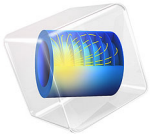

Corrosion Under an Evans Droplet

Introduction

An Evans droplet experiment is a century-old corrosion experiment for demonstrating oxygen transport-limited corrosion. A droplet of water is placed on a metal surface, and over time the surface features differences in the radial direction of the surface in terms of amount of corroded material and deposited corrosion products.

This tutorial model defines corrosion of an iron surface in contact with a water droplet in a surrounding atmosphere containing both carbon dioxide and oxygen. The model accounts for charge and mass transport of a multitude of species as well as iron dissolution, oxygen reduction, carbonic acid equilibria and iron hydroxide formation.

The model computes the transient and spatial distributions of the various species within the droplet. A spatial gradient in pH is demonstrated and is attributed to the complex interplay between the dissolved iron and the carbonic acid.

The model is based on several journal papers (Ref. 1–Ref. 3).

Model Definition

Figure 1 shows the model geometry, defining an elliptical electrolyte droplet (with a 90° wetting angle) covering an iron metal surface. The geometry is defined in 2D with axial symmetry.

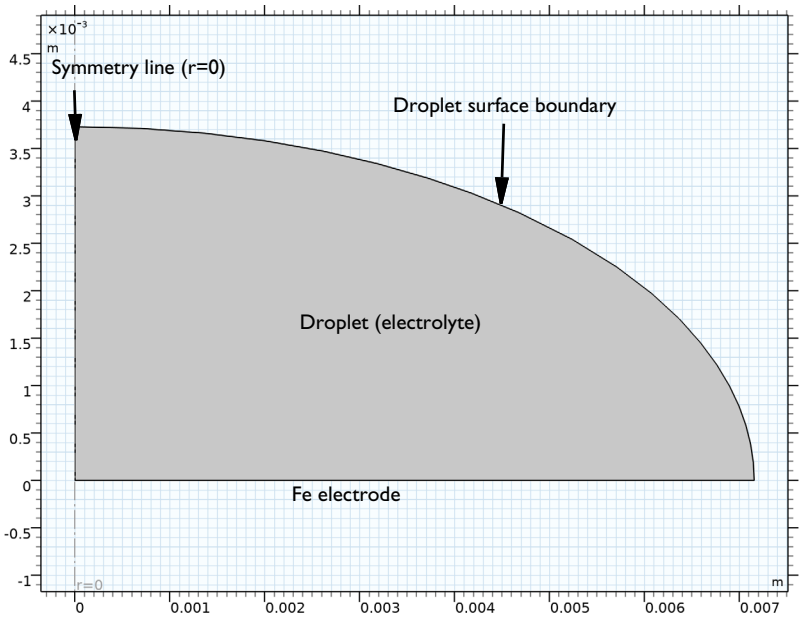

Figure 1: Model geometry.

The model is defined using the **Tertiary Current Distribution, Nernst-Planck** interface, solving for the electrolyte phase potential and the concentrations of the electrolyte species H^+, OH^-, Fe^{2+}, O_2, CO_2, H_2CO_3, HCO_3^-, and CO_3^{2-}.

Oxygen reduction occurs on the metal surface, which, due to limited oxygen diffusion, is more dominant toward the periphery of the droplet:

$$4H^+ + 4e^- + O_2 \rightarrow 2H_2O \quad (1)$$

Iron is oxidized to counterbalance the oxygen reduction reaction:

$$Fe(s) \rightarrow Fe^{2+} + 2e^- \quad (2)$$

Concentration-dependent Butler–Volmer electrode kinetics expressions are used for both the oxygen-reduction and iron-dissolution reactions. The combination of these two reactions gives rise to a mixed electrode potential of the metal surface.

Dissolved iron forms iron hydroxide due to a precipitation reaction at the electrode surface:

$$\mathrm{Fe^{2+}} + 2\mathrm{OH^-} \rightarrow \mathrm{Fe(OH)_2(s)} \tag{3}$$

The hydroxide precipitation reaction depends on the concentration of the iron and hydroxide ions, and is defined to occur irreversibly when the solubility product of the hydroxide is exceeded.

