG3.GT.BIG) BIG=BIG3
      BIG4=ABS(DGOX(5)*OXY(1,J+1)/(2.*HH**2.))
      IF (BIG4.GT.BIG) BIG=BIG4
      BIG5=ABS(DGOX(5)*OXY(1,J)/(HH**2.))
      IF (BIG5.GT.BIG) BIG=BIG5
      BIG6=ABS(DGOX(5)*OXY(1,J-1)/(2.*HH**2.))
      IF (BIG6.GT.BIG) BIG=BIG6
      BIG7=ABS(EQ2(2,J)/2.)
      IF (BIG7.GT.BIG) BIG=BIG7
      BIG8=ABS(EQ2(1,J)/2)
      IF (BIG8.GT.BIG) BIG=BIG8
      BIG9=ABS(OXY(2,J)/DT)
      IF (BIG9.GT.BIG) BIG=BIG9
      BIG10=ABS(OXY(1,J)/DT)
      IF (BIG10.GT.BIG) BIG=BIG10
      IF (ABS(G(5)).LT.BIG*EBIG) G(5)=0

C     For H2O2, reacting species,DIFF(6),H202,RHP,G6
      G(6)=DGOX(6)*(HPR(2,J+1)-2.*HPR(2,J)+HPR(2,J-1)
     1      +HPR(1,J+1)-2.*HPR(1,J)+HPR(1,J-1))/(2.*HH**2.)
     2      +(RHP(2,J)+RHP(1,J))/2.-(HPR(2,J)-HPR(1,J))/DT


      B(6,6)=DGOX(6)/HH**2.+1./DT
      B(6,12)=-1./2.
      D(6,6)=-DGOX(6)/(2.*HH**2.)
      A(6,6)=-DGOX(6)/(2.*HH**2.)


      BIG=ABS(DGOX(6)*HPR(2,J+1)/(2.*HH**2.))
      BIG2=ABS(DGOX(6)*HPR(2,J)/(HH**2.))
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      IF (BIG2.GT.BIG) BIG=BIG2
      BIG3=ABS(DGOX(6)*HPR(2,J-1)/(2.*HH**2.))
      IF (BIG3.GT.BIG) BIG=BIG3
      BIG4=ABS(DGOX(6)*HPR(1,J+1)/(2.*HH**2.))
      IF (BIG4.GT.BIG) BIG=BIG4
      BIG5=ABS(DGOX(6)*HPR(1,J)/(HH**2.))
      IF (BIG5.GT.BIG) BIG=BIG5
      BIG6=ABS(DGOX(6)*HPR(1,J-1)/(2.*HH**2.))
      IF (BIG6.GT.BIG) BIG=BIG6
      BIG7=ABS(RHP(2,J)/2.)
      IF (BIG7.GT.BIG) BIG=BIG7
      BIG8=ABS(RHP(1,J)/2)
      IF (BIG8.GT.BIG) BIG=BIG8
      BIG9=ABS(HPR(2,J)/DT)
      IF (BIG9.GT.BIG) BIG=BIG9
      BIG10=ABS(HPR(1,J)/DT)
      IF (BIG10.GT.BIG) BIG=BIG10
      IF (ABS(G(6)).LT.BIG*EBIG) G(6)=0

C     For CX-GOx2, enzyme
      G(7)=(EQ1(2,J)+EQ1(1,J))/2.-(RGA(2,J)+RGA(1,J))/2.
     1 -(GOA(2,J)-GOA(1,J))/DT

      B(7,7)=+1./DT
      B(7,9)=-1./2.
      B(7,10)=1./2.

      IF (ABS(EQ1(2,J)).GT.BIG) BIG=ABS(EQ1(2,J))
      IF (ABS(EQ1(1,J)).GT.BIG) BIG=ABS(EQ1(1,J))
      IF (ABS(RGA(2,J)).GT.BIG) BIG=ABS(RGA(2,J))
      IF (ABS(RGA(1,J)).GT.BIG) BIG=ABS(RGA(1,J))
      IF (ABS(GOA(2,J)/DT).GT.BIG) BIG=ABS(GOA(2,J)/DT)
      IF (ABS(GOA(1,J)/DT).GT.BIG) BIG=ABS(GOA(1,J)/DT)
      IF (ABS(G(7)).LT.BIG*EBIG) G(7)=0

C     For CX-GOx, enzyme
      G(8)=(EQ2(2,J)+EQ2(1,J))/2.-(RHP(2,J)+RHP(1,J))/2.
     1 -(GOP(2,J)-GOP(1,J))/DT
      B(8,8)=+1./DT
      B(8,11)=-1./2.
      B(8,12)=1./2.

      IF (ABS(EQ2(2,J)).GT.BIG) BIG=ABS(EQ2(2,J))
      IF (ABS(EQ2(1,J)).GT.BIG) BIG=ABS(EQ2(1,J))
      IF (ABS(RHP(2,J)).GT.BIG) BIG=ABS(RHP(2,J))
      IF (ABS(RHP(1,J)).GT.BIG) BIG=ABS(RHP(1,J))
      IF (ABS(GOP(2,J)/DT).GT.BIG) BIG=ABS(GOP(2,J)/DT)
      IF (ABS(GOP(1,J)/DT).GT.BIG) BIG=ABS(GOP(1,J)/DT)
      IF (ABS(G(8)).LT.BIG*EBIG) G(8)=0


C     REACTION1
  214 G(9)=-(EQ1(2,J)+EQ1(1,J))/2.
     1 +ratef1*((GLU(2,J)+GLU(1,J))*(GOX(2,J)+GOX(1,J))/4.
     2 -(GOA(2,J)+GOA(1,J))/2./equilib1)
      B(9,1)=-ratef1*(GOX(2,J)+GOX(1,J))/4.
      B(9,2)=-ratef1*(GLU(2,J)+GLU(1,J))/4.
      B(9,7)=ratef1/2./equilib1
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      B(9,9)=+1./2.

      BIG=ABS(EQ1(2,J)/2.)
      BIG2=ABS(EQ1(1,J)/2.)
      IF (BIG2.GT.BIG) BIG=BIG2
      BIG3=ABS(ratef1*GLU(2,J)*GOX(2,J)/4.)
      IF (BIG3.GT.BIG) BIG=BIG3
      BIG4=ABS(ratef1*GLU(1,J)*GOX(2,J)/4)
      IF (BIG4.GT.BIG) BIG=BIG4
      BIG5=ABS(ratef1*GLU(2,J)*GOX(1,J)/4)
      IF (BIG5.GT.BIG) BIG=BIG5
      BIG6=ABS(ratef1*GLU(1,J)*GOX(1,J)/4)
      IF (BIG6.GT.BIG) BIG=BIG6
      BIG7=ABS(ratef1*GOA(2,J)/2./equilib1)
      IF (BIG7.GT.BIG) BIG=BIG7
      BIG8=ABS(ratef1*GOA(1,J)/2./equilib1)
      IF (BIG8.GT.BIG) BIG=BIG8
      IF (ABS(G(9)).LT.BIG*EBIG) G(9)=0


C     REACTION2
  215 G(10)=-(RGA(2,J)+RGA(1,J))/2.+ratef2*(GOA(2,J)+GOA(1,J))/2.
      B(10,7)=-ratef2/2.
      B(10,10)=+1./2.

      BIG=ABS(RGA(2,J)/2.)
      BIG2=ABS(RGA(1,J)/2.)
      IF (BIG2.GT.BIG) BIG=BIG2
      BIG3=ABS(ratef2*GOA(2,J)/2.)
      IF (BIG3.GT.BIG) BIG=BIG3
      BIG4=ABS(ratef2*GOA(1,J)/2.)
      IF (BIG4.GT.BIG) BIG=BIG4
      IF (ABS(G(10)).LT.BIG*EBIG) G(10)=0

C     REACTION3
  216 G(11)=-(EQ2(2,J)+EQ2(1,J))/2.
     1 +ratef3*((GOR(2,J)+GOR(1,J))*(OXY(2,J)+OXY(1,J))/4.
     2 -(GOP(2,J)+GOP(1,J))/2./equilib3)
      B(11,4)=-ratef3*(OXY(2,J)+OXY(1,J))/4.
      B(11,5)=-ratef3*(GOR(2,J)+GOR(1,J))/4.
      B(11,8)=ratef3/2./equilib3
      B(11,11)=+1./2.

      BIG=ABS(EQ2(2,J)/2.)
      BIG2=ABS(EQ2(1,J)/2.)
      IF (BIG2.GT.BIG) BIG=BIG2
      BIG3=ABS(ratef3*GOR(2,J)*OXY(2,J)/4.)
      IF (BIG3.GT.BIG) BIG=BIG3
      BIG4=ABS(ratef3*GOR(1,J)*OXY(2,J)/4)
      IF (BIG4.GT.BIG) BIG=BIG4
      BIG5=ABS(ratef3*GOR(2,J)*OXY(1,J)/4)
      IF (BIG5.GT.BIG) BIG=BIG5
      BIG6=ABS(ratef3*GOR(1,J)*OXY(1,J)/4)
      IF (BIG6.GT.BIG) BIG=BIG6
      BIG7=ABS(ratef3*GOP(2,J)/2./EQUILIB3)
      IF (BIG7.GT.BIG) BIG=BIG7
      BIG8=ABS(ratef3*GOP(1,J)/2./EQUILIB3)
      IF (BIG8.GT.BIG) BIG=BIG8
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      IF (ABS(G(11)).LT.BIG*EBIG) G(11)=0

C     REACTION4
  217 G(12)=-(RHP(2,J)+RHP(1,J))/2.+ratef4*(GOP(2,J)+GOP(1,J))/2.
      B(12,8)=-ratef4/2.
      B(12,12)=+1./2.

      BIG=ABS(RHP(2,J)/2.)
      BIG2=ABS(RHP(1,J)/2.)
      IF (BIG2.GT.BIG) BIG=BIG2
      BIG3=ABS(ratef4*GOP(2,J)/2.)
      IF (BIG3.GT.BIG) BIG=BIG3
      BIG4=ABS(ratef4*GOP(1,J)/2.)
      IF (BIG4.GT.BIG) BIG=BIG4
      IF (ABS(G(12)).LT.BIG*EBIG) G(12)=0

C     REACTION5
  218 G(13)=-(ANM(2,J)+ANM(1,J))/2.+ratef5*((GLUA(2,J)+GLUA(1,J))/2.
     1   -(GLU(2,J)+GLU(1,J))/2./equilib5)
      B(13,1)=ratef5/2./equilib5
      B(13,14)=-ratef5/2.
      B(13,13)=+1./2.

      BIG=ABS(ANM(2,J)/2.)
      BIG2=ABS(ANM(1,J)/2.)
      IF (BIG2.GT.BIG) BIG=BIG2
      BIG3=ABS(ratef5*GLUA(2,J)/2.)
      IF (BIG3.GT.BIG) BIG=BIG3
      BIG4=ABS(ratef5*GLUA(1,J)/2.)
      IF (BIG4.GT.BIG) BIG=BIG4
      BIG5=ABS(ratef5*GLU(2,J)/2./equilib5)
      IF (BIG5.GT.BIG) BIG=BIG5
      BIG6=ABS(ratef5*GLU(1,J)/2./equilib5)
      IF (BIG6.GT.BIG) BIG=BIG6
      IF (ABS(G(13)).LT.BIG*EBIG) G(13)=0.0

C     For alpha Glucose, being consumed only
      G(14)=DGOX(9)*(GLUA(2,J+1)-2.*GLUA(2,J)+GLUA(2,J-1)
     1      +GLUA(1,J+1)-2.*GLUA(1,J)+GLUA(1,J-1))/(2.*HH**2.)
     2      -(ANM(2,J)+ANM(1,J))/2.-(GLUA(2,J)-GLUA(1,J))/DT
      B(14,14)=DGOX(9)/HH**2.+1./DT
      D(14,14)=-DGOX(9)/(2.*HH**2.)
      A(14,14)=-DGOX(9)/(2.*HH**2.)
      B(14,13)=1./2.

      BIG=ABS(DGOX(9)*(GLUA(2,J+1))/(2.*HH**2.))
      BIG2=ABS(DGOX(9)*(GLUA(2,J))/(HH**2.))
      IF (BIG2.GT.BIG) BIG=BIG2
      BIG3=ABS(DGOX(9)*(GLUA(2,J-1))/(2.*HH**2.))
      IF (BIG3.GT.BIG) BIG=BIG3
      BIG4=ABS(DGOX(9)*(GLUA(1,J+1))/(2.*HH**2.))
      IF (BIG4.GT.BIG) BIG=BIG4
      BIG5=ABS(DGOX(9)*(GLUA(1,J))/(HH**2.))
      IF (BIG5.GT.BIG) BIG=BIG5
      BIG6=ABS(DGOX(9)*(GLUA(1,J-1))/(2.*HH**2.))
      IF (BIG6.GT.BIG) BIG=BIG6
      BIG7=ABS(ANM(2,J)/2.)
      IF (BIG7.GT.BIG) BIG=BIG7
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      BIG8=ABS(ANM(1,J)/2.)
      IF (BIG8.GT.BIG) BIG=BIG8
      BIG9=ABS(GLUA(2,J)/DT)
      IF (BIG9.GT.BIG) BIG=BIG9
      BIG10=ABS(GLUA(1,J)/DT)
      IF (BIG10.GT.BIG) BIG=BIG10
      IF (ABS(G(14)).LT.BIG*EBIG) G(14)=0.0

C Gluconic acid dissociation

      G(15)=equilib6*(GLA(2,J)+GLA(1,J))/2.-(GLI(2,J)+GLI(1,J))*
     1    (HYD(2,J)+HYD(1,J))/4.
      B(15,3)=-equilib6/2.
      B(15,15)=(HYD(2,J)+HYD(1,J))/4.
      B(15,16)=(GLI(2,J)+GLI(1,J))/4.

      BIG=ABS(equilib6*GLA(2,J)/2.)
      BIG2=ABS(equilib6*GLA(1,J)/2.)
      IF (BIG2.GT.BIG) BIG=BIG2
      BIG3=ABS(GLI(2,J)*HYD(2,J)/4.)
      IF (BIG3.GT.BIG) BIG=BIG3
      BIG4=ABS(GLI(2,J)*HYD(1,J)/4)
      IF (BIG4.GT.BIG) BIG=BIG4
      BIG5=ABS(GLI(1,J)*HYD(2,J)/4)
      IF (BIG5.GT.BIG) BIG=BIG5
      BIG6=ABS(GLI(1,J)*HYD(1,J)/4)
      IF (BIG6.GT.BIG) BIG=BIG6
      IF (ABS(G(15)).LT.BIG*EBIG) G(15)=0

C Hydrogen ion, hydroxide ion, gluconate ion, bicarbonate ion flux
      G(16)=DGOX(11)*(HYD(2,J+1)-2.*HYD(2,J)+HYD(2,J-1)
     1       +HYD(1,J+1)-2.*HYD(1,J)+HYD(1,J-1))/(2.*HH**2.)
     2   -DGOX(15)*(OHI(2,J+1)-2.*OHI(2,J)+OHI(2,J-1)
     3       +OHI(1,J+1)-2.*OHI(1,J)+OHI(1,J-1))/(2.*HH**2.)
     4   -DGOX(10)*(GLI(2,J+1)-2.*GLI(2,J)+GLI(2,J-1)
     5       +GLI(1,J+1)-2.*GLI(1,J)+GLI(1,J-1))/(2.*HH**2.)
     6   -DGOX(14)*(CBI(2,J+1)-2.*CBI(2,J)+CBI(2,J-1)
     7       +CBI(1,J+1)-2.*CBI(1,J)+CBI(1,J-1))/(2.*HH**2.)
     8   -(HYD(2,J)-HYD(1,J))/DT+(OHI(2,J)-OHI(1,J))/DT
     9   +(GLI(2,J)-GLI(1,J))/DT+(CBI(2,J)-CBI(1,J))/DT

      B(16,16)=DGOX(11)/HH**2.+1./DT
      D(16,16)=-DGOX(11)/(2.*HH**2.)
      A(16,16)=-DGOX(11)/(2.*HH**2.)
      B(16,17)=-DGOX(15)/HH**2.-1./DT
      D(16,17)=DGOX(15)/(2.*HH**2.)
      A(16,17)=DGOX(15)/(2.*HH**2.)
      B(16,15)=-DGOX(10)/HH**2.-1./DT
      D(16,15)=DGOX(10)/(2.*HH**2.)
      A(16,15)=DGOX(10)/(2.*HH**2.)
      B(16,20)=-DGOX(14)/HH**2.-1./DT
      D(16,20)=DGOX(14)/(2.*HH**2.)
      A(16,20)=DGOX(14)/(2.*HH**2.)

      BIG=ABS(DGOX(11)*(HYD(2,J+1))/(2.*HH**2.))
      BIG2=ABS(DGOX(11)*(HYD(2,J))/(HH**2.))
      IF (BIG2.GT.BIG) BIG=BIG2
      BIG3=ABS(DGOX(11)*(HYD(2,J-1))/(2.*HH**2.))
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      IF (BIG3.GT.BIG) BIG=BIG3
      BIG4=ABS(DGOX(11)*(HYD(1,J+1))/(2.*HH**2.))
      IF (BIG4.GT.BIG) BIG=BIG4
      BIG5=ABS(DGOX(11)*(HYD(1,J))/(HH**2.))
      IF (BIG5.GT.BIG) BIG=BIG5
      BIG6=ABS(DGOX(11)*(HYD(1,J-1))/(2.*HH**2.))
      IF (BIG6.GT.BIG) BIG=BIG6
      BIG7=ABS(DGOX(15)*OHI(2,J+1)/(2.*HH**2.))
      IF (BIG7.GT.BIG) BIG=BIG7
      BIG8=ABS(DGOX(15)*OHI(2,J)/(HH**2.))
      IF (BIG8.GT.BIG) BIG=BIG8
      BIG9=ABS(DGOX(15)*OHI(2,J-1)/(2.*HH**2.))
      IF (BIG9.GT.BIG) BIG=BIG9
      BIG10=ABS(DGOX(15)*OHI(1,J+1)/(2.*HH**2.))
      IF (BIG10.GT.BIG) BIG=BIG10
      BIG11=ABS(DGOX(15)*OHI(1,J)/(HH**2.))
      IF (BIG11.GT.BIG) BIG=BIG11
      BIG12=ABS(DGOX(15)*OHI(1,J-1)/(2.*HH**2.))
      IF (BIG12.GT.BIG) BIG=BIG12
      BIG13=ABS(DGOX(10)*GLI(2,J+1)/(2.*HH**2.))
      IF (BIG13.GT.BIG) BIG=BIG13
      BIG14=ABS(DGOX(10)*GLI(2,J)/(HH**2.))
      IF (BIG14.GT.BIG) BIG=BIG14
      BIG15=ABS(DGOX(10)*GLI(2,J-1)/(2.*HH**2.))
      IF (BIG15.GT.BIG) BIG=BIG15
      BIG16=ABS(DGOX(10)*GLI(1,J+1)/(2.*HH**2.))
      IF (BIG16.GT.BIG) BIG=BIG16
      BIG17=ABS(DGOX(10)*GLI(1,J)/(HH**2.))
      IF (BIG17.GT.BIG) BIG=BIG17
      BIG18=ABS(DGOX(10)*GLI(1,J-1)/(2.*HH**2.))
      IF (BIG18.GT.BIG) BIG=BIG18
      BIG19=ABS(DGOX(14)*CBI(2,J+1)/(2.*HH**2.))
      IF (BIG19.GT.BIG) BIG=BIG19
      BIG20=ABS(DGOX(14)*CBI(2,J)/(HH**2.))
      IF (BIG20.GT.BIG) BIG=BIG20
      BIG21=ABS(DGOX(14)*CBI(2,J-1)/(2.*HH**2.))
      IF (BIG21.GT.BIG) BIG=BIG21
      BIG22=ABS(DGOX(14)*CBI(1,J+1)/(2.*HH**2.))
      IF (BIG22.GT.BIG) BIG=BIG22
      BIG23=ABS(DGOX(14)*CBI(1,J)/(HH**2.))
      IF (BIG23.GT.BIG) BIG=BIG23
      BIG24=ABS(DGOX(14)*CBI(1,J-1)/(2.*HH**2.))
      IF (BIG24.GT.BIG) BIG=BIG24
      BIG25=ABS(HYD(2,J)/DT)
      IF (BIG25.GT.BIG) BIG=BIG25
      BIG26=ABS(HYD(1,J)/DT)
      IF (BIG26.GT.BIG) BIG=BIG26
      BIG27=ABS(OHI(2,J)/DT)
      IF (BIG27.GT.BIG) BIG=BIG27
      BIG28=ABS(OHI(1,J)/DT)
      IF (BIG28.GT.BIG) BIG=BIG28
      BIG29=ABS(GLI(2,J)/DT)
      IF (BIG29.GT.BIG) BIG=BIG29
      BIG30=ABS(GLI(1,J)/DT)
      IF (BIG30.GT.BIG) BIG=BIG30
      BIG31=ABS(CBI(2,J)/DT)
      IF (BIG31.GT.BIG) BIG=BIG31
      BIG32=ABS(CBI(1,J)/DT)
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      IF (BIG32.GT.BIG) BIG=BIG32
      IF (ABS(G(16)).LT.BIG*EBIG) G(16)=0

c Water Dissociation
      G(17)=equilib9 -(HYD(2,J)+HYD(1,J))*(OHI(2,J)+OHI(1,J))/4.
      B(17,17)=(HYD(2,J)+HYD(1,J))/4.
      B(17,16)=(OHI(2,J)+OHI(1,J))/4.

      BIG=ABS(equilib9)
      BIG2=ABS(HYD(2,J)*OHI(2,J)/4.)
      IF (BIG2.GT.BIG) BIG=BIG2
      BIG3=ABS(HYD(2,J)*OHI(1,J)/4.)
      IF (BIG3.GT.BIG) BIG=BIG3
      BIG4=ABS(HYD(1,J)*OHI(2,J)/4.)
      IF (BIG4.GT.BIG) BIG=BIG4
      BIG5=ABS(HYD(1,J)*OHI(1,J)/4.)
      IF (BIG5.GT.BIG) BIG=BIG5
      IF (ABS(G(17)).LT.BIG*EBIG) G(17)=0

C CO2 Hydration

      G(18)=equilib7*(CO2(2,J)+CO2(1,J))/2.-(CBA(2,J)+CBA(1,J))/2.
      B(18,18)=-equilib7/2.
      B(18,19)=1./2.

      BIG=ABS(equilib7*CO2(2,J)/2.)
      BIG2=ABS(equilib7*CO2(1,J)/2.)
      IF (BIG2.GT.BIG) BIG=BIG2
      BIG3=ABS(CBA(2,J)/2.)
      IF (BIG3.GT.BIG) BIG=BIG3
      BIG4=ABS(CBA(1,J)/2.)
      IF (BIG4.GT.BIG) BIG=BIG4
      IF (ABS(G(18)).LT.BIG*EBIG) G(18)=0

C Carbonic acid dissociation

      G(19)=equilib8*(CBA(2,J)+CBA(1,J))/2.-(CBI(2,J)+CBI(1,J))
     1  *(HYD(2,J)+HYD(1,J))/4.
      B(19,19)=-equilib8/2.
      B(19,20)=(HYD(2,J)+HYD(1,J))/4.
      B(19,16)=(CBI(2,J)+CBI(1,J))/4.

      BIG=ABS(equilib8*CBA(2,J)/2.)
      BIG2=ABS(equilib8*CBA(1,J)/2.)
      IF (BIG2.GT.BIG) BIG=BIG2
      BIG3=ABS(CBI(2,J)*HYD(2,J)/4.)
      IF (BIG3.GT.BIG) BIG=BIG3
      BIG4=ABS(CBI(2,J)*HYD(1,J)/4.)
      IF (BIG4.GT.BIG) BIG=BIG4
      BIG5=ABS(CBI(1,J)*HYD(2,J)/4.)
      IF (BIG5.GT.BIG) BIG=BIG5
      BIG6=ABS(CBI(1,J)*HYD(1,J)/4.)
      IF (BIG6.GT.BIG) BIG=BIG6
      IF (ABS(G(19)).LT.BIG*EBIG) G(19)=0

C FLUX OF CO2, CARBONIC ACID, BICARBONATE ION
      G(20)=DGOX(12)*(CO2(2,J+1)-2.*CO2(2,J)+CO2(2,J-1)
     1      +CO2(1,J+1)-2.*CO2(1,J)+CO2(1,J-1))/(2.*HH**2.)
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     2    +DGOX(13)*(CBA(2,J+1)-2.*CBA(2,J)+CBA(2,J-1)
     3        +CBA(1,J+1)-2.*CBA(1,J)+CBA(1,J-1))/(2.*HH**2.)
     4    +DGOX(14)*(CBI(2,J+1)-2.*CBI(2,J)+CBI(2,J-1)
     5        +CBI(1,J+1)-2.*CBI(1,J)+CBI(1,J-1))/(2.*HH**2.)
     8    -(CO2(2,J)-CO2(1,J))/DT-(CBA(2,J)-CBA(1,J))/DT
     9    -(CBI(2,J)-CBI(1,J))/DT

      B(20,20)=DGOX(14)/HH**2.+1./DT
      D(20,20)=-DGOX(14)/(2.*HH**2.)
      A(20,20)=-DGOX(14)/(2.*HH**2.)
      B(20,18)=DGOX(12)/HH**2.+1./DT
      D(20,18)=-DGOX(12)/(2.*HH**2.)
      A(20,18)=-DGOX(12)/(2.*HH**2.)
      B(20,19)=DGOX(13)/HH**2.+1./DT
      D(20,19)=-DGOX(13)/(2.*HH**2.)
      A(20,19)=-DGOX(13)/(2.*HH**2.)


      BIG=ABS(DGOX(12)*(CO2(2,J+1))/(2.*HH**2.))
      BIG2=ABS(DGOX(12)*(CO2(2,J))/(HH**2.))
      IF (BIG2.GT.BIG) BIG=BIG2
      BIG3=ABS(DGOX(12)*(CO2(2,J-1))/(2.*HH**2.))
      IF (BIG3.GT.BIG) BIG=BIG3
      BIG4=ABS(DGOX(12)*(CO2(1,J+1))/(2.*HH**2.))
      IF (BIG4.GT.BIG) BIG=BIG4
      BIG5=ABS(DGOX(12)*(CO2(1,J))/(HH**2.))
      IF (BIG5.GT.BIG) BIG=BIG5
      BIG6=ABS(DGOX(12)*(CO2(1,J-1))/(2.*HH**2.))
      IF (BIG6.GT.BIG) BIG=BIG6
      BIG7=ABS(DGOX(13)*CBA(2,J+1)/(2.*HH**2.))
      IF (BIG7.GT.BIG) BIG=BIG7
      BIG8=ABS(DGOX(13)*CBA(2,J)/(HH**2.))
      IF (BIG8.GT.BIG) BIG=BIG8
      BIG9=ABS(DGOX(13)*CBA(2,J-1)/(2.*HH**2.))
      IF (BIG9.GT.BIG) BIG=BIG9
      BIG10=ABS(DGOX(13)*CBA(1,J+1)/(2.*HH**2.))
      IF (BIG10.GT.BIG) BIG=BIG10
      BIG11=ABS(DGOX(13)*CBA(1,J)/(HH**2.))
      IF (BIG11.GT.BIG) BIG=BIG11
      BIG12=ABS(DGOX(13)*CBA(1,J-1)/(2.*HH**2.))
      IF (BIG12.GT.BIG) BIG=BIG12
      BIG13=ABS(DGOX(14)*CBI(2,J+1)/(2.*HH**2.))
      IF (BIG13.GT.BIG) BIG=BIG13
      BIG14=ABS(DGOX(14)*CBI(2,J)/(HH**2.))
      IF (BIG14.GT.BIG) BIG=BIG14
      BIG15=ABS(DGOX(14)*CBI(2,J-1)/(2.*HH**2.))
      IF (BIG15.GT.BIG) BIG=BIG15
      BIG16=ABS(DGOX(14)*CBI(1,J+1)/(2.*HH**2.))
      IF (BIG16.GT.BIG) BIG=BIG16
      BIG17=ABS(DGOX(14)*CBI(1,J)/(HH**2.))
      IF (BIG17.GT.BIG) BIG=BIG17
      BIG18=ABS(DGOX(14)*CBI(1,J-1)/(2.*HH**2.))
      IF (BIG18.GT.BIG) BIG=BIG18
      BIG19=ABS(CO2(2,J)/DT)
      IF (BIG19.GT.BIG) BIG=BIG19
      BIG20=ABS(CO2(1,J)/DT)
      IF (BIG20.GT.BIG) BIG=BIG20
      BIG21=ABS(CBA(2,J)/DT)
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       IF (BIG21.GT.BIG) BIG=BIG21
       BIG22=ABS(CBA(1,J)/DT)
       IF (BIG22.GT.BIG) BIG=BIG22
       BIG23=ABS(CBI(2,J)/DT)
       IF (BIG23.GT.BIG) BIG=BIG23
       BIG24=ABS(CBI(1,J)/DT)
       IF (BIG24.GT.BIG) BIG=BIG24
       IF (ABS(G(20)).LT.BIG*EBIG) G(20)=0


C       For Acetaminophen
      G(21)=DGOX(16)*(ACE(2,J+1)-2.*ACE(2,J)+ACE(2,J-1)
     1        +ACE(1,J+1)-2.*ACE(1,J)+ACE(1,J-1))/(2.*HH**2.)
     2      -(ACE(2,J)-ACE(1,J))/DT

      B(21,21)=DGOX(16)/HH**2.+1./DT
      D(21,21)=-DGOX(16)/(2.*HH**2.)
      A(21,21)=-DGOX(16)/(2.*HH**2.)


       BIG=ABS(DGOX(16)*(ACE(2,J+1))/(2.*HH**2.))
       BIG2=ABS(DGOX(16)*(ACE(2,J))/(HH**2.))
       IF (BIG2.GT.BIG) BIG=BIG2
       BIG3=ABS(DGOX(16)*(ACE(2,J-1))/(2.*HH**2.))
       IF (BIG3.GT.BIG) BIG=BIG3
       BIG4=ABS(DGOX(16)*(ACE(1,J+1))/(2.*HH**2.))
       IF (BIG4.GT.BIG) BIG=BIG4
       BIG5=ABS(DGOX(16)*(ACE(1,J))/(HH**2.))
       IF (BIG5.GT.BIG) BIG=BIG5
       BIG6=ABS(DGOX(16)*(ACE(1,J-1))/(2.*HH**2.))
       IF (BIG6.GT.BIG) BIG=BIG6
       BIG7=ABS(ACE(2,J)/DT)
       IF (BIG7.GT.BIG) BIG=BIG7
       BIG8=ABS(ACE(1,J)/DT)
       IF (BIG8.GT.BIG) BIG=BIG8
       IF (ABS(G(21)).LT.BIG*EBIG) G(21)=0

C      DOUBLE lAYER voLTAGE - DUMMY

      G(22)=(VDL(2,J)+VDL(1,J))/2.

      B(22,22)=-1./2.

       BIG=ABS(VDL(2,J)/2.)
       BIG2=ABS(VDL(1,J)/2.)
       IF (BIG2.GT.BIG) BIG=BIG2
       IF (ABS(G(22)).LT.BIG*EBIG) G(22)=0


      RETURN
      END




c      SAVE G OUT DATA


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      SUBROUTINE COUPLER2(J)
      IMPLICIT DOUBLE PRECISION (A-H, O-Z)
      COMMON/BAB/ A(22,22),B(22,22),C(22,80001),D(22,45),G(22),X(22,22)
     1   ,Y(22,22)
      COMMON/NSN/ N, NJ
      COMMON/GLC/ NTIME,LL
      COMMON/VAR/ DIFF(16),H,EBIG,HH,IJ ,KJ,TT,VAP,HHH,DT,RE,AKB,BB,CDL
      COMMON/VARR/ HHHH,HHHHH,MJ,LJ
      COMMON/DIN/ DGOX(16),DGLM(16),DIRM(16),DBULK(16)
      COMMON/SPCI/ GLU(2,80001),GOX(2,80001),GLA(2,80001),GOR(2,80001)
      COMMON/SPCII/ OXY(2,80001),HPR(2,80001),GOA(2,80001),GOP(2,80001)
      COMMON/RXT/ EQ1(2,80001),RGA(2,80001),EQ2(2,80001),RHP(2,80001)
      COMMON/SPCIII/ ANM(2,80001),GLUA(2,80001),GLI(2,80001)
      COMMON/SPCIV/ HYD(2,80001),OHI(2,80001),CO2(2,80001),CBA(2,80001)
      COMMON/SPCV/ CBI(2,80001),ACE(2,800001)
      COMMON/VOL/ VDL(2,80001)
      COMMON/POR/ POR1,POR2,PORGLU,PARION,PARACE
      COMMON/RTE/ ratef1,equilib1,ratef2,ratef3,equilib3,ratef4
      COMMON/RTD/ ratef5,equilib5,equilib6,equilib7,equilib8,equilib9
      COMMON/BUL/ CBULK(16),PARH2O2,PAR02,PARGLUCOSE,JCOUNT

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


      COEFF1H=DGLM(1)/H
      COEFF1HH=DGOX(1)/HH
      COEFF3H=DGLM(3)/H
      COEFF3HH=DGOX(3)/HH
      COEFF5H=DGLM(5)/H
      COEFF5HH=DGOX(5)/HH
      COEFF6H=DGLM(6)/H
      COEFF6HH=DGOX(6)/HH
      COEFF9H=DGLM(9)/H
      COEFF9HH=DGOX(9)/HH
      COEFF10H=DGLM(10)/H
      COEFF10HH=DGOX(10)/HH
      COEFF11H=DGLM(11)/H
      COEFF11HH=DGOX(11)/HH
      COEFF12H=DGLM(12)/H
      COEFF12HH=DGOX(12)/HH
      COEFF13H=DGLM(13)/H
      COEFF13HH=DGOX(13)/HH
      COEFF14H=DGLM(14)/H
      COEFF14HH=DGOX(14)/HH
      COEFF15H=DGLM(15)/H
      COEFF15HH=DGOX(15)/HH
      COEFF16H=DGLM(16)/H
      COEFF16HH=DGOX(16)/HH

C       For Glucose, being consumed only
      G(1)=COEFF1H/2.*(GLU(2,J+1)+GLU(1,J+1)-GLU(2,J)-GLU(1,J))
     1      -COEFF1HH/2.*(GLU(2,J)+GLU(1,J)-GLU(2,J-1)-GLU(1,J-1))
     2      -(HH/2.)*(3.*(EQ1(2,J)+EQ1(1,J))+(EQ1(2,J-1)+EQ1(1,J-1)))/8.
     3      +(H/2.)*(3.*(ANM(2,J)+ANM(1,J))+(ANM(2,J+1)+ANM(1,J+1)))/8.
     4      +(HH/2.)*(3.*(ANM(2,J)+ANM(1,J))+(ANM(2,J-1)+ANM(1,J-1)))/8.
     5    -H/2.*(3.*(GLU(2,J)-GLU(1,J))+(GLU(2,J+1)-GLU(1,J+1)))/(4.*DT)
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     6    -HH/2.*(3.*(GLU(2,J)-GLU(1,J))+(GLU(2,J-1)-GLU(1,J-1)))/(4.*DT)

       B(1,1)=COEFF1H/2.+COEFF1HH/2.+H/2.*3./(4.*DT)+HH/2.*3./(4.*DT)
       D(1,1)=-COEFF1H/2.+H/2./(4.*DT)
       A(1,1)=-COEFF1HH/2.+HH/2./(4.*DT)
       B(1,9)=+(HH/2.)*(3./8.)
       A(1,9)=+(HH/2.)*(1./8.)
       B(1,13)=-(H/2.)*(3./8.)-(HH/2.)*(3./8.)
       D(1,13)=-(H/2.)*(1./8.)
       A(1,13)=-(HH/2.)*(1./8.)


