Faraday's Law

How can one predict the amount of product made in an electrolytic reaction?

Why?

In an electrolytic reaction, an electrical current is used to run a nonspontaneous redox reaction. This might be separating a metal from molten alloy or electroplating an object submersed in a metal cation solution. It may even be the electrolysis of water to collect oxygen and hydrogen gas. In any case, it is helpful to know how long the reaction will need to run to get the desired amount of product.

Model 1 – Collecting Pure Metal from Alloy

Experiment A

Trial	Run Time (hrs)	Current (Amperes)	Mass Ag Collected (g)
1	1.00	2.00	8.05
2	2.00	2.00	16.10
3	3.00	2.00	24.15
4	4.00	2.00	32.20
5	5.00	2.00	40.25
6	6.00	2.00	48.30

Experiment B

Trial	Run Time (hrs)	Current (Amperes)	Mass Na Collected (g)
1	1.00	2.00	1.72
2	2.00	2.00	3.43
3	3.00	2.00	5.15
4	4.00	2.00	6.86
5	5.00	2.00	8.58
6	6.00	2.00	10.29

1. Model 1 shows data collected from two experiments where electric current was run through molten alloy containing the desired metal.

   a. Will the desired metal be collected at the anode