EQUILIBRIUM REACTIONS

The following equilibrium reactions are present in the electrolyte:

$$\begin{aligned} \mathrm{H_2O(l)} &\Leftrightarrow \mathrm{H^+(aq)} + \mathrm{OH^-(aq)} && K_1 = 6.418 \cdot 10^{-15} \\ \mathrm{CO_2(aq)} + \mathrm{H_2O(aq)} &\Leftrightarrow \mathrm{H_2CO_3(aq)} && K_2 = 2.580 \cdot 10^{-3} \\ \mathrm{H_2CO_3(aq)} &\Leftrightarrow \mathrm{H^+(aq)} + \mathrm{HCO_3^-(aq)} && K_3 = 1.251 \cdot 10^{-4} \\ \mathrm{HCO_3^-(aq)} &\Leftrightarrow \mathrm{H^+(aq)} + \mathrm{CO_3^{2-}(aq)} && K_4 = 1.382 \cdot 10^{-10} \end{aligned} \tag{4}$$

Here, K_1 through K_4 are the equilibrium constants at 293.15 K (Ref. 2).

The water dissociation equilibrium reaction is built-in for the Tertiary Current Distribution, Nernst–Planck interface when using a water-based with electroneutrality charge conservation model. The other three carbonic acid reactions are modeled using Equilibrium Reaction domain nodes, one for each reaction. Each Equilibrium Reaction node solves for one additional degree of freedom each, representing the local reaction rate required to fulfill the equilibrium expression. These equilibrium expressions are based on the reaction stoichiometry and the equilibrium constant K_k according to

$$K_k = \prod_i a(c_i)^{v_{ik}} \tag{5}$$

where c_i (SI unit: $\mathrm{mol/m^3}$) is the concentration of species i and v_{ik} is the stoichiometric coefficient of species i in reaction k. The activity of a species, $a(c_i)$ is obtained by dividing the concentration with reference concentration of 1 M, except for $\mathrm{O_2}$.

As a result of the above equilibrium reactions, the gaseous $\mathrm{CO_2}$ dissolved at the droplet surface forms carbonic acid, generally lowering the pH.

The model is solved using a time-dependent solver, simulating the transient and spatial evolution of the species considered for 600 seconds. Fixed concentrations of O_2 and CO_2 are set at the upper droplet boundary facing the surrounding atmosphere.

Results and Discussion

Figure 2 shows the iron ion concentration distribution within the Evans droplet at 30 s (left) and 300 s (right). It can be seen that the iron ion concentration is higher toward the periphery of the droplet closer to the metal surface when compared to the center of the droplet. This an effect of the oxygen reduction currents being larger toward the rim of the electrode surface due to the limited oxygen transport, in combination with the limited electrolyte conductivity, thus favoring iron oxidation toward the rim.

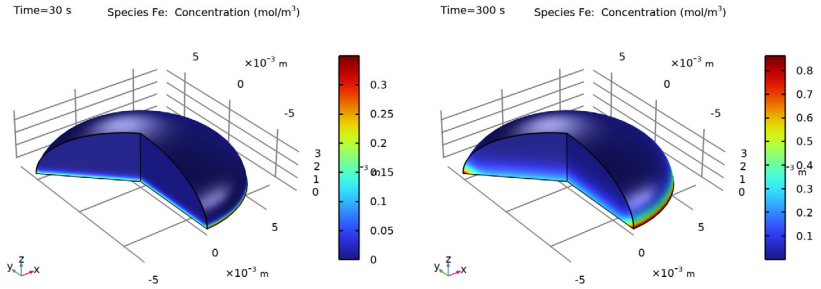

Figure 2: Iron ion concentration distribution within the droplet at time t = 30 s (left) and t = 300 s (right).

Figure 3 shows the anodic current density distribution along the electrode surface underneath the droplet at 600 s. It is found to be higher toward the periphery of the droplet, indicating that the corrosion rate is higher toward the periphery than at the core

of the droplet. This explains the higher iron ion concentration toward the periphery of the droplet than that at the center of droplet, as seen in Figure 2.