       BIG=ABS(COEFF1H/2.*GLU(2,J+1))
       BIG2=ABS(COEFF1H/2.*GLU(1,J+1))
       IF (BIG2.GT.BIG) BIG=BIG2
       BIG3=ABS(COEFF1H/2.*GLU(2,J))
       IF (BIG3.GT.BIG) BIG=BIG3
       BIG4=ABS(COEFF1H/2.*GLU(1,J))
       IF (BIG4.GT.BIG) BIG=BIG4
       BIG5=ABS(COEFF1HH/2.*GLU(2,J))
       IF (BIG5.GT.BIG) BIG=BIG5
       BIG6=ABS(COEFF1HH/2.*GLU(1,J))
       IF (BIG6.GT.BIG) BIG=BIG6
       BIG7=ABS(COEFF1HH/2.*GLU(2,J-1))
       IF (BIG7.GT.BIG) BIG=BIG7
       BIG8=ABS(COEFF1HH/2.*GLU(1,J-1))
       IF (BIG8.GT.BIG) BIG=BIG8
       BIG9=ABS(HH/2.*3.*EQ1(2,J)/8.)
       IF (BIG9.GT.BIG) BIG=BIG9
       BIG10=ABS(HH/2.*3.*EQ1(1,J)/8.)
       IF (BIG10.GT.BIG) BIG=BIG10
       BIG11=ABS(HH/2.*EQ1(2,J-1)/8.)
       IF (BIG11.GT.BIG) BIG=BIG11
       BIG12=ABS(HH/2.*EQ1(1,J-1)/8.)
       IF (BIG12.GT.BIG) BIG=BIG12
       BIG13=ABS(H/2.*3.*GLU(2,J)/(4.*DT))
       IF (BIG13.GT.BIG) BIG=BIG13
       BIG14=ABS(H/2.*3.*GLU(1,J)/(4.*DT))
       IF (BIG14.GT.BIG) BIG=BIG14
       BIG15=ABS(H/2.*GLU(2,J+1)/(4.*DT))
       IF (BIG15.GT.BIG) BIG=BIG15
       BIG16=ABS(H/2.*GLU(1,J+1)/(4.*DT))
       IF (BIG16.GT.BIG) BIG=BIG16
       BIG17=ABS(HH/2.*3.*GLU(2,J)/(4.*DT))
       IF (BIG17.GT.BIG) BIG=BIG17
       BIG18=ABS(HH/2.*3.*GLU(1,J)/(4.*DT))
       IF (BIG18.GT.BIG) BIG=BIG18
       BIG19=ABS(HH/2.*GLU(2,J-1)/(4.*DT))
       IF (BIG19.GT.BIG) BIG=BIG19
       BIG20=ABS(HH/2.*GLU(1,J-1)/(4.*DT))
       IF (BIG20.GT.BIG) BIG=BIG20
       BIG21=ABS(H/2.*3.*ANM(2,J)/8.)
       IF (BIG21.GT.BIG) BIG=BIG21
       BIG22=ABS(H/2.*3.*ANM(1,J)/8.)
       IF (BIG22.GT.BIG) BIG=BIG22
       BIG23=ABS(H/2.*ANM(2,J+1)/8.)
       IF (BIG23.GT.BIG) BIG=BIG23
       BIG24=ABS(H/2.*ANM(1,J+1)/8.)
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      IF (BIG24.GT.BIG) BIG=BIG24
      BIG25=ABS(HH/2.*3.*ANM(2,J)/8.)
      IF (BIG25.GT.BIG) BIG=BIG25
      BIG26=ABS(HH/2.*3.*ANM(1,J)/8.)
      IF (BIG26.GT.BIG) BIG=BIG26
      BIG27=ABS(HH/2.*ANM(2,J-1)/8.)
      IF (BIG27.GT.BIG) BIG=BIG27
      BIG28=ABS(HH/2.*ANM(1,J-1)/8.)
      IF (BIG28.GT.BIG) BIG=BIG28
      IF (ABS(G(1)).LT.BIG*EBIG) G(1)=0

C     For GOx, enzyme
      G(2)=-(EQ1(2,J)+EQ1(1,J))/2.+(RHP(2,J)+RHP(1,J))/2.
     1  -(GOX(2,J)-GOX(1,J))/DT
      B(2,2)=+1./DT
      B(2,9)=+1./2.
      B(2,12)=-1./2.


      IF (ABS(EQ1(2,J)).GT.BIG) BIG=ABS(EQ1(2,J))
      IF (ABS(EQ1(1,J)).GT.BIG) BIG=ABS(EQ1(1,J))
      IF (ABS(RHP(2,J)).GT.BIG) BIG=ABS(RHP(2,J))
      IF (ABS(RHP(1,J)).GT.BIG) BIG=ABS(RHP(1,J))
      IF (ABS(GOX(2,J)/DT).GT.BIG) BIG=ABS(GOX(2,J)/DT)
      IF (ABS(GOX(1,J)/DT).GT.BIG) BIG=ABS(GOX(1,J)/DT)
      IF (ABS(G(2)).LT.BIG*EBIG) G(2)=0

C     For Gluconic Acid, being produced only
      G(3)=COEFF3H/2.*(GLA(2,J+1)+GLA(1,J+1)-GLA(2,J)-GLA(1,J))
     1       -COEFF3HH/2.*(GLA(2,J)+GLA(1,J)-GLA(2,J-1)-GLA(1,J-1))
     2       +COEFF10H/2.*(GLI(2,J+1)+GLI(1,J+1)-GLI(2,J)-GLI(1,J))
     3       -COEFF10HH/2.*(GLI(2,J)+GLI(1,J)-GLI(2,J-1)-GLI(1,J-1))
     4       +(HH/2.)*(3.*(RGA(2,J)+RGA(1,J))+(RGA(2,J-1)+RGA(1,J-1)))/8.
     5     -H/2.*(3.*(GLA(2,J)-GLA(1,J))+(GLA(2,J+1)-GLA(1,J+1)))/(4.*DT)
     6   -HH/2.*(3.*(GLA(2,J)-GLA(1,J))+(GLA(2,J-1)-GLA(1,J-1)))/(4.*DT)
     7     -H/2.*(3.*(GLI(2,J)-GLI(1,J))+(GLI(2,J+1)-GLI(1,J+1)))/(4.*DT)
     8   -HH/2.*(3.*(GLI(2,J)-GLI(1,J))+(GLI(2,J-1)-GLI(1,J-1)))/(4.*DT)

      B(3,3)=COEFF3H/2.+COEFF3HH/2.+H/2.*3./(4.*DT)+HH/2.*3./(4.*DT)
      D(3,3)=-COEFF3H/2.+H/2./(4.*DT)
      A(3,3)=-COEFF3HH/2.+HH/2./(4.*DT)
      B(3,15)=COEFF10H/2.+COEFF10HH/2.+H/2.*3./(4.*DT)+HH/2.*3./(4.*DT)
      D(3,15)=-COEFF10H/2.+H/2./(4.*DT)
      A(3,15)=-COEFF10HH/2.+HH/2./(4.*DT)
      B(3,10)=-(HH/2.)*(3./8.)
      A(3,10)=-(HH/2.)*(1./8.)


      BIG=ABS(COEFF3H/2.*GLA(2,J+1))
      BIG2=ABS(COEFF3H/2.*GLA(1,J+1))
      IF (BIG2.GT.BIG) BIG=BIG2
      BIG3=ABS(COEFF3H/2.*GLA(2,J))
      IF (BIG3.GT.BIG) BIG=BIG3
      BIG4=ABS(COEFF3H/2.*GLA(1,J))
      IF (BIG4.GT.BIG) BIG=BIG4
      BIG5=ABS(COEFF3HH/2.*GLA(2,J))
      IF (BIG5.GT.BIG) BIG=BIG5
      BIG6=ABS(COEFF3HH/2.*GLA(1,J))
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      IF (BIG6.GT.BIG) BIG=BIG6
      BIG7=ABS(COEFF3HH/2.*GLA(2,J-1))
      IF (BIG7.GT.BIG) BIG=BIG7
      BIG8=ABS(COEFF3HH/2.*GLA(1,J-1))
      IF (BIG8.GT.BIG) BIG=BIG8
      BIG9=ABS(HH/2.*3.*RGA(2,J)/8.)
      IF (BIG9.GT.BIG) BIG=BIG9
      BIG10=ABS(HH/2.*3.*RGA(1,J)/8.)
      IF (BIG10.GT.BIG) BIG=BIG10
      BIG11=ABS(HH/2.*RGA(2,J-1)/8.)
      IF (BIG11.GT.BIG) BIG=BIG11
      BIG12=ABS(HH/2.*RGA(1,J-1)/8.)
      IF (BIG12.GT.BIG) BIG=BIG12
      BIG13=ABS(H/2.*3.*GLA(2,J)/(4.*DT))
      IF (BIG13.GT.BIG) BIG=BIG13
      BIG14=ABS(H/2.*3.*GLA(1,J)/(4.*DT))
      IF (BIG14.GT.BIG) BIG=BIG14
      BIG15=ABS(H/2.*GLA(2,J+1)/(4.*DT))
      IF (BIG15.GT.BIG) BIG=BIG15
      BIG16=ABS(H/2.*GLA(1,J+1)/(4.*DT))
      IF (BIG16.GT.BIG) BIG=BIG16
      BIG17=ABS(HH/2.*3.*GLA(2,J)/(4.*DT))
      IF (BIG17.GT.BIG) BIG=BIG17
      BIG18=ABS(HH/2.*3.*GLA(1,J)/(4.*DT))
      IF (BIG18.GT.BIG) BIG=BIG18
      BIG19=ABS(HH/2.*GLA(2,J-1)/(4.*DT))
      IF (BIG19.GT.BIG) BIG=BIG19
      BIG20=ABS(HH/2.*GLA(1,J-1)/(4.*DT))
      IF (BIG20.GT.BIG) BIG=BIG20
      BIG21=ABS(COEFF10H/2.*GLI(2,J+1))
      IF (BIG21.GT.BIG) BIG=BIG21
      BIG22=ABS(COEFF10H/2.*GLI(1,J+1))
      IF (BIG22.GT.BIG) BIG=BIG22
      BIG23=ABS(COEFF10H/2.*GLI(2,J))
      IF (BIG23.GT.BIG) BIG=BIG23
      BIG24=ABS(COEFF10H/2.*GLI(1,J))
      IF (BIG24.GT.BIG) BIG=BIG24
      BIG25=ABS(COEFF10HH/2.*GLI(2,J))
      IF (BIG25.GT.BIG) BIG=BIG25
      BIG26=ABS(COEFF10HH/2.*GLI(1,J))
      IF (BIG26.GT.BIG) BIG=BIG26
      BIG27=ABS(COEFF10HH/2.*GLI(2,J-1))
      IF (BIG27.GT.BIG) BIG=BIG27
      BIG28=ABS(COEFF10HH/2.*GLI(1,J-1))
      IF (BIG28.GT.BIG) BIG=BIG28
      BIG29=ABS(H/2.*3.*GLI(2,J)/(4.*DT))
      IF (BIG29.GT.BIG) BIG=BIG29
      BIG30=ABS(H/2.*3.*GLI(1,J)/(4.*DT))
      IF (BIG30.GT.BIG) BIG=BIG30
      BIG31=ABS(H/2.*GLI(2,J+1)/(4.*DT))
      IF (BIG31.GT.BIG) BIG=BIG31
      BIG32=ABS(H/2.*GLI(1,J+1)/(4.*DT))
      IF (BIG32.GT.BIG) BIG=BIG32
      BIG33=ABS(HH/2.*3.*GLI(2,J)/(4.*DT))
      IF (BIG33.GT.BIG) BIG=BIG33
      BIG34=ABS(HH/2.*3.*GLI(1,J)/(4.*DT))
      IF (BIG34.GT.BIG) BIG=BIG34
      BIG35=ABS(HH/2.*GLI(2,J-1)/(4.*DT))
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      IF (BIG35.GT.BIG) BIG=BIG35
      BIG36=ABS(HH/2.*GLI(1,J-1)/(4.*DT))
      IF (BIG36.GT.BIG) BIG=BIG36
      IF (ABS(G(3)).LT.BIG*EBIG) G(3)=0

C     For GOx2, enzyme
      G(4)=CBULK(2)+CBULK(4)+CBULK(7)+CBULK(8)-(GOX(2,J)+GOX(1,J))/2.
     1 -(GOR(2,J)+GOR(1,J))/2.-(GOA(2,J)+GOA(1,J))/2.
     2 -(GOP(2,J)+GOP(1,J))/2.
      B(4,4)=+1./2.
      B(4,2)=+1./2.
      B(4,7)=+1./2.
      B(4,8)=+1./2.

      BIG=ABS(CBULK(2))
      IF (ABS(CBULK(4)).GT.BIG) BIG=ABS(CBULK(4))
      IF (ABS(CBULK(7)).GT.BIG) BIG=ABS(CBULK(7))
      IF (ABS(CBULK(8)).GT.BIG) BIG=ABS(CBULK(8))
      IF (ABS(GOX(2,J)/2.).GT.BIG) BIG=ABS(GOX(2,J)/2.)
      IF (ABS(GOX(1,J)/2.).GT.BIG) BIG=ABS(GOX(1,J)/2.)
      IF (ABS(GOR(2,J)/2.).GT.BIG) BIG=ABS(GOR(2,J)/2.)
      IF (ABS(GOR(1,J)/2.).GT.BIG) BIG=ABS(GOR(1,J)/2.)
      IF (ABS(GOA(2,J)/2.).GT.BIG) BIG=ABS(GOA(2,J)/2.)
      IF (ABS(GOA(1,J)/2.).GT.BIG) BIG=ABS(GOA(1,J)/2.)
      IF (ABS(GOP(2,J)/2.).GT.BIG) BIG=ABS(GOP(2,J)/2.)
      IF (ABS(GOP(1,J)/2.).GT.BIG) BIG=ABS(GOP(1,J)/2.)
      IF (ABS(G(4)).LT.BIG*EBIG) G(4)=0

C     For O2, being consumed only G(5), COEFF5, -EQ2 (11)
      G(5)=COEFF5H/2.*(OXY(2,J+1)+OXY(1,J+1)-OXY(2,J)-OXY(1,J))
     1      -COEFF5HH/2.*(OXY(2,J)+OXY(1,J)-OXY(2,J-1)-OXY(1,J-1))
     2      -(HH/2.)*(3.*(EQ2(2,J)+EQ2(1,J))+(EQ2(2,J-1)+EQ2(1,J-1)))/8.
     3    -H/2.*(3.*(OXY(2,J)-OXY(1,J))+(OXY(2,J+1)-OXY(1,J+1)))/(4.*DT)
     4   -HH/2.*(3.*(OXY(2,J)-OXY(1,J))+(OXY(2,J-1)-OXY(1,J-1)))/(4.*DT)

      B(5,5)=COEFF5H/2.+COEFF5HH/2.+H/2.*3./(4.*DT)+HH/2.*3./(4.*DT)
      D(5,5)=-COEFF5H/2.+H/2./(4.*DT)
      A(5,5)=-COEFF5HH/2.+HH/2./(4.*DT)
      B(5,11)=+(HH/2.)*(3./8.)
      A(5,11)=+(HH/2.)*(1./8.)


      BIG=ABS(COEFF5H/2.*OXY(2,J+1))
      BIG2=ABS(COEFF5H/2.*OXY(1,J+1))
      IF (BIG2.GT.BIG) BIG=BIG2
      BIG3=ABS(COEFF5H/2.*OXY(2,J))
      IF (BIG3.GT.BIG) BIG=BIG3
      BIG4=ABS(COEFF5H/2.*OXY(1,J))
      IF (BIG4.GT.BIG) BIG=BIG4
      BIG5=ABS(COEFF5HH/2.*OXY(2,J))
      IF (BIG5.GT.BIG) BIG=BIG5
      BIG6=ABS(COEFF5HH/2.*OXY(1,J))
      IF (BIG6.GT.BIG) BIG=BIG6
      BIG7=ABS(COEFF5HH/2.*OXY(2,J-1))
      IF (BIG7.GT.BIG) BIG=BIG7
      BIG8=ABS(COEFF5HH/2.*OXY(1,J-1))
      IF (BIG8.GT.BIG) BIG=BIG8
      BIG9=ABS(HH/2.*3.*EQ2(2,J)/8.)
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      IF (BIG9.GT.BIG) BIG=BIG9
      BIG10=ABS(HH/2.*3.*EQ2(1,J)/8.)
      IF (BIG10.GT.BIG) BIG=BIG10
      BIG11=ABS(HH/2.*EQ2(2,J-1)/8.)
      IF (BIG11.GT.BIG) BIG=BIG11
      BIG12=ABS(HH/2.*EQ2(1,J-1)/8.)
      IF (BIG12.GT.BIG) BIG=BIG12
      BIG13=ABS(H/2.*3.*OXY(2,J)/(4.*DT))
      IF (BIG13.GT.BIG) BIG=BIG13
      BIG14=ABS(H/2.*3.*OXY(1,J)/(4.*DT))
      IF (BIG14.GT.BIG) BIG=BIG14
      BIG15=ABS(H/2.*OXY(2,J+1)/(4.*DT))
      IF (BIG15.GT.BIG) BIG=BIG15
      BIG16=ABS(H/2.*OXY(1,J+1)/(4.*DT))
      IF (BIG16.GT.BIG) BIG=BIG16
      BIG17=ABS(HH/2.*3.*OXY(2,J)/(4.*DT))
      IF (BIG17.GT.BIG) BIG=BIG17
      BIG18=ABS(HH/2.*3.*OXY(1,J)/(4.*DT))
      IF (BIG18.GT.BIG) BIG=BIG18
      BIG19=ABS(HH/2.*OXY(2,J-1)/(4.*DT))
      IF (BIG19.GT.BIG) BIG=BIG19
      BIG20=ABS(HH/2.*OXY(1,J-1)/(4.*DT))
      IF (BIG20.GT.BIG) BIG=BIG20
      IF (ABS(G(5)).LT.BIG*EBIG) G(5)=0

C     For H2O2, reacting species COEFF6, G(6), +RHP (12), HPR
      G(6)=COEFF6H/2.*(HPR(2,J+1)+HPR(1,J+1)-HPR(2,J)-HPR(1,J))
     1    -COEFF6HH/2.*(HPR(2,J)+HPR(1,J)-HPR(2,J-1)-HPR(1,J-1))
     2    +(HH/2.)*(3.*(RHP(2,J)+RHP(1,J))+(RHP(2,J-1)+RHP(1,J-1)))/8.
     3   -H/2.*(3.*(HPR(2,J)-HPR(1,J))+(HPR(2,J+1)-HPR(1,J+1)))/(4.*DT)
     4  -HH/2.*(3.*(HPR(2,J)-HPR(1,J))+(HPR(2,J-1)-HPR(1,J-1)))/(4.*DT)

      B(6,6)=COEFF6H/2.+COEFF6HH/2.+H/2.*3./(4.*DT)+HH/2.*3./(4.*DT)
      D(6,6)=-COEFF6H/2.+H/2./(4.*DT)
      A(6,6)=-COEFF6HH/2.+HH/2./(4.*DT)
      B(6,12)=-(HH/2.)*(3./8.)
      A(6,12)=-(HH/2.)*(1./8.)


      BIG=ABS(COEFF6H/2.*HPR(2,J+1))
      BIG2=ABS(COEFF6H/2.*HPR(1,J+1))
      IF (BIG2.GT.BIG) BIG=BIG2
      BIG3=ABS(COEFF6H/2.*HPR(2,J))
      IF (BIG3.GT.BIG) BIG=BIG3
      BIG4=ABS(COEFF6H/2.*HPR(1,J))
      IF (BIG4.GT.BIG) BIG=BIG4
      BIG5=ABS(COEFF6HH/2.*HPR(2,J))
      IF (BIG5.GT.BIG) BIG=BIG5
      BIG6=ABS(COEFF6HH/2.*HPR(1,J))
      IF (BIG6.GT.BIG) BIG=BIG6
      BIG7=ABS(COEFF6HH/2.*HPR(2,J-1))
      IF (BIG7.GT.BIG) BIG=BIG7
      BIG8=ABS(COEFF6HH/2.*HPR(1,J-1))
      IF (BIG8.GT.BIG) BIG=BIG8
      BIG9=ABS(HH/2.*3.*RHP(2,J)/8.)
      IF (BIG9.GT.BIG) BIG=BIG9
      BIG10=ABS(HH/2.*3.*RHP(1,J)/8.)
      IF (BIG10.GT.BIG) BIG=BIG10
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       BIG11=ABS(HH/2.*RHP(2,J-1)/8.)
       IF (BIG11.GT.BIG) BIG=BIG11
       BIG12=ABS(HH/2.*RHP(1,J-1)/8.)
       IF (BIG12.GT.BIG) BIG=BIG12
       BIG13=ABS(H/2.*3.*HPR(2,J)/(4.*DT))
       IF (BIG13.GT.BIG) BIG=BIG13
       BIG14=ABS(H/2.*3.*HPR(1,J)/(4.*DT))
       IF (BIG14.GT.BIG) BIG=BIG14
       BIG15=ABS(H/2.*HPR(2,J+1)/(4.*DT))
       IF (BIG15.GT.BIG) BIG=BIG15
       BIG16=ABS(H/2.*HPR(1,J+1)/(4.*DT))
       IF (BIG16.GT.BIG) BIG=BIG16
       BIG17=ABS(HH/2.*3.*HPR(2,J)/(4.*DT))
       IF (BIG17.GT.BIG) BIG=BIG17
       BIG18=ABS(HH/2.*3.*HPR(1,J)/(4.*DT))
       IF (BIG18.GT.BIG) BIG=BIG18
       BIG19=ABS(HH/2.*HPR(2,J-1)/(4.*DT))
       IF (BIG19.GT.BIG) BIG=BIG19
       BIG20=ABS(HH/2.*HPR(1,J-1)/(4.*DT))
       IF (BIG20.GT.BIG) BIG=BIG20
       IF (ABS(G(6)).LT.BIG*EBIG) G(6)=0

C      For CX-GOx2, enzyme
      G(7)=(EQ1(2,J)+EQ1(1,J))/2.-(RGA(2,J)+RGA(1,J))/2.
     1 -(GOA(2,J)-GOA(1,J))/DT

      B(7,7)=+1./DT
      B(7,9)=-1./2.
      B(7,10)=1./2.

       IF (ABS(EQ1(2,J)).GT.BIG) BIG=ABS(EQ1(2,J))
       IF (ABS(EQ1(1,J)).GT.BIG) BIG=ABS(EQ1(1,J))
       IF (ABS(RGA(2,J)).GT.BIG) BIG=ABS(RGA(2,J))
       IF (ABS(RGA(1,J)).GT.BIG) BIG=ABS(RGA(1,J))
       IF (ABS(GOA(2,J)/DT).GT.BIG) BIG=ABS(GOA(2,J)/DT)
       IF (ABS(GOA(1,J)/DT).GT.BIG) BIG=ABS(GOA(1,J)/DT)
       IF (ABS(G(7)).LT.BIG*EBIG) G(7)=0

C      For CX-GOx, enzyme
      G(8)=(EQ2(2,J)+EQ2(1,J))/2.-(RHP(2,J)+RHP(1,J))/2.
     1 -(GOP(2,J)-GOP(1,J))/DT
      B(8,8)=+1./DT
      B(8,11)=-1./2.
      B(8,12)=1./2.

       IF (ABS(EQ2(2,J)).GT.BIG) BIG=ABS(EQ2(2,J))
       IF (ABS(EQ2(1,J)).GT.BIG) BIG=ABS(EQ2(1,J))
       IF (ABS(RHP(2,J)).GT.BIG) BIG=ABS(RHP(2,J))
       IF (ABS(RHP(1,J)).GT.BIG) BIG=ABS(RHP(1,J))
       IF (ABS(GOP(2,J)/DT).GT.BIG) BIG=ABS(GOP(2,J)/DT)
       IF (ABS(GOP(1,J)/DT).GT.BIG) BIG=ABS(GOP(1,J)/DT)
       IF (ABS(G(8)).LT.BIG*EBIG) G(8)=0


C     REACTION1
  214 G(9)=-(EQ1(2,J)+EQ1(1,J))/2.
     1 +ratef1*((GLU(2,J)+GLU(1,J))*(GOX(2,J)+GOX(1,J))/4.
     2 -(GOA(2,J)+GOA(1,J))/2./equilib1)
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      B(9,1)=-ratef1*(GOX(2,J)+GOX(1,J))/4.
      B(9,2)=-ratef1*(GLU(2,J)+GLU(1,J))/4.
      B(9,7)=ratef1/2./equilib1
      B(9,9)=+1./2.

      BIG=ABS(EQ1(2,J)/2.)
      BIG2=ABS(EQ1(1,J)/2.)
      IF (BIG2.GT.BIG) BIG=BIG2
      BIG3=ABS(ratef1*GLU(2,J)*GOX(2,J)/4.)
      IF (BIG3.GT.BIG) BIG=BIG3
      BIG4=ABS(ratef1*GLU(1,J)*GOX(2,J)/4)
      IF (BIG4.GT.BIG) BIG=BIG4
      BIG5=ABS(ratef1*GLU(2,J)*GOX(1,J)/4)
      IF (BIG5.GT.BIG) BIG=BIG5
      BIG6=ABS(ratef1*GLU(1,J)*GOX(1,J)/4)
      IF (BIG6.GT.BIG) BIG=BIG6
      BIG7=ABS(ratef1*GOA(2,J)/2./equilib1)
      IF (BIG7.GT.BIG) BIG=BIG7
      BIG8=ABS(ratef1*GOA(1,J)/2./equilib1)
      IF (BIG8.GT.BIG) BIG=BIG8
      IF (ABS(G(9)).LT.BIG*EBIG) G(9)=0

C     REACTION2
  215 G(10)=-(RGA(2,J)+RGA(1,J))/2.+ratef2*(GOA(2,J)+GOA(1,J))/2.
      B(10,7)=-ratef2/2.
      B(10,10)=+1./2.

      BIG=ABS(RGA(2,J)/2.)
      BIG2=ABS(RGA(1,J)/2.)
      IF (BIG2.GT.BIG) BIG=BIG2
      BIG3=ABS(ratef2*GOA(2,J)/2.)
      IF (BIG3.GT.BIG) BIG=BIG3
      BIG4=ABS(ratef2*GOA(1,J)/2.)
      IF (BIG4.GT.BIG) BIG=BIG4
      IF (ABS(G(10)).LT.BIG*EBIG) G(10)=0

C     REACTION3
  216 G(11)=-(EQ2(2,J)+EQ2(1,J))/2.
     1 +ratef3*((GOR(2,J)+GOR(1,J))*(OXY(2,J)+OXY(1,J))/4.
     2 -(GOP(2,J)+GOP(1,J))/2./equilib3)
      B(11,4)=-ratef3*(OXY(2,J)+OXY(1,J))/4.
      B(11,5)=-ratef3*(GOR(2,J)+GOR(1,J))/4.
      B(11,8)=ratef3/2./equilib3
      B(11,11)=+1./2.

      BIG=ABS(EQ2(2,J)/2.)
      BIG2=ABS(EQ2(1,J)/2.)
      IF (BIG2.GT.BIG) BIG=BIG2
      BIG3=ABS(ratef3*GOR(2,J)*OXY(2,J)/4.)
      IF (BIG3.GT.BIG) BIG=BIG3
      BIG4=ABS(ratef3*GOR(1,J)*OXY(2,J)/4)
      IF (BIG4.GT.BIG) BIG=BIG4
      BIG5=ABS(ratef3*GOR(2,J)*OXY(1,J)/4)
      IF (BIG5.GT.BIG) BIG=BIG5
      BIG6=ABS(ratef3*GOR(1,J)*OXY(1,J)/4)
      IF (BIG6.GT.BIG) BIG=BIG6
      BIG7=ABS(ratef3*GOP(2,J)/2./EQUILIB3)
      IF (BIG7.GT.BIG) BIG=BIG7
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      BIG8=ABS(ratef3*GOP(1,J)/2./EQUILIB3)
      IF (BIG8.GT.BIG) BIG=BIG8
      IF (ABS(G(11)).LT.BIG*EBIG) G(11)=0

C     REACTION4
  217 G(12)=-(RHP(2,J)+RHP(1,J))/2.+ratef4*(GOP(2,J)+GOP(1,J))/2.
      B(12,8)=-ratef4/2.
      B(12,12)=+1./2.

      BIG=ABS(RHP(2,J)/2.)
      BIG2=ABS(RHP(1,J)/2.)
      IF (BIG2.GT.BIG) BIG=BIG2
      BIG3=ABS(ratef4*GOP(2,J)/2.)
      IF (BIG3.GT.BIG) BIG=BIG3
      BIG4=ABS(ratef4*GOP(1,J)/2.)
      IF (BIG4.GT.BIG) BIG=BIG4
      IF (ABS(G(12)).LT.BIG*EBIG) G(12)=0

C     REACTION5
  218 G(13)=-(ANM(2,J)+ANM(1,J))/2.+ratef5*((GLUA(2,J)+GLUA(1,J))/2.
     1    -(GLU(2,J)+GLU(1,J))/2./equilib5)
      B(13,1)=ratef5/2./equilib5
      B(13,14)=-ratef5/2.
      B(13,13)=+1./2.

      BIG=ABS(ANM(2,J)/2.)
      BIG2=ABS(ANM(1,J)/2.)
      IF (BIG2.GT.BIG) BIG=BIG2
      BIG3=ABS(ratef5*GLUA(2,J)/2.)
      IF (BIG3.GT.BIG) BIG=BIG3
      BIG4=ABS(ratef5*GLUA(1,J)/2.)
      IF (BIG4.GT.BIG) BIG=BIG4
      BIG5=ABS(ratef5*GLU(2,J)/2./equilib5)
      IF (BIG5.GT.BIG) BIG=BIG5
      BIG6=ABS(ratef5*GLU(1,J)/2./equilib5)
      IF (BIG6.GT.BIG) BIG=BIG6
      IF (ABS(G(13)).LT.BIG*EBIG) G(13)=0.0

C     For alpha Glucose, being consumed only
      G(14)=COEFF9H/2.*(GLUA(2,J+1)+GLUA(1,J+1)-GLUA(2,J)-GLUA(1,J))
     1        -COEFF9HH/2.*(GLUA(2,J)+GLUA(1,J)-GLUA(2,J-1)-GLUA(1,J-1))
     2        -(H/2.)*(3.*(ANM(2,J)+ANM(1,J))+(ANM(2,J+1)+ANM(1,J+1)))/8.
     3        -(HH/2.)*(3.*(ANM(2,J)+ANM(1,J))+(ANM(2,J-1)+ANM(1,J-1)))/8.
     4        -H/2.
     5        *(3.*(GLUA(2,J)-GLUA(1,J))+(GLUA(2,J+1)-GLUA(1,J+1)))/(4.*DT)
     6        -HH/2.
     7        *(3.*(GLUA(2,J)-GLUA(1,J))+(GLUA(2,J-1)-GLUA(1,J-1)))/(4.*DT)


      B(14,14)=COEFF9H/2.+COEFF9HH/2.+H/2.*3./(4.*DT)
     1  +HH/2.*3./(4.*DT)
      D(14,14)=-COEFF9H/2.+H/2./(4.*DT)
      A(14,14)=-COEFF9HH/2.+HH/2./(4.*DT)
      B(14,13)=+(H/2.)*(3./8.)+(HH/2.)*(3./8.)
      D(14,13)=+(H/2.)*(1./8.)
      A(14,13)=+(HH/2.)*(1./8.)

      BIG=ABS(COEFF9H/2.*GLUA(2,J+1))
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      BIG2=ABS(COEFF9H/2.*GLUA(1,J+1))
      IF (BIG2.GT.BIG) BIG=BIG2
      BIG3=ABS(COEFF9H/2.*GLUA(2,J))
      IF (BIG3.GT.BIG) BIG=BIG3
      BIG4=ABS(COEFF9H/2.*GLUA(1,J))
      IF (BIG4.GT.BIG) BIG=BIG4
      BIG5=ABS(COEFF9HH/2.*GLUA(2,J))
      IF (BIG5.GT.BIG) BIG=BIG5
      BIG6=ABS(COEFF9HH/2.*GLUA(1,J))
      IF (BIG6.GT.BIG) BIG=BIG6
      BIG7=ABS(COEFF9HH/2.*GLUA(2,J-1))
      IF (BIG7.GT.BIG) BIG=BIG7
      BIG8=ABS(COEFF9HH/2.*GLUA(1,J-1))
      IF (BIG8.GT.BIG) BIG=BIG8
      BIG9=ABS(H/2.*3.*GLUA(2,J)/(4.*DT))
      IF (BIG9.GT.BIG) BIG=BIG9
      BIG10=ABS(H/2.*3.*GLUA(1,J)/(4.*DT))
      IF (BIG10.GT.BIG) BIG=BIG10
      BIG11=ABS(H/2.*GLUA(2,J+1)/(4.*DT))
      IF (BIG11.GT.BIG) BIG=BIG11
      BIG12=ABS(H/2.*GLUA(1,J+1)/(4.*DT))
      IF (BIG12.GT.BIG) BIG=BIG12
      BIG13=ABS(HH/2.*3.*GLUA(2,J)/(4.*DT))
      IF (BIG13.GT.BIG) BIG=BIG13
      BIG14=ABS(HH/2.*3.*GLUA(1,J)/(4.*DT))
      IF (BIG14.GT.BIG) BIG=BIG14
      BIG15=ABS(HH/2.*GLUA(2,J-1)/(4.*DT))
      IF (BIG15.GT.BIG) BIG=BIG15
      BIG16=ABS(HH/2.*GLUA(1,J-1)/(4.*DT))
      IF (BIG16.GT.BIG) BIG=BIG16
      BIG17=ABS(H/2.*3.*ANM(2,J)/8.)
      IF (BIG17.GT.BIG) BIG=BIG17
      BIG18=ABS(H/2.*3.*ANM(1,J)/8.)
      IF (BIG18.GT.BIG) BIG=BIG18
      BIG19=ABS(H/2.*ANM(2,J+1)/8.)
      IF (BIG19.GT.BIG) BIG=BIG19
      BIG20=ABS(H/2.*ANM(1,J+1)/8.)
      IF (BIG20.GT.BIG) BIG=BIG20
      BIG21=ABS(HH/2.*3.*ANM(2,J)/8.)
      IF (BIG21.GT.BIG) BIG=BIG21
      BIG22=ABS(HH/2.*3.*ANM(1,J)/8.)
      IF (BIG22.GT.BIG) BIG=BIG22
      BIG23=ABS(HH/2.*ANM(2,J-1)/8.)
      IF (BIG23.GT.BIG) BIG=BIG23
      BIG24=ABS(HH/2.*ANM(1,J-1)/8.)
      IF (BIG24.GT.BIG) BIG=BIG24
      IF (ABS(G(14)).LT.BIG*EBIG) G(14)=0

C Gluconic acid dissociation

      G(15)=equilib6*(GLA(2,J)+GLA(1,J))/2.-(GLI(2,J)+GLI(1,J))*
     1  (HYD(2,J)+HYD(1,J))/4.
      B(15,3)=-equilib6/2.
      B(15,15)=(HYD(2,J)+HYD(1,J))/4.
      B(15,16)=(GLI(2,J)+GLI(1,J))/4.