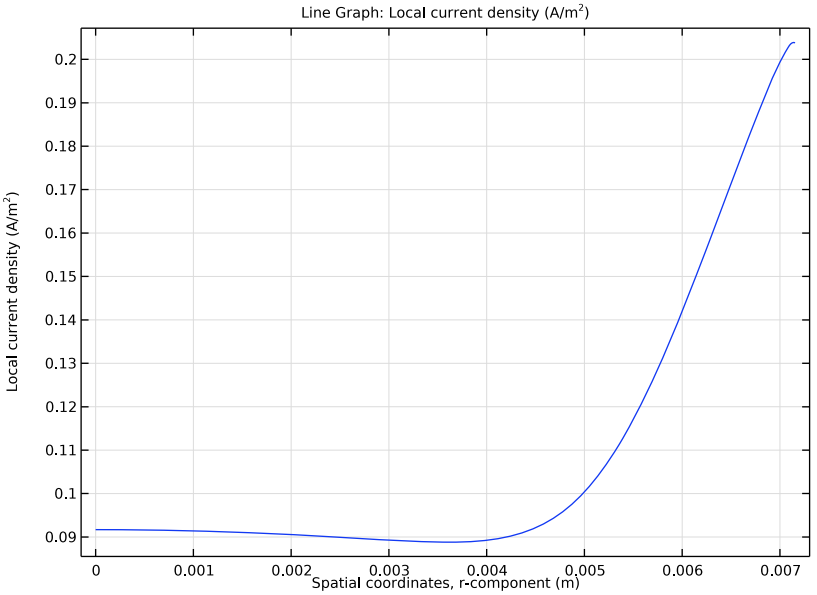

Figure 3: Anodic current density distribution along the iron electrode surface at time t = 600 s.

Figure 4 shows the CO_2 concentration distribution within the droplet at 30 s (left) and 300 s (right). It can be seen that the CO_2 concentration is reduced close to the electrode surface. This is related to the carbonic acid equilibria in combination with the increased pH.

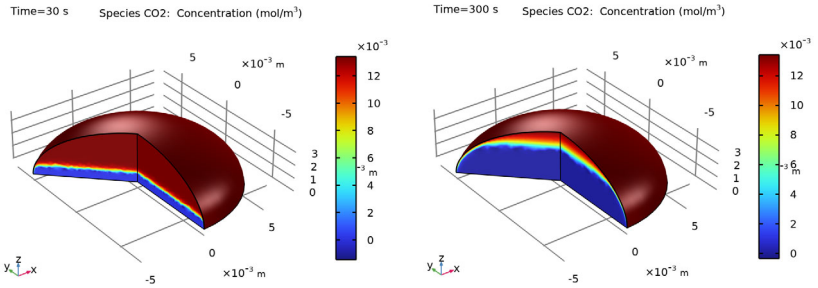

Figure 4: CO_2 concentration distribution within the droplet at time t = 30 s (left) and t = 300 s (right).

Figure 5 shows the pH distribution within the droplet at 30 s (left) and 300 s (right). The pH changes over time are substantial. It can also be seen that the pH is increased in the vicinity of the metal surface, when compared to the pH closer to the droplet surface. The pH changes are generally attributed to the dissolution of iron atoms which need to be counter-balanced by hydroxide ions from water autoprotolysis.

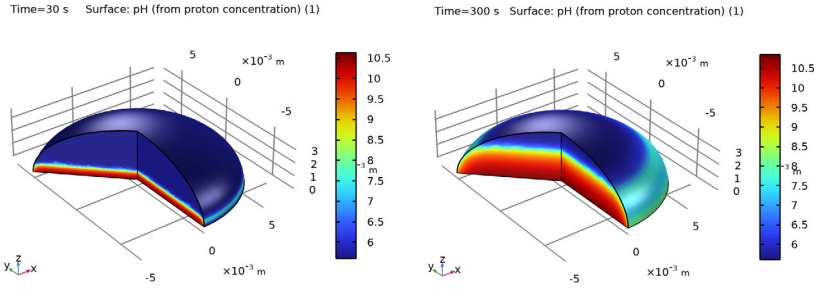

Figure 5: pH distribution within the droplet at time t = 30 s (left) and t = 300 s (right).