      BIG=ABS(equilib6*GLA(2,J)/2.)
      BIG2=ABS(equilib6*GLA(1,J)/2.)
```

```
      IF (BIG2.GT.BIG) BIG=BIG2
      BIG3=ABS(GLI(2,J)*HYD(2,J)/4.)
      IF (BIG3.GT.BIG) BIG=BIG3
      BIG4=ABS(GLI(2,J)*HYD(1,J)/4)
      IF (BIG4.GT.BIG) BIG=BIG4
      BIG5=ABS(GLI(1,J)*HYD(2,J)/4)
      IF (BIG5.GT.BIG) BIG=BIG5
      BIG6=ABS(GLI(1,J)*HYD(1,J)/4)
      IF (BIG6.GT.BIG) BIG=BIG6
      IF (ABS(G(15)).LT.BIG*EBIG) G(15)=0

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

      G(16)=COEFF11H/2.*(HYD(2,J+1)+HYD(1,J+1)-HYD(2,J)-HYD(1,J))
     1        -COEFF11HH/2.*(HYD(2,J)+HYD(1,J)-HYD(2,J-1)-HYD(1,J-1))
     2        -COEFF15H/2.*(OHI(2,J+1)+OHI(1,J+1)-OHI(2,J)-OHI(1,J))
     3        +COEFF15HH/2.*(OHI(2,J)+OHI(1,J)-OHI(2,J-1)-OHI(1,J-1))
     4        -COEFF10H/2.*(GLI(2,J+1)+GLI(1,J+1)-GLI(2,J)-GLI(1,J))
     5        +COEFF10HH/2.*(GLI(2,J)+GLI(1,J)-GLI(2,J-1)-GLI(1,J-1))
     6        -COEFF14H/2.*(CBI(2,J+1)+CBI(1,J+1)-CBI(2,J)-CBI(1,J))
     7        +COEFF14HH/2.*(CBI(2,J)+CBI(1,J)-CBI(2,J-1)-CBI(1,J-1))
     8      -H/2.*(3.*(HYD(2,J)-HYD(1,J))+(HYD(2,J+1)-HYD(1,J+1)))/(4.*DT)
     9    -HH/2.*(3.*(HYD(2,J)-HYD(1,J))+(HYD(2,J-1)-HYD(1,J-1)))/(4.*DT)
     1      +H/2.*(3.*(OHI(2,J)-OHI(1,J))+(OHI(2,J+1)-OHI(1,J+1)))/(4.*DT)
     2    +HH/2.*(3.*(OHI(2,J)-OHI(1,J))+(OHI(2,J-1)-OHI(1,J-1)))/(4.*DT)
     3      +H/2.*(3.*(GLI(2,J)-GLI(1,J))+(GLI(2,J+1)-GLI(1,J+1)))/(4.*DT)
     4    +HH/2.*(3.*(GLI(2,J)-GLI(1,J))+(GLI(2,J-1)-GLI(1,J-1)))/(4.*DT)
     5      +H/2.*(3.*(CBI(2,J)-CBI(1,J))+(CBI(2,J+1)-CBI(1,J+1)))/(4.*DT)
     6    +HH/2.*(3.*(CBI(2,J)-CBI(1,J))+(CBI(2,J-1)-CBI(1,J-1)))/(4.*DT)

      B(16,16)=COEFF11H/2.+COEFF11HH/2.+H/2.*3./(4.*DT)
     1 +HH/2.*3./(4.*DT)
      D(16,16)=-COEFF11H/2.+H/2./(4.*DT)
      A(16,16)=-COEFF11HH/2.+HH/2./(4.*DT)

      B(16,17)=-COEFF15H/2.-COEFF15HH/2.-H/2.*3./(4.*DT)
     1 -HH/2.*3./(4.*DT)
      D(16,17)=+COEFF15H/2.-H/2./(4.*DT)
      A(16,17)=+COEFF15HH/2.-HH/2./(4.*DT)

      B(16,15)=-COEFF10H/2.-COEFF10HH/2.-H/2.*3./(4.*DT)
     1 -HH/2.*3./(4.*DT)
      D(16,15)=+COEFF10H/2.-H/2./(4.*DT)
      A(16,15)=+COEFF10HH/2.-HH/2./(4.*DT)

      B(16,20)=-COEFF14H/2.-COEFF14HH/2.-H/2.*3./(4.*DT)
     1 -HH/2.*3./(4.*DT)
      D(16,20)=+COEFF14H/2.-H/2./(4.*DT)
      A(16,20)=+COEFF14HH/2.-HH/2./(4.*DT)

      BIG=ABS(COEFF11H/2.*HYD(2,J+1))
      BIG2=ABS(COEFF11H/2.*HYD(1,J+1))
      IF (BIG2.GT.BIG) BIG=BIG2
      BIG3=ABS(COEFF11H/2.*HYD(2,J))
      IF (BIG3.GT.BIG) BIG=BIG3
      BIG4=ABS(COEFF11H/2.*HYD(1,J))
      IF (BIG4.GT.BIG) BIG=BIG4
      BIG5=ABS(COEFF11HH/2.*HYD(2,J))
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          IF (BIG5.GT.BIG) BIG=BIG5
          BIG6=ABS(COEFF11HH/2.*HYD(1,J))
          IF (BIG6.GT.BIG) BIG=BIG6
          BIG7=ABS(COEFF11HH/2.*HYD(2,J-1))
          IF (BIG7.GT.BIG) BIG=BIG7
          BIG8=ABS(COEFF11HH/2.*HYD(1,J-1))
          IF (BIG8.GT.BIG) BIG=BIG8
          BIG9=ABS(H/2.*3.*HYD(2,J)/(4.*DT))
          IF (BIG9.GT.BIG) BIG=BIG9
          BIG10=ABS(H/2.*3.*HYD(1,J)/(4.*DT))
          IF (BIG10.GT.BIG) BIG=BIG10
          BIG11=ABS(H/2.*HYD(2,J+1)/(4.*DT))
          IF (BIG11.GT.BIG) BIG=BIG11
          BIG12=ABS(H/2.*HYD(1,J+1)/(4.*DT))
          IF (BIG12.GT.BIG) BIG=BIG12
          BIG13=ABS(HH/2.*3.*HYD(2,J)/(4.*DT))
          IF (BIG13.GT.BIG) BIG=BIG13
          BIG14=ABS(HH/2.*3.*HYD(1,J)/(4.*DT))
          IF (BIG14.GT.BIG) BIG=BIG14
          BIG15=ABS(HH/2.*HYD(2,J-1)/(4.*DT))
          IF (BIG15.GT.BIG) BIG=BIG15
          BIG16=ABS(HH/2.*HYD(1,J-1)/(4.*DT))
          IF (BIG16.GT.BIG) BIG=BIG16
          BIG17=ABS(COEFF15H/2.*OHI(2,J+1))
          IF (BIG17.GT.BIG) BIG=BIG17
          BIG18=ABS(COEFF15H/2.*OHI(1,J+1))
          IF (BIG18.GT.BIG) BIG=BIG18
          BIG19=ABS(COEFF15H/2.*OHI(2,J))
          IF (BIG19.GT.BIG) BIG=BIG19
          BIG20=ABS(COEFF15H/2.*OHI(1,J))
          IF (BIG20.GT.BIG) BIG=BIG20
          BIG21=ABS(COEFF15HH/2.*OHI(2,J))
          IF (BIG21.GT.BIG) BIG=BIG21
          BIG22=ABS(COEFF15HH/2.*OHI(1,J))
          IF (BIG22.GT.BIG) BIG=BIG22
          BIG23=ABS(COEFF15HH/2.*OHI(2,J-1))
          IF (BIG23.GT.BIG) BIG=BIG23
          BIG24=ABS(COEFF15HH/2.*OHI(1,J-1))
          IF (BIG24.GT.BIG) BIG=BIG24
          BIG25=ABS(H/2.*3.*OHI(2,J)/(4.*DT))
          IF (BIG25.GT.BIG) BIG=BIG25
          BIG26=ABS(H/2.*3.*OHI(1,J)/(4.*DT))
          IF (BIG26.GT.BIG) BIG=BIG26
          BIG27=ABS(H/2.*OHI(2,J+1)/(4.*DT))
          IF (BIG27.GT.BIG) BIG=BIG27
          BIG28=ABS(H/2.*OHI(1,J+1)/(4.*DT))
          IF (BIG28.GT.BIG) BIG=BIG28
          BIG29=ABS(HH/2.*3.*OHI(2,J)/(4.*DT))
          IF (BIG29.GT.BIG) BIG=BIG29
          BIG30=ABS(HH/2.*3.*OHI(1,J)/(4.*DT))
          IF (BIG30.GT.BIG) BIG=BIG30
          BIG31=ABS(HH/2.*OHI(2,J-1)/(4.*DT))
          IF (BIG31.GT.BIG) BIG=BIG31
          BIG32=ABS(HH/2.*OHI(1,J-1)/(4.*DT))
          IF (BIG32.GT.BIG) BIG=BIG32
          BIG33=ABS(COEFF10H/2.*GLI(2,J+1))
          IF (BIG33.GT.BIG) BIG=BIG33
          BIG34=ABS(COEFF10H/2.*GLI(1,J+1))
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      IF (BIG34.GT.BIG) BIG=BIG34
      BIG35=ABS(COEFF10H/2.*GLI(2,J))
      IF (BIG35.GT.BIG) BIG=BIG35
      BIG36=ABS(COEFF10H/2.*GLI(1,J))
      IF (BIG36.GT.BIG) BIG=BIG36
      BIG37=ABS(COEFF10HH/2.*GLI(2,J))
      IF (BIG37.GT.BIG) BIG=BIG37
      BIG38=ABS(COEFF10HH/2.*GLI(1,J))
      IF (BIG38.GT.BIG) BIG=BIG38
      BIG39=ABS(COEFF10HH/2.*GLI(2,J-1))
      IF (BIG39.GT.BIG) BIG=BIG39
      BIG40=ABS(COEFF10HH/2.*GLI(1,J-1))
      IF (BIG40.GT.BIG) BIG=BIG40
      BIG41=ABS(H/2.*3.*GLI(2,J)/(4.*DT))
      IF (BIG41.GT.BIG) BIG=BIG41
      BIG42=ABS(H/2.*3.*GLI(1,J)/(4.*DT))
      IF (BIG42.GT.BIG) BIG=BIG42
      BIG43=ABS(H/2.*GLI(2,J+1)/(4.*DT))
      IF (BIG43.GT.BIG) BIG=BIG43
      BIG44=ABS(H/2.*GLI(1,J+1)/(4.*DT))
      IF (BIG44.GT.BIG) BIG=BIG44
      BIG45=ABS(HH/2.*3.*GLI(2,J)/(4.*DT))
      IF (BIG45.GT.BIG) BIG=BIG45
      BIG46=ABS(HH/2.*3.*GLI(1,J)/(4.*DT))
      IF (BIG46.GT.BIG) BIG=BIG46
      BIG47=ABS(HH/2.*GLI(2,J-1)/(4.*DT))
      IF (BIG47.GT.BIG) BIG=BIG47
      BIG48=ABS(HH/2.*GLI(1,J-1)/(4.*DT))
      IF (BIG48.GT.BIG) BIG=BIG48
      BIG49=ABS(COEFF14H/2.*CBI(2,J+1))
      IF (BIG49.GT.BIG) BIG=BIG49
      BIG50=ABS(COEFF14H/2.*CBI(1,J+1))
      IF (BIG50.GT.BIG) BIG=BIG50
      BIG51=ABS(COEFF14H/2.*CBI(2,J))
      IF (BIG51.GT.BIG) BIG=BIG51
      BIG52=ABS(COEFF14H/2.*CBI(1,J))
      IF (BIG52.GT.BIG) BIG=BIG52
      BIG53=ABS(COEFF14HH/2.*CBI(2,J))
      IF (BIG53.GT.BIG) BIG=BIG53
      BIG54=ABS(COEFF14HH/2.*CBI(1,J))
      IF (BIG54.GT.BIG) BIG=BIG54
      BIG55=ABS(COEFF14HH/2.*CBI(2,J-1))
      IF (BIG55.GT.BIG) BIG=BIG55
      BIG56=ABS(COEFF14HH/2.*CBI(1,J-1))
      IF (BIG56.GT.BIG) BIG=BIG56
      BIG57=ABS(H/2.*3.*CBI(2,J)/(4.*DT))
      IF (BIG57.GT.BIG) BIG=BIG57
      BIG58=ABS(H/2.*3.*CBI(1,J)/(4.*DT))
      IF (BIG58.GT.BIG) BIG=BIG58
      BIG59=ABS(H/2.*CBI(2,J+1)/(4.*DT))
      IF (BIG59.GT.BIG) BIG=BIG59
      BIG60=ABS(H/2.*CBI(1,J+1)/(4.*DT))
      IF (BIG60.GT.BIG) BIG=BIG60
      BIG61=ABS(HH/2.*3.*CBI(2,J)/(4.*DT))
      IF (BIG61.GT.BIG) BIG=BIG61
      BIG62=ABS(HH/2.*3.*CBI(1,J)/(4.*DT))
      IF (BIG62.GT.BIG) BIG=BIG62
      BIG63=ABS(HH/2.*CBI(2,J-1)/(4.*DT))
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      IF (BIG63.GT.BIG) BIG=BIG63
      BIG64=ABS(HH/2.*CBI(1,J-1)/(4.*DT))
      IF (BIG64.GT.BIG) BIG=BIG64
      IF (ABS(G(16)).LT.BIG*EBIG) G(16)=0

c Water Dissociation
      G(17)=equilib9-(HYD(2,J)+HYD(1,J))*(OHI(2,J)+OHI(1,J))/4.
      B(17,17)=(HYD(2,J)+HYD(1,J))/4.
      B(17,16)=(OHI(2,J)+OHI(1,J))/4.

      BIG=ABS(equilib9)
      BIG2=ABS(HYD(2,J)*OHI(2,J)/4.)
      IF (BIG2.GT.BIG) BIG=BIG2
      BIG3=ABS(HYD(2,J)*OHI(1,J)/4.)
      IF (BIG3.GT.BIG) BIG=BIG3
      BIG4=ABS(HYD(1,J)*OHI(2,J)/4.)
      IF (BIG4.GT.BIG) BIG=BIG4
      BIG5=ABS(HYD(1,J)*OHI(1,J)/4.)
      IF (BIG5.GT.BIG) BIG=BIG5
      IF (ABS(G(17)).LT.BIG*EBIG) G(17)=0

C CO2 Hydration

      G(18)=equilib7*(CO2(2,J)+CO2(1,J))/2.-(CBA(2,J)+CBA(1,J))/2.
      B(18,18)=-equilib7/2.
      B(18,19)=1./2.

      BIG=ABS(equilib7*CO2(2,J)/2.)
      BIG2=ABS(equilib7*CO2(1,J)/2.)
      IF (BIG2.GT.BIG) BIG=BIG2
      BIG3=ABS(CBA(2,J)/2.)
      IF (BIG3.GT.BIG) BIG=BIG3
      BIG4=ABS(CBA(1,J)/2.)
      IF (BIG4.GT.BIG) BIG=BIG4
      IF (ABS(G(18)).LT.BIG*EBIG) G(18)=0

C Carbonic acid dissociation

      G(19)=equilib8*(CBA(2,J)+CBA(1,J))/2.-(CBI(2,J)+CBI(1,J))
     1  *(HYD(2,J)+HYD(1,J))/4.
      B(19,19)=-equilib8/2.
      B(19,20)=(HYD(2,J)+HYD(1,J))/4.
      B(19,16)=(CBI(2,J)+CBI(1,J))/4.

      BIG=ABS(equilib8*CBA(2,J)/2.)
      BIG2=ABS(equilib8*CBA(1,J)/2.)
      IF (BIG2.GT.BIG) BIG=BIG2
      BIG3=ABS(CBI(2,J)*HYD(2,J)/4.)
      IF (BIG3.GT.BIG) BIG=BIG3
      BIG4=ABS(CBI(2,J)*HYD(1,J)/4.)
      IF (BIG4.GT.BIG) BIG=BIG4
      BIG5=ABS(CBI(1,J)*HYD(2,J)/4.)
      IF (BIG5.GT.BIG) BIG=BIG5
      BIG6=ABS(CBI(1,J)*HYD(1,J)/4.)
      IF (BIG6.GT.BIG) BIG=BIG6
      IF (ABS(G(19)).LT.BIG*EBIG) G(19)=0

C FLUX OF CO2, CARBONIC ACID, BICARBONATE ION
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      G(20)=COEFF12H/2.*(CO2(2,J+1)+CO2(1,J+1)-CO2(2,J)-CO2(1,J))
     1      -COEFF12HH/2.*(CO2(2,J)+CO2(1,J)-CO2(2,J-1)-CO2(1,J-1))
     2      +COEFF13H/2.*(CBA(2,J+1)+CBA(1,J+1)-CBA(2,J)-CBA(1,J))
     3      -COEFF13HH/2.*(CBA(2,J)+CBA(1,J)-CBA(2,J-1)-CBA(1,J-1))
     4      +COEFF14H/2.*(CBI(2,J+1)+CBI(1,J+1)-CBI(2,J)-CBI(1,J))
     5      -COEFF14HH/2.*(CBI(2,J)+CBI(1,J)-CBI(2,J-1)-CBI(1,J-1))
     6    -H/2.*(3.*(CO2(2,J)-CO2(1,J))+(CO2(2,J+1)-CO2(1,J+1)))/(4.*DT)
     7   -HH/2.*(3.*(CO2(2,J)-CO2(1,J))+(CO2(2,J-1)-CO2(1,J-1)))/(4.*DT)
     8    -H/2.*(3.*(CBA(2,J)-CBA(1,J))+(CBA(2,J+1)-CBA(1,J+1)))/(4.*DT)
     9   -HH/2.*(3.*(CBA(2,J)-CBA(1,J))+(CBA(2,J-1)-CBA(1,J-1)))/(4.*DT)
     1    -H/2.*(3.*(CBI(2,J)-CBI(1,J))+(CBI(2,J+1)-CBI(1,J+1)))/(4.*DT)
     2   -HH/2.*(3.*(CBI(2,J)-CBI(1,J))+(CBI(2,J-1)-CBI(1,J-1)))/(4.*DT)

      B(20,20)=COEFF14H/2.+COEFF14HH/2.+H/2.*3./(4.*DT)
     1 +HH/2.*3./(4.*DT)
      D(20,20)=-COEFF14H/2.+H/2./(4.*DT)
      A(20,20)=-COEFF14HH/2.+HH/2./(4.*DT)
      B(20,18)=COEFF12H/2.+COEFF12HH/2.+H/2.*3./(4.*DT)
     1 +HH/2.*3./(4.*DT)
      D(20,18)=-COEFF12H/2.+H/2./(4.*DT)
      A(20,18)=-COEFF12HH/2.+HH/2./(4.*DT)
      B(20,19)=COEFF13H/2.+COEFF13HH/2.+H/2.*3./(4.*DT)
     1 +HH/2.*3./(4.*DT)
      D(20,19)=-COEFF13H/2.+H/2./(4.*DT)
      A(20,19)=-COEFF13HH/2.+HH/2./(4.*DT)

      BIG=ABS(COEFF12H/2.*CO2(2,J+1))
      BIG2=ABS(COEFF12H/2.*CO2(1,J+1))
      IF (BIG2.GT.BIG) BIG=BIG2
      BIG3=ABS(COEFF12H/2.*CO2(2,J))
      IF (BIG3.GT.BIG) BIG=BIG3
      BIG4=ABS(COEFF12H/2.*CO2(1,J))
      IF (BIG4.GT.BIG) BIG=BIG4
      BIG5=ABS(COEFF12HH/2.*CO2(2,J))
      IF (BIG5.GT.BIG) BIG=BIG5
      BIG6=ABS(COEFF12HH/2.*CO2(1,J))
      IF (BIG6.GT.BIG) BIG=BIG6
      BIG7=ABS(COEFF12HH/2.*CO2(2,J-1))
      IF (BIG7.GT.BIG) BIG=BIG7
      BIG8=ABS(COEFF12HH/2.*CO2(1,J-1))
      IF (BIG8.GT.BIG) BIG=BIG8
      BIG9=ABS(H/2.*3.*CO2(2,J)/(4.*DT))
      IF (BIG9.GT.BIG) BIG=BIG9
      BIG10=ABS(H/2.*3.*CO2(1,J)/(4.*DT))
      IF (BIG10.GT.BIG) BIG=BIG10
      BIG11=ABS(H/2.*CO2(2,J+1)/(4.*DT))
      IF (BIG11.GT.BIG) BIG=BIG11
      BIG12=ABS(H/2.*CO2(1,J+1)/(4.*DT))
      IF (BIG12.GT.BIG) BIG=BIG12
      BIG13=ABS(HH/2.*3.*CO2(2,J)/(4.*DT))
      IF (BIG13.GT.BIG) BIG=BIG13
      BIG14=ABS(HH/2.*3.*CO2(1,J)/(4.*DT))
      IF (BIG14.GT.BIG) BIG=BIG14
      BIG15=ABS(HH/2.*CO2(2,J-1)/(4.*DT))
      IF (BIG15.GT.BIG) BIG=BIG15
      BIG16=ABS(HH/2.*CO2(1,J-1)/(4.*DT))
      IF (BIG16.GT.BIG) BIG=BIG16
      BIG17=ABS(COEFF13H/2.*CBA(2,J+1))
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      IF (BIG17.GT.BIG) BIG=BIG17
      BIG18=ABS(COEFF13H/2.*CBA(1,J+1))
      IF (BIG18.GT.BIG) BIG=BIG18
      BIG19=ABS(COEFF13H/2.*CBA(2,J))
      IF (BIG19.GT.BIG) BIG=BIG19
      BIG20=ABS(COEFF13H/2.*CBA(1,J))
      IF (BIG20.GT.BIG) BIG=BIG20
      BIG21=ABS(COEFF13HH/2.*CBA(2,J))
      IF (BIG21.GT.BIG) BIG=BIG21
      BIG22=ABS(COEFF13HH/2.*CBA(1,J))
      IF (BIG22.GT.BIG) BIG=BIG22
      BIG23=ABS(COEFF13HH/2.*CBA(2,J-1))
      IF (BIG23.GT.BIG) BIG=BIG23
      BIG24=ABS(COEFF13HH/2.*CBA(1,J-1))
      IF (BIG24.GT.BIG) BIG=BIG24
      BIG25=ABS(H/2.*3.*CBA(2,J)/(4.*DT))
      IF (BIG25.GT.BIG) BIG=BIG25
      BIG26=ABS(H/2.*3.*CBA(1,J)/(4.*DT))
      IF (BIG26.GT.BIG) BIG=BIG26
      BIG27=ABS(H/2.*CBA(2,J+1)/(4.*DT))
      IF (BIG27.GT.BIG) BIG=BIG27
      BIG28=ABS(H/2.*CBA(1,J+1)/(4.*DT))
      IF (BIG28.GT.BIG) BIG=BIG28
      BIG29=ABS(HH/2.*3.*CBA(2,J)/(4.*DT))
      IF (BIG29.GT.BIG) BIG=BIG29
      BIG30=ABS(HH/2.*3.*CBA(1,J)/(4.*DT))
      IF (BIG30.GT.BIG) BIG=BIG30
      BIG31=ABS(HH/2.*CBA(2,J-1)/(4.*DT))
      IF (BIG31.GT.BIG) BIG=BIG31
      BIG32=ABS(HH/2.*CBA(1,J-1)/(4.*DT))
      IF (BIG32.GT.BIG) BIG=BIG32
      BIG33=ABS(COEFF14H/2.*CBI(2,J+1))
      IF (BIG33.GT.BIG) BIG=BIG33
      BIG34=ABS(COEFF14H/2.*CBI(1,J+1))
      IF (BIG34.GT.BIG) BIG=BIG34
      BIG35=ABS(COEFF14H/2.*CBI(2,J))
      IF (BIG35.GT.BIG) BIG=BIG35
      BIG36=ABS(COEFF14H/2.*CBI(1,J))
      IF (BIG36.GT.BIG) BIG=BIG36
      BIG37=ABS(COEFF14HH/2.*CBI(2,J))
      IF (BIG37.GT.BIG) BIG=BIG37
      BIG38=ABS(COEFF14HH/2.*CBI(1,J))
      IF (BIG38.GT.BIG) BIG=BIG38
      BIG39=ABS(COEFF14HH/2.*CBI(2,J-1))
      IF (BIG39.GT.BIG) BIG=BIG39
      BIG40=ABS(COEFF14HH/2.*CBI(1,J-1))
      IF (BIG40.GT.BIG) BIG=BIG40
      BIG41=ABS(H/2.*3.*CBI(2,J)/(4.*DT))
      IF (BIG41.GT.BIG) BIG=BIG41
      BIG42=ABS(H/2.*3.*CBI(1,J)/(4.*DT))
      IF (BIG42.GT.BIG) BIG=BIG42
      BIG43=ABS(H/2.*CBI(2,J+1)/(4.*DT))
      IF (BIG43.GT.BIG) BIG=BIG43
      BIG44=ABS(H/2.*CBI(1,J+1)/(4.*DT))
      IF (BIG44.GT.BIG) BIG=BIG44
      BIG45=ABS(HH/2.*3.*CBI(2,J)/(4.*DT))
      IF (BIG45.GT.BIG) BIG=BIG45
      BIG46=ABS(HH/2.*3.*CBI(1,J)/(4.*DT))
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      IF (BIG46.GT.BIG) BIG=BIG46
      BIG47=ABS(HH/2.*CBI(2,J-1)/(4.*DT))
      IF (BIG47.GT.BIG) BIG=BIG47
      BIG48=ABS(HH/2.*CBI(1,J-1)/(4.*DT))
      IF (BIG48.GT.BIG) BIG=BIG48
      IF (ABS(G(20)).LT.BIG*EBIG) G(20)=0


C     For H2O2, reacting species
      G(21)=COEFF16H/2.*(ACE(2,J+1)+ACE(1,J+1)-ACE(2,J)-ACE(1,J))
     1        -COEFF16HH/2.*(ACE(2,J)+ACE(1,J)-ACE(2,J-1)-ACE(1,J-1))
     4      -H/2.*(3.*(ACE(2,J)-ACE(1,J))+(ACE(2,J+1)-ACE(1,J+1)))/(4.*DT)
     5    -HH/2.*(3.*(ACE(2,J)-ACE(1,J))+(ACE(2,J-1)-ACE(1,J-1)))/(4.*DT)

      B(21,21)=COEFF16H/2.+COEFF16HH/2.
     1 +H/2.*3./(4.*DT)+HH/2.*3./(4.*DT)
      D(21,21)=-COEFF16H/2.+H/2./(4.*DT)
      A(21,21)=-COEFF16HH/2.+HH/2./(4.*DT)


      BIG=ABS(COEFF16H/2.*ACE(2,J+1))
      BIG2=ABS(COEFF16H/2.*ACE(1,J+1))
      IF (BIG2.GT.BIG) BIG=BIG2
      BIG3=ABS(COEFF16H/2.*ACE(2,J))
      IF (BIG3.GT.BIG) BIG=BIG3
      BIG4=ABS(COEFF16H/2.*ACE(1,J))
      IF (BIG4.GT.BIG) BIG=BIG4
      BIG5=ABS(COEFF16HH/2.*ACE(2,J))
      IF (BIG5.GT.BIG) BIG=BIG5
      BIG6=ABS(COEFF16HH/2.*ACE(1,J))
      IF (BIG6.GT.BIG) BIG=BIG6
      BIG7=ABS(COEFF16HH/2.*ACE(2,J-1))
      IF (BIG7.GT.BIG) BIG=BIG7
      BIG8=ABS(COEFF16HH/2.*ACE(1,J-1))
      IF (BIG8.GT.BIG) BIG=BIG8
      BIG17=ABS(H/2.*3.*ACE(2,J)/(4.*DT))
      IF (BIG17.GT.BIG) BIG=BIG17
      BIG18=ABS(H/2.*3.*ACE(1,J)/(4.*DT))
      IF (BIG18.GT.BIG) BIG=BIG18
      BIG19=ABS(H/2.*ACE(2,J+1)/(4.*DT))
      IF (BIG19.GT.BIG) BIG=BIG19
      BIG20=ABS(H/2.*ACE(1,J+1)/(4.*DT))
      IF (BIG20.GT.BIG) BIG=BIG20
      BIG21=ABS(HH/2.*3.*ACE(2,J)/(4.*DT))
      IF (BIG21.GT.BIG) BIG=BIG21
      BIG22=ABS(HH/2.*3.*ACE(1,J)/(4.*DT))
      IF (BIG22.GT.BIG) BIG=BIG22
      BIG23=ABS(HH/2.*ACE(2,J-1)/(4.*DT))
      IF (BIG23.GT.BIG) BIG=BIG23
      BIG24=ABS(HH/2.*ACE(1,J-1)/(4.*DT))
      IF (BIG24.GT.BIG) BIG=BIG24
      IF (ABS(G(21)).LT.BIG*EBIG) G(21)=0

C     DOUBLE lAYER voLTAGE - DUMMY
      G(22)=(VDL(2,J)+VDL(1,J))/2.

      B(22,22)=-1./2.

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      BIG=ABS(VDL(2,J)/2.)
      BIG2=ABS(VDL(1,J)/2.)
      IF (BIG2.GT.BIG) BIG=BIG2
      IF (ABS(G(22)).LT.BIG*EBIG) G(22)=0

C     212 WRITE(12,301) J,  (G(K),K=1,N)
      RETURN
      END

      SUBROUTINE OUTER(J)
      IMPLICIT DOUBLE PRECISION (A-H, O-Z)
      COMMON/BAB/ A(22,22),B(22,22),C(22,80001),D(22,45),G(22),X(22,22)
     1   ,Y(22,22)
      COMMON/NSN/ N, NJ
      COMMON/GLC/ NTIME,LL
      COMMON/VAR/ DIFF(16),H,EBIG,HH,IJ ,KJ,TT,VAP,HHH,DT,RE,AKB,BB,CDL
      COMMON/VARR/ HHHH,HHHHH,MJ,LJ
      COMMON/DIN/ DGOX(16),DGLM(16),DIRM(16),DBULK(16)
      COMMON/SPCI/ GLU(2,80001),GOX(2,80001),GLA(2,80001),GOR(2,80001)
      COMMON/SPCII/ OXY(2,80001),HPR(2,80001),GOA(2,80001),GOP(2,80001)
      COMMON/RXT/ EQ1(2,80001),RGA(2,80001),EQ2(2,80001),RHP(2,80001)
      COMMON/SPCIII/ ANM(2,80001),GLUA(2,80001),GLI(2,80001)
      COMMON/SPCIV/ HYD(2,80001),OHI(2,80001),CO2(2,80001),CBA(2,80001)
      COMMON/SPCV/ CBI(2,80001),ACE(2,800001)
      COMMON/VOL/ VDL(2,80001)
      COMMON/POR/ POR1,POR2,PORGLU,PARION,PARACE
      COMMON/RTE/ ratef1 ,equilib1 ,ratef2 ,ratef3 ,equilib3 ,ratef4
      COMMON/RTD/ ratef5 ,equilib5 ,equilib6 ,equilib7 ,equilib8 ,equilib9
      COMMON/BUL/ CBULK(16),PARH2O2,PAR02,PARGLUCOSE,JCOUNT

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

C      For Glucose, being consumed only
      G(1)=DGLM(1)*(GLU(2,J+1)-2.*GLU(2,J)+GLU(2,J-1)
     1      +GLU(1,J+1)-2.*GLU(1,J)+GLU(1,J-1))/(2.*H**2.)
     2    +(ANM(2,J)+ANM(1,J))/2.-(GLU(2,J)-GLU(1,J))/DT

      B(1,1)=DGLM(1)/H**2.+1./DT
      D(1,1)=-DGLM(1)/(2.*H**2.)
      A(1,1)=-DGLM(1)/(2.*H**2.)
      B(1,13)=-1./2.


      BIG=ABS(DGLM(1)*(GLU(2,J+1))/(2.*H**2.))
      BIG2=ABS(DGLM(1)*(GLU(2,J))/(H**2.))
      IF (BIG2.GT.BIG) BIG=BIG2
      BIG3=ABS(DGLM(1)*(GLU(2,J-1))/(2.*H**2.))
      IF (BIG3.GT.BIG) BIG=BIG3
      BIG4=ABS(DGLM(1)*(GLU(1,J+1))/(2.*H**2.))
      IF (BIG4.GT.BIG) BIG=BIG4
      BIG5=ABS(DGLM(1)*(GLU(1,J))/(H**2.))
      IF (BIG5.GT.BIG) BIG=BIG5
      BIG6=ABS(DGLM(1)*(GLU(1,J-1))/(2.*H**2.))
      IF (BIG6.GT.BIG) BIG=BIG6
      BIG7=ABS(GLU(2,J)/DT)
      IF (BIG7.GT.BIG) BIG=BIG7
      BIG8=ABS(GLU(1,J)/DT)
      IF (BIG8.GT.BIG) BIG=BIG8
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      BIG9=ABS(ANM(2,J)/2.)
      IF (BIG9.GT.BIG) BIG=BIG9
      BIG10=ABS(ANM(1,J)/2.)
      IF (BIG10.GT.BIG) BIG=BIG10
      IF (ABS(G(1)).LT.BIG*EBIG) G(1)=0



C     For GOx, enzyme
      G(2)=(GOX(2,J)+GOX(1,J))/2.
      B(2,2)=-1./2.

C     For Gluconic Acid, being produced only
      G(3)=DGLM(3)*(GLA(2,J+1)-2.*GLA(2,J)+GLA(2,J-1)
     1      +GLA(1,J+1)-2.*GLA(1,J)+GLA(1,J-1))/(2.*H**2.)
     2      +DGLM(10)*(GLI(2,J+1)-2.*GLI(2,J)+GLI(2,J-1)
     3      +GLI(1,J+1)-2.*GLI(1,J)+GLI(1,J-1))/(2.*H**2.)
     2     -(GLA(2,J)-GLA(1,J))/DT-(GLI(2,J)-GLI(1,J))/DT

      B(3,3)=DGLM(3)/H**2.+1./DT
      D(3,3)=-DGLM(3)/(2.*H**2.)
      A(3,3)=-DGLM(3)/(2.*H**2.)
      B(3,15)=DGLM(10)/H**2.+1./DT
      D(3,15)=-DGLM(10)/(2.*H**2.)
      A(3,15)=-DGLM(10)/(2.*H**2.)


      BIG=ABS(DGLM(3)*(GLA(2,J+1))/(2.*H**2.))
      BIG2=ABS(DGLM(3)*(GLA(2,J))/(H**2.))
      IF (BIG2.GT.BIG) BIG=BIG2
      BIG3=ABS(DGLM(3)*(GLA(2,J-1))/(2.*H**2.))
      IF (BIG3.GT.BIG) BIG=BIG3
      BIG4=ABS(DGLM(3)*(GLA(1,J+1))/(2.*H**2.))
      IF (BIG4.GT.BIG) BIG=BIG4
      BIG5=ABS(DGLM(3)*(GLA(1,J))/(H**2.))
      IF (BIG5.GT.BIG) BIG=BIG5
      BIG6=ABS(DGLM(3)*(GLA(1,J-1))/(2.*H**2.))
      IF (BIG6.GT.BIG) BIG=BIG6
      BIG7=ABS(GLA(2,J)/DT)
      IF (BIG7.GT.BIG) BIG=BIG7
      BIG8=ABS(GLA(1,J)/DT)
      IF (BIG8.GT.BIG) BIG=BIG8
      BIG9=ABS(DGLM(10)*(GLI(2,J+1))/(2.*H**2.))
      IF (BIG9.GT.BIG) BIG=BIG9
      BIG10=ABS(DGLM(10)*(GLI(2,J))/(H**2.))
      IF (BIG10.GT.BIG) BIG=BIG10
      BIG11=ABS(DGLM(10)*(GLI(2,J-1))/(2.*H**2.))
      IF (BIG11.GT.BIG) BIG=BIG11
      BIG12=ABS(DGLM(10)*(GLI(1,J+1))/(2.*H**2.))
      IF (BIG12.GT.BIG) BIG=BIG12
      BIG13=ABS(DGLM(10)*(GLI(1,J))/(H**2.))
      IF (BIG13.GT.BIG) BIG=BIG13
      BIG14=ABS(DGLM(10)*(GLI(1,J-1))/(2.*H**2.))
      IF (BIG14.GT.BIG) BIG=BIG14
      BIG15=ABS(GLI(2,J)/DT)
      IF (BIG15.GT.BIG) BIG=BIG15
      BIG16=ABS(GLI(1,J)/DT)
      IF (BIG16.GT.BIG) BIG=BIG16
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      IF (ABS(G(3)).LT.BIG*EBIG) G(3)=0

C     For GOx2, enzyme
      G(4)=(GOR(2,J)+GOR(1,J))/2.
      B(4,4)=-1./2.

C     For O2, being consumed only
      G(5)=DGLM(5)*(OXY(2,J+1)-2.*OXY(2,J)+OXY(2,J-1)
     1     +OXY(1,J+1)-2.*OXY(1,J)+OXY(1,J-1))/(2.*H**2.)
     2    -(OXY(2,J)-OXY(1,J))/DT

      B(5,5)=DGLM(5)/H**2.+1./DT
      D(5,5)=-DGLM(5)/(2.*H**2.)
      A(5,5)=-DGLM(5)/(2.*H**2.)


      BIG=ABS(DGLM(5)*(OXY(2,J+1))/(2.*H**2.))
      BIG2=ABS(DGLM(5)*(OXY(2,J))/(H**2.))
      IF (BIG2.GT.BIG) BIG=BIG2
      BIG3=ABS(DGLM(5)*(OXY(2,J-1))/(2.*H**2.))
      IF (BIG3.GT.BIG) BIG=BIG3
      BIG4=ABS(DGLM(5)*(OXY(1,J+1))/(2.*H**2.))
      IF (BIG4.GT.BIG) BIG=BIG4
      BIG5=ABS(DGLM(5)*(OXY(1,J))/(H**2.))
      IF (BIG5.GT.BIG) BIG=BIG5
      BIG6=ABS(DGLM(5)*(OXY(1,J-1))/(2.*H**2.))
      IF (BIG6.GT.BIG) BIG=BIG6
      BIG7=ABS(OXY(2,J)/DT)
      IF (BIG7.GT.BIG) BIG=BIG7
      BIG8=ABS(OXY(1,J)/DT)
      IF (BIG8.GT.BIG) BIG=BIG8
      IF (ABS(G(5)).LT.BIG*EBIG) G(5)=0

C     For H2O2, reacting species
      G(6)=DGLM(6)*(HPR(2,J+1)-2.*HPR(2,J)+HPR(2,J-1)
     1     +HPR(1,J+1)-2.*HPR(1,J)+HPR(1,J-1))/(2.*H**2.)
     2    -(HPR(2,J)-HPR(1,J))/DT

      B(6,6)=DGLM(6)/H**2.+1./DT
      D(6,6)=-DGLM(6)/(2.*H**2.)
      A(6,6)=-DGLM(6)/(2.*H**2.)


      BIG=ABS(DGLM(6)*(HPR(2,J+1))/(2.*H**2.))
      BIG2=ABS(DGLM(6)*(HPR(2,J))/(H**2.))
      IF (BIG2.GT.BIG) BIG=BIG2
      BIG3=ABS(DGLM(6)*(HPR(2,J-1))/(2.*H**2.))
      IF (BIG3.GT.BIG) BIG=BIG3
      BIG4=ABS(DGLM(6)*(HPR(1,J+1))/(2.*H**2.))
      IF (BIG4.GT.BIG) BIG=BIG4
      BIG5=ABS(DGLM(6)*(HPR(1,J))/(H**2.))
      IF (BIG5.GT.BIG) BIG=BIG5
      BIG6=ABS(DGLM(6)*(HPR(1,J-1))/(2.*H**2.))
      IF (BIG6.GT.BIG) BIG=BIG6
      BIG7=ABS(HPR(2,J)/DT)
      IF (BIG7.GT.BIG) BIG=BIG7
      BIG8=ABS(HPR(1,J)/DT)
      IF (BIG8.GT.BIG) BIG=BIG8
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      IF (ABS(G(6)).LT.BIG*EBIG) G(6)=0

C     For CX-GOx2, enzyme complex
      G(7)=(GOA(2,J)+GOA(1,J))/2.
      B(7,7)=-1./2.

C     For CX-GOx, enzyme complex
      G(8)=(GOP(2,J)+GOP(1,J))/2.
      B(8,8)=-1./2.

C     For Reaction 1 Enzymatic Catalysis
      G(9)=(EQ1(2,J)+EQ1(1,J))/2.
      B(9,9)=-1./2.

C     For Reaction 2
      G(10)=(RGA(2,J)+RGA(1,J))/2.
      B(10,10)=-1./2.

C     For Reaction 3 Meditation/regeneration
      G(11)=(EQ2(2,J)+EQ2(1,J))/2.
      B(11,11)=-1./2.

C     For Reaction 4
      G(12)=(RHP(2,J)+RHP(1,J))/2.
      B(12,12)=-1./2.

C     REACTION5
  218 G(13)=-(ANM(2,J)+ANM(1,J))/2.+ratef5*((GLUA(2,J)+GLUA(1,J))/2.
     1   -(GLU(2,J)+GLU(1,J))/2./equilib5)
      B(13,1)=ratef5/2./equilib5
      B(13,14)=-ratef5/2.
      B(13,13)=+1./2.

      BIG=ABS(ANM(2,J)/2.)
      BIG2=ABS(ANM(1,J)/2.)
      IF (BIG2.GT.BIG) BIG=BIG2
      BIG3=ABS(ratef5*GLUA(2,J)/2.)
      IF (BIG3.GT.BIG) BIG=BIG3
      BIG4=ABS(ratef5*GLUA(1,J)/2.)
      IF (BIG4.GT.BIG) BIG=BIG4
      BIG5=ABS(ratef5*GLU(2,J)/2./equilib5)
      IF (BIG5.GT.BIG) BIG=BIG5
      BIG6=ABS(ratef5*GLU(1,J)/2./equilib5)
      IF (BIG6.GT.BIG) BIG=BIG6
      IF (ABS(G(13)).LT.BIG*EBIG) G(13)=0.0

C     For alpha Glucose, being consumed only
      G(14)=DGLM(9)*(GLUA(2,J+1)-2.*GLUA(2,J)+GLUA(2,J-1)
     1      +GLUA(1,J+1)-2.*GLUA(1,J)+GLUA(1,J-1))/(2.*H**2.)
     2      -(ANM(2,J)+ANM(1,J))/2.-(GLUA(2,J)-GLUA(1,J))/DT
      B(14,14)=DGLM(9)/H**2.+1./DT
      D(14,14)=-DGLM(9)/(2.*H**2.)
      A(14,14)=-DGLM(9)/(2.*H**2.)
      B(14,13)=1./2.

      BIG=ABS(DGLM(9)*(GLUA(2,J+1))/(2.*H**2.))
      BIG2=ABS(DGLM(9)*(GLUA(2,J))/(H**2.))
      IF (BIG2.GT.BIG) BIG=BIG2
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      BIG3=ABS(DGLM(9)*(GLUA(2,J-1))/(2.*H**2.))
      IF (BIG3.GT.BIG) BIG=BIG3
      BIG4=ABS(DGLM(9)*(GLUA(1,J+1))/(2.*H**2.))
      IF (BIG4.GT.BIG) BIG=BIG4
      BIG5=ABS(DGLM(9)*(GLUA(1,J))/(H**2.))
      IF (BIG5.GT.BIG) BIG=BIG5
      BIG6=ABS(DGLM(9)*(GLUA(1,J-1))/(2.*H**2.))
      IF (BIG6.GT.BIG) BIG=BIG6
      BIG7=ABS(ANM(2,J)/2.)
      IF (BIG7.GT.BIG) BIG=BIG7
      BIG8=ABS(ANM(1,J)/2.)
      IF (BIG8.GT.BIG) BIG=BIG8
      BIG9=ABS(GLUA(2,J)/DT)
      IF (BIG9.GT.BIG) BIG=BIG9
      BIG10=ABS(GLUA(1,J)/DT)
      IF (BIG10.GT.BIG) BIG=BIG10
      IF (ABS(G(14)).LT.BIG*EBIG) G(14)=0.0

C Gluconic acid dissociation

      G(15)=equilib6*(GLA(2,J)+GLA(1,J))/2.-(GLI(2,J)+GLI(1,J))*
     1   (HYD(2,J)+HYD(1,J))/4.
      B(15,3)=-equilib6/2.
      B(15,15)=(HYD(2,J)+HYD(1,J))/4.
      B(15,16)=(GLI(2,J)+GLI(1,J))/4.

      BIG=ABS(equilib6*GLA(2,J)/2.)
      BIG2=ABS(equilib6*GLA(1,J)/2.)
      IF (BIG2.GT.BIG) BIG=BIG2
      BIG3=ABS(GLI(2,J)*HYD(2,J)/4.)
      IF (BIG3.GT.BIG) BIG=BIG3
      BIG4=ABS(GLI(2,J)*HYD(1,J)/4)
      IF (BIG4.GT.BIG) BIG=BIG4
      BIG5=ABS(GLI(1,J)*HYD(2,J)/4)
      IF (BIG5.GT.BIG) BIG=BIG5
      BIG6=ABS(GLI(1,J)*HYD(1,J)/4)
      IF (BIG6.GT.BIG) BIG=BIG6
      IF (ABS(G(15)).LT.BIG*EBIG) G(15)=0

C Hydrogen ion, hydroxide ion, gluconate ion, bicarbonate ion flux
      G(16)=DGLM(11)*(HYD(2,J+1)-2.*HYD(2,J)+HYD(2,J-1)
     1      +HYD(1,J+1)-2.*HYD(1,J)+HYD(1,J-1))/(2.*H**2.)
     2   -DGLM(15)*(OHI(2,J+1)-2.*OHI(2,J)+OHI(2,J-1)
     3      +OHI(1,J+1)-2.*OHI(1,J)+OHI(1,J-1))/(2.*H**2.)
     4   -DGLM(10)*(GLI(2,J+1)-2.*GLI(2,J)+GLI(2,J-1)
     5      +GLI(1,J+1)-2.*GLI(1,J)+GLI(1,J-1))/(2.*H**2.)
     6   -DGLM(14)*(CBI(2,J+1)-2.*CBI(2,J)+CBI(2,J-1)
     7      +CBI(1,J+1)-2.*CBI(1,J)+CBI(1,J-1))/(2.*H**2.)
     8   -(HYD(2,J)-HYD(1,J))/DT+(OHI(2,J)-OHI(1,J))/DT
     9   +(GLI(2,J)-GLI(1,J))/DT+(CBI(2,J)-CBI(1,J))/DT

      B(16,16)=DGLM(11)/H**2.+1./DT
      D(16,16)=-DGLM(11)/(2.*H**2.)
      A(16,16)=-DGLM(11)/(2.*H**2.)
      B(16,17)=-DGLM(15)/H**2.-1./DT
      D(16,17)=DGLM(15)/(2.*H**2.)
      A(16,17)=DGLM(15)/(2.*H**2.)
      B(16,15)=-DGLM(10)/H**2.-1./DT
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      D(16,15)=DGLM(10)/(2.*H**2.)
      A(16,15)=DGLM(10)/(2.*H**2.)
      B(16,20)=-DGLM(14)/H**2.-1./DT
      D(16,20)=DGLM(14)/(2.*H**2.)
      A(16,20)=DGLM(14)/(2.*H**2.)

      BIG=ABS(DGLM(11)*(HYD(2,J+1))/(2.*H**2.))
      BIG2=ABS(DGLM(11)*(HYD(2,J))/(H**2.))
      IF (BIG2.GT.BIG) BIG=BIG2
      BIG3=ABS(DGLM(11)*(HYD(2,J-1))/(2.*H**2.))
      IF (BIG3.GT.BIG) BIG=BIG3
      BIG4=ABS(DGLM(11)*(HYD(1,J+1))/(2.*H**2.))
      IF (BIG4.GT.BIG) BIG=BIG4
      BIG5=ABS(DGLM(11)*(HYD(1,J))/(H**2.))
      IF (BIG5.GT.BIG) BIG=BIG5
      BIG6=ABS(DGLM(11)*(HYD(1,J-1))/(2.*H**2.))
      IF (BIG6.GT.BIG) BIG=BIG6
      BIG7=ABS(DGLM(15)*OHI(2,J+1)/(2.*H**2.))
      IF (BIG7.GT.BIG) BIG=BIG7
      BIG8=ABS(DGLM(15)*OHI(2,J)/(H**2.))
      IF (BIG8.GT.BIG) BIG=BIG8
      BIG9=ABS(DGLM(15)*OHI(2,J-1)/(2.*H**2.))
      IF (BIG9.GT.BIG) BIG=BIG9
      BIG10=ABS(DGLM(15)*OHI(1,J+1)/(2.*H**2.))
      IF (BIG10.GT.BIG) BIG=BIG10
      BIG11=ABS(DGLM(15)*OHI(1,J)/(H**2.))
      IF (BIG11.GT.BIG) BIG=BIG11
      BIG12=ABS(DGLM(15)*OHI(1,J-1)/(2.*H**2.))
      IF (BIG12.GT.BIG) BIG=BIG12
      BIG13=ABS(DGLM(10)*GLI(2,J+1)/(2.*H**2.))
      IF (BIG13.GT.BIG) BIG=BIG13
      BIG14=ABS(DGLM(10)*GLI(2,J)/(H**2.))
      IF (BIG14.GT.BIG) BIG=BIG14
      BIG15=ABS(DGLM(10)*GLI(2,J-1)/(2.*H**2.))
      IF (BIG15.GT.BIG) BIG=BIG15
      BIG16=ABS(DGLM(10)*GLI(1,J+1)/(2.*H**2.))
      IF (BIG16.GT.BIG) BIG=BIG16
      BIG17=ABS(DGLM(10)*GLI(1,J)/(H**2.))
      IF (BIG17.GT.BIG) BIG=BIG17
      BIG18=ABS(DGLM(10)*GLI(1,J-1)/(2.*H**2.))
      IF (BIG18.GT.BIG) BIG=BIG18
      BIG19=ABS(DGLM(14)*CBI(2,J+1)/(2.*H**2.))
      IF (BIG19.GT.BIG) BIG=BIG19
      BIG20=ABS(DGLM(14)*CBI(2,J)/(H**2.))
      IF (BIG20.GT.BIG) BIG=BIG20
      BIG21=ABS(DGLM(14)*CBI(2,J-1)/(2.*H**2.))
      IF (BIG21.GT.BIG) BIG=BIG21
      BIG22=ABS(DGLM(14)*CBI(1,J+1)/(2.*H**2.))
      IF (BIG22.GT.BIG) BIG=BIG22
      BIG23=ABS(DGLM(14)*CBI(1,J)/(H**2.))
      IF (BIG23.GT.BIG) BIG=BIG23
      BIG24=ABS(DGLM(14)*CBI(1,J-1)/(2.*H**2.))
      IF (BIG24.GT.BIG) BIG=BIG24
      BIG25=ABS(HYD(2,J)/DT)
      IF (BIG25.GT.BIG) BIG=BIG25
      BIG26=ABS(HYD(1,J)/DT)
      IF (BIG26.GT.BIG) BIG=BIG26
      BIG27=ABS(OHI(2,J)/DT)
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      IF (BIG27.GT.BIG) BIG=BIG27
      BIG28=ABS(OHI(1,J)/DT)
      IF (BIG28.GT.BIG) BIG=BIG28
      BIG29=ABS(GLI(2,J)/DT)
      IF (BIG29.GT.BIG) BIG=BIG29
      BIG30=ABS(GLI(1,J)/DT)
      IF (BIG30.GT.BIG) BIG=BIG30
      BIG31=ABS(CBI(2,J)/DT)
      IF (BIG31.GT.BIG) BIG=BIG31
      BIG32=ABS(CBI(1,J)/DT)
      IF (BIG32.GT.BIG) BIG=BIG32
      IF (ABS(G(16)).LT.BIG*EBIG) G(16)=0

c Water Dissociation
      G(17)=equilib9 -(HYD(2,J)+HYD(1,J))*(OHI(2,J)+OHI(1,J))/4.
      B(17,17)=(HYD(2,J)+HYD(1,J))/4.
      B(17,16)=(OHI(2,J)+OHI(1,J))/4.

      BIG=ABS(equilib9)
      BIG2=ABS(HYD(2,J)*OHI(2,J)/4.)
      IF (BIG2.GT.BIG) BIG=BIG2
      BIG3=ABS(HYD(2,J)*OHI(1,J)/4.)
      IF (BIG3.GT.BIG) BIG=BIG3
      BIG4=ABS(HYD(1,J)*OHI(2,J)/4.)
      IF (BIG4.GT.BIG) BIG=BIG4
      BIG5=ABS(HYD(1,J)*OHI(1,J)/4.)
      IF (BIG5.GT.BIG) BIG=BIG5
      IF (ABS(G(17)).LT.BIG*EBIG) G(17)=0

C CO2 Hydration

      G(18)=equilib7*(CO2(2,J)+CO2(1,J))/2.-(CBA(2,J)+CBA(1,J))/2.
      B(18,18)=-equilib7/2.
      B(18,19)=1./2.

      BIG=ABS(equilib7*CO2(2,J)/2.)
      BIG2=ABS(equilib7*CO2(1,J)/2.)
      IF (BIG2.GT.BIG) BIG=BIG2
      BIG3=ABS(CBA(2,J)/2.)
      IF (BIG3.GT.BIG) BIG=BIG3
      BIG4=ABS(CBA(1,J)/2.)
      IF (BIG4.GT.BIG) BIG=BIG4
      IF (ABS(G(18)).LT.BIG*EBIG) G(18)=0

C Carbonic acid dissociation

      G(19)=equilib8*(CBA(2,J)+CBA(1,J))/2.-(CBI(2,J)+CBI(1,J))
     1  *(HYD(2,J)+HYD(1,J))/4.
      B(19,19)=-equilib8/2.
      B(19,20)=(HYD(2,J)+HYD(1,J))/4.
      B(19,16)=(CBI(2,J)+CBI(1,J))/4.

      BIG=ABS(equilib8*CBA(2,J)/2.)
      BIG2=ABS(equilib8*CBA(1,J)/2.)
      IF (BIG2.GT.BIG) BIG=BIG2
      BIG3=ABS(CBI(2,J)*HYD(2,J)/4.)
      IF (BIG3.GT.BIG) BIG=BIG3
      BIG4=ABS(CBI(2,J)*HYD(1,J)/4.)
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      IF (BIG4.GT.BIG) BIG=BIG4
      BIG5=ABS(CBI(1,J)*HYD(2,J)/4.)
      IF (BIG5.GT.BIG) BIG=BIG5
      BIG6=ABS(CBI(1,J)*HYD(1,J)/4.)
      IF (BIG6.GT.BIG) BIG=BIG6
      IF (ABS(G(19)).LT.BIG*EBIG) G(19)=0

C FLUX OF CO2, CARBONIC ACID, BICARBONATE ION
      G(20)=DGLM(12)*(CO2(2,J+1)-2.*CO2(2,J)+CO2(2,J-1)
     1        +CO2(1,J+1)-2.*CO2(1,J)+CO2(1,J-1))/(2.*H**2.)
     2    +DGLM(13)*(CBA(2,J+1)-2.*CBA(2,J)+CBA(2,J-1)
     3        +CBA(1,J+1)-2.*CBA(1,J)+CBA(1,J-1))/(2.*H**2.)
     4    +DGLM(14)*(CBI(2,J+1)-2.*CBI(2,J)+CBI(2,J-1)
     5        +CBI(1,J+1)-2.*CBI(1,J)+CBI(1,J-1))/(2.*H**2.)
     8    -(CO2(2,J)-CO2(1,J))/DT-(CBA(2,J)-CBA(1,J))/DT
     9    -(CBI(2,J)-CBI(1,J))/DT

      B(20,20)=DGLM(14)/H**2.+1./DT
      D(20,20)=-DGLM(14)/(2.*H**2.)
      A(20,20)=-DGLM(14)/(2.*H**2.)
      B(20,18)=DGLM(12)/H**2.+1./DT
      D(20,18)=-DGLM(12)/(2.*H**2.)
      A(20,18)=-DGLM(12)/(2.*H**2.)
      B(20,19)=DGLM(13)/H**2.+1./DT
      D(20,19)=-DGLM(13)/(2.*H**2.)
      A(20,19)=-DGLM(13)/(2.*H**2.)


      BIG=ABS(DGLM(12)*(CO2(2,J+1))/(2.*H**2.))
      BIG2=ABS(DGLM(12)*(CO2(2,J))/(H**2.))
      IF (BIG2.GT.BIG) BIG=BIG2
      BIG3=ABS(DGLM(12)*(CO2(2,J-1))/(2.*H**2.))
      IF (BIG3.GT.BIG) BIG=BIG3
      BIG4=ABS(DGLM(12)*(CO2(1,J+1))/(2.*H**2.))
      IF (BIG4.GT.BIG) BIG=BIG4
      BIG5=ABS(DGLM(12)*(CO2(1,J))/(H**2.))
      IF (BIG5.GT.BIG) BIG=BIG5
      BIG6=ABS(DGLM(12)*(CO2(1,J-1))/(2.*H**2.))
      IF (BIG6.GT.BIG) BIG=BIG6
      BIG7=ABS(DGLM(13)*CBA(2,J+1)/(2.*H**2.))
      IF (BIG7.GT.BIG) BIG=BIG7
      BIG8=ABS(DGLM(13)*CBA(2,J)/(H**2.))
      IF (BIG8.GT.BIG) BIG=BIG8
      BIG9=ABS(DGLM(13)*CBA(2,J-1)/(2.*H**2.))
      IF (BIG9.GT.BIG) BIG=BIG9
      BIG10=ABS(DGLM(13)*CBA(1,J+1)/(2.*H**2.))
      IF (BIG10.GT.BIG) BIG=BIG10
      BIG11=ABS(DGLM(13)*CBA(1,J)/(H**2.))
      IF (BIG11.GT.BIG) BIG=BIG11
      BIG12=ABS(DGLM(13)*CBA(1,J-1)/(2.*H**2.))
      IF (BIG12.GT.BIG) BIG=BIG12
      BIG13=ABS(DGLM(14)*CBI(2,J+1)/(2.*H**2.))
      IF (BIG13.GT.BIG) BIG=BIG13
      BIG14=ABS(DGLM(14)*CBI(2,J)/(H**2.))
      IF (BIG14.GT.BIG) BIG=BIG14
      BIG15=ABS(DGLM(14)*CBI(2,J-1)/(2.*H**2.))
      IF (BIG15.GT.BIG) BIG=BIG15
      BIG16=ABS(DGLM(14)*CBI(1,J+1)/(2.*H**2.))
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      IF (BIG16.GT.BIG) BIG=BIG16
      BIG17=ABS(DGLM(14)*CBI(1,J)/(H**2.))
      IF (BIG17.GT.BIG) BIG=BIG17
      BIG18=ABS(DGLM(14)*CBI(1,J-1)/(2.*H**2.))
      IF (BIG18.GT.BIG) BIG=BIG18
      BIG19=ABS(CO2(2,J)/DT)
      IF (BIG19.GT.BIG) BIG=BIG19
      BIG20=ABS(CO2(1,J)/DT)
      IF (BIG20.GT.BIG) BIG=BIG20
      BIG21=ABS(CBA(2,J)/DT)
      IF (BIG21.GT.BIG) BIG=BIG21
      BIG22=ABS(CBA(1,J)/DT)
      IF (BIG22.GT.BIG) BIG=BIG22
      BIG23=ABS(CBI(2,J)/DT)
      IF (BIG23.GT.BIG) BIG=BIG23
      BIG24=ABS(CBI(1,J)/DT)
      IF (BIG24.GT.BIG) BIG=BIG24
      IF (ABS(G(20)).LT.BIG*EBIG) G(20)=0

C     For Acetaminophen
      G(21)=DGLM(16)*(ACE(2,J+1)-2.*ACE(2,J)+ACE(2,J-1)
     1      +ACE(1,J+1)-2.*ACE(1,J)+ACE(1,J-1))/(2.*H**2.)
     2    -(ACE(2,J)-ACE(1,J))/DT

      B(21,21)=DGLM(16)/H**2.+1./DT
      D(21,21)=-DGLM(16)/(2.*H**2.)
      A(21,21)=-DGLM(16)/(2.*H**2.)


      BIG=ABS(DGLM(16)*(ACE(2,J+1))/(2.*H**2.))
      BIG2=ABS(DGLM(16)*(ACE(2,J))/(H**2.))
      IF (BIG2.GT.BIG) BIG=BIG2
      BIG3=ABS(DGLM(16)*(ACE(2,J-1))/(2.*H**2.))
      IF (BIG3.GT.BIG) BIG=BIG3
      BIG4=ABS(DGLM(16)*(ACE(1,J+1))/(2.*H**2.))
      IF (BIG4.GT.BIG) BIG=BIG4
      BIG5=ABS(DGLM(16)*(ACE(1,J))/(H**2.))
      IF (BIG5.GT.BIG) BIG=BIG5
      BIG6=ABS(DGLM(16)*(ACE(1,J-1))/(2.*H**2.))
      IF (BIG6.GT.BIG) BIG=BIG6
      BIG7=ABS(ACE(2,J)/DT)
      IF (BIG7.GT.BIG) BIG=BIG7
      BIG8=ABS(ACE(1,J)/DT)
      IF (BIG8.GT.BIG) BIG=BIG8
      IF (ABS(G(21)).LT.BIG*EBIG) G(21)=0

c     INTERFACE VOLTAGE - DUMMY
      G(22)=(VDL(2,J)+VDL(1,J))/2.

      B(22,22)=-1./2.

      BIG=ABS(VDL(2,J)/2.)
      BIG2=ABS(VDL(1,J)/2.)
      IF (BIG2.GT.BIG) BIG=BIG2
      IF (ABS(G(22)).LT.BIG*EBIG) G(22)=0

      RETURN
      END
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      SUBROUTINE FORCEC(J)
      IMPLICIT DOUBLE PRECISION (A-H, O-Z)
      COMMON/BAB/ A(22,22),B(22,22),C(22,80001),D(22,45),G(22),X(22,22)
     1   ,Y(22,22)
      COMMON/NSN/ N, NJ
      COMMON/GLC/ NTIME,LL
      COMMON/VAR/ DIFF(16),H,EBIG,HH,IJ ,KJ ,TT,VAP,HHH,DT,RE,AKB,BB,CDL
      COMMON/VARR/ HHHH,HHHHH,MJ,LJ
      COMMON/DIN/ DGOX(16),DGLM(16),DIRM(16),DBULK(16)
      COMMON/SPCI/ GLU(2,80001),GOX(2,80001),GLA(2,80001),GOR(2,80001)
      COMMON/SPCII/ OXY(2,80001),HPR(2,80001),GOA(2,80001),GOP(2,80001)
      COMMON/RXT/ EQ1(2,80001),RGA(2,80001),EQ2(2,80001),RHP(2,80001)
      COMMON/SPCIII/ ANM(2,80001),GLUA(2,80001),GLI(2,80001)
      COMMON/SPCIV/ HYD(2,80001),OHI(2,80001),CO2(2,80001),CBA(2,80001)
      COMMON/SPCV/ CBI(2,80001),ACE(2,800001)
      COMMON/VOL/ VDL(2,80001)
      COMMON/POR/ POR1,POR2,PORGLU,PARION,PARACE
      COMMON/RTE/ ratef1 ,equilib1 ,ratef2 ,ratef3 ,equilib3 ,ratef4
      COMMON/RTD/ ratef5 ,equilib5 ,equilib6 ,equilib7 ,equilib8 ,equilib9
      COMMON/BUL/ CBULK(16),PARH2O2,PAR02,PARGLUCOSE,JCOUNT

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

C      For Glucose, being consumed only
      G(1)=DGLM(1)*(PARGLUCOSE*GLU(2,J+1)-2.*GLU(2,J)+GLU(2,J-1)
     1     +PARGLUCOSE*GLU(1,J+1)-2.*GLU(1,J)+GLU(1,J-1))/(2.*H**2.)
     2    +(ANM(2,J)+ANM(1,J))/2.-(GLU(2,J)-GLU(1,J))/DT

      B(1,1)=DGLM(1)/H**2.+1./DT
      D(1,1)=-PARGLUCOSE*DGLM(1)/(2.*H**2.)
      A(1,1)=-DGLM(1)/(2.*H**2.)
      B(1,13)=-1./2.


      BIG=ABS(DGLM(1)*(GLU(2,J+1))/(2.*H**2.)*PARGLUCOSE)
      BIG2=ABS(DGLM(1)*(GLU(2,J))/(H**2.))
      IF (BIG2.GT.BIG) BIG=BIG2
      BIG3=ABS(DGLM(1)*(GLU(2,J-1))/(2.*H**2.))
      IF (BIG3.GT.BIG) BIG=BIG3
      BIG4=ABS(DGLM(1)*(GLU(1,J+1))/(2.*H**2.)*PARGLUCOSE)
      IF (BIG4.GT.BIG) BIG=BIG4
      BIG5=ABS(DGLM(1)*(GLU(1,J))/(H**2.))
      IF (BIG5.GT.BIG) BIG=BIG5
      BIG6=ABS(DGLM(1)*(GLU(1,J-1))/(2.*H**2.))
      IF (BIG6.GT.BIG) BIG=BIG6
      BIG7=ABS(GLU(2,J)/DT)
      IF (BIG7.GT.BIG) BIG=BIG7
      BIG8=ABS(GLU(1,J)/DT)
      IF (BIG8.GT.BIG) BIG=BIG8
      BIG9=ABS(ANM(2,J)/2.)
      IF (BIG9.GT.BIG) BIG=BIG9
      BIG10=ABS(ANM(1,J)/2.)
      IF (BIG10.GT.BIG) BIG=BIG10
      IF (ABS(G(1)).LT.BIG*EBIG) G(1)=0

C      For GOx, enzyme
      G(2)=(GOX(2,J)+GOX(1,J))/2.
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      B(2,2)=-1./2.

C      For Gluconic Acid, being produced only
      G(3)=DGLM(3)*(PARGLUCOSE*GLA(2,J+1)-2.*GLA(2,J)+GLA(2,J-1)
     1        +PARGLUCOSE*GLA(1,J+1)-2.*GLA(1,J)+GLA(1,J-1))/(2.*H**2.)
     2        +DGLM(10)*(PARGLUCOSE*GLI(2,J+1)-2.*GLI(2,J)+GLI(2,J-1)
     3        +PARGLUCOSE*GLI(1,J+1)-2.*GLI(1,J)+GLI(1,J-1))/(2.*H**2.)
     2      -(GLA(2,J)-GLA(1,J))/DT-(GLI(2,J)-GLI(1,J))/DT

      B(3,3)=DGLM(3)/H**2.+1./DT
      D(3,3)=-DGLM(3)/(2.*H**2.)*PARGLUCOSE
      A(3,3)=-DGLM(3)/(2.*H**2.)
      B(3,15)=DGLM(10)/H**2.+1./DT
      D(3,15)=-DGLM(10)/(2.*H**2.)*PARGLUCOSE
      A(3,15)=-DGLM(10)/(2.*H**2.)


      BIG=ABS(DGLM(3)*(GLA(2,J+1))/(2.*H**2.)*PARGLUCOSE)
      BIG2=ABS(DGLM(3)*(GLA(2,J))/(H**2.))
      IF (BIG2.GT.BIG) BIG=BIG2
      BIG3=ABS(DGLM(3)*(GLA(2,J-1))/(2.*H**2.))
      IF (BIG3.GT.BIG) BIG=BIG3
      BIG4=ABS(DGLM(3)*(GLA(1,J+1))/(2.*H**2.)*PARGLUCOSE)
      IF (BIG4.GT.BIG) BIG=BIG4
      BIG5=ABS(DGLM(3)*(GLA(1,J))/(H**2.))
      IF (BIG5.GT.BIG) BIG=BIG5
      BIG6=ABS(DGLM(3)*(GLA(1,J-1))/(2.*H**2.))
      IF (BIG6.GT.BIG) BIG=BIG6
      BIG7=ABS(GLA(2,J)/DT)
      IF (BIG7.GT.BIG) BIG=BIG7
      BIG8=ABS(GLA(1,J)/DT)
      IF (BIG8.GT.BIG) BIG=BIG8
      BIG9=ABS(DGLM(10)*(GLI(2,J+1))/(2.*H**2.)*PARGLUCOSE)
      IF (BIG9.GT.BIG) BIG=BIG9
      BIG10=ABS(DGLM(10)*(GLI(2,J))/(H**2.))
      IF (BIG10.GT.BIG) BIG=BIG10
      BIG11=ABS(DGLM(10)*(GLI(2,J-1))/(2.*H**2.))
      IF (BIG11.GT.BIG) BIG=BIG11
      BIG12=ABS(DGLM(10)*(GLI(1,J+1))/(2.*H**2.)*PARGLUCOSE)
      IF (BIG12.GT.BIG) BIG=BIG12
      BIG13=ABS(DGLM(10)*(GLI(1,J))/(H**2.))
      IF (BIG13.GT.BIG) BIG=BIG13
      BIG14=ABS(DGLM(10)*(GLI(1,J-1))/(2.*H**2.))
      IF (BIG14.GT.BIG) BIG=BIG14
      BIG15=ABS(GLI(2,J)/DT)
      IF (BIG15.GT.BIG) BIG=BIG15
      BIG16=ABS(GLI(1,J)/DT)
      IF (BIG16.GT.BIG) BIG=BIG16
      IF (ABS(G(3)).LT.BIG*EBIG) G(3)=0

C      For GOx2, enzyme
      G(4)=(GOR(2,J)+GOR(1,J))/2.
      B(4,4)=-1./2.

C      For O2, being consumed only
      G(5)=DGLM(5)*(PAR02*OXY(2,J+1)-2.*OXY(2,J)+OXY(2,J-1)
     1        +PAR02*OXY(1,J+1)-2.*OXY(1,J)+OXY(1,J-1))/(2.*H**2.)
     2      -(OXY(2,J)-OXY(1,J))/DT
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      B(5,5)=DGLM(5)/H**2.+1./DT
      D(5,5)=-DGLM(5)/(2.*H**2.)*PAR02
      A(5,5)=-DGLM(5)/(2.*H**2.)