Figure 6 shows surface plot of the ferrous hydroxide precipitation thickness along the electrode surface underneath the droplet and streamline plot of the electrolyte current density over the droplet domain at 600 s. The precipitation thickness is found to be higher toward the core of the droplet than along the periphery of the droplet. This is a result of the pH being slightly higher toward the rim due to the higher CO_2 (and carbonic acid)

concentration at the atmospheric boundary. Streamline plot shows the ionic current flow from the rim toward the core of the droplet.

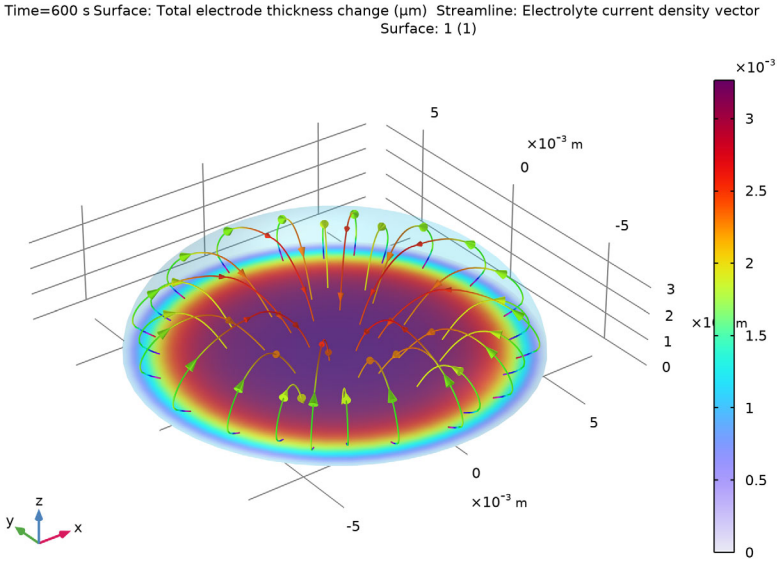

Figure 6: Ferrous hydroxide precipitation thickness along the iron electrode surface and streamline plot of the electrolyte current density at time t = 600 s.

References

1. A. Sainz-Rosales, X. Ocampo-Lazcarro, A. Hernández-Pérez, A.G. González-Gutiérrez, E.R. Larios-Durán, C.P. de León, F.C. Walsh, M. Bárcena-Soto and N. Casillas, "Classic Evans's Drop Corrosion Experiment Investigated in Terms of a Tertiary Current and Potential Distribution," *Corrosion and Materials Degradation*, vol. 3, no. 2, pp. 270–280, 2022.

2. M. Nordsveen, S. Nesic, R. Nyborg, and A. Stangeland, "A Mechanistic Model for Carbon Dioxide Corrosion of Mild Steel in the Presence of Protective Iron Carbonate Films-Part 1: Theory and Verification," *Corrosion*, vol. 59, no. 5, pp. 443–456, 2003.

3. A. Kahyarian and S. Nesic, "On the mechanism of carbon dioxide corrosion of mild steel: Experimental investigation and mathematical modeling at elevated pressures and non-ideal solutions," *Corrosion Science*, vol. 173, no. 108719, pp. 1–27, 2020.

Application Library path: `Corrosion_Module/Atmospheric_Corrosion/evans_droplet`

Modeling Instructions

From the **File** menu, choose **New**.

NEW

In the **New** window, click **Model Wizard**.

MODEL WIZARD

1 In the **Model Wizard** window, click **2D Axisymmetric**.

2 In the **Select Physics** tree, select **Electrochemistry>Tertiary Current Distribution, Nernst-Planck>Tertiary, Water-Based with Electroneutrality (tcd)**.

3 Click **Add**.

4 In the **Number of species** text field, type 6.

5 In the **Concentrations (mol/m³)** table, enter the following settings:

cFe
cO2
cCO2
cH2CO3
cHCO3
cCO3

6 Click **Study**.

7 In the **Select Study** tree, select **Preset Studies for Selected Physics Interfaces> Time Dependent with Initialization**.

8 Click **Done**.

GLOBAL DEFINITIONS

Load the model parameters from a text file.

Parameters 1

1 In the **Model Builder** window, under **Global Definitions** click **Parameters 1**.

2 In the **Settings** window for **Parameters**, locate the **Parameters** section.

3 Click **Load from File**.

4 Browse to the model's Application Libraries folder and double-click the file `evans_droplet_parameters.txt`.

GEOMETRY 1

The geometry consists of a sector of an eclipse.