      BIG=ABS(DGLM(5)*(OXY(2,J+1))/(2.*H**2.)*PAR02)
      BIG2=ABS(DGLM(5)*(OXY(2,J))/(H**2.))
      IF (BIG2.GT.BIG) BIG=BIG2
      BIG3=ABS(DGLM(5)*(OXY(2,J-1))/(2.*H**2.))
      IF (BIG3.GT.BIG) BIG=BIG3
      BIG4=ABS(DGLM(5)*(OXY(1,J+1))/(2.*H**2.)*PAR02)
      IF (BIG4.GT.BIG) BIG=BIG4
      BIG5=ABS(DGLM(5)*(OXY(1,J))/(H**2.))
      IF (BIG5.GT.BIG) BIG=BIG5
      BIG6=ABS(DGLM(5)*(OXY(1,J-1))/(2.*H**2.))
      IF (BIG6.GT.BIG) BIG=BIG6
      BIG7=ABS(OXY(2,J)/DT)
      IF (BIG7.GT.BIG) BIG=BIG7
      BIG8=ABS(OXY(1,J)/DT)
      IF (BIG8.GT.BIG) BIG=BIG8
      IF (ABS(G(5)).LT.BIG*EBIG) G(5)=0

C     For H2O2, reacting species
      G(6)=DGLM(6)*(PARH2O2*HPR(2,J+1)-2.*HPR(2,J)+HPR(2,J-1)
     1        +PARH2O2*HPR(1,J+1)-2.*HPR(1,J)+HPR(1,J-1))/(2.*H**2.)
     2      -(HPR(2,J)-HPR(1,J))/DT

      B(6,6)=DGLM(6)/H**2.+1./DT
      D(6,6)=-DGLM(6)/(2.*H**2.)*PARH2O2
      A(6,6)=-DGLM(6)/(2.*H**2.)


      BIG=ABS(DGLM(6)*(HPR(2,J+1))/(2.*H**2.)*PARH2O2)
      BIG2=ABS(DGLM(6)*(HPR(2,J))/(H**2.))
      IF (BIG2.GT.BIG) BIG=BIG2
      BIG3=ABS(DGLM(6)*(HPR(2,J-1))/(2.*H**2.))
      IF (BIG3.GT.BIG) BIG=BIG3
      BIG4=ABS(DGLM(6)*(HPR(1,J+1))/(2.*H**2.)*PARH2O2)
      IF (BIG4.GT.BIG) BIG=BIG4
      BIG5=ABS(DGLM(6)*(HPR(1,J))/(H**2.))
      IF (BIG5.GT.BIG) BIG=BIG5
      BIG6=ABS(DGLM(6)*(HPR(1,J-1))/(2.*H**2.))
      IF (BIG6.GT.BIG) BIG=BIG6
      BIG7=ABS(HPR(2,J)/DT)
      IF (BIG7.GT.BIG) BIG=BIG7
      BIG8=ABS(HPR(1,J)/DT)
      IF (BIG8.GT.BIG) BIG=BIG8
      IF (ABS(G(6)).LT.BIG*EBIG) G(6)=0

C     For CX-GOx2, enzyme complex
      G(7)=(GOA(2,J)+GOA(1,J))/2.
      B(7,7)=-1./2.

C     For CX-GOx, enzyme complex
      G(8)=(GOP(2,J)+GOP(1,J))/2.
      B(8,8)=-1./2.
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C      For Reaction 1 Enzymatic Catalysis
      G(9)=(EQ1(2,J)+EQ1(1,J))/2.
      B(9,9)=-1./2.

C      For Reaction 2
      G(10)=(RGA(2,J)+RGA(1,J))/2.
      B(10,10)=-1./2.

C      For Reaction 3 Meditation/regeneration
      G(11)=(EQ2(2,J)+EQ2(1,J))/2.
      B(11,11)=-1./2.

C      For Reaction 4
      G(12)=(RHP(2,J)+RHP(1,J))/2.
      B(12,12)=-1./2.

C     REACTION5
  218 G(13)=-(ANM(2,J)+ANM(1,J))/2.+ratef5*((GLUA(2,J)+GLUA(1,J))/2.
     1    -(GLU(2,J)+GLU(1,J))/2./equilib5)
      B(13,1)=ratef5/2./equilib5
      B(13,14)=-ratef5/2.
      B(13,13)=+1./2.

      BIG=ABS(ANM(2,J)/2.)
      BIG2=ABS(ANM(1,J)/2.)
      IF (BIG2.GT.BIG) BIG=BIG2
      BIG3=ABS(ratef5*GLUA(2,J)/2.)
      IF (BIG3.GT.BIG) BIG=BIG3
      BIG4=ABS(ratef5*GLUA(1,J)/2.)
      IF (BIG4.GT.BIG) BIG=BIG4
      BIG5=ABS(ratef5*GLU(2,J)/2./equilib5)
      IF (BIG5.GT.BIG) BIG=BIG5
      BIG6=ABS(ratef5*GLU(1,J)/2./equilib5)
      IF (BIG6.GT.BIG) BIG=BIG6
      IF (ABS(G(13)).LT.BIG*EBIG) G(13)=0.0

C      For alpha Glucose, being consumed only
      G(14)=DGLM(9)*(PARGLUCOSE*GLUA(2,J+1)-2.*GLUA(2,J)+GLUA(2,J-1)
     1       +PARGLUCOSE*GLUA(1,J+1)-2.*GLUA(1,J)+GLUA(1,J-1))/(2.*H**2.)
     2       -(ANM(2,J)+ANM(1,J))/2.-(GLUA(2,J)-GLUA(1,J))/DT
      B(14,14)=DGLM(9)/H**2.+1./DT
      D(14,14)=-DGLM(9)/(2.*H**2.)*PARGLUCOSE
      A(14,14)=-DGLM(9)/(2.*H**2.)
      B(14,13)=1./2.

      BIG=ABS(DGLM(9)*(GLUA(2,J+1))/(2.*H**2.)*PARGLUCOSE)
      BIG2=ABS(DGLM(9)*(GLUA(2,J))/(H**2.))
      IF (BIG2.GT.BIG) BIG=BIG2
      BIG3=ABS(DGLM(9)*(GLUA(2,J-1))/(2.*H**2.))
      IF (BIG3.GT.BIG) BIG=BIG3
      BIG4=ABS(DGLM(9)*(GLUA(1,J+1))/(2.*H**2.)*PARGLUCOSE)
      IF (BIG4.GT.BIG) BIG=BIG4
      BIG5=ABS(DGLM(9)*(GLUA(1,J))/(H**2.))
      IF (BIG5.GT.BIG) BIG=BIG5
      BIG6=ABS(DGLM(9)*(GLUA(1,J-1))/(2.*H**2.))
      IF (BIG6.GT.BIG) BIG=BIG6
      BIG7=ABS(ANM(2,J)/2.)
      IF (BIG7.GT.BIG) BIG=BIG7
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      BIG8=ABS(ANM(1,J)/2.)
      IF (BIG8.GT.BIG) BIG=BIG8
      BIG9=ABS(GLUA(2,J)/DT)
      IF (BIG9.GT.BIG) BIG=BIG9
      BIG10=ABS(GLUA(1,J)/DT)
      IF (BIG10.GT.BIG) BIG=BIG10
      IF (ABS(G(14)).LT.BIG*EBIG) G(14)=0.0

C Gluconic acid dissociation

      G(15)=equilib6*(GLA(2,J)+GLA(1,J))/2.-(GLI(2,J)+GLI(1,J))*
     1   (HYD(2,J)+HYD(1,J))/4.
      B(15,3)=-equilib6/2.
      B(15,15)=(HYD(2,J)+HYD(1,J))/4.
      B(15,16)=(GLI(2,J)+GLI(1,J))/4.

      BIG=ABS(equilib6*GLA(2,J)/2.)
      BIG2=ABS(equilib6*GLA(1,J)/2.)
      IF (BIG2.GT.BIG) BIG=BIG2
      BIG3=ABS(GLI(2,J)*HYD(2,J)/4.)
      IF (BIG3.GT.BIG) BIG=BIG3
      BIG4=ABS(GLI(2,J)*HYD(1,J)/4)
      IF (BIG4.GT.BIG) BIG=BIG4
      BIG5=ABS(GLI(1,J)*HYD(2,J)/4)
      IF (BIG5.GT.BIG) BIG=BIG5
      BIG6=ABS(GLI(1,J)*HYD(1,J)/4)
      IF (BIG6.GT.BIG) BIG=BIG6
      IF (ABS(G(15)).LT.BIG*EBIG) G(15)=0
C Hydrogen ion, hydroxide ion, gluconate ion, bicarbonate ion flux
      G(16)=DGLM(11)*(PARION*HYD(2,J+1)-2.*HYD(2,J)+HYD(2,J-1)
     1       +PARION*HYD(1,J+1)-2.*HYD(1,J)+HYD(1,J-1))/(2.*H**2.)
     2   -DGLM(15)*(PARION*OHI(2,J+1)-2.*OHI(2,J)+OHI(2,J-1)
     3       +PARION*OHI(1,J+1)-2.*OHI(1,J)+OHI(1,J-1))/(2.*H**2.)
     4   -DGLM(10)*(PARGLUCOSE*GLI(2,J+1)-2.*GLI(2,J)+GLI(2,J-1)
     5       +PARGLUCOSE*GLI(1,J+1)-2.*GLI(1,J)+GLI(1,J-1))/(2.*H**2.)
     6   -DGLM(14)*(PARION*CBI(2,J+1)-2.*CBI(2,J)+CBI(2,J-1)
     7       +PARION*CBI(1,J+1)-2.*CBI(1,J)+CBI(1,J-1))/(2.*H**2.)
     8   -(HYD(2,J)-HYD(1,J))/DT+(OHI(2,J)-OHI(1,J))/DT
     9   +(GLI(2,J)-GLI(1,J))/DT+(CBI(2,J)-CBI(1,J))/DT

      B(16,16)=DGLM(11)/H**2.+1./DT
      D(16,16)=-DGLM(11)/(2.*H**2.)*PARION
      A(16,16)=-DGLM(11)/(2.*H**2.)
      B(16,17)=-DGLM(15)/H**2.-1./DT
      D(16,17)=DGLM(15)/(2.*H**2.)*PARION
      A(16,17)=DGLM(15)/(2.*H**2.)
      B(16,15)=-DGLM(10)/H**2.-1./DT
      D(16,15)=DGLM(10)/(2.*H**2.)*PARGLUCOSE
      A(16,15)=DGLM(10)/(2.*H**2.)
      B(16,20)=-DGLM(14)/H**2.-1./DT
      D(16,20)=DGLM(14)/(2.*H**2.)*PARION
      A(16,20)=DGLM(14)/(2.*H**2.)

      BIG=ABS(DGLM(11)*(HYD(2,J+1))/(2.*H**2.)*PARION)
      BIG2=ABS(DGLM(11)*(HYD(2,J))/(H**2.))
      IF (BIG2.GT.BIG) BIG=BIG2
      BIG3=ABS(DGLM(11)*(HYD(2,J-1))/(2.*H**2.))
      IF (BIG3.GT.BIG) BIG=BIG3
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      BIG4=ABS(DGLM(11)*(HYD(1,J+1))/(2.*H**2.)*PARION)
      IF (BIG4.GT.BIG) BIG=BIG4
      BIG5=ABS(DGLM(11)*(HYD(1,J))/(H**2.))
      IF (BIG5.GT.BIG) BIG=BIG5
      BIG6=ABS(DGLM(11)*(HYD(1,J-1))/(2.*H**2.))
      IF (BIG6.GT.BIG) BIG=BIG6
      BIG7=ABS(DGLM(15)*OHI(2,J+1)/(2.*H**2.)*PARION)
      IF (BIG7.GT.BIG) BIG=BIG7
      BIG8=ABS(DGLM(15)*OHI(2,J)/(H**2.))
      IF (BIG8.GT.BIG) BIG=BIG8
      BIG9=ABS(DGLM(15)*OHI(2,J-1)/(2.*H**2.))
      IF (BIG9.GT.BIG) BIG=BIG9
      BIG10=ABS(DGLM(15)*OHI(1,J+1)/(2.*H**2.)*PARION)
      IF (BIG10.GT.BIG) BIG=BIG10
      BIG11=ABS(DGLM(15)*OHI(1,J)/(H**2.))
      IF (BIG11.GT.BIG) BIG=BIG11
      BIG12=ABS(DGLM(15)*OHI(1,J-1)/(2.*H**2.))
      IF (BIG12.GT.BIG) BIG=BIG12
      BIG13=ABS(DGLM(10)*GLI(2,J+1)/(2.*H**2.)*PARGLUCOSE)
      IF (BIG13.GT.BIG) BIG=BIG13
      BIG14=ABS(DGLM(10)*GLI(2,J)/(H**2.))
      IF (BIG14.GT.BIG) BIG=BIG14
      BIG15=ABS(DGLM(10)*GLI(2,J-1)/(2.*H**2.))
      IF (BIG15.GT.BIG) BIG=BIG15
      BIG16=ABS(DGLM(10)*GLI(1,J+1)/(2.*H**2.)*PARGLUCOSE)
      IF (BIG16.GT.BIG) BIG=BIG16
      BIG17=ABS(DGLM(10)*GLI(1,J)/(H**2.))
      IF (BIG17.GT.BIG) BIG=BIG17
      BIG18=ABS(DGLM(10)*GLI(1,J-1)/(2.*H**2.))
      IF (BIG18.GT.BIG) BIG=BIG18
      BIG19=ABS(DGLM(14)*CBI(2,J+1)/(2.*H**2.)*PARION)
      IF (BIG19.GT.BIG) BIG=BIG19
      BIG20=ABS(DGLM(14)*CBI(2,J)/(H**2.))
      IF (BIG20.GT.BIG) BIG=BIG20
      BIG21=ABS(DGLM(14)*CBI(2,J-1)/(2.*H**2.))
      IF (BIG21.GT.BIG) BIG=BIG21
      BIG22=ABS(DGLM(14)*CBI(1,J+1)/(2.*H**2.)*PARION)
      IF (BIG22.GT.BIG) BIG=BIG22
      BIG23=ABS(DGLM(14)*CBI(1,J)/(H**2.))
      IF (BIG23.GT.BIG) BIG=BIG23
      BIG24=ABS(DGLM(14)*CBI(1,J-1)/(2.*H**2.))
      IF (BIG24.GT.BIG) BIG=BIG24
      BIG25=ABS(HYD(2,J)/DT)
      IF (BIG25.GT.BIG) BIG=BIG25
      BIG26=ABS(HYD(1,J)/DT)
      IF (BIG26.GT.BIG) BIG=BIG26
      BIG27=ABS(OHI(2,J)/DT)
      IF (BIG27.GT.BIG) BIG=BIG27
      BIG28=ABS(OHI(1,J)/DT)
      IF (BIG28.GT.BIG) BIG=BIG28
      BIG29=ABS(GLI(2,J)/DT)
      IF (BIG29.GT.BIG) BIG=BIG29
      BIG30=ABS(GLI(1,J)/DT)
      IF (BIG30.GT.BIG) BIG=BIG30
      BIG31=ABS(CBI(2,J)/DT)
      IF (BIG31.GT.BIG) BIG=BIG31
      BIG32=ABS(CBI(1,J)/DT)
      IF (BIG32.GT.BIG) BIG=BIG32
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        IF (ABS(G(16)).LT.BIG*EBIG) G(16)=0

c Water Dissociation
        G(17)=equilib9 -(HYD(2,J)+HYD(1,J))*(OHI(2,J)+OHI(1,J))/4.
        B(17,17)=(HYD(2,J)+HYD(1,J))/4.
        B(17,16)=(OHI(2,J)+OHI(1,J))/4.

        BIG=ABS(equilib9)
        BIG2=ABS(HYD(2,J)*OHI(2,J)/4.)
        IF (BIG2.GT.BIG) BIG=BIG2
        BIG3=ABS(HYD(2,J)*OHI(1,J)/4.)
        IF (BIG3.GT.BIG) BIG=BIG3
        BIG4=ABS(HYD(1,J)*OHI(2,J)/4.)
        IF (BIG4.GT.BIG) BIG=BIG4
        BIG5=ABS(HYD(1,J)*OHI(1,J)/4.)
        IF (BIG5.GT.BIG) BIG=BIG5
        IF (ABS(G(17)).LT.BIG*EBIG) G(17)=0

C CO2 Hydration

        G(18)=equilib7*(CO2(2,J)+CO2(1,J))/2.-(CBA(2,J)+CBA(1,J))/2.
        B(18,18)=-equilib7/2.
        B(18,19)=1./2.

        BIG=ABS(equilib7*CO2(2,J)/2.)
        BIG2=ABS(equilib7*CO2(1,J)/2.)
        IF (BIG2.GT.BIG) BIG=BIG2
        BIG3=ABS(CBA(2,J)/2.)
        IF (BIG3.GT.BIG) BIG=BIG3
        BIG4=ABS(CBA(1,J)/2.)
        IF (BIG4.GT.BIG) BIG=BIG4
        IF (ABS(G(18)).LT.BIG*EBIG) G(18)=0

C Carbonic acid dissociation

        G(19)=equilib8*(CBA(2,J)+CBA(1,J))/2.-(CBI(2,J)+CBI(1,J))
       1 *(HYD(2,J)+HYD(1,J))/4.
        B(19,19)=-equilib8/2.
        B(19,20)=(HYD(2,J)+HYD(1,J))/4.
        B(19,16)=(CBI(2,J)+CBI(1,J))/4.

        BIG=ABS(equilib8*CBA(2,J)/2.)
        BIG2=ABS(equilib8*CBA(1,J)/2.)
        IF (BIG2.GT.BIG) BIG=BIG2
        BIG3=ABS(CBI(2,J)*HYD(2,J)/4.)
        IF (BIG3.GT.BIG) BIG=BIG3
        BIG4=ABS(CBI(2,J)*HYD(1,J)/4.)
        IF (BIG4.GT.BIG) BIG=BIG4
        BIG5=ABS(CBI(1,J)*HYD(2,J)/4.)
        IF (BIG5.GT.BIG) BIG=BIG5
        BIG6=ABS(CBI(1,J)*HYD(1,J)/4.)
        IF (BIG6.GT.BIG) BIG=BIG6
        IF (ABS(G(19)).LT.BIG*EBIG) G(19)=0

C FLUX OF CO2, CARBONIC ACID, BICARBONATE ION
        G(20)=DGLM(12)*(PARION*CO2(2,J+1)-2.*CO2(2,J)+CO2(2,J-1)
       1      +PARION*CO2(1,J+1)-2.*CO2(1,J)+CO2(1,J-1))/(2.*H**2.)
       2   +DGLM(13)*(PARION*CBA(2,J+1)-2.*CBA(2,J)+CBA(2,J-1)
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     3        +PARION*CBA(1,J+1)-2.*CBA(1,J)+CBA(1,J-1))/(2.*H**2.)
     4    +DGLM(14)*(PARION*CBI(2,J+1)-2.*CBI(2,J)+CBI(2,J-1)
     5        +PARION*CBI(1,J+1)-2.*CBI(1,J)+CBI(1,J-1))/(2.*H**2.)
     8    -(CO2(2,J)-CO2(1,J))/DT-(CBA(2,J)-CBA(1,J))/DT
     9    -(CBI(2,J)-CBI(1,J))/DT

      B(20,20)=DGLM(14)/H**2.+1./DT
      D(20,20)=-DGLM(14)/(2.*H**2.)*PARION
      A(20,20)=-DGLM(14)/(2.*H**2.)
      B(20,18)=DGLM(12)/H**2.+1./DT
      D(20,18)=-DGLM(12)/(2.*H**2.)*PARION
      A(20,18)=-DGLM(12)/(2.*H**2.)
      B(20,19)=DGLM(13)/H**2.+1./DT
      D(20,19)=-DGLM(13)/(2.*H**2.)*PARION
      A(20,19)=-DGLM(13)/(2.*H**2.)


      BIG=ABS(DGLM(12)*(CO2(2,J+1))/(2.*H**2.)*PARION)
      BIG2=ABS(DGLM(12)*(CO2(2,J))/(H**2.))
      IF (BIG2.GT.BIG) BIG=BIG2
      BIG3=ABS(DGLM(12)*(CO2(2,J-1))/(2.*H**2.))
      IF (BIG3.GT.BIG) BIG=BIG3
      BIG4=ABS(DGLM(12)*(CO2(1,J+1))/(2.*H**2.)*PARION)
      IF (BIG4.GT.BIG) BIG=BIG4
      BIG5=ABS(DGLM(12)*(CO2(1,J))/(H**2.))
      IF (BIG5.GT.BIG) BIG=BIG5
      BIG6=ABS(DGLM(12)*(CO2(1,J-1))/(2.*H**2.))
      IF (BIG6.GT.BIG) BIG=BIG6
      BIG7=ABS(DGLM(13)*CBA(2,J+1)/(2.*H**2.)*PARION)
      IF (BIG7.GT.BIG) BIG=BIG7
      BIG8=ABS(DGLM(13)*CBA(2,J)/(H**2.))
      IF (BIG8.GT.BIG) BIG=BIG8
      BIG9=ABS(DGLM(13)*CBA(2,J-1)/(2.*H**2.))
      IF (BIG9.GT.BIG) BIG=BIG9
      BIG10=ABS(DGLM(13)*CBA(1,J+1)/(2.*H**2.)*PARION)
      IF (BIG10.GT.BIG) BIG=BIG10
      BIG11=ABS(DGLM(13)*CBA(1,J)/(H**2.))
      IF (BIG11.GT.BIG) BIG=BIG11
      BIG12=ABS(DGLM(13)*CBA(1,J-1)/(2.*H**2.))
      IF (BIG12.GT.BIG) BIG=BIG12
      BIG13=ABS(DGLM(14)*CBI(2,J+1)/(2.*H**2.)*PARION)
      IF (BIG13.GT.BIG) BIG=BIG13
      BIG14=ABS(DGLM(14)*CBI(2,J)/(H**2.))
      IF (BIG14.GT.BIG) BIG=BIG14
      BIG15=ABS(DGLM(14)*CBI(2,J-1)/(2.*H**2.))
      IF (BIG15.GT.BIG) BIG=BIG15
      BIG16=ABS(DGLM(14)*CBI(1,J+1)/(2.*H**2.)*PARION)
      IF (BIG16.GT.BIG) BIG=BIG16
      BIG17=ABS(DGLM(14)*CBI(1,J)/(H**2.))
      IF (BIG17.GT.BIG) BIG=BIG17
      BIG18=ABS(DGLM(14)*CBI(1,J-1)/(2.*H**2.))
      IF (BIG18.GT.BIG) BIG=BIG18
      BIG19=ABS(CO2(2,J)/DT)
      IF (BIG19.GT.BIG) BIG=BIG19
      BIG20=ABS(CO2(1,J)/DT)
      IF (BIG20.GT.BIG) BIG=BIG20
      BIG21=ABS(CBA(2,J)/DT)
      IF (BIG21.GT.BIG) BIG=BIG21
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      BIG22=ABS(CBA(1,J)/DT)
      IF (BIG22.GT.BIG) BIG=BIG22
      BIG23=ABS(CBI(2,J)/DT)
      IF (BIG23.GT.BIG) BIG=BIG23
      BIG24=ABS(CBI(1,J)/DT)
      IF (BIG24.GT.BIG) BIG=BIG24
      IF (ABS(G(20)).LT.BIG*EBIG) G(20)=0

C     For Acetaminophen
      G(21)=DGLM(16)*(PARACE*ACE(2,J+1)-2.*ACE(2,J)+ACE(2,J-1)
     1      +PARACE*ACE(1,J+1)-2.*ACE(1,J)+ACE(1,J-1))/(2.*H**2.)
     2    -(ACE(2,J)-ACE(1,J))/DT

      B(21,21)=DGLM(16)/H**2.+1./DT
      D(21,21)=-DGLM(16)/(2.*H**2.)*PARACE
      A(21,21)=-DGLM(16)/(2.*H**2.)


      BIG=ABS(DGLM(16)*(ACE(2,J+1))/(2.*H**2.)*PARACE)
      BIG2=ABS(DGLM(16)*(ACE(2,J))/(H**2.))
      IF (BIG2.GT.BIG) BIG=BIG2
      BIG3=ABS(DGLM(16)*(ACE(2,J-1))/(2.*H**2.))
      IF (BIG3.GT.BIG) BIG=BIG3
      BIG4=ABS(DGLM(16)*(ACE(1,J+1))/(2.*H**2.)*PARACE)
      IF (BIG4.GT.BIG) BIG=BIG4
      BIG5=ABS(DGLM(16)*(ACE(1,J))/(H**2.))
      IF (BIG5.GT.BIG) BIG=BIG5
      BIG6=ABS(DGLM(16)*(ACE(1,J-1))/(2.*H**2.))
      IF (BIG6.GT.BIG) BIG=BIG6
      BIG7=ABS(ACE(2,J)/DT)
      IF (BIG7.GT.BIG) BIG=BIG7
      BIG8=ABS(ACE(1,J)/DT)
      IF (BIG8.GT.BIG) BIG=BIG8
      IF (ABS(G(21)).LT.BIG*EBIG) G(21)=0

c     INTERFACE VOLTAGE - DUMMY
      G(22)=(VDL(2,J)+VDL(1,J))/2.

      B(22,22)=-1./2.

      BIG=ABS(VDL(2,J)/2.)
      BIG2=ABS(VDL(1,J)/2.)
      IF (BIG2.GT.BIG) BIG=BIG2
      IF (ABS(G(22)).LT.BIG*EBIG) G(22)=0

      RETURN
      END

      SUBROUTINE COUPLER3(J)
      IMPLICIT DOUBLE PRECISION (A-H, O-Z)
      COMMON/BAB/ A(22,22),B(22,22),C(22,80001),D(22,45),G(22),X(22,22)
     1  ,Y(22,22)
      COMMON/NSN/ N, NJ
      COMMON/GLC/ NTIME,LL
      COMMON/VAR/ DIFF(16),H,EBIG,HH,IJ ,KJ,TT,VAP,HHH,DT,RE,AKB,BB,CDL
      COMMON/VARR/ HHHH,HHHHH,MJ,LJ
      COMMON/DIN/ DGOX(16),DGLM(16),DIRM(16),DBULK(16)
      COMMON/SPCI/ GLU(2,80001),GOX(2,80001),GLA(2,80001),GOR(2,80001)
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      COMMON/SPCII/ OXY(2,80001),HPR(2,80001),GOA(2,80001),GOP(2,80001)
      COMMON/RXT/ EQ1(2,80001),RGA(2,80001),EQ2(2,80001),RHP(2,80001)
      COMMON/SPCIII/ ANM(2,80001),GLUA(2,80001),GLI(2,80001)
      COMMON/SPCIV/ HYD(2,80001),OHI(2,80001),CO2(2,80001),CBA(2,80001)
      COMMON/SPCV/ CBI(2,80001),ACE(2,800001)
      COMMON/VOL/ VDL(2,80001)
      COMMON/POR/ POR1,POR2,PORGLU,PARION,PARACE
      COMMON/RTE/ ratef1,equilib1,ratef2,ratef3,equilib3,ratef4
      COMMON/RTD/ ratef5,equilib5,equilib6,equilib7,equilib8,equilib9
      COMMON/BUL/ CBULK(16),PARH2O2,PAR02,PARGLUCOSE,JCOUNT

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

      COEFF1HHHHH=DBULK(1)/HHHHH
      COEFF1H=DGLM(1)/H
      COEFF3HHHHH=DBULK(3)/HHHHH
      COEFF3H=DGLM(3)/H
      COEFF5HHHHH=DBULK(5)/HHHHH
      COEFF5H=DGLM(5)/H
      COEFF6HHHHH=DBULK(6)/HHHHH
      COEFF6H=DGLM(6)/H
      COEFF9HHHHH=DBULK(9)/HHHHH
      COEFF9H=DGLM(9)/H
      COEFF10HHHHH=DBULK(10)/HHHHH
      COEFF10H=DGLM(10)/H
      COEFF11HHHHH=DBULK(11)/HHHHH
      COEFF11H=DGLM(11)/H
      COEFF12HHHHH=DBULK(12)/HHHHH
      COEFF12H=DGLM(12)/H
      COEFF13HHHHH=DBULK(13)/HHHHH
      COEFF13H=DGLM(13)/H
      COEFF14HHHHH=DBULK(14)/HHHHH
      COEFF14H=DGLM(14)/H
      COEFF15HHHHH=DBULK(15)/HHHHH
      COEFF15H=DGLM(15)/H
      COEFF16HHHHH=DBULK(16)/HHHHH
      COEFF16H=DGLM(16)/H

C      For Glucose, being consumed only
      G(1)=COEFF1HHHHH/2.*(GLU(2,J+1)+GLU(1,J+1)-GLU(2,J)-GLU(1,J))
     1        -COEFF1H/2.*(PARGLUCOSE*(GLU(2,J)
     2        +GLU(1,J))-GLU(2,J-1)-GLU(1,J-1))
     3        +(HHHHH/2.)*(3.*(ANM(2,J)+ANM(1,J))
     4        +(ANM(2,J+1)+ANM(1,J+1)))/8.
     4        +(H/2.)*(3.*PARGLUCOSE*(ANM(2,J)+ANM(1,J))
     5        +(ANM(2,J-1)+ANM(1,J-1)))/8.
     5      -HHHHH/2.*(3.*(GLU(2,J)-GLU(1,J))
     5      +(GLU(2,J+1)-GLU(1,J+1)))/(4.*DT)
     6    -H/2.*(3.*PARGLUCOSE*(GLU(2,J)-GLU(1,J))
     7      +(GLU(2,J-1)-GLU(1,J-1)))/(4.*DT)

      B(1,1)=COEFF1HHHHH/2.+PARGLUCOSE*COEFF1H/2.+HHHHH/2.*3./(4.*DT)
     1    +H/2.*3.*PARGLUCOSE/(4.*DT)
      D(1,1)=-COEFF1HHHHH/2.+HHHHH/2./(4.*DT)
      A(1,1)=-COEFF1H/2.+H/2./(4.*DT)
      B(1,13)=-(HHHHH/2.)*(3./8.) -(H/2.)*PARGLUCOSE*(3./8.)
      D(1,13)=-(HHHHH/2.)*(1./8.)
      A(1,13)=-(H/2.)*(1./8.)
```

```

      BIG=ABS(COEFF1HHHHH/2.*GLU(2,J+1))
      BIG2=ABS(COEFF1HHHHH/2.*GLU(1,J+1))
      IF (BIG2.GT.BIG) BIG=BIG2
      BIG3=ABS(COEFF1HHHHH/2.*GLU(2,J))
      IF (BIG3.GT.BIG) BIG=BIG3
      BIG4=ABS(COEFF1HHHHH/2.*GLU(1,J))
      IF (BIG4.GT.BIG) BIG=BIG4
      BIG5=ABS(COEFF1H/2.*GLU(2,J)*PARGLUCOSE)
      IF (BIG5.GT.BIG) BIG=BIG5
      BIG6=ABS(COEFF1H/2.*GLU(1,J)*PARGLUCOSE)
      IF (BIG6.GT.BIG) BIG=BIG6
      BIG7=ABS(COEFF1H/2.*GLU(2,J-1))
      IF (BIG7.GT.BIG) BIG=BIG7
      BIG8=ABS(COEFF1H/2.*GLU(1,J-1))
      IF (BIG8.GT.BIG) BIG=BIG8
      BIG13=ABS(HHHHH/2.*3.*GLU(2,J)/(4.*DT))
      IF (BIG13.GT.BIG) BIG=BIG13
      BIG14=ABS(HHHHH/2.*3.*GLU(1,J)/(4.*DT))
      IF (BIG14.GT.BIG) BIG=BIG14
      BIG15=ABS(HHHHH/2.*GLU(2,J+1)/(4.*DT))
      IF (BIG15.GT.BIG) BIG=BIG15
      BIG16=ABS(HHHHH/2.*GLU(1,J+1)/(4.*DT))
      IF (BIG16.GT.BIG) BIG=BIG16
      BIG17=ABS(H/2.*3.*GLU(2,J)/(4.*DT)*PARGLUCOSE)
      IF (BIG17.GT.BIG) BIG=BIG17
      BIG18=ABS(H/2.*3.*GLU(1,J)/(4.*DT)*PARGLUCOSE)
      IF (BIG18.GT.BIG) BIG=BIG18
      BIG19=ABS(H/2.*GLU(2,J-1)/(4.*DT))
      IF (BIG19.GT.BIG) BIG=BIG19
      BIG20=ABS(H/2.*GLU(1,J-1)/(4.*DT))
      IF (BIG20.GT.BIG) BIG=BIG20
      BIG21=ABS(HHHHH/2.*3.*ANM(2,J)/8.)
      IF (BIG21.GT.BIG) BIG=BIG21
      BIG22=ABS(HHHHH/2.*3.*ANM(1,J)/8.)
      IF (BIG22.GT.BIG) BIG=BIG22
      BIG23=ABS(HHHHH/2.*ANM(2,J+1)/8.)
      IF (BIG23.GT.BIG) BIG=BIG23
      BIG24=ABS(HHHHH/2.*ANM(1,J+1)/8.)
      IF (BIG24.GT.BIG) BIG=BIG24
      BIG25=ABS(H/2.*3.*ANM(2,J)/8.*PARGLUCOSE)
      IF (BIG25.GT.BIG) BIG=BIG25
      BIG26=ABS(H/2.*3.*ANM(1,J)/8.*PARGLUCOSE)
      IF (BIG26.GT.BIG) BIG=BIG26
      BIG27=ABS(H/2.*ANM(2,J-1)/8.)
      IF (BIG27.GT.BIG) BIG=BIG27
      BIG28=ABS(H/2.*ANM(1,J-1)/8.)
      IF (BIG28.GT.BIG) BIG=BIG28
      IF (ABS(G(1)).LT.BIG*EBIG) G(1)=0

C     For GOx, enzyme
      G(2)=(GOX(2,J)+GOX(1,J))/2.
      B(2,2)=-1./2.