Ellipse 1 (e1)

1 In the **Geometry** toolbar, click **Ellipse**.

2 In the **Settings** window for **Ellipse**, locate the **Size and Shape** section.

3 In the **a-semiaxis** text field, type `a`.

4 In the **b-semiaxis** text field, type `b`.

5 In the **Sector angle** text field, type `90`.

6 Click **Build All Objects**.

DEFINITIONS

Variables 1

Load the model variables from a text file.

1 In the **Home** toolbar, click **Variables** and choose **Local Variables**.

2 In the **Settings** window for **Variables**, locate the **Variables** section.

3 Click **Load from File**.

4 Browse to the model's Application Libraries folder and double-click the file `evans_droplet_variables.txt`.

TERTIARY CURRENT DISTRIBUTION, NERNST-PLANCK (TCD)

Start by defining the physics.

Species Charges 1

1 In the **Model Builder** window, under **Component 1 (comp1)>Tertiary Current Distribution, Nernst-Planck (tcd)** click **Species Charges 1**.

2 In the **Settings** window for **Species Charges**, locate the **Charge** section.

3 In the z_{cFe} text field, type `zFe`.

4 In the z_{cHCO3} text field, type `zHCO3`.

5 In the z_{cCO3} text field, type `zCO3`.

Electrolyte 1

1 In the **Model Builder** window, click **Electrolyte 1**.

2 In the **Settings** window for **Electrolyte**, locate the **Diffusion** section.

3 In the D_{cFe} text field, type `DFe`.

4 In the D_{cO2} text field, type `DO2`.

5 In the D_{cCO2} text field, type `DCO2`.

6 In the D_{cH2CO3} text field, type `DH2CO3`.

7 In the D_{cHCO3} text field, type `DHCO3`.

8 In the D_{cCO3} text field, type `DCO3`.

9 In the D_{cH} text field, type `DH`.

10 In the D_{cOH} text field, type `DOH`.

Initial Values 1

Set the initial values to the concentration of the species in the bulk.

1 In the **Model Builder** window, click **Initial Values 1**.

2 In the **Settings** window for **Initial Values**, locate the **Initial Values** section.

3 In the $cO2$ text field, type `cO20`.

4 In the $cCO2$ text field, type `cCO20`.

5 In the $cH2CO3$ text field, type `cH2CO30`.

6 In the $cHCO3$ text field, type `cHCO30`.

7 In the $phil$ text field, type `phi0`.

Electrode Surface 1

Use the Dissolving-Depositing Species section to include precipitation of ferrous hydroxide at the surface.

1 In the **Physics** toolbar, click **Boundaries** and choose **Electrode Surface**.

2 Select Boundary 2 only.

3 In the **Settings** window for **Electrode Surface**, click to expand the **Dissolving-Depositing Species** section.

4 Click **Add**.

5 In the table, enter the following settings:

Species	Density (kg/m^3)	Molar mass (kg/mol)
FeOH2	rho_FeOH2	M_FeOH2

Electrode Reaction: Iron Dissolution

1 In the **Model Builder** window, under **Component 1 (comp1)>Tertiary Current Distribution, Nernst-Planck (tcd)>Electrode Surface 1** click **Electrode Reaction 1**.

2 In the **Settings** window for **Electrode Reaction**, type `Electrode Reaction: Iron Dissolution` in the **Label** text field.

3 Locate the **Stoichiometric Coefficients** section. In the n text field, type `2`.

4 In the ν_{cFe} text field, type `-1`.

5 Locate the **Equilibrium Potential** section. In the $E_{eq,ref}(T)$ text field, type `Eeq_ref_Fe`.

6 Locate the **Electrode Kinetics** section. In the $i_{0,ref}(T)$ text field, type `i0_ref_Fe`.

7 In the α_a text field, type `alphaa_Fe`.

Electrode Surface 1

In the **Model Builder** window, click **Electrode Surface 1**.

Electrode Reaction: Oxygen Reduction

1 In the **Physics** toolbar, click **Attributes** and choose **Electrode Reaction**.

2 In the **Settings** window for **Electrode Reaction**, type `Electrode Reaction: Oxygen Reduction` in the **Label** text field.