C     For Gluconic Acid, being produced only
      G(3)=COEFF3HHHHH/2.*(GLA(2,J+1)+GLA(1,J+1)-GLA(2,J)-GLA(1,J))
     1     -COEFF3H/2.*(PARGLUCOSE*(GLA(2,J)+GLA(1,J))
     2     -GLA(2,J-1)-GLA(1,J-1))
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     2      +COEFF10HHHHH/2.*(GLI(2,J+1)+GLI(1,J+1)-GLI(2,J)-GLI(1,J))
     3      -COEFF10H/2.*(PARGLUCOSE*(GLI(2,J)+GLI(1,J))
     4      -GLI(2,J-1)-GLI(1,J-1))
     5      -HHHHH/2.*(3.*(GLA(2,J)-GLA(1,J))
     6      +(GLA(2,J+1)-GLA(1,J+1)))/(4.*DT)
     6      -H/2.*(3.*PARGLUCOSE*(GLA(2,J)-GLA(1,J))
     7      +(GLA(2,J-1)-GLA(1,J-1)))/(4.*DT)
     7      -HHHHH/2.*(3.*(GLI(2,J)-GLI(1,J))
     8      +(GLI(2,J+1)-GLI(1,J+1)))/(4.*DT)
     8      -H/2.*(3.*PARGLUCOSE*(GLI(2,J)-GLI(1,J))
     9      +(GLI(2,J-1)-GLI(1,J-1)))/(4.*DT)

      B(3,3)=COEFF3HHHHH/2.+PARGLUCOSE*COEFF3H/2.+HHHHH/2.*3./(4.*DT)
     1    +PARGLUCOSE*H/2.*3./(4.*DT)
      D(3,3)=-COEFF3HHHHH/2.+HHHHH/2./(4.*DT)
      A(3,3)=-COEFF3H/2.+H/2./(4.*DT)
      B(3,15)=COEFF10HHHHH/2.+PARGLUCOSE*COEFF10H/2.
     1  +HHHHH/2.*3./(4.*DT)+PARGLUCOSE*H/2.*3./(4.*DT)
      D(3,15)=-COEFF10HHHHH/2.+HHHHH/2./(4.*DT)
      A(3,15)=-COEFF10H/2.+H/2./(4.*DT)


      BIG=ABS(COEFF3HHHHH/2.*GLA(2,J+1))
      BIG2=ABS(COEFF3HHHHH/2.*GLA(1,J+1))
      IF (BIG2.GT.BIG) BIG=BIG2
      BIG3=ABS(COEFF3HHHHH/2.*GLA(2,J))
      IF (BIG3.GT.BIG) BIG=BIG3
      BIG4=ABS(COEFF3HHHHH/2.*GLA(1,J))
      IF (BIG4.GT.BIG) BIG=BIG4
      BIG5=ABS(COEFF3H/2.*GLA(2,J)*PARGLUCOSE)
      IF (BIG5.GT.BIG) BIG=BIG5
      BIG6=ABS(COEFF3H/2.*GLA(1,J)*PARGLUCOSE)
      IF (BIG6.GT.BIG) BIG=BIG6
      BIG7=ABS(COEFF3H/2.*GLA(2,J-1))
      IF (BIG7.GT.BIG) BIG=BIG7
      BIG8=ABS(COEFF3H/2.*GLA(1,J-1))
      IF (BIG8.GT.BIG) BIG=BIG8
      BIG13=ABS(HHHHH/2.*3.*GLA(2,J)/(4.*DT))
      IF (BIG13.GT.BIG) BIG=BIG13
      BIG14=ABS(HHHHH/2.*3.*GLA(1,J)/(4.*DT))
      IF (BIG14.GT.BIG) BIG=BIG14
      BIG15=ABS(HHHHH/2.*GLA(2,J+1)/(4.*DT))
      IF (BIG15.GT.BIG) BIG=BIG15
      BIG16=ABS(HHHHH/2.*GLA(1,J+1)/(4.*DT))
      IF (BIG16.GT.BIG) BIG=BIG16
      BIG17=ABS(H/2.*3.*GLA(2,J)/(4.*DT)*PARGLUCOSE)
      IF (BIG17.GT.BIG) BIG=BIG17
      BIG18=ABS(H/2.*3.*GLA(1,J)/(4.*DT)*PARGLUCOSE)
      IF (BIG18.GT.BIG) BIG=BIG18
      BIG19=ABS(H/2.*GLA(2,J-1)/(4.*DT))
      IF (BIG19.GT.BIG) BIG=BIG19
      BIG20=ABS(H/2.*GLA(1,J-1)/(4.*DT))
      IF (BIG20.GT.BIG) BIG=BIG20
      BIG21=ABS(COEFF10HHHHH/2.*GLI(2,J+1))
      IF (BIG21.GT.BIG) BIG=BIG21
      BIG22=ABS(COEFF10HHHHH/2.*GLI(1,J+1))
      IF (BIG22.GT.BIG) BIG=BIG22
      BIG23=ABS(COEFF10HHHHH/2.*GLI(2,J))
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      IF (BIG23.GT.BIG) BIG=BIG23
      BIG24=ABS(COEFF10HHHHH/2.*GLI(1,J))
      IF (BIG24.GT.BIG) BIG=BIG24
      BIG25=ABS(COEFF10H/2.*GLI(2,J)*PARGLUCOSE)
      IF (BIG25.GT.BIG) BIG=BIG25
      BIG26=ABS(COEFF10H/2.*GLI(1,J)*PARGLUCOSE)
      IF (BIG26.GT.BIG) BIG=BIG26
      BIG27=ABS(COEFF10H/2.*GLI(2,J-1))
      IF (BIG27.GT.BIG) BIG=BIG27
      BIG28=ABS(COEFF10H/2.*GLI(1,J-1))
      IF (BIG28.GT.BIG) BIG=BIG28
      BIG29=ABS(HHHHH/2.*3.*GLI(2,J)/(4.*DT))
      IF (BIG29.GT.BIG) BIG=BIG29
      BIG30=ABS(HHHHH/2.*3.*GLI(1,J)/(4.*DT))
      IF (BIG30.GT.BIG) BIG=BIG30
      BIG31=ABS(HHHHH/2.*GLI(2,J+1)/(4.*DT))
      IF (BIG31.GT.BIG) BIG=BIG31
      BIG32=ABS(HHHHH/2.*GLI(1,J+1)/(4.*DT))
      IF (BIG32.GT.BIG) BIG=BIG32
      BIG33=ABS(H/2.*3.*GLI(2,J)/(4.*DT)*PARGLUCOSE)
      IF (BIG33.GT.BIG) BIG=BIG33
      BIG34=ABS(H/2.*3.*GLI(1,J)/(4.*DT)*PARGLUCOSE)
      IF (BIG34.GT.BIG) BIG=BIG34
      BIG35=ABS(H/2.*GLI(2,J-1)/(4.*DT))
      IF (BIG35.GT.BIG) BIG=BIG35
      BIG36=ABS(H/2.*GLI(1,J-1)/(4.*DT))
      IF (BIG36.GT.BIG) BIG=BIG36
      IF (ABS(G(3)).LT.BIG*EBIG) G(3)=0

C     For GOx2, enzyme
      G(4)=(GOR(2,J)+GOR(1,J))/2.
      B(4,4)=-1./2.

C     For O2, being consumed only G(5), COEFF5, -EQ2 (11)
      G(5)=COEFF5HHHHH/2.*(OXY(2,J+1)+OXY(1,J+1)-OXY(2,J)-OXY(1,J))
     1      -COEFF5H/2.*(PAR02*(OXY(2,J)+OXY(1,J))-OXY(2,J-1)-OXY(1,J-1))
     3     -HHHHH/2.*(3.*(OXY(2,J)-OXY(1,J))
     4     +(OXY(2,J+1)-OXY(1,J+1))))/(4.*DT)
     4     -H/2.*(3.*PAR02*(OXY(2,J)-OXY(1,J))
     5     +(OXY(2,J-1)-OXY(1,J-1))))/(4.*DT)

      B(5,5)=COEFF5HHHHH/2.+PAR02*COEFF5H/2.+HHHHH/2.*3./(4.*DT)
     1     +PAR02*H/2.*3./(4.*DT)
      D(5,5)=-COEFF5HHHHH/2.+HHHHH/2./(4.*DT)
      A(5,5)=-COEFF5H/2.+H/2./(4.*DT)



      BIG=ABS(COEFF5HHHHH/2.*OXY(2,J+1))
      BIG2=ABS(COEFF5HHHHH/2.*OXY(1,J+1))
      IF (BIG2.GT.BIG) BIG=BIG2
      BIG3=ABS(COEFF5HHHHH/2.*OXY(2,J))
      IF (BIG3.GT.BIG) BIG=BIG3
      BIG4=ABS(COEFF5HHHHH/2.*OXY(1,J))
      IF (BIG4.GT.BIG) BIG=BIG4
      BIG5=ABS(COEFF5H/2.*OXY(2,J)*PAR02)
      IF (BIG5.GT.BIG) BIG=BIG5
      BIG6=ABS(COEFF5H/2.*OXY(1,J)*PAR02)
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      IF (BIG6.GT.BIG) BIG=BIG6
      BIG7=ABS(COEFF5H/2.*OXY(2,J-1))
      IF (BIG7.GT.BIG) BIG=BIG7
      BIG8=ABS(COEFF5H/2.*OXY(1,J-1))
      IF (BIG8.GT.BIG) BIG=BIG8
      BIG13=ABS(HHHHH/2.*3.*OXY(2,J)/(4.*DT))
      IF (BIG13.GT.BIG) BIG=BIG13
      BIG14=ABS(HHHHH/2.*3.*OXY(1,J)/(4.*DT))
      IF (BIG14.GT.BIG) BIG=BIG14
      BIG15=ABS(HHHHH/2.*OXY(2,J+1)/(4.*DT))
      IF (BIG15.GT.BIG) BIG=BIG15
      BIG16=ABS(HHHHH/2.*OXY(1,J+1)/(4.*DT))
      IF (BIG16.GT.BIG) BIG=BIG16
      BIG17=ABS(H/2.*3.*OXY(2,J)/(4.*DT)*PAR02)
      IF (BIG17.GT.BIG) BIG=BIG17
      BIG18=ABS(H/2.*3.*OXY(1,J)/(4.*DT)*PAR02)
      IF (BIG18.GT.BIG) BIG=BIG18
      BIG19=ABS(H/2.*OXY(2,J-1)/(4.*DT))
      IF (BIG19.GT.BIG) BIG=BIG19
      BIG20=ABS(H/2.*OXY(1,J-1)/(4.*DT))
      IF (BIG20.GT.BIG) BIG=BIG20
      IF (ABS(G(5)).LT.BIG*EBIG) G(5)=0

C     For H2O2, reacting species COEFF6, G(6), +RHP (12), HPR
      G(6)=COEFF6HHHHH/2.*(HPR(2,J+1)+HPR(1,J+1)-HPR(2,J)-HPR(1,J))
     1  -COEFF6H/2.*(PARH2O2*(HPR(2,J)+HPR(1,J))-HPR(2,J-1)-HPR(1,J-1))
     3  -HHHHH/2.*(3.*(HPR(2,J)-HPR(1,J))
     4  +(HPR(2,J+1)-HPR(1,J+1)))/(4.*DT)
     4  -H/2.*(3.*PARH2O2*(HPR(2,J)-HPR(1,J))
     5  +(HPR(2,J-1)-HPR(1,J-1)))/(4.*DT)

      B(6,6)=COEFF6HHHHH/2.+PARH2O2*COEFF6H/2.+HHHHH/2.*3./(4.*DT)
     1 +PARH2O2*H/2.*3./(4.*DT)
      D(6,6)=-COEFF6HHHHH/2.+HHHHH/2./(4.*DT)
      A(6,6)=-COEFF6H/2.+H/2./(4.*DT)


      BIG=ABS(COEFF6HHHHH/2.*HPR(2,J+1))
      BIG2=ABS(COEFF6HHHHH/2.*HPR(1,J+1))
      IF (BIG2.GT.BIG) BIG=BIG2
      BIG3=ABS(COEFF6HHHHH/2.*HPR(2,J))
      IF (BIG3.GT.BIG) BIG=BIG3
      BIG4=ABS(COEFF6HHHHH/2.*HPR(1,J))
      IF (BIG4.GT.BIG) BIG=BIG4
      BIG5=ABS(COEFF6H/2.*HPR(2,J)*PARH2O2)
      IF (BIG5.GT.BIG) BIG=BIG5
      BIG6=ABS(COEFF6H/2.*HPR(1,J)*PARH2O2)
      IF (BIG6.GT.BIG) BIG=BIG6
      BIG7=ABS(COEFF6H/2.*HPR(2,J-1))
      IF (BIG7.GT.BIG) BIG=BIG7
      BIG8=ABS(COEFF6H/2.*HPR(1,J-1))
      IF (BIG8.GT.BIG) BIG=BIG8
      BIG13=ABS(HHHHH/2.*3.*HPR(2,J)/(4.*DT))
      IF (BIG13.GT.BIG) BIG=BIG13
      BIG14=ABS(HHHHH/2.*3.*HPR(1,J)/(4.*DT))
      IF (BIG14.GT.BIG) BIG=BIG14
      BIG15=ABS(HHHHH/2.*HPR(2,J+1)/(4.*DT))
      IF (BIG15.GT.BIG) BIG=BIG15
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      BIG16=ABS(HHHHH/2.*HPR(1,J+1)/(4.*DT))
      IF (BIG16.GT.BIG) BIG=BIG16
      BIG17=ABS(H/2.*3.*HPR(2,J)/(4.*DT)*PARH2O2)
      IF (BIG17.GT.BIG) BIG=BIG17
      BIG18=ABS(H/2.*3.*HPR(1,J)/(4.*DT)*PARH2O2)
      IF (BIG18.GT.BIG) BIG=BIG18
      BIG19=ABS(H/2.*HPR(2,J-1)/(4.*DT))
      IF (BIG19.GT.BIG) BIG=BIG19
      BIG20=ABS(H/2.*HPR(1,J-1)/(4.*DT))
      IF (BIG20.GT.BIG) BIG=BIG20
      IF (ABS(G(6)).LT.BIG*EBIG) G(6)=0

C     For CX-GOx2, enzyme complex
      G(7)=(GOA(2,J)+GOA(1,J))/2.
      B(7,7)=-1./2.

C     For CX-GOx, enzyme complex
      G(8)=(GOP(2,J)+GOP(1,J))/2.
      B(8,8)=-1./2.

C     For Reaction 1 Enzymatic Catalysis
      G(9)=(EQ1(2,J)+EQ1(1,J))/2.
      B(9,9)=-1./2.

C     For Reaction 2
      G(10)=(RGA(2,J)+RGA(1,J))/2.
      B(10,10)=-1./2.

C     For Reaction 3 Meditation/regeneration
      G(11)=(EQ2(2,J)+EQ2(1,J))/2.
      B(11,11)=-1./2.

C     For Reaction 4
      G(12)=(RHP(2,J)+RHP(1,J))/2.
      B(12,12)=-1./2.

C     REACTION5
  218 G(13)=-(ANM(2,J)+ANM(1,J))/2.+ratef5*((GLUA(2,J)+GLUA(1,J))/2.
     1  -(GLU(2,J)+GLU(1,J))/2./equilib5)
      B(13,1)=ratef5/2./equilib5
      B(13,14)=-ratef5/2.
      B(13,13)=+1./2.

      BIG=ABS(ANM(2,J)/2.)
      BIG2=ABS(ANM(1,J)/2.)
      IF (BIG2.GT.BIG) BIG=BIG2
      BIG3=ABS(ratef5*GLUA(2,J)/2.)
      IF (BIG3.GT.BIG) BIG=BIG3
      BIG4=ABS(ratef5*GLUA(1,J)/2.)
      IF (BIG4.GT.BIG) BIG=BIG4
      BIG5=ABS(ratef5*GLU(2,J)/2./equilib5)
      IF (BIG5.GT.BIG) BIG=BIG5
      BIG6=ABS(ratef5*GLU(1,J)/2./equilib5)
      IF (BIG6.GT.BIG) BIG=BIG6
      IF (ABS(G(13)).LT.BIG*EBIG) G(13)=0.0

C     For alpha Glucose, being consumed only
      G(14)=COEFF9HHHHH/2.*(GLUA(2,J+1)+GLUA(1,J+1)-GLUA(2,J)-GLUA(1,J))
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     1    -COEFF9H/2.*(PARGLUCOSE*(GLUA(2,J)
     2    +GLUA(1,J))-GLUA(2,J-1)-GLUA(1,J-1))
     2   -(HHHHH/2.)*(3.*(ANM(2,J)+ANM(1,J))+(ANM(2,J+1)+ANM(1,J+1)))/8.
     3    -(H/2.)*(3.*PARGLUCOSE*(ANM(2,J)
     4    +ANM(1,J))+(ANM(2,J-1)+ANM(1,J-1)))/8.
     4    -HHHHH/2.
     5    *(3.*(GLUA(2,J)-GLUA(1,J))+(GLUA(2,J+1)-GLUA(1,J+1)))/(4.*DT)
     6    -H/2.
     7    *(3.*PARGLUCOSE*(GLUA(2,J)-GLUA(1,J))
     8    +(GLUA(2,J-1)-GLUA(1,J-1)))/(4.*DT)


      B(14,14)=COEFF9HHHHH/2.+COEFF9H/2.*PARGLUCOSE+HHHHH/2.*3./(4.*DT)
     1 +H/2.*3.*PARGLUCOSE/(4.*DT)
      D(14,14)=-COEFF9HHHHH/2.+HHHHH/2./(4.*DT)
      A(14,14)=-COEFF9H/2.+H/2./(4.*DT)
      B(14,13)=+(HHHHH/2.)*(3./8.)+(H/2.)*(3./8.)*PARGLUCOSE
      D(14,13)=+(HHHHH/2.)*(1./8.)
      A(14,13)=+(H/2.)*(1./8.)

      BIG=ABS(COEFF9HHHHH/2.*GLUA(2,J+1))
      BIG2=ABS(COEFF9HHHHH/2.*GLUA(1,J+1))
      IF (BIG2.GT.BIG) BIG=BIG2
      BIG3=ABS(COEFF9HHHHH/2.*GLUA(2,J))
      IF (BIG3.GT.BIG) BIG=BIG3
      BIG4=ABS(COEFF9HHHHH/2.*GLUA(1,J))
      IF (BIG4.GT.BIG) BIG=BIG4
      BIG5=ABS(COEFF9H/2.*GLUA(2,J)*PARGLUCOSE)
      IF (BIG5.GT.BIG) BIG=BIG5
      BIG6=ABS(COEFF9H/2.*GLUA(1,J))
      IF (BIG6.GT.BIG) BIG=BIG6
      BIG7=ABS(COEFF9H/2.*GLUA(2,J-1))
      IF (BIG7.GT.BIG) BIG=BIG7
      BIG8=ABS(COEFF9H/2.*GLUA(1,J-1))
      IF (BIG8.GT.BIG) BIG=BIG8
      BIG9=ABS(HHHHH/2.*3.*GLUA(2,J)/(4.*DT))
      IF (BIG9.GT.BIG) BIG=BIG9
      BIG10=ABS(HHHHH/2.*3.*GLUA(1,J)/(4.*DT))
      IF (BIG10.GT.BIG) BIG=BIG10
      BIG11=ABS(HHHHH/2.*GLUA(2,J+1)/(4.*DT))
      IF (BIG11.GT.BIG) BIG=BIG11
      BIG12=ABS(HHHHH/2.*GLUA(1,J+1)/(4.*DT))
      IF (BIG12.GT.BIG) BIG=BIG12
      BIG13=ABS(H/2.*3.*GLUA(2,J)/(4.*DT)*PARGLUCOSE)
      IF (BIG13.GT.BIG) BIG=BIG13
      BIG14=ABS(H/2.*3.*GLUA(1,J)/(4.*DT)*PARGLUCOSE)
      IF (BIG14.GT.BIG) BIG=BIG14
      BIG15=ABS(H/2.*GLUA(2,J-1)/(4.*DT))
      IF (BIG15.GT.BIG) BIG=BIG15
      BIG16=ABS(H/2.*GLUA(1,J-1)/(4.*DT))
      IF (BIG16.GT.BIG) BIG=BIG16
      BIG17=ABS(HHHHH/2.*3.*ANM(2,J)/8.)
      IF (BIG17.GT.BIG) BIG=BIG17
      BIG18=ABS(HHHHH/2.*3.*ANM(1,J)/8.)
      IF (BIG18.GT.BIG) BIG=BIG18
      BIG19=ABS(HHHHH/2.*ANM(2,J+1)/8.)
      IF (BIG19.GT.BIG) BIG=BIG19
      BIG20=ABS(HHHHH/2.*ANM(1,J+1)/8.)
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      IF (BIG20.GT.BIG) BIG=BIG20
      BIG21=ABS(H/2.*3.*ANM(2,J)/8.*PARGLUCOSE)
      IF (BIG21.GT.BIG) BIG=BIG21
      BIG22=ABS(H/2.*3.*ANM(1,J)/8.*PARGLUCOSE)
      IF (BIG22.GT.BIG) BIG=BIG22
      BIG23=ABS(H/2.*ANM(2,J-1)/8.)
      IF (BIG23.GT.BIG) BIG=BIG23
      BIG24=ABS(H/2.*ANM(1,J-1)/8.)
      IF (BIG24.GT.BIG) BIG=BIG24
      IF (ABS(G(14)).LT.BIG*EBIG) G(14)=0

C Gluconic acid dissociation

      G(15)=equilib6*(GLA(2,J)+GLA(1,J))/2.-(GLI(2,J)+GLI(1,J))*
     1    (HYD(2,J)+HYD(1,J))/4.
      B(15,3)=-equilib6/2.
      B(15,15)=(HYD(2,J)+HYD(1,J))/4.
      B(15,16)=(GLI(2,J)+GLI(1,J))/4.

      BIG=ABS(equilib6*GLA(2,J)/2.)
      BIG2=ABS(equilib6*GLA(1,J)/2.)
      IF (BIG2.GT.BIG) BIG=BIG2
      BIG3=ABS(GLI(2,J)*HYD(2,J)/4.)
      IF (BIG3.GT.BIG) BIG=BIG3
      BIG4=ABS(GLI(2,J)*HYD(1,J)/4)
      IF (BIG4.GT.BIG) BIG=BIG4
      BIG5=ABS(GLI(1,J)*HYD(2,J)/4)
      IF (BIG5.GT.BIG) BIG=BIG5
      BIG6=ABS(GLI(1,J)*HYD(1,J)/4)
      IF (BIG6.GT.BIG) BIG=BIG6
      IF (ABS(G(15)).LT.BIG*EBIG) G(15)=0

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

      G(16)=COEFF11HHHHH/2.*(HYD(2,J+1)+HYD(1,J+1)-HYD(2,J)-HYD(1,J))
     1    -COEFF11H/2.*(PARION*(HYD(2,J)+HYD(1,J))-HYD(2,J-1)-HYD(1,J-1))
     2        -COEFF15HHHHH/2.*(OHI(2,J+1)+OHI(1,J+1)-OHI(2,J)-OHI(1,J))
     3    +COEFF15H/2.*(PARION*(OHI(2,J)+OHI(1,J))-OHI(2,J-1)-OHI(1,J-1))
     4        -COEFF10HHHHH/2.*(GLI(2,J+1)+GLI(1,J+1)-GLI(2,J)-GLI(1,J))
     5        +COEFF10H/2.*(PARGLUCOSE*(GLI(2,J)+GLI(1,J))
     6        -GLI(2,J-1)-GLI(1,J-1))
     6        -COEFF14HHHHH/2.*(CBI(2,J+1)+CBI(1,J+1)-CBI(2,J)-CBI(1,J))
     7    +COEFF14H/2.*(PARION*(CBI(2,J)+CBI(1,J))-CBI(2,J-1)-CBI(1,J-1))
     8    -HHHHH/2.*(3.*(HYD(2,J)-HYD(1,J))
     9    +(HYD(2,J+1)-HYD(1,J+1)))/(4.*DT)
     9    -H/2.*(3.*PARION*(HYD(2,J)-HYD(1,J))
     1    +(HYD(2,J-1)-HYD(1,J-1)))/(4.*DT)
     1     +HHHHH/2.*(3.*(OHI(2,J)-OHI(1,J))
     2     +(OHI(2,J+1)-OHI(1,J+1)))/(4.*DT)
     2    +H/2.*(3.*PARION*(OHI(2,J)-OHI(1,J))
     3    +(OHI(2,J-1)-OHI(1,J-1)))/(4.*DT)
     3     +HHHHH/2.*(3.*(GLI(2,J)-GLI(1,J))
     4    +(GLI(2,J+1)-GLI(1,J+1)))/(4.*DT)
     4    +H/2.*(3.*PARGLUCOSE*(GLI(2,J)-GLI(1,J))
     5    +(GLI(2,J-1)-GLI(1,J-1)))/(4.*DT)
     5    +HHHHH/2.*(3.*(CBI(2,J)-CBI(1,J))
     6    +(CBI(2,J+1)-CBI(1,J+1)))/(4.*DT)
     6    +H/2.*(3.*PARION*(CBI(2,J)-CBI(1,J))
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     7    +(CBI(2,J-1)-CBI(1,J-1)))/(4.*DT)

      B(16,16)=COEFF11HHHHH/2.+PARION*COEFF11H/2.+HHHHH/2.*3./(4.*DT)
     1  +H/2.*3.*PARION/(4.*DT)
      D(16,16)=-COEFF11HHHHH/2.+HHHHH/2./(4.*DT)
      A(16,16)=-COEFF11H/2.+H/2./(4.*DT)

      B(16,17)=-COEFF15HHHHH/2.-PARION*COEFF15H/2.-HHHHH/2.*3./(4.*DT)
     1  -H/2.*3.*PARION/(4.*DT)
      D(16,17)=+COEFF15HHHHH/2.-HHHHH/2./(4.*DT)
      A(16,17)=+COEFF15H/2.-H/2./(4.*DT)

      B(16,15)=-COEFF10HHHHH/2.-PARGLUCOSE*COEFF10H/2.
     1    -HHHHH/2.*3./(4.*DT)-H/2.*3.*PARGLUCOSE/(4.*DT)
      D(16,15)=+COEFF10HHHHH/2.-HHHHH/2./(4.*DT)
      A(16,15)=+COEFF10H/2.-H/2./(4.*DT)

      B(16,20)=-COEFF14HHHHH/2.-PARION*COEFF14H/2.-HHHHH/2.*3./(4.*DT)
     1  -H/2.*3.*PARION/(4.*DT)
      D(16,20)=+COEFF14HHHHH/2.-HHHHH/2./(4.*DT)
      A(16,20)=+COEFF14H/2.-H/2./(4.*DT)

      BIG=ABS(COEFF11HHHHH/2.*HYD(2,J+1))
      BIG2=ABS(COEFF11HHHHH/2.*HYD(1,J+1))
      IF  (BIG2.GT.BIG)  BIG=BIG2
      BIG3=ABS(COEFF11HHHHH/2.*HYD(2,J))
      IF  (BIG3.GT.BIG)  BIG=BIG3
      BIG4=ABS(COEFF11HHHHH/2.*HYD(1,J))
      IF  (BIG4.GT.BIG)  BIG=BIG4
      BIG5=ABS(COEFF11H/2.*HYD(2,J)*PARION)
      IF  (BIG5.GT.BIG)  BIG=BIG5
      BIG6=ABS(COEFF11H/2.*HYD(1,J)*PARION)
      IF  (BIG6.GT.BIG)  BIG=BIG6
      BIG7=ABS(COEFF11H/2.*HYD(2,J-1))
      IF  (BIG7.GT.BIG)  BIG=BIG7
      BIG8=ABS(COEFF11H/2.*HYD(1,J-1))
      IF  (BIG8.GT.BIG)  BIG=BIG8
      BIG9=ABS(HHHHH/2.*3.*HYD(2,J)/(4.*DT))
      IF  (BIG9.GT.BIG)  BIG=BIG9
      BIG10=ABS(HHHHH/2.*3.*HYD(1,J)/(4.*DT))
      IF  (BIG10.GT.BIG)  BIG=BIG10
      BIG11=ABS(HHHHH/2.*HYD(2,J+1)/(4.*DT))
      IF  (BIG11.GT.BIG)  BIG=BIG11
      BIG12=ABS(HHHHH/2.*HYD(1,J+1)/(4.*DT))
      IF  (BIG12.GT.BIG)  BIG=BIG12
      BIG13=ABS(H/2.*3.*HYD(2,J)*PARION/(4.*DT))
      IF  (BIG13.GT.BIG)  BIG=BIG13
      BIG14=ABS(H/2.*3.*HYD(1,J)*PARION/(4.*DT))
      IF  (BIG14.GT.BIG)  BIG=BIG14
      BIG15=ABS(H/2.*HYD(2,J-1)/(4.*DT))
      IF  (BIG15.GT.BIG)  BIG=BIG15
      BIG16=ABS(H/2.*HYD(1,J-1)/(4.*DT))
      IF  (BIG16.GT.BIG)  BIG=BIG16
      BIG17=ABS(COEFF15HHHHH/2.*OHI(2,J+1))
      IF  (BIG17.GT.BIG)  BIG=BIG17
      BIG18=ABS(COEFF15HHHHH/2.*OHI(1,J+1))
      IF  (BIG18.GT.BIG)  BIG=BIG18
      BIG19=ABS(COEFF15HHHHH/2.*OHI(2,J))
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      IF (BIG19.GT.BIG) BIG=BIG19
      BIG20=ABS(COEFF15HHHHH/2.*OHI(1,J))
      IF (BIG20.GT.BIG) BIG=BIG20
      BIG21=ABS(COEFF15H/2.*OHI(2,J)*PARION)
      IF (BIG21.GT.BIG) BIG=BIG21
      BIG22=ABS(COEFF15H/2.*OHI(1,J)*PARION)
      IF (BIG22.GT.BIG) BIG=BIG22
      BIG23=ABS(COEFF15H/2.*OHI(2,J-1))
      IF (BIG23.GT.BIG) BIG=BIG23
      BIG24=ABS(COEFF15H/2.*OHI(1,J-1))
      IF (BIG24.GT.BIG) BIG=BIG24
      BIG25=ABS(HHHHH/2.*3.*OHI(2,J)/(4.*DT))
      IF (BIG25.GT.BIG) BIG=BIG25
      BIG26=ABS(HHHHH/2.*3.*OHI(1,J)/(4.*DT))
      IF (BIG26.GT.BIG) BIG=BIG26
      BIG27=ABS(HHHHH/2.*OHI(2,J+1)/(4.*DT))
      IF (BIG27.GT.BIG) BIG=BIG27
      BIG28=ABS(HHHHH/2.*OHI(1,J+1)/(4.*DT))
      IF (BIG28.GT.BIG) BIG=BIG28
      BIG29=ABS(H/2.*3.*OHI(2,J)/(4.*DT)*PARION)
      IF (BIG29.GT.BIG) BIG=BIG29
      BIG30=ABS(H/2.*3.*OHI(1,J)/(4.*DT)*PARION)
      IF (BIG30.GT.BIG) BIG=BIG30
      BIG31=ABS(H/2.*OHI(2,J-1)/(4.*DT))
      IF (BIG31.GT.BIG) BIG=BIG31
      BIG32=ABS(H/2.*OHI(1,J-1)/(4.*DT))
      IF (BIG32.GT.BIG) BIG=BIG32
      BIG33=ABS(COEFF10HHHHH/2.*GLI(2,J+1))
      IF (BIG33.GT.BIG) BIG=BIG33
      BIG34=ABS(COEFF10HHHHH/2.*GLI(1,J+1))
      IF (BIG34.GT.BIG) BIG=BIG34
      BIG35=ABS(COEFF10HHHHH/2.*GLI(2,J))
      IF (BIG35.GT.BIG) BIG=BIG35
      BIG36=ABS(COEFF10HHHHH/2.*GLI(1,J))
      IF (BIG36.GT.BIG) BIG=BIG36
      BIG37=ABS(COEFF10H/2.*GLI(2,J)*PARGLUCOSE)
      IF (BIG37.GT.BIG) BIG=BIG37
      BIG38=ABS(COEFF10H/2.*GLI(1,J)*PARGLUCOSE)
      IF (BIG38.GT.BIG) BIG=BIG38
      BIG39=ABS(COEFF10H/2.*GLI(2,J-1))
      IF (BIG39.GT.BIG) BIG=BIG39
      BIG40=ABS(COEFF10H/2.*GLI(1,J-1))
      IF (BIG40.GT.BIG) BIG=BIG40
      BIG41=ABS(HHHHH/2.*3.*GLI(2,J)/(4.*DT))
      IF (BIG41.GT.BIG) BIG=BIG41
      BIG42=ABS(HHHHH/2.*3.*GLI(1,J)/(4.*DT))
      IF (BIG42.GT.BIG) BIG=BIG42
      BIG43=ABS(HHHHH/2.*GLI(2,J+1)/(4.*DT))
      IF (BIG43.GT.BIG) BIG=BIG43
      BIG44=ABS(HHHHH/2.*GLI(1,J+1)/(4.*DT))
      IF (BIG44.GT.BIG) BIG=BIG44
      BIG45=ABS(H/2.*3.*GLI(2,J)/(4.*DT)*PARGLUCOSE)
      IF (BIG45.GT.BIG) BIG=BIG45
      BIG46=ABS(H/2.*3.*GLI(1,J)/(4.*DT)*PARGLUCOSE)
      IF (BIG46.GT.BIG) BIG=BIG46
      BIG47=ABS(H/2.*GLI(2,J-1)/(4.*DT))
      IF (BIG47.GT.BIG) BIG=BIG47
      BIG48=ABS(H/2.*GLI(1,J-1)/(4.*DT))
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      IF (BIG48.GT.BIG) BIG=BIG48
      BIG49=ABS(COEFF14HHHHH/2.*CBI(2,J+1))
      IF (BIG49.GT.BIG) BIG=BIG49
      BIG50=ABS(COEFF14HHHHH/2.*CBI(1,J+1))
      IF (BIG50.GT.BIG) BIG=BIG50
      BIG51=ABS(COEFF14HHHHH/2.*CBI(2,J))
      IF (BIG51.GT.BIG) BIG=BIG51
      BIG52=ABS(COEFF14HHHHH/2.*CBI(1,J))
      IF (BIG52.GT.BIG) BIG=BIG52
      BIG53=ABS(COEFF14H/2.*CBI(2,J)*PARION)
      IF (BIG53.GT.BIG) BIG=BIG53
      BIG54=ABS(COEFF14H/2.*CBI(1,J)*PARION)
      IF (BIG54.GT.BIG) BIG=BIG54
      BIG55=ABS(COEFF14H/2.*CBI(2,J-1))
      IF (BIG55.GT.BIG) BIG=BIG55
      BIG56=ABS(COEFF14H/2.*CBI(1,J-1))
      IF (BIG56.GT.BIG) BIG=BIG56
      BIG57=ABS(HHHHH/2.*3.*CBI(2,J)/(4.*DT))
      IF (BIG57.GT.BIG) BIG=BIG57
      BIG58=ABS(HHHHH/2.*3.*CBI(1,J)/(4.*DT))
      IF (BIG58.GT.BIG) BIG=BIG58
      BIG59=ABS(HHHHH/2.*CBI(2,J+1)/(4.*DT))
      IF (BIG59.GT.BIG) BIG=BIG59
      BIG60=ABS(HHHHH/2.*CBI(1,J+1)/(4.*DT))
      IF (BIG60.GT.BIG) BIG=BIG60
      BIG61=ABS(H/2.*3.*CBI(2,J)/(4.*DT)*PARION)
      IF (BIG61.GT.BIG) BIG=BIG61
      BIG62=ABS(H/2.*3.*CBI(1,J)/(4.*DT)*PARION)
      IF (BIG62.GT.BIG) BIG=BIG62
      BIG63=ABS(H/2.*CBI(2,J-1)/(4.*DT))
      IF (BIG63.GT.BIG) BIG=BIG63
      BIG64=ABS(H/2.*CBI(1,J-1)/(4.*DT))
      IF (BIG64.GT.BIG) BIG=BIG64
      IF (ABS(G(16)).LT.BIG*EBIG) G(16)=0

c Water Dissociation
      G(17)=equilib9-(HYD(2,J)+HYD(1,J))*(OHI(2,J)+OHI(1,J))/4.
      B(17,17)=(HYD(2,J)+HYD(1,J))/4.
      B(17,16)=(OHI(2,J)+OHI(1,J))/4.

      BIG=ABS(equilib9)
      BIG2=ABS(HYD(2,J)*OHI(2,J)/4.)
      IF (BIG2.GT.BIG) BIG=BIG2
      BIG3=ABS(HYD(2,J)*OHI(1,J)/4.)
      IF (BIG3.GT.BIG) BIG=BIG3
      BIG4=ABS(HYD(1,J)*OHI(2,J)/4.)
      IF (BIG4.GT.BIG) BIG=BIG4
      BIG5=ABS(HYD(1,J)*OHI(1,J)/4.)
      IF (BIG5.GT.BIG) BIG=BIG5
      IF (ABS(G(17)).LT.BIG*EBIG) G(17)=0

C CO2 Hydration

      G(18)=equilib7*(CO2(2,J)+CO2(1,J))/2.-(CBA(2,J)+CBA(1,J))/2.
      B(18,18)=-equilib7/2.
      B(18,19)=1./2.

      BIG=ABS(equilib7*CO2(2,J)/2.)
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      BIG2=ABS(equilib7*CO2(1,J)/2.)
      IF (BIG2.GT.BIG) BIG=BIG2
      BIG3=ABS(CBA(2,J)/2.)
      IF (BIG3.GT.BIG) BIG=BIG3
      BIG4=ABS(CBA(1,J)/2.)
      IF (BIG4.GT.BIG) BIG=BIG4
      IF (ABS(G(18)).LT.BIG*EBIG) G(18)=0

C Carbonic acid dissociation

      G(19)=equilib8*(CBA(2,J)+CBA(1,J))/2.-(CBI(2,J)+CBI(1,J))
     1 *(HYD(2,J)+HYD(1,J))/4.
      B(19,19)=-equilib8/2.
      B(19,20)=(HYD(2,J)+HYD(1,J))/4.
      B(19,16)=(CBI(2,J)+CBI(1,J))/4.