3 Locate the **Stoichiometric Coefficients** section. In the n text field, type `4`.

4 In the ν_{cO2} text field, type `-1`.

5 Locate the **Equilibrium Potential** section. In the $E_{eq,ref}(T)$ text field, type `Eeq_ref_O2`.

6 From the **Balance reaction charges and define reference state using** list, choose **OH**.

7 Click to expand the **Reference Concentrations** section. In the table, enter the following settings:

Electrolyte species	Reference concentrations (mol/m^3)
cO2	`cO2_sol`

8 Locate the **Electrode Kinetics** section. In the $i_{0,ref}(T)$ text field, type `i0_ref_O2*(tcd.eta_er2<0)`.

9 In the α_a text field, type `alphaa_O2`.

Electrode Surface 1

In the **Model Builder** window, click **Electrode Surface 1**.

Nonfaradaic Reactions: Ferrous Hydroxide Precipitation

1 In the **Physics** toolbar, click **Attributes** and choose **Nonfaradaic Reactions**.

2 In the **Settings** window for **Nonfaradaic Reactions**, type `Nonfaradaic Reactions: Ferrous Hydroxide Precipitation` in the **Label** text field.

3 Locate the **Reaction Rate** section. Select the **Species cFe** check box.

4 In the $R_{0,\mathrm{cFe}}$ text field, type `-rFeOH2`.

5 In the **Reaction rate for dissolving-depositing species** table, enter the following settings:

Species	Reaction rate (mol/(m^2*s))
FeOH2	rFeOH2

Concentration 1

Set concentrations for the gaseous species at the droplet surface boundary facing the atmosphere.

1 In the **Physics** toolbar, click **Boundaries** and choose **Concentration**.

2 Select Boundary 3 only.

3 In the **Settings** window for **Concentration**, locate the **Concentration** section.

4 Select the **Species cO2** check box.

5 Select the **Species cCO2** check box.

6 In the $c_{0,\mathrm{cO2}}$ text field, type `cO2s`.

7 In the $c_{0,\mathrm{cCO2}}$ text field, type `cCO2O`.

Equilibrium Reaction 1

Now add three equilibrium reactions as follows:

1 In the **Physics** toolbar, click **Domains** and choose **Equilibrium Reaction**.

2 In the **Settings** window for **Equilibrium Reaction**, locate the **Domain Selection** section.

3 From the **Selection** list, choose **All domains**.

4 Locate the **Equilibrium Condition** section. In the K_{eq} text field, type `KCO2H`.

5 Locate the **Stoichiometric Coefficients** section. In the ν_{cCO2} text field, type `-1`.

6 In the ν_{cH2CO3} text field, type `1`.

Equilibrium Reaction 2

1 In the **Physics** toolbar, click **Domains** and choose **Equilibrium Reaction**.

2 In the **Settings** window for **Equilibrium Reaction**, locate the **Domain Selection** section.

3 From the **Selection** list, choose **All domains**.

4 Locate the **Equilibrium Condition** section. In the K_{eq} text field, type `KH2CO3`.

5 Locate the **Stoichiometric Coefficients** section. In the ν_{cH2CO3} text field, type `-1`.

6 In the ν_{cHCO3} text field, type 1.

7 In the ν_{cH} text field, type 1.

Equilibrium Reaction 3

1 In the **Physics** toolbar, click **Domains** and choose **Equilibrium Reaction**.

2 In the **Settings** window for **Equilibrium Reaction**, locate the **Domain Selection** section.

3 From the **Selection** list, choose **All domains**.

4 Locate the **Equilibrium Condition** section. In the K_{eq} text field, type KHCO3.

5 Locate the **Stoichiometric Coefficients** section. In the ν_{cHCO3} text field, type -1.

6 In the ν_{cCO3} text field, type 1.

7 In the ν_{cH} text field, type 1.

MESH 1

Build a mesh using a finer resolution at the electrode surface.