      BIG=ABS(equilib8*CBA(2,J)/2.)
      BIG2=ABS(equilib8*CBA(1,J)/2.)
      IF (BIG2.GT.BIG) BIG=BIG2
      BIG3=ABS(CBI(2,J)*HYD(2,J)/4.)
      IF (BIG3.GT.BIG) BIG=BIG3
      BIG4=ABS(CBI(2,J)*HYD(1,J)/4.)
      IF (BIG4.GT.BIG) BIG=BIG4
      BIG5=ABS(CBI(1,J)*HYD(2,J)/4.)
      IF (BIG5.GT.BIG) BIG=BIG5
      BIG6=ABS(CBI(1,J)*HYD(1,J)/4.)
      IF (BIG6.GT.BIG) BIG=BIG6
      IF (ABS(G(19)).LT.BIG*EBIG) G(19)=0

C FLUX OF CO2, CARBONIC ACID, BICARBONATE ION
      G(20)=COEFF12HHHHH/2.*(CO2(2,J+1)+CO2(1,J+1)-CO2(2,J)-CO2(1,J))
     1    -COEFF12H/2.*(PARION*(CO2(2,J)+CO2(1,J))-CO2(2,J-1)-CO2(1,J-1))
     2      +COEFF13HHHHH/2.*(CBA(2,J+1)+CBA(1,J+1)-CBA(2,J)-CBA(1,J))
     3    -COEFF13H/2.*(PARION*(CBA(2,J)+CBA(1,J))-CBA(2,J-1)-CBA(1,J-1))
     4      +COEFF14HHHHH/2.*(CBI(2,J+1)+CBI(1,J+1)-CBI(2,J)-CBI(1,J))
     5    -COEFF14H/2.*(PARION*(CBI(2,J)+CBI(1,J))-CBI(2,J-1)-CBI(1,J-1))
     6    -HHHHH/2.*(3.*(CO2(2,J)-CO2(1,J))
     7    +(CO2(2,J+1)-CO2(1,J+1)))/(4.*DT)
     7  -H/2.*(3.*PARION*(CO2(2,J)-CO2(1,J))
     8  +(CO2(2,J-1)-CO2(1,J-1)))/(4.*DT)
     8    -HHHHH/2.*(3.*(CBA(2,J)-CBA(1,J))
     9  +(CBA(2,J+1)-CBA(1,J+1)))/(4.*DT)
     9  -H/2.*(3.*PARION*(CBA(2,J)-CBA(1,J))
     1  +(CBA(2,J-1)-CBA(1,J-1)))/(4.*DT)
     1    -HHHHH/2.*(3.*(CBI(2,J)-CBI(1,J))
     2  +(CBI(2,J+1)-CBI(1,J+1)))/(4.*DT)
     2  -H/2.*(3.*PARION*(CBI(2,J)-CBI(1,J))
     3  +(CBI(2,J-1)-CBI(1,J-1)))/(4.*DT)

      B(20,20)=COEFF14HHHHH/2.+PARION*COEFF14H/2.+HHHHH/2.*3./(4.*DT)
     1 +H/2.*3./(4.*DT)*PARION
      D(20,20)=-COEFF14HHHHH/2.+HHHHH/2./(4.*DT)
      A(20,20)=-COEFF14H/2.+H/2./(4.*DT)
      B(20,18)=COEFF12HHHHH/2.+PARION*COEFF12H/2.+HHHHH/2.*3./(4.*DT)
     1 +H/2.*3./(4.*DT)*PARION
      D(20,18)=-COEFF12HHHHH/2.+HHHHH/2./(4.*DT)
      A(20,18)=-COEFF12H/2.+H/2./(4.*DT)
      B(20,19)=COEFF13HHHHH/2.+PARION*COEFF13H/2.+HHHHH/2.*3./(4.*DT)
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     1  +H/2.*3./(4.*DT)*PARION
      D(20,19)=-COEFF13HHHHH/2.+HHHHH/2./(4.*DT)
      A(20,19)=-COEFF13H/2.+H/2./(4.*DT)

      BIG=ABS(COEFF12HHHHH/2.*CO2(2,J+1))
      BIG2=ABS(COEFF12HHHHH/2.*CO2(1,J+1))
      IF (BIG2.GT.BIG) BIG=BIG2
      BIG3=ABS(COEFF12HHHHH/2.*CO2(2,J))
      IF (BIG3.GT.BIG) BIG=BIG3
      BIG4=ABS(COEFF12HHHHH/2.*CO2(1,J))
      IF (BIG4.GT.BIG) BIG=BIG4
      BIG5=ABS(COEFF12H/2.*CO2(2,J)*PARION)
      IF (BIG5.GT.BIG) BIG=BIG5
      BIG6=ABS(COEFF12H/2.*CO2(1,J)*PARION)
      IF (BIG6.GT.BIG) BIG=BIG6
      BIG7=ABS(COEFF12H/2.*CO2(2,J-1))
      IF (BIG7.GT.BIG) BIG=BIG7
      BIG8=ABS(COEFF12H/2.*CO2(1,J-1))
      IF (BIG8.GT.BIG) BIG=BIG8
      BIG9=ABS(HHHHH/2.*3.*CO2(2,J)/(4.*DT))
      IF (BIG9.GT.BIG) BIG=BIG9
      BIG10=ABS(HHHHH/2.*3.*CO2(1,J)/(4.*DT))
      IF (BIG10.GT.BIG) BIG=BIG10
      BIG11=ABS(HHHHH/2.*CO2(2,J+1)/(4.*DT))
      IF (BIG11.GT.BIG) BIG=BIG11
      BIG12=ABS(HHHHH/2.*CO2(1,J+1)/(4.*DT))
      IF (BIG12.GT.BIG) BIG=BIG12
      BIG13=ABS(H/2.*3.*CO2(2,J)/(4.*DT)*PARION)
      IF (BIG13.GT.BIG) BIG=BIG13
      BIG14=ABS(H/2.*3.*CO2(1,J)/(4.*DT)*PARION)
      IF (BIG14.GT.BIG) BIG=BIG14
      BIG15=ABS(H/2.*CO2(2,J-1)/(4.*DT))
      IF (BIG15.GT.BIG) BIG=BIG15
      BIG16=ABS(H/2.*CO2(1,J-1)/(4.*DT))
      IF (BIG16.GT.BIG) BIG=BIG16
      BIG17=ABS(COEFF13HHHHH/2.*CBA(2,J+1))
      IF (BIG17.GT.BIG) BIG=BIG17
      BIG18=ABS(COEFF13HHHHH/2.*CBA(1,J+1))
      IF (BIG18.GT.BIG) BIG=BIG18
      BIG19=ABS(COEFF13HHHHH/2.*CBA(2,J))
      IF (BIG19.GT.BIG) BIG=BIG19
      BIG20=ABS(COEFF13HHHHH/2.*CBA(1,J))
      IF (BIG20.GT.BIG) BIG=BIG20
      BIG21=ABS(COEFF13H/2.*CBA(2,J)*PARION)
      IF (BIG21.GT.BIG) BIG=BIG21
      BIG22=ABS(COEFF13H/2.*CBA(1,J)*PARION)
      IF (BIG22.GT.BIG) BIG=BIG22
      BIG23=ABS(COEFF13H/2.*CBA(2,J-1))
      IF (BIG23.GT.BIG) BIG=BIG23
      BIG24=ABS(COEFF13H/2.*CBA(1,J-1))
      IF (BIG24.GT.BIG) BIG=BIG24
      BIG25=ABS(HHHHH/2.*3.*CBA(2,J)/(4.*DT))
      IF (BIG25.GT.BIG) BIG=BIG25
      BIG26=ABS(HHHHH/2.*3.*CBA(1,J)/(4.*DT))
      IF (BIG26.GT.BIG) BIG=BIG26
      BIG27=ABS(HHHHH/2.*CBA(2,J+1)/(4.*DT))
      IF (BIG27.GT.BIG) BIG=BIG27
      BIG28=ABS(HHHHH/2.*CBA(1,J+1)/(4.*DT))
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      IF (BIG28.GT.BIG) BIG=BIG28
      BIG29=ABS(H/2.*3.*CBA(2,J)/(4.*DT)*PARION)
      IF (BIG29.GT.BIG) BIG=BIG29
      BIG30=ABS(H/2.*3.*CBA(1,J)/(4.*DT)*PARION)
      IF (BIG30.GT.BIG) BIG=BIG30
      BIG31=ABS(H/2.*CBA(2,J-1)/(4.*DT))
      IF (BIG31.GT.BIG) BIG=BIG31
      BIG32=ABS(H/2.*CBA(1,J-1)/(4.*DT))
      IF (BIG32.GT.BIG) BIG=BIG32
      BIG33=ABS(COEFF14HHHHH/2.*CBI(2,J+1))
      IF (BIG33.GT.BIG) BIG=BIG33
      BIG34=ABS(COEFF14HHHHH/2.*CBI(1,J+1))
      IF (BIG34.GT.BIG) BIG=BIG34
      BIG35=ABS(COEFF14HHHHH/2.*CBI(2,J))
      IF (BIG35.GT.BIG) BIG=BIG35
      BIG36=ABS(COEFF14HHHHH/2.*CBI(1,J))
      IF (BIG36.GT.BIG) BIG=BIG36
      BIG37=ABS(COEFF14H/2.*CBI(2,J)*PARION)
      IF (BIG37.GT.BIG) BIG=BIG37
      BIG38=ABS(COEFF14H/2.*CBI(1,J)*PARION)
      IF (BIG38.GT.BIG) BIG=BIG38
      BIG39=ABS(COEFF14H/2.*CBI(2,J-1))
      IF (BIG39.GT.BIG) BIG=BIG39
      BIG40=ABS(COEFF14H/2.*CBI(1,J-1))
      IF (BIG40.GT.BIG) BIG=BIG40
      BIG41=ABS(HHHHH/2.*3.*CBI(2,J)/(4.*DT))
      IF (BIG41.GT.BIG) BIG=BIG41
      BIG42=ABS(HHHHH/2.*3.*CBI(1,J)/(4.*DT))
      IF (BIG42.GT.BIG) BIG=BIG42
      BIG43=ABS(HHHHH/2.*CBI(2,J+1)/(4.*DT))
      IF (BIG43.GT.BIG) BIG=BIG43
      BIG44=ABS(HHHHH/2.*CBI(1,J+1)/(4.*DT))
      IF (BIG44.GT.BIG) BIG=BIG44
      BIG45=ABS(H/2.*3.*CBI(2,J)/(4.*DT)*PARION)
      IF (BIG45.GT.BIG) BIG=BIG45
      BIG46=ABS(H/2.*3.*CBI(1,J)/(4.*DT)*PARION)
      IF (BIG46.GT.BIG) BIG=BIG46
      BIG47=ABS(H/2.*CBI(2,J-1)/(4.*DT))
      IF (BIG47.GT.BIG) BIG=BIG47
      BIG48=ABS(H/2.*CBI(1,J-1)/(4.*DT))
      IF (BIG48.GT.BIG) BIG=BIG48
      IF (ABS(G(20)).LT.BIG*EBIG) G(20)=0

C     For acetaminophen, reacting species
      G(21)=COEFF16HHHHH/2.*(ACE(2,J+1)+ACE(1,J+1)-ACE(2,J)-ACE(1,J))
     1     -COEFF16H/2.*(PARACE*(ACE(2,J)+ACE(1,J))-ACE(2,J-1)-ACE(1,J-1))
     4     -HHHHH/2.*(3.*(ACE(2,J)-ACE(1,J))
     5     +(ACE(2,J+1)-ACE(1,J+1)))/(4.*DT)
     5   -H/2.*(3.*PARACE*(ACE(2,J)-ACE(1,J))
     6   +(ACE(2,J-1)-ACE(1,J-1)))/(4.*DT)

      B(21,21)=COEFF16HHHHH/2.+COEFF16H/2.*PARACE
     1 +HHHHH/2.*3./(4.*DT)+H/2.*3./(4.*DT)*PARACE
      D(21,21)=-COEFF16HHHHH/2.+HHHHH/2./(4.*DT)
      A(21,21)=-COEFF16H/2.+H/2./(4.*DT)


      BIG=ABS(COEFF16HHHHH/2.*ACE(2,J+1))
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      BIG2=ABS(COEFF16HHHHH/2.*ACE(1,J+1))
      IF (BIG2.GT.BIG) BIG=BIG2
      BIG3=ABS(COEFF16HHHHH/2.*ACE(2,J))
      IF (BIG3.GT.BIG) BIG=BIG3
      BIG4=ABS(COEFF16HHHHH/2.*ACE(1,J))
      IF (BIG4.GT.BIG) BIG=BIG4
      BIG5=ABS(COEFF16H/2.*ACE(2,J)*PARACE)
      IF (BIG5.GT.BIG) BIG=BIG5
      BIG6=ABS(COEFF16H/2.*ACE(1,J)*PARACE)
      IF (BIG6.GT.BIG) BIG=BIG6
      BIG7=ABS(COEFF16H/2.*ACE(2,J-1))
      IF (BIG7.GT.BIG) BIG=BIG7
      BIG8=ABS(COEFF16H/2.*ACE(1,J-1))
      IF (BIG8.GT.BIG) BIG=BIG8
      BIG17=ABS(HHHHH/2.*3.*ACE(2,J)/(4.*DT))
      IF (BIG17.GT.BIG) BIG=BIG17
      BIG18=ABS(HHHHH/2.*3.*ACE(1,J)/(4.*DT))
      IF (BIG18.GT.BIG) BIG=BIG18
      BIG19=ABS(HHHHH/2.*ACE(2,J+1)/(4.*DT))
      IF (BIG19.GT.BIG) BIG=BIG19
      BIG20=ABS(HHHHH/2.*ACE(1,J+1)/(4.*DT))
      IF (BIG20.GT.BIG) BIG=BIG20
      BIG21=ABS(H/2.*3.*ACE(2,J)/(4.*DT)*PARACE)
      IF (BIG21.GT.BIG) BIG=BIG21
      BIG22=ABS(H/2.*3.*ACE(1,J)/(4.*DT)*PARACE)
      IF (BIG22.GT.BIG) BIG=BIG22
      BIG23=ABS(H/2.*ACE(2,J-1)/(4.*DT))
      IF (BIG23.GT.BIG) BIG=BIG23
      BIG24=ABS(H/2.*ACE(1,J-1)/(4.*DT))
      IF (BIG24.GT.BIG) BIG=BIG24
      IF (ABS(G(21)).LT.BIG*EBIG) G(21)=0

C       DOUBLE lAYER voLTAGE - DUMMY
      G(22)=(VDL(2,J)+VDL(1,J))/2.

      B(22,22)=-1./2.

      BIG=ABS(VDL(2,J)/2.)
      BIG2=ABS(VDL(1,J)/2.)
      IF (BIG2.GT.BIG) BIG=BIG2
      IF (ABS(G(22)).LT.BIG*EBIG) G(22)=0

C     212 WRITE(12,301) J, (G(K),K=1,N)
      RETURN
      END

      SUBROUTINE BULKDIFF(J)
      IMPLICIT DOUBLE PRECISION (A-H, O-Z)
      COMMON/BAB/ A(22,22),B(22,22),C(22,80001),D(22,45),G(22),X(22,22)
     1    ,Y(22,22)
      COMMON/NSN/ N, NJ
      COMMON/GLC/ NTIME,LL
      COMMON/VAR/ DIFF(16),H,EBIG,HH,IJ ,KJ,TT,VAP,HHH,DT,RE,AKB,BB,CDL
      COMMON/VARR/ HHHH,HHHHH,MJ,LJ
      COMMON/DIN/ DGOX(16),DGLM(16),DIRM(16),DBULK(16)
      COMMON/SPCI/ GLU(2,80001),GOX(2,80001),GLA(2,80001),GOR(2,80001)
      COMMON/SPCII/ OXY(2,80001),HPR(2,80001),GOA(2,80001),GOP(2,80001)
      COMMON/RXT/ EQ1(2,80001),RGA(2,80001),EQ2(2,80001),RHP(2,80001)
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      COMMON/SPCIII/ ANM(2,80001),GLUA(2,80001),GLI(2,80001)
      COMMON/SPCIV/ HYD(2,80001),OHI(2,80001),CO2(2,80001),CBA(2,80001)
      COMMON/SPCV/ CBI(2,80001),ACE(2,800001)
      COMMON/VOL/ VDL(2,80001)
      COMMON/POR/ POR1,POR2,PORGLU,PARION,PARACE
      COMMON/RTE/ ratef1,equilib1,ratef2,ratef3,equilib3,ratef4
      COMMON/RTD/ ratef5,equilib5,equilib6,equilib7,equilib8,equilib9
      COMMON/BUL/ CBULK(16),PARH2O2,PAR02,PARGLUCOSE,JCOUNT

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

C      For Glucose, being consumed only
      G(1)=DBULK(1)*(GLU(2,J+1)-2.*GLU(2,J)+GLU(2,J-1)
     1       +GLU(1,J+1)-2.*GLU(1,J)+GLU(1,J-1))/(2.*HHHHH**2.)
     2     +(ANM(2,J)+ANM(1,J))/2.-(GLU(2,J)-GLU(1,J))/DT

      B(1,1)=DBULK(1)/HHHHH**2.+1./DT
      D(1,1)=-DBULK(1)/(2.*HHHHH**2.)
      A(1,1)=-DBULK(1)/(2.*HHHHH**2.)
      B(1,13)=-1./2.

      BIG=ABS(DBULK(1)*(GLU(2,J+1))/(2.*HHHHH**2.))
      BIG2=ABS(DBULK(1)*(GLU(2,J))/(HHHHH**2.))
      IF (BIG2.GT.BIG) BIG=BIG2
      BIG3=ABS(DBULK(1)*(GLU(2,J-1))/(2.*HHHHH**2.))
      IF (BIG3.GT.BIG) BIG=BIG3
      BIG4=ABS(DBULK(1)*(GLU(1,J+1))/(2.*HHHHH**2.))
      IF (BIG4.GT.BIG) BIG=BIG4
      BIG5=ABS(DBULK(1)*(GLU(1,J))/(HHHHH**2.))
      IF (BIG5.GT.BIG) BIG=BIG5
      BIG6=ABS(DBULK(1)*(GLU(1,J-1))/(2.*HHHHH**2.))
      IF (BIG6.GT.BIG) BIG=BIG6
      BIG7=ABS(GLU(2,J)/DT)
      IF (BIG7.GT.BIG) BIG=BIG7
      BIG8=ABS(GLU(1,J)/DT)
      IF (BIG8.GT.BIG) BIG=BIG8
      BIG9=ABS(ANM(2,J)/2.)
      IF (BIG9.GT.BIG) BIG=BIG9
      BIG10=ABS(ANM(1,J)/2.)
      IF (BIG10.GT.BIG) BIG=BIG10
      IF (ABS(G(1)).LT.BIG*EBIG) G(1)=0

C      For GOx, enzyme
      G(2)=(GOX(2,J)+GOX(1,J))/2.
      B(2,2)=-1./2.

C      For Gluconic Acid, being produced only
      G(3)=DBULK(3)*(GLA(2,J+1)-2.*GLA(2,J)+GLA(2,J-1)
     1       +GLA(1,J+1)-2.*GLA(1,J)+GLA(1,J-1))/(2.*HHHHH**2.)
     2       +DBULK(10)*(GLI(2,J+1)-2.*GLI(2,J)+GLI(2,J-1)
     3       +GLI(1,J+1)-2.*GLI(1,J)+GLI(1,J-1))/(2.*HHHHH**2.)
     2     -(GLA(2,J)-GLA(1,J))/DT-(GLI(2,J)-GLI(1,J))/DT

      B(3,3)=DBULK(3)/HHHHH**2.+1./DT
      D(3,3)=-DBULK(3)/(2.*HHHHH**2.)
      A(3,3)=-DBULK(3)/(2.*HHHHH**2.)
      B(3,15)=DBULK(10)/HHHHH**2.+1./DT
      D(3,15)=-DBULK(10)/(2.*HHHHH**2.)
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      A(3,15)=-DBULK(10)/(2.*HHHHH**2.)

      BIG=ABS(DBULK(3)*(GLA(2,J+1))/(2.*HHHHH**2.))
      BIG2=ABS(DBULK(3)*(GLA(2,J))/(HHHHH**2.))
      IF (BIG2.GT.BIG) BIG=BIG2
      BIG3=ABS(DBULK(3)*(GLA(2,J-1))/(2.*HHHHH**2.))
      IF (BIG3.GT.BIG) BIG=BIG3
      BIG4=ABS(DBULK(3)*(GLA(1,J+1))/(2.*HHHHH**2.))
      IF (BIG4.GT.BIG) BIG=BIG4
      BIG5=ABS(DBULK(3)*(GLA(1,J))/(HHHHH**2.))
      IF (BIG5.GT.BIG) BIG=BIG5
      BIG6=ABS(DBULK(3)*(GLA(1,J-1))/(2.*HHHHH**2.))
      IF (BIG6.GT.BIG) BIG=BIG6
      BIG7=ABS(GLA(2,J)/DT)
      IF (BIG7.GT.BIG) BIG=BIG7
      BIG8=ABS(GLA(1,J)/DT)
      IF (BIG8.GT.BIG) BIG=BIG8
      BIG9=ABS(DBULK(10)*(GLI(2,J+1))/(2.*HHHHH**2.))
      IF (BIG9.GT.BIG) BIG=BIG9
      BIG10=ABS(DBULK(10)*(GLI(2,J))/(HHHHH**2.))
      IF (BIG10.GT.BIG) BIG=BIG10
      BIG11=ABS(DBULK(10)*(GLI(2,J-1))/(2.*HHHHH**2.))
      IF (BIG11.GT.BIG) BIG=BIG11
      BIG12=ABS(DBULK(10)*(GLI(1,J+1))/(2.*HHHHH**2.))
      IF (BIG12.GT.BIG) BIG=BIG12
      BIG13=ABS(DBULK(10)*(GLI(1,J))/(HHHHH**2.))
      IF (BIG13.GT.BIG) BIG=BIG13
      BIG14=ABS(DBULK(10)*(GLI(1,J-1))/(2.*HHHHH**2.))
      IF (BIG14.GT.BIG) BIG=BIG14
      BIG15=ABS(GLI(2,J)/DT)
      IF (BIG15.GT.BIG) BIG=BIG15
      BIG16=ABS(GLI(1,J)/DT)
      IF (BIG16.GT.BIG) BIG=BIG16
      IF (ABS(G(3)).LT.BIG*EBIG) G(3)=0

C     For GOx2, enzyme
      G(4)=(GOR(2,J)+GOR(1,J))/2.
      B(4,4)=-1./2.

C     For O2, being consumed only
      G(5)=DBULK(5)*(OXY(2,J+1)-2.*OXY(2,J)+OXY(2,J-1)
     1      +OXY(1,J+1)-2.*OXY(1,J)+OXY(1,J-1))/(2.*HHHHH**2.)
     2    -(OXY(2,J)-OXY(1,J))/DT

      B(5,5)=DBULK(5)/HHHHH**2.+1./DT
      D(5,5)=-DBULK(5)/(2.*HHHHH**2.)
      A(5,5)=-DBULK(5)/(2.*HHHHH**2.)


      BIG=ABS(DBULK(5)*(OXY(2,J+1))/(2.*HHHHH**2.))
      BIG2=ABS(DBULK(5)*(OXY(2,J))/(HHHHH**2.))
      IF (BIG2.GT.BIG) BIG=BIG2
      BIG3=ABS(DBULK(5)*(OXY(2,J-1))/(2.*HHHHH**2.))
      IF (BIG3.GT.BIG) BIG=BIG3
      BIG4=ABS(DBULK(5)*(OXY(1,J+1))/(2.*HHHHH**2.))
      IF (BIG4.GT.BIG) BIG=BIG4
      BIG5=ABS(DBULK(5)*(OXY(1,J))/(HHHHH**2.))
      IF (BIG5.GT.BIG) BIG=BIG5
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      BIG6=ABS(DBULK(5)*(OXY(1,J-1))/(2.*HHHHH**2.))
      IF (BIG6.GT.BIG) BIG=BIG6
      BIG7=ABS(OXY(2,J)/DT)
      IF (BIG7.GT.BIG) BIG=BIG7
      BIG8=ABS(OXY(1,J)/DT)
      IF (BIG8.GT.BIG) BIG=BIG8
      IF (ABS(G(5)).LT.BIG*EBIG) G(5)=0

C     For H2O2, reacting species
      G(6)=DBULK(6)*(HPR(2,J+1)-2.*HPR(2,J)+HPR(2,J-1)
     1     +HPR(1,J+1)-2.*HPR(1,J)+HPR(1,J-1))/(2.*HHHHH**2.)
     2    -(HPR(2,J)-HPR(1,J))/DT

      B(6,6)=DBULK(6)/HHHHH**2.+1./DT
      D(6,6)=-DBULK(6)/(2.*HHHHH**2.)
      A(6,6)=-DBULK(6)/(2.*HHHHH**2.)

      BIG=ABS(DBULK(6)*(HPR(2,J+1))/(2.*HHHHH**2.))
      BIG2=ABS(DBULK(6)*(HPR(2,J))/(HHHHH**2.))
      IF (BIG2.GT.BIG) BIG=BIG2
      BIG3=ABS(DBULK(6)*(HPR(2,J-1))/(2.*HHHHH**2.))
      IF (BIG3.GT.BIG) BIG=BIG3
      BIG4=ABS(DBULK(6)*(HPR(1,J+1))/(2.*HHHHH**2.))
      IF (BIG4.GT.BIG) BIG=BIG4
      BIG5=ABS(DBULK(6)*(HPR(1,J))/(HHHHH**2.))
      IF (BIG5.GT.BIG) BIG=BIG5
      BIG6=ABS(DBULK(6)*(HPR(1,J-1))/(2.*HHHHH**2.))
      IF (BIG6.GT.BIG) BIG=BIG6
      BIG7=ABS(HPR(2,J)/DT)
      IF (BIG7.GT.BIG) BIG=BIG7
      BIG8=ABS(HPR(1,J)/DT)
      IF (BIG8.GT.BIG) BIG=BIG8
      IF (ABS(G(6)).LT.BIG*EBIG) G(6)=0

C     For CX-GOx2, enzyme complex
      G(7)=(GOA(2,J)+GOA(1,J))/2.
      B(7,7)=-1./2.

C     For CX-GOx, enzyme complex
      G(8)=(GOP(2,J)+GOP(1,J))/2.
      B(8,8)=-1./2.

C     For Reaction 1 Enzymatic Catalysis
      G(9)=(EQ1(2,J)+EQ1(1,J))/2.
      B(9,9)=-1./2.

C     For Reaction 2
      G(10)=(RGA(2,J)+RGA(1,J))/2.
      B(10,10)=-1./2.

C     For Reaction 3 Meditation/regeneration
      G(11)=(EQ2(2,J)+EQ2(1,J))/2.
      B(11,11)=-1./2.

C     For Reaction 4
      G(12)=(RHP(2,J)+RHP(1,J))/2.
      B(12,12)=-1./2.

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C       REACTION5
  218 G(13)=-(ANM(2,J)+ANM(1,J))/2.+ratef5*((GLUA(2,J)+GLUA(1,J))/2.
     1  -(GLU(2,J)+GLU(1,J))/2./equilib5)
      B(13,1)=ratef5/2./equilib5
      B(13,14)=-ratef5/2.
      B(13,13)=+1./2.

      BIG=ABS(ANM(2,J)/2.)
      BIG2=ABS(ANM(1,J)/2.)
      IF (BIG2.GT.BIG) BIG=BIG2
      BIG3=ABS(ratef5*GLUA(2,J)/2.)
      IF (BIG3.GT.BIG) BIG=BIG3
      BIG4=ABS(ratef5*GLUA(1,J)/2.)
      IF (BIG4.GT.BIG) BIG=BIG4
      BIG5=ABS(ratef5*GLU(2,J)/2./equilib5)
      IF (BIG5.GT.BIG) BIG=BIG5
      BIG6=ABS(ratef5*GLU(1,J)/2./equilib5)
      IF (BIG6.GT.BIG) BIG=BIG6
      IF (ABS(G(13)).LT.BIG*EBIG) G(13)=0.0

C       For alpha Glucose, being consumed only
      G(14)=DBULK(9)*(GLUA(2,J+1)-2.*GLUA(2,J)+GLUA(2,J-1)
     1     +GLUA(1,J+1)-2.*GLUA(1,J)+GLUA(1,J-1))/(2.*HHHHH**2.)
     2     -(ANM(2,J)+ANM(1,J))/2.-(GLUA(2,J)-GLUA(1,J))/DT
      B(14,14)=DBULK(9)/HHHHH**2.+1./DT
      D(14,14)=-DBULK(9)/(2.*HHHHH**2.)
      A(14,14)=-DBULK(9)/(2.*HHHHH**2.)
      B(14,13)=1./2.

      BIG=ABS(DBULK(9)*(GLUA(2,J+1))/(2.*HHHHH**2.))
      BIG2=ABS(DBULK(9)*(GLUA(2,J))/(HHHHH**2.))
      IF (BIG2.GT.BIG) BIG=BIG2
      BIG3=ABS(DBULK(9)*(GLUA(2,J-1))/(2.*HHHHH**2.))
      IF (BIG3.GT.BIG) BIG=BIG3
      BIG4=ABS(DBULK(9)*(GLUA(1,J+1))/(2.*HHHHH**2.))
      IF (BIG4.GT.BIG) BIG=BIG4
      BIG5=ABS(DBULK(9)*(GLUA(1,J))/(HHHHH**2.))
      IF (BIG5.GT.BIG) BIG=BIG5
      BIG6=ABS(DBULK(9)*(GLUA(1,J-1))/(2.*HHHHH**2.))
      IF (BIG6.GT.BIG) BIG=BIG6
      BIG7=ABS(ANM(2,J)/2.)
      IF (BIG7.GT.BIG) BIG=BIG7
      BIG8=ABS(ANM(1,J)/2.)
      IF (BIG8.GT.BIG) BIG=BIG8
      BIG9=ABS(GLUA(2,J)/DT)
      IF (BIG9.GT.BIG) BIG=BIG9
      BIG10=ABS(GLUA(1,J)/DT)
      IF (BIG10.GT.BIG) BIG=BIG10
      IF (ABS(G(14)).LT.BIG*EBIG) G(14)=0.0

C Gluconic acid dissociation

      G(15)=equilib6*(GLA(2,J)+GLA(1,J))/2.-(GLI(2,J)+GLI(1,J))*
     1  (HYD(2,J)+HYD(1,J))/4.
      B(15,3)=-equilib6/2.
      B(15,15)=(HYD(2,J)+HYD(1,J))/4.
      B(15,16)=(GLI(2,J)+GLI(1,J))/4.

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```fortran
      BIG=ABS(equilib6*GLA(2,J)/2.)
      BIG2=ABS(equilib6*GLA(1,J)/2.)
      IF (BIG2.GT.BIG) BIG=BIG2
      BIG3=ABS(GLI(2,J)*HYD(2,J)/4.)
      IF (BIG3.GT.BIG) BIG=BIG3
      BIG4=ABS(GLI(2,J)*HYD(1,J)/4)
      IF (BIG4.GT.BIG) BIG=BIG4
      BIG5=ABS(GLI(1,J)*HYD(2,J)/4)
      IF (BIG5.GT.BIG) BIG=BIG5
      BIG6=ABS(GLI(1,J)*HYD(1,J)/4)
      IF (BIG6.GT.BIG) BIG=BIG6
      IF (ABS(G(15)).LT.BIG*EBIG) G(15)=0
C Hydrogen ion, hydroxide ion, gluconate ion, bicarbonate ion flux
      G(16)=DBULK(11)*(HYD(2,J+1)-2.*HYD(2,J)+HYD(2,J-1)
     1      +HYD(1,J+1)-2.*HYD(1,J)+HYD(1,J-1))/(2.*HHHHH**2.)
     2  -DBULK(15)*(OHI(2,J+1)-2.*OHI(2,J)+OHI(2,J-1)
     3      +OHI(1,J+1)-2.*OHI(1,J)+OHI(1,J-1))/(2.*HHHHH**2.)
     4  -DBULK(10)*(GLI(2,J+1)-2.*GLI(2,J)+GLI(2,J-1)
     5      +GLI(1,J+1)-2.*GLI(1,J)+GLI(1,J-1))/(2.*HHHHH**2.)
     6  -DBULK(14)*(CBI(2,J+1)-2.*CBI(2,J)+CBI(2,J-1)
     7      +CBI(1,J+1)-2.*CBI(1,J)+CBI(1,J-1))/(2.*HHHHH**2.)
     8  -(HYD(2,J)-HYD(1,J))/DT+(OHI(2,J)-OHI(1,J))/DT
     9  +(GLI(2,J)-GLI(1,J))/DT+(CBI(2,J)-CBI(1,J))/DT

      B(16,16)=DBULK(11)/HHHHH**2.+1./DT
      D(16,16)=-DBULK(11)/(2.*HHHHH**2.)
      A(16,16)=-DBULK(11)/(2.*HHHHH**2.)
      B(16,17)=-DBULK(15)/HHHHH**2.-1./DT
      D(16,17)=DBULK(15)/(2.*HHHHH**2.)
      A(16,17)=DBULK(15)/(2.*HHHHH**2.)
      B(16,15)=-DBULK(10)/HHHHH**2.-1./DT
      D(16,15)=DBULK(10)/(2.*HHHHH**2.)
      A(16,15)=DBULK(10)/(2.*HHHHH**2.)
      B(16,20)=-DBULK(14)/HHHHH**2.-1./DT
      D(16,20)=DBULK(14)/(2.*HHHHH**2.)
      A(16,20)=DBULK(14)/(2.*HHHHH**2.)