1 In the **Model Builder** window, under **Component 1 (comp1)** click **Mesh 1**.

2 In the **Settings** window for **Mesh**, locate the **Sequence Type** section.

3 From the list, choose **User-controlled mesh**.

Size 1

1 In the **Model Builder** window, right-click **Free Triangular 1** and choose **Size**.

2 In the **Settings** window for **Size**, locate the **Geometric Entity Selection** section.

3 From the **Geometric entity level** list, choose **Boundary**.

4 Select Boundary 2 only.

5 Locate the **Element Size** section. From the **Predefined** list, choose **Extremely fine**.

6 Click **Build All**.

STUDY 1

Step 2: Time Dependent

1 In the **Model Builder** window, under **Study 1** click **Step 2: Time Dependent**.

2 In the **Settings** window for **Time Dependent**, locate the **Study Settings** section.

3 In the **Output times** text field, type range(0,30,600).

4 In the **Home** toolbar, click **Compute**.

RESULTS

Several plots are added by default. The following steps reproduce the plots from the Results and Discussion section:

Concentration, Fe, 3D (tcd)

1. In the **Model Builder** window, under **Results** click **Concentration, Fe, 3D (tcd)**.
2. In the **Settings** window for **3D Plot Group**, locate the **Data** section.
3. From the **Time (s)** list, choose **30**.
4. In the **Concentration, Fe, 3D (tcd)** toolbar, click **Plot**.
5. From the **Time (s)** list, choose **300**.
6. In the **Concentration, Fe, 3D (tcd)** toolbar, click **Plot**.

The Fe concentration plots should look like Figure 2.

Fe Oxidation Current Density

Next, plot anodic current density variation at the electrode surface.

1. In the **Home** toolbar, click **Add Plot Group** and choose **1D Plot Group**.
2. In the **Settings** window for **1D Plot Group**, type `Fe Oxidation Current Density` in the **Label** text field.
3. Locate the **Data** section. From the **Time selection** list, choose **Last**.

Line Graph 1

1. In the **Fe Oxidation Current Density** toolbar, click **Line Graph**.
2. Select Boundary 2 only.
3. In the **Settings** window for **Line Graph**, click **Replace Expression** in the upper-right corner of the **y-Axis Data** section. From the menu, choose **Component 1 (comp1)> Tertiary Current Distribution, Nernst-Planck>Electrode kinetics>tcd.iloc_er1 - Local current density - A/m²**.
4. Select Boundary 2 only.
5. In the **Fe Oxidation Current Density** toolbar, click **Plot**.
6. Locate the **x-Axis Data** section. From the **Parameter** list, choose **Expression**.
7. In the **Expression** text field, type `r`.
8. In the **Fe Oxidation Current Density** toolbar, click **Plot**.

The plot should look like Figure 3.

Concentration, CO2, 3D (tcd)

1. In the **Model Builder** window, under **Results** click **Concentration, CO2, 3D (tcd)**.

2 In the **Settings** window for **3D Plot Group**, locate the **Data** section.

3 From the **Time (s)** list, choose **30**.

4 In the **Concentration, CO2, 3D (tcd)** toolbar, click **Plot**.

5 From the **Time (s)** list, choose **300**.

6 In the **Concentration, CO2, 3D (tcd)** toolbar, click **Plot**.

The CO2 concentration plots should look like Figure 4.

pH, 3D (tcd)

Next plot the pH variation.

1 In the **Home** toolbar, click **Add Plot Group** and choose **3D Plot Group**.

2 In the **Settings** window for **3D Plot Group**, type `pH, 3D (tcd)` in the **Label** text field.

Surface 1

1 Right-click **pH, 3D (tcd)** and choose **Surface**.

2 In the **Settings** window for **Surface**, locate the **Expression** section.

3 In the **Expression** text field, type `tcd.pH`.

pH, 3D (tcd)

1 In the **Model Builder** window, click **pH, 3D (tcd)**.

2 In the **Settings** window for **3D Plot Group**, locate the **Data** section.

3 From the **Time (s)** list, choose **30**.

4 In the **pH, 3D (tcd)** toolbar, click **Plot**.

5 From the **Time (s)** list, choose **300**.

6 In the **pH, 3D (tcd)** toolbar, click **Plot**.

The pH plots should look like Figure 5.

Revolution 2D 3

Finally, create a new revolution dataset to plot the precipitation thickness change under the entire droplet.

1 In the **Model Builder** window, expand the **Results>Datasets** node.

2 Right-click **Results>Datasets** and choose **Revolution 2D**.

3 In the **Settings** window for **Revolution 2D**, click to expand the **Revolution Layers** section.

Total Electrode Thickness Change, 3D (tcd)

1 In the **Model Builder** window, under **Results** click **Total Electrode Thickness Change, 3D (tcd)**.

2 In the **Settings** window for **3D Plot Group**, locate the **Data** section.

3 From the **Dataset** list, choose **Revolution 2D 3**.

4 Locate the **Plot Settings** section. Clear the **Plot dataset edges** check box.

Surface 1

1 In the **Model Builder** window, expand the **Total Electrode Thickness Change, 3D (tcd)** node, then click **Surface 1**.

2 In the **Settings** window for **Surface**, locate the **Coloring and Style** section.

3 Click **Change Color Table**.

4 In the **Color Table** dialog box, select **Rainbow>Prism** in the tree.

5 Click **OK**.

Total Electrode Thickness Change, 3D (tcd)

In the **Model Builder** window, click **Total Electrode Thickness Change, 3D (tcd)**.

Streamline 1

1 In the **Total Electrode Thickness Change, 3D (tcd)** toolbar, click **Streamline**.

2 In the **Settings** window for **Streamline**, locate the **Streamline Positioning** section.

3 From the **Positioning** list, choose **Uniform density**.

4 In the **Separating distance** text field, type `0.1`.

5 Locate the **Coloring and Style** section. Find the **Line style** subsection. From the **Type** list, choose **Tube**.

6 Select the **Radius scale factor** check box. In the associated text field, type `2.5e-5`.

7 Find the **Point style** subsection. From the **Type** list, choose **Arrow**.

8 From the **Arrow length** list, choose **Logarithmic**.

Color Expression 1

1 In the **Total Electrode Thickness Change, 3D (tcd)** toolbar, click **Color Expression**.

2 In the **Settings** window for **Color Expression**, click **Replace Expression** in the upper-right corner of the **Expression** section. From the menu, choose **Component 1 (comp1)> Tertiary Current Distribution, Nernst-Planck>tcd.IlMag - Electrolyte current density magnitude - A/m²**.

3 Locate the **Coloring and Style** section. Click **Change Color Table**.

4 In the **Color Table** dialog box, select **Rainbow>CyclicClassic** in the tree.

5 Click **OK**.

6 In the **Settings** window for **Color Expression**, locate the **Coloring and Style** section.

7 Clear the **Color legend** check box.

Total Electrode Thickness Change, 3D (tcd)

In the **Model Builder** window, under **Results** click **Total Electrode Thickness Change, 3D (tcd)**.

Surface 2

1 In the **Total Electrode Thickness Change, 3D (tcd)** toolbar, click **Surface**.

2 In the **Settings** window for **Surface**, locate the **Expression** section.

3 In the **Expression** text field, type `1`.

4 Locate the **Coloring and Style** section. Clear the **Color legend** check box.

Selection 1

1 In the **Total Electrode Thickness Change, 3D (tcd)** toolbar, click **Selection**.

2 Select Domain 1 only.

Surface 2

In the **Model Builder** window, click **Surface 2**.

Transparency 1

1 In the **Total Electrode Thickness Change, 3D (tcd)** toolbar, click **Transparency**.

2 In the **Settings** window for **Transparency**, locate the **Transparency** section.

3 In the **Transparency** text field, type `0.85`.

Surface 2

In the **Model Builder** window, click **Surface 2**.

Material Appearance 1

1 In the **Total Electrode Thickness Change, 3D (tcd)** toolbar, click **Material Appearance**.

2 In the **Settings** window for **Material Appearance**, locate the **Appearance** section.

3 From the **Appearance** list, choose **Custom**.

4 From the **Material type** list, choose **Water**.

Total Electrode Thickness Change, 3D (tcd)

1 In the **Model Builder** window, under **Results** click **Total Electrode Thickness Change, 3D (tcd)**.

2 In the **Total Electrode Thickness Change, 3D (tcd)** toolbar, click **Plot**.

The ferrous hydroxide precipitation change plot should look like Figure 6.