      BIG=ABS(DBULK(11)*(HYD(2,J+1))/(2.*HHHHH**2.))
      BIG2=ABS(DBULK(11)*(HYD(2,J))/(HHHHH**2.))
      IF (BIG2.GT.BIG) BIG=BIG2
      BIG3=ABS(DBULK(11)*(HYD(2,J-1))/(2.*HHHHH**2.))
      IF (BIG3.GT.BIG) BIG=BIG3
      BIG4=ABS(DBULK(11)*(HYD(1,J+1))/(2.*HHHHH**2.))
      IF (BIG4.GT.BIG) BIG=BIG4
      BIG5=ABS(DBULK(11)*(HYD(1,J))/(HHHHH**2.))
      IF (BIG5.GT.BIG) BIG=BIG5
      BIG6=ABS(DBULK(11)*(HYD(1,J-1))/(2.*HHHHH**2.))
      IF (BIG6.GT.BIG) BIG=BIG6
      BIG7=ABS(DBULK(15)*OHI(2,J+1)/(2.*HHHHH**2.))
      IF (BIG7.GT.BIG) BIG=BIG7
      BIG8=ABS(DBULK(15)*OHI(2,J)/(HHHHH**2.))
      IF (BIG8.GT.BIG) BIG=BIG8
      BIG9=ABS(DBULK(15)*OHI(2,J-1)/(2.*HHHHH**2.))
      IF (BIG9.GT.BIG) BIG=BIG9
      BIG10=ABS(DBULK(15)*OHI(1,J+1)/(2.*HHHHH**2.))
      IF (BIG10.GT.BIG) BIG=BIG10
      BIG11=ABS(DBULK(15)*OHI(1,J)/(HHHHH**2.))
      IF (BIG11.GT.BIG) BIG=BIG11
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      BIG12=ABS(DBULK(15)*OHI(1,J-1)/(2.*HHHHH**2.))
      IF (BIG12.GT.BIG) BIG=BIG12
      BIG13=ABS(DBULK(10)*GLI(2,J+1)/(2.*HHHHH**2.))
      IF (BIG13.GT.BIG) BIG=BIG13
      BIG14=ABS(DBULK(10)*GLI(2,J)/(HHHHH**2.))
      IF (BIG14.GT.BIG) BIG=BIG14
      BIG15=ABS(DBULK(10)*GLI(2,J-1)/(2.*HHHHH**2.))
      IF (BIG15.GT.BIG) BIG=BIG15
      BIG16=ABS(DBULK(10)*GLI(1,J+1)/(2.*HHHHH**2.))
      IF (BIG16.GT.BIG) BIG=BIG16
      BIG17=ABS(DBULK(10)*GLI(1,J)/(HHHHH**2.))
      IF (BIG17.GT.BIG) BIG=BIG17
      BIG18=ABS(DBULK(10)*GLI(1,J-1)/(2.*HHHHH**2.))
      IF (BIG18.GT.BIG) BIG=BIG18
      BIG19=ABS(DBULK(14)*CBI(2,J+1)/(2.*HHHHH**2.))
      IF (BIG19.GT.BIG) BIG=BIG19
      BIG20=ABS(DBULK(14)*CBI(2,J)/(HHHHH**2.))
      IF (BIG20.GT.BIG) BIG=BIG20
      BIG21=ABS(DBULK(14)*CBI(2,J-1)/(2.*HHHHH**2.))
      IF (BIG21.GT.BIG) BIG=BIG21
      BIG22=ABS(DBULK(14)*CBI(1,J+1)/(2.*HHHHH**2.))
      IF (BIG22.GT.BIG) BIG=BIG22
      BIG23=ABS(DBULK(14)*CBI(1,J)/(HHHHH**2.))
      IF (BIG23.GT.BIG) BIG=BIG23
      BIG24=ABS(DBULK(14)*CBI(1,J-1)/(2.*HHHHH**2.))
      IF (BIG24.GT.BIG) BIG=BIG24
      BIG25=ABS(HYD(2,J)/DT)
      IF (BIG25.GT.BIG) BIG=BIG25
      BIG26=ABS(HYD(1,J)/DT)
      IF (BIG26.GT.BIG) BIG=BIG26
      BIG27=ABS(OHI(2,J)/DT)
      IF (BIG27.GT.BIG) BIG=BIG27
      BIG28=ABS(OHI(1,J)/DT)
      IF (BIG28.GT.BIG) BIG=BIG28
      BIG29=ABS(GLI(2,J)/DT)
      IF (BIG29.GT.BIG) BIG=BIG29
      BIG30=ABS(GLI(1,J)/DT)
      IF (BIG30.GT.BIG) BIG=BIG30
      BIG31=ABS(CBI(2,J)/DT)
      IF (BIG31.GT.BIG) BIG=BIG31
      BIG32=ABS(CBI(1,J)/DT)
      IF (BIG32.GT.BIG) BIG=BIG32
      IF (ABS(G(16)).LT.BIG*EBIG) G(16)=0

c Water Dissociation
      G(17)=equilib9 -(HYD(2,J)+HYD(1,J))*(OHI(2,J)+OHI(1,J))/4.
      B(17,17)=(HYD(2,J)+HYD(1,J))/4.
      B(17,16)=(OHI(2,J)+OHI(1,J))/4.

      BIG=ABS(equilib9)
      BIG2=ABS(HYD(2,J)*OHI(2,J)/4.)
      IF (BIG2.GT.BIG) BIG=BIG2
      BIG3=ABS(HYD(2,J)*OHI(1,J)/4.)
      IF (BIG3.GT.BIG) BIG=BIG3
      BIG4=ABS(HYD(1,J)*OHI(2,J)/4.)
      IF (BIG4.GT.BIG) BIG=BIG4
      BIG5=ABS(HYD(1,J)*OHI(1,J)/4.)
      IF (BIG5.GT.BIG) BIG=BIG5
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      IF (ABS(G(17)).LT.BIG*EBIG) G(17)=0

C CO2 Hydration
      G(18)=equilib7*(CO2(2,J)+CO2(1,J))/2.-(CBA(2,J)+CBA(1,J))/2.
      B(18,18)=-equilib7/2.
      B(18,19)=1./2.

      BIG=ABS(equilib7*CO2(2,J)/2.)
      BIG2=ABS(equilib7*CO2(1,J)/2.)
      IF (BIG2.GT.BIG) BIG=BIG2
      BIG3=ABS(CBA(2,J)/2.)
      IF (BIG3.GT.BIG) BIG=BIG3
      BIG4=ABS(CBA(1,J)/2.)
      IF (BIG4.GT.BIG) BIG=BIG4
      IF (ABS(G(18)).LT.BIG*EBIG) G(18)=0

C Carbonic acid dissociation
      G(19)=equilib8*(CBA(2,J)+CBA(1,J))/2.-(CBI(2,J)+CBI(1,J))
     1 *(HYD(2,J)+HYD(1,J))/4.
      B(19,19)=-equilib8/2.
      B(19,20)=(HYD(2,J)+HYD(1,J))/4.
      B(19,16)=(CBI(2,J)+CBI(1,J))/4.

      BIG=ABS(equilib8*CBA(2,J)/2.)
      BIG2=ABS(equilib8*CBA(1,J)/2.)
      IF (BIG2.GT.BIG) BIG=BIG2
      BIG3=ABS(CBI(2,J)*HYD(2,J)/4.)
      IF (BIG3.GT.BIG) BIG=BIG3
      BIG4=ABS(CBI(2,J)*HYD(1,J)/4.)
      IF (BIG4.GT.BIG) BIG=BIG4
      BIG5=ABS(CBI(1,J)*HYD(2,J)/4.)
      IF (BIG5.GT.BIG) BIG=BIG5
      BIG6=ABS(CBI(1,J)*HYD(1,J)/4.)
      IF (BIG6.GT.BIG) BIG=BIG6
      IF (ABS(G(19)).LT.BIG*EBIG) G(19)=0

C FLUX OF CO2, CARBONIC ACID, BICARBONATE ION
      G(20)=DBULK(12)*(CO2(2,J+1)-2.*CO2(2,J)+CO2(2,J-1)
     1       +CO2(1,J+1)-2.*CO2(1,J)+CO2(1,J-1))/(2.*HHHHH**2.)
     2   +DBULK(13)*(CBA(2,J+1)-2.*CBA(2,J)+CBA(2,J-1)
     3       +CBA(1,J+1)-2.*CBA(1,J)+CBA(1,J-1))/(2.*HHHHH**2.)
     4   +DBULK(14)*(CBI(2,J+1)-2.*CBI(2,J)+CBI(2,J-1)
     5       +CBI(1,J+1)-2.*CBI(1,J)+CBI(1,J-1))/(2.*HHHHH**2.)
     8   -(CO2(2,J)-CO2(1,J))/DT-(CBA(2,J)-CBA(1,J))/DT
     9   -(CBI(2,J)-CBI(1,J))/DT

      B(20,20)=DBULK(14)/HHHHH**2.+1./DT
      D(20,20)=-DBULK(14)/(2.*HHHHH**2.)
      A(20,20)=-DBULK(14)/(2.*HHHHH**2.)
      B(20,18)=DBULK(12)/HHHHH**2.+1./DT
      D(20,18)=-DBULK(12)/(2.*HHHHH**2.)
      A(20,18)=-DBULK(12)/(2.*HHHHH**2.)
      B(20,19)=DBULK(13)/HHHHH**2.+1./DT
      D(20,19)=-DBULK(13)/(2.*HHHHH**2.)
      A(20,19)=-DBULK(13)/(2.*HHHHH**2.)

      BIG=ABS(DBULK(12)*(CO2(2,J+1))/(2.*HHHHH**2.))
      BIG2=ABS(DBULK(12)*(CO2(2,J))/(HHHHH**2.))
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      IF (BIG2.GT.BIG) BIG=BIG2
      BIG3=ABS(DBULK(12)*(CO2(2,J-1))/(2.*HHHHH**2.))
      IF (BIG3.GT.BIG) BIG=BIG3
      BIG4=ABS(DBULK(12)*(CO2(1,J+1))/(2.*HHHHH**2.))
      IF (BIG4.GT.BIG) BIG=BIG4
      BIG5=ABS(DBULK(12)*(CO2(1,J))/(HHHHH**2.))
      IF (BIG5.GT.BIG) BIG=BIG5
      BIG6=ABS(DBULK(12)*(CO2(1,J-1))/(2.*HHHHH**2.))
      IF (BIG6.GT.BIG) BIG=BIG6
      BIG7=ABS(DBULK(13)*CBA(2,J+1)/(2.*HHHHH**2.))
      IF (BIG7.GT.BIG) BIG=BIG7
      BIG8=ABS(DBULK(13)*CBA(2,J)/(HHHHH**2.))
      IF (BIG8.GT.BIG) BIG=BIG8
      BIG9=ABS(DBULK(13)*CBA(2,J-1)/(2.*HHHHH**2.))
      IF (BIG9.GT.BIG) BIG=BIG9
      BIG10=ABS(DBULK(13)*CBA(1,J+1)/(2.*HHHHH**2.))
      IF (BIG10.GT.BIG) BIG=BIG10
      BIG11=ABS(DBULK(13)*CBA(1,J)/(HHHHH**2.))
      IF (BIG11.GT.BIG) BIG=BIG11
      BIG12=ABS(DBULK(13)*CBA(1,J-1)/(2.*HHHHH**2.))
      IF (BIG12.GT.BIG) BIG=BIG12
      BIG13=ABS(DBULK(14)*CBI(2,J+1)/(2.*HHHHH**2.))
      IF (BIG13.GT.BIG) BIG=BIG13
      BIG14=ABS(DBULK(14)*CBI(2,J)/(HHHHH**2.))
      IF (BIG14.GT.BIG) BIG=BIG14
      BIG15=ABS(DBULK(14)*CBI(2,J-1)/(2.*HHHHH**2.))
      IF (BIG15.GT.BIG) BIG=BIG15
      BIG16=ABS(DBULK(14)*CBI(1,J+1)/(2.*HHHHH**2.))
      IF (BIG16.GT.BIG) BIG=BIG16
      BIG17=ABS(DBULK(14)*CBI(1,J)/(HHHHH**2.))
      IF (BIG17.GT.BIG) BIG=BIG17
      BIG18=ABS(DBULK(14)*CBI(1,J-1)/(2.*HHHHH**2.))
      IF (BIG18.GT.BIG) BIG=BIG18
      BIG19=ABS(CO2(2,J)/DT)
      IF (BIG19.GT.BIG) BIG=BIG19
      BIG20=ABS(CO2(1,J)/DT)
      IF (BIG20.GT.BIG) BIG=BIG20
      BIG21=ABS(CBA(2,J)/DT)
      IF (BIG21.GT.BIG) BIG=BIG21
      BIG22=ABS(CBA(1,J)/DT)
      IF (BIG22.GT.BIG) BIG=BIG22
      BIG23=ABS(CBI(2,J)/DT)
      IF (BIG23.GT.BIG) BIG=BIG23
      BIG24=ABS(CBI(1,J)/DT)
      IF (BIG24.GT.BIG) BIG=BIG24
      IF (ABS(G(20)).LT.BIG*EBIG) G(20)=0

C     For Acetaminophen
      G(21)=DBULK(16)*(ACE(2,J+1)-2.*ACE(2,J)+ACE(2,J-1)
     1      +ACE(1,J+1)-2.*ACE(1,J)+ACE(1,J-1))/(2.*HHHHH**2.)
     2     -(ACE(2,J)-ACE(1,J))/DT

      B(21,21)=DBULK(16)/HHHHH**2.+1./DT
      D(21,21)=-DBULK(16)/(2.*HHHHH**2.)
      A(21,21)=-DBULK(16)/(2.*HHHHH**2.)


      BIG=ABS(DBULK(16)*(ACE(2,J+1))/(2.*HHHHH**2.))
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      BIG2=ABS(DBULK(16)*(ACE(2,J))/(HHHHH**2.))
      IF (BIG2.GT.BIG) BIG=BIG2
      BIG3=ABS(DBULK(16)*(ACE(2,J-1))/(2.*HHHHH**2.))
      IF (BIG3.GT.BIG) BIG=BIG3
      BIG4=ABS(DBULK(16)*(ACE(1,J+1))/(2.*HHHHH**2.))
      IF (BIG4.GT.BIG) BIG=BIG4
      BIG5=ABS(DBULK(16)*(ACE(1,J))/(HHHHH**2.))
      IF (BIG5.GT.BIG) BIG=BIG5
      BIG6=ABS(DBULK(16)*(ACE(1,J-1))/(2.*HHHHH**2.))
      IF (BIG6.GT.BIG) BIG=BIG6
      BIG7=ABS(ACE(2,J)/DT)
      IF (BIG7.GT.BIG) BIG=BIG7
      BIG8=ABS(ACE(1,J)/DT)
      IF (BIG8.GT.BIG) BIG=BIG8
      IF (ABS(G(21)).LT.BIG*EBIG) G(21)=0

c     INTERFACE VOLTAGE - DUMMY
      G(22)=(VDL(2,J)+VDL(1,J))/2.

      B(22,22)=-1./2.

      BIG=ABS(VDL(2,J)/2.)
      BIG2=ABS(VDL(1,J)/2.)
      IF (BIG2.GT.BIG) BIG=BIG2
      IF (ABS(G(22)).LT.BIG*EBIG) G(22)=0

      RETURN
      END

      SUBROUTINE BCNJ(J)
      IMPLICIT DOUBLE PRECISION (A-H, O-Z)
      COMMON/BAB/ A(22,22),B(22,22),C(22,80001),D(22,45),G(22),X(22,22)
     1    ,Y(22,22)
      COMMON/NSN/ N, NJ
      COMMON/GLC/ NTIME,LL
      COMMON/VAR/ DIFF(16),H,EBIG,HH,IJ,KJ,TT,VAP,HHH,DT,RE,AKB,BB,CDL
      COMMON/VARR/ HHHH,HHHHH,MJ,LJ
      COMMON/DIN/ DGOX(16),DGLM(16),DIRM(16),DBULK(16)
      COMMON/SPCI/ GLU(2,80001),GOX(2,80001),GLA(2,80001),GOR(2,80001)
      COMMON/SPCII/ OXY(2,80001),HPR(2,80001),GOA(2,80001),GOP(2,80001)
      COMMON/RXT/ EQ1(2,80001),RGA(2,80001),EQ2(2,80001),RHP(2,80001)
      COMMON/SPCIII/ ANM(2,80001),GLUA(2,80001),GLI(2,80001)
      COMMON/SPCIV/ HYD(2,80001),OHI(2,80001),CO2(2,80001),CBA(2,80001)
      COMMON/SPCV/ CBI(2,80001),ACE(2,800001)
      COMMON/VOL/ VDL(2,80001)
      COMMON/POR/ POR1,POR2,PORGLU,PARION,PARACE
      COMMON/RTE/ ratef1,equilib1,ratef2,ratef3,equilib3,ratef4
      COMMON/RTD/ ratef5,equilib5,equilib6,equilib7,equilib8,equilib9
      COMMON/BUL/ CBULK(16),PARH2O2,PAR02,PARGLUCOSE,JCOUNT

  301 FORMAT (5x,'J=' I5,   13E18.9)

C     For Glucose,  being consumed only
      G(1)=CBULK(1)-(GLU(2,J)+GLU(1,J))/2.
      B(1,1)=1./2.

      BIG=ABS(CBULK(1))
      IF (ABS((GLU(2,J)+GLU(1,J))/2.).GT.BIG)
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     1   BIG=ABS((GLU(2,J)+GLU(1,J))/2.)
      IF (ABS(G(1)).LT.BIG*EBIG) G(1)=0

C     For GOx, enzyme
      G(2)=(GOX(2,J)+GOX(1,J))/2.
      B(2,2)=-1./2.

      BIG=ABS((GOX(2,J)+GOX(1,J))/2.)
      IF (ABS(G(2)).LT.BIG*EBIG) G(2)=0

C     For Gluconic Acid, being produced only
      G(3)=CBULK(3)-(GLA(2,J)+GLA(1,J))/2.
     1 +CBULK(10)-(GLI(2,J)+GLI(1,J))/2.
      B(3,3)=1./2.
      B(3,15)=1./2.

      BIG=ABS(CBULK(3))
      IF (ABS((GLA(2,J)+GLA(1,J))/2.).GT.BIG)
     1   BIG=ABS((GLA(2,J)+GLA(1,J))/2.)
      IF (ABS((GLI(2,J)+GLI(1,J))/2.).GT.BIG)
     2   BIG=ABS((GLI(2,J)+GLA(1,J))/2.)
      IF (ABS(G(3)).LT.BIG*EBIG) G(3)=0

C     For GOx2, enzyme
      G(4)=(GOR(2,J)+GOR(1,J))/2.
      B(4,4)=-1./2.

      BIG=ABS((GOR(2,J)+GOR(1,J))/2.)
      IF (ABS(G(4)).LT.BIG*EBIG) G(4)=0

C     For O2, being consumed only
      G(5)=CBULK(5)-(OXY(2,J)+OXY(1,J))/2.
      B(5,5)=1./2.

      BIG=ABS(CBULK(5))
      IF (ABS((OXY(2,J)+OXY(1,J))/2.).GT.BIG)
     1   BIG=ABS((OXY(2,J)+OXY(1,J))/2.)
      IF (ABS(G(5)).LT.BIG*EBIG) G(5)=0

C     For H2O2, reacting species
      G(6)=CBULK(6)-(HPR(2,J)+HPR(1,J))/2.
      B(6,6)=1./2.

      BIG=ABS(CBULK(6))
      IF (ABS((HPR(2,J)+HPR(1,J))/2.).GT.BIG)
     1   BIG=ABS((HPR(2,J)+HPR(1,J))/2.)
      IF (ABS(G(6)).LT.BIG*EBIG) G(6)=0

C     For CX-GOx2, enzyme complex
      G(7)=(GOA(2,J)+GOA(1,J))/2.
      B(7,7)=-1./2.

      BIG=ABS((GOA(2,J)+GOA(1,J))/2.)
      IF (ABS(G(7)).LT.BIG*EBIG) G(7)=0

C     For CX-GOx, enzyme complex
      G(8)=(GOP(2,J)+GOP(1,J))/2.
      B(8,8)=-1./2.
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      BIG=ABS((GOP(2,J)+GOP(1,J))/2.)
      IF (ABS(G(8)).LT.BIG*EBIG) G(8)=0

C     For Reaction 1 Enzymatic Catalysis
      G(9)=(EQ1(2,J)+EQ1(1,J))/2.
      B(9,9)=-1./2.

      BIG=ABS((EQ1(2,J)+EQ1(1,J))/2.)
      IF (ABS(G(9)).LT.BIG*EBIG) G(9)=0

C     For Reaction 2
      G(10)=(RGA(2,J)+RGA(1,J))/2.
      B(10,10)=-1./2.

      BIG=ABS((RGA(2,J)+RGA(1,J))/2.)
      IF (ABS(G(10)).LT.BIG*EBIG) G(10)=0

C     For Reaction 3 Meditation/regeneration
      G(11)=(EQ2(2,J)+EQ2(1,J))/2.
      B(11,11)=-1./2.

      BIG=ABS((EQ2(2,J)+EQ2(1,J))/2.)
      IF (ABS(G(11)).LT.BIG*EBIG) G(11)=0

C     For Reaction 4
      G(12)=(RHP(2,J)+RHP(1,J))/2.
      B(12,12)=-1./2.

      BIG=ABS((RHP(2,J)+RHP(1,J))/2.)
      IF (ABS(G(12)).LT.BIG*EBIG) G(12)=0

C     For Reaction 5, Anomerization
  218 G(13)=-(ANM(2,J)+ANM(1,J))/2.+ratef5*((GLUA(2,J)+GLUA(1,J))/2.
     1   -(GLU(2,J)+GLU(1,J))/2./equilib5)
      B(13,1)=ratef5/2./equilib5
      B(13,14)=-ratef5/2.
      B(13,13)=+1./2.

      BIG=ABS(ANM(2,J)/2.)
      BIG2=ABS(ANM(1,J)/2.)
      IF (BIG2.GT.BIG) BIG=BIG2
      BIG3=ABS(ratef5*GLUA(2,J)/2.)
      IF (BIG3.GT.BIG) BIG=BIG3
      BIG4=ABS(ratef5*GLUA(1,J)/2.)
      IF (BIG4.GT.BIG) BIG=BIG4
      BIG5=ABS(ratef5*GLU(2,J)/2./equilib5)
      IF (BIG5.GT.BIG) BIG=BIG5
      BIG6=ABS(ratef5*GLU(1,J)/2./equilib5)
      IF (BIG6.GT.BIG) BIG=BIG6
      IF (ABS(G(13)).LT.BIG*EBIG) G(13)=0

C     Alpha-Glucose
      G(14)=CBULK(9)-(GLUA(2,J)+GLUA(1,J))/2.
      B(14,14)=1./2

      BIG=ABS(CBULK(9))
      BIG2=ABS(GLUA(2,J)/2.)
```

```
      IF (BIG2.GT.BIG) BIG=BIG2
      BIG3=ABS(GLUA(1,J)/2.)
      IF (BIG3.GT.BIG) BIG=BIG3
      IF (ABS(G(14)).LT.BIG*EBIG) G(14)=0

C       Gluconic acid dissociation
      G(15)=equilib6*(GLA(2,J)+GLA(1,J))/2.-(GLI(2,J)+GLI(1,J))*
     1   (HYD(2,J)+HYD(1,J))/4.
      B(15,3)=-equilib6/2.
      B(15,15)=(HYD(2,J)+HYD(1,J))/4.
      B(15,16)=(GLI(2,J)+GLI(1,J))/4.

      BIG=ABS(equilib6*GLA(2,J)/2.)
      BIG2=ABS(equilib6*GLA(1,J)/2.)
      IF (BIG2.GT.BIG) BIG=BIG2
      BIG3=ABS(GLI(2,J)*HYD(2,J)/4.)
      IF (BIG3.GT.BIG) BIG=BIG3
      BIG4=ABS(GLI(2,J)*HYD(1,J)/4)
      IF (BIG4.GT.BIG) BIG=BIG4
      BIG5=ABS(GLI(1,J)*HYD(2,J)/4)
      IF (BIG5.GT.BIG) BIG=BIG5
      BIG6=ABS(GLI(1,J)*HYD(1,J)/4)
      IF (BIG6.GT.BIG) BIG=BIG6
      IF (ABS(G(15)).LT.BIG*EBIG) G(15)=0


C Flux balance of hydrogen, hydroxide, gluconate, bicarbonate ion
      G(16)=CBULK(11)-(HYD(2,J)+HYD(1,J))/2.
     1 -CBULK(15)+(OHI(2,J)+OHI(1,J))/2.
     2 -CBULK(10)+(GLI(2,J)+GLI(1,J))/2.
     3 -CBULK(14)+(CBI(2,J)+CBI(1,J))/2.
      B(16,16)=1./2.
      B(16,17)=-1./2.
      B(16,15)=-1./2.
      B(16,20)=-1./2.

      BIG=ABS(CBULK(11))
      BIG2=ABS(CBULK(15))
      IF (BIG2.GT.BIG) BIG=BIG2
      BIG3=ABS(CBULK(10))
      IF (BIG3.GT.BIG) BIG=BIG3
      BIG4=ABS(CBULK(14))
      IF (BIG4.GT.BIG) BIG=BIG4
      BIG5=ABS(HYD(2,J)/2.)
      IF (BIG5.GT.BIG) BIG=BIG5
      BIG6=ABS(HYD(1,J)/2.)
      IF (BIG6.GT.BIG) BIG=BIG6
      BIG7=ABS(OHI(2,J)/2.)
      IF (BIG7.GT.BIG) BIG=BIG7
      BIG8=ABS(OHI(1,J)/2.)
      IF (BIG8.GT.BIG) BIG=BIG8
      BIG9=ABS(GLI(2,J)/2.)
      IF (BIG9.GT.BIG) BIG=BIG9
      BIG10=ABS(GLI(1,J)/2.)
      IF (BIG10.GT.BIG) BIG=BIG10
      BIG11=ABS(CBI(2,J)/2.)
      IF (BIG11.GT.BIG) BIG=BIG11
      BIG12=ABS(CBI(1,J)/2.)
```

```
      IF (BIG12.GT.BIG) BIG=BIG12
      IF (ABS(G(16)).LT.BIG*EBIG) G(16)=0

C       Water Dissociation
      G(17)=equilib9-(HYD(2,J)+HYD(1,J))*(OHI(2,J)+OHI(1,J))/4.
      B(17,17)=(HYD(2,J)+HYD(1,J))/4.
      B(17,16)=(OHI(2,J)+OHI(1,J))/4.

      BIG=ABS(equilib9)
      BIG2=ABS(HYD(2,J)*OHI(2,J)/4.)
      IF (BIG2.GT.BIG) BIG=BIG2
      BIG3=ABS(HYD(2,J)*OHI(1,J)/4.)
      IF (BIG3.GT.BIG) BIG=BIG3
      BIG4=ABS(HYD(1,J)*OHI(2,J)/4.)
      IF (BIG4.GT.BIG) BIG=BIG4
      BIG5=ABS(HYD(1,J)*OHI(1,J)/4.)
      IF (BIG5.GT.BIG) BIG=BIG5
      IF (ABS(G(17)).LT.BIG*EBIG) G(17)=0

C       CO2 hydration
      G(18)=equilib7*(CO2(2,J)+CO2(1,J))/2.-(CBA(2,J)+CBA(1,J))/2.
      B(18,18)=-equilib7/2.
      B(18,19)=1./2.

      BIG=ABS(equilib7*CO2(2,J)/2.)
      BIG2=ABS(equilib7*CO2(1,J)/2.)
      IF (BIG2.GT.BIG) BIG=BIG2
      BIG3=ABS(CBA(2,J)/2.)
      IF (BIG3.GT.BIG) BIG=BIG3
      BIG4=ABS(CBA(1,J)/2.)
      IF (BIG4.GT.BIG) BIG=BIG4
      IF (ABS(G(18)).LT.BIG*EBIG) G(18)=0

C       Carbonic acid dissociation
      G(19)=equilib8*(CBA(2,J)+CBA(1,J))/2.-(CBI(2,J)+CBI(1,J))
     1  *(HYD(2,J)+HYD(1,J))/4.
      B(19,19)=-equilib8/2.
      B(19,20)=(HYD(2,J)+HYD(1,J))/4.
      B(19,16)=(CBI(2,J)+CBI(1,J))/4.

      BIG=ABS(equilib8*CBA(2,J)/2.)
      BIG2=ABS(equilib8*CBA(1,J)/2.)
      IF (BIG2.GT.BIG) BIG=BIG2
      BIG3=ABS(CBI(2,J)*HYD(2,J)/4.)
      IF (BIG3.GT.BIG) BIG=BIG3
      BIG4=ABS(CBI(2,J)*HYD(1,J)/4.)
      IF (BIG4.GT.BIG) BIG=BIG4
      BIG5=ABS(CBI(2,J)*HYD(2,J)/4.)
      IF (BIG5.GT.BIG) BIG=BIG5
      BIG6=ABS(CBI(2,J)*HYD(1,J)/4.)
      IF (BIG6.GT.BIG) BIG=BIG6
      IF (ABS(G(19)).LT.BIG*EBIG) G(19)=0

C       Carbonate ion flux balance
      G(20)=CBULK(12)-(CO2(2,J)+CO2(1,J))/2.
     1  +CBULK(13)-(CBA(2,J)+CBA(1,J))/2.
     2  +CBULK(14)-(CBI(2,J)+CBI(1,J))/2.
      B(20,20)=1./2.
```

```
      B(20,18)=1./2.
      B(20,19)=1./2.

      BIG=ABS(CBULK(12))
      BIG2=ABS(CBULK(13))
      IF (BIG2.GT.BIG) BIG=BIG2
      BIG3=ABS(CBULK(14))
      IF (BIG3.GT.BIG) BIG=BIG3
      BIG4=ABS(CO2(2,J)/2.)
      IF (BIG4.GT.BIG) BIG=BIG4
      BIG5=ABS(CO2(1,J)/2.)
      IF (BIG5.GT.BIG) BIG=BIG5
      BIG6=ABS(CBA(2,J)/2.)
      IF (BIG6.GT.BIG) BIG=BIG6
      BIG7=ABS(CBA(1,J)/2.)
      IF (BIG7.GT.BIG) BIG=BIG7
      BIG8=ABS(CBI(2,J)/2.)
      IF (BIG8.GT.BIG) BIG=BIG8
      BIG9=ABS(CBI(1,J)/2.)
      IF (BIG9.GT.BIG) BIG=BIG9
      IF (ABS(G(20)).LT.BIG*EBIG) G(20)=0

C     For Acetaminophen
      G(21)=CBULK(16)-(ACE(2,J)+ACE(1,J))/2.

      B(21,21)=1./2.

      BIG=ABS(CBULK(16))
      BIG2=ABS(ACE(2,J)/2.)
      IF (ABS((ACE(2,J)+ACE(1,J))/2.).GT.BIG)
     1   BIG=ABS((ACE(2,J)+ACE(1,J))/2.)
      IF (ABS(G(21)).LT.BIG*EBIG) G(21)=0

C     DOUBLE LAYER VOLTAGE - DUMMY

      G(22)=(VDL(2,J)+VDL(1,J))/2.

      B(22,22)=-1./2.

      BIG=ABS(VDL(2,J)/2.)
      BIG2=ABS(VDL(1,J)/2.)
      IF (BIG2.GT.BIG) BIG=BIG2
      IF (ABS(G(22)).LT.BIG*EBIG) G(22)=0

      RETURN
      END

C     Subroutine MATINV
      SUBROUTINE MATINV(N,M,DETERM)
      IMPLICIT DOUBLE PRECISION (A-H,O-Z)
      COMMON/BAB/ A(22,22),B(22,22),C(22,80001),D(22,45),G(22),X(22,22)
     1    ,Y(22,22)
      COMMON/NSN/ NTEMP, NJ
      DIMENSION ID(22)
      DETERM=1.01
      DO 1 I=1,N
    1 ID(I)=0
      DO 18 NN=1,N
```

```
      BMAX=1.1
      DO 6 I=1,N
       IF(ID(I).NE.0) GO TO 6
      BNEXT=0.0
      BTRY=0.0
      DO 5 J=1,N
       IF (ID(J).NE.0) GO TO 5
       IF (DABS(B(I,J)).LE.BNEXT) GO TO 5
      BNEXT=DABS(B(I,J))
       IF (BNEXT.LE.BTRY) GO TO 5
      BNEXT=BTRY
      BTRY=DABS(B(I,J))
       JC=J
    5 CONTINUE
       IF(BNEXT.GE.BMAX*BTRY) GO TO 6
      BMAX=BNEXT/BTRY
      IROW=I
      JCOL=JC
    6 CONTINUE
       IF (ID(JC).EQ.0) GO TO 8
      DETERM=0.0
      RETURN
    8  ID(JCOL)=1
       IF (JCOL.EQ.IROW) GO TO 12
      DO 10 J=1,N
      SAVE=B(IROW,J)
      B(IROW,J)=B(JCOL,J)
   10 B(JCOL,J)=SAVE
      DO 11 K=1,M
      SAVE=D(IROW,K)
      D(IROW,K)=D(JCOL,K)
   11 D(JCOL,K)=SAVE
   12  F=1.0/B(JCOL,JCOL)
      DO 13 J=1,N
   13 B(JCOL,J)=B(JCOL,J)*F
      DO 14 K=1,M
   14 D(JCOL,K)=D(JCOL,K)*F
      DO 18 I=1,N
       IF (I.EQ.JCOL)  GO TO 18
       F=B(I,JCOL)
      DO 16  J=1,N
   16 B(I,J)=B(I,J)-F*B(JCOL,J)
      DO 17 K=1,M
   17 D(I,K)=D(I,K)-F*D(JCOL,K)
   18 CONTINUE
      RETURN
      END

C     SUBROUTINE  BAND(J)
      SUBROUTINE BAND(J)
       IMPLICIT DOUBLE PRECISION (A-H,O-Z)
       DIMENSION E(22,23,80001)
      COMMON/BAB/ A(22,22),B(22,22),C(22,80001),D(22,45),G(22),X(22,22)
     1   ,Y(22,22)
      COMMON/NSN/ N,NJ
      SAVE E, NP1
  101 FORMAT(15H DETERM=0 AT J=,I4)
       IF (J-2) 1,6,8
```

```
    1 NP1=N+1
      DO 2 I=1,N
      D(I,2*N+1)=G(I)
      DO 2 L=1,N
      LPN=L+N
    2 D(I,LPN)=X(I,L)
      CALL MATINV(N, 2*N+1,DETERM)
      IF (DETERM) 4,3,4
    3 PRINT 101,J
    4 DO 5 K=1,N
      E(K,NP1,1)=D(K,2*N+1)
      DO 5 L=1,N
      E(K,L,1)=-D(K,L)
      LPN=L+N
    5 X(K,L)=-D(K,LPN)
      RETURN
    6 DO 7 I=1,N
      DO 7 K=1,N
      DO 7 L=1,N
    7 D(I,K)=D(I,K)+A(I,L)*X(L,K)
    8 IF (J-NJ) 11,9,9
    9 DO 10 I=1,N
      DO 10 L=1,N
      G(I)=G(I)-Y(I,L)*E(L,NP1,J-2)
      DO 10 M=1,N
   10 A(I,L)=A(I,L)+Y(I,M)*E(M,L,J-2)
   11 DO 12 I=1,N
      D(I,NP1)=-G(I)
      DO 12 L=1,N
      D(I,NP1)=D(I,NP1)+A(I,L)*E(L,NP1,J-1)
      DO 12 K=1,N
   12 B(I,K)=B(I,K)+A(I,L)*E(L,K,J-1)
      CALL MATINV(N,NP1,DETERM)
      IF (DETERM) 14, 13, 14
   13 PRINT 101,J
   14 DO 15 K=1,N
      DO 15 M=1,NP1
   15 E(K,M,J)=-D(K,M)
      IF (J-NJ) 20,16,16
   16 DO 17 K=1,N
   17 C(K,J)=E(K,NP1,J)
      DO 18 JJ=2,NJ
      M=NJ-JJ+1
      DO 18 K=1,N
      C(K,M)=E(K,NP1,M)
      DO 18 L=1,N
   18 C(K,M)=C(K,M)+E(K,L,M)*C(L,M+1)
      DO 19 L=1,N
      DO 19 K=1,N
   19 C(K,1)=C(K,1)+X(K,L)*C(L,3)
   20 RETURN
      END
```

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BIOGRAPHICAL SKETCH

Samuel Jacobs received his Bachelor of Science in chemical engineering in 2013 from the Univeristy of Minnesota - Duluth. He worked as a process development engineering for Hutchinson Technology (TDK) from 2013 to 2016. He received his Master of Science degree in chemical engineering in 2018 from the University of Minnesota - Duluth while researching the dynamic response of lead-halid perovskite solar cells. He is a PhD candidate in Professor Mark Orazem's group, focusing on understanding and modeling the transient response of electrochemical glucose sensors. He is a member of the Electrochemical Society and served as the student safety council leader in 2021 and 2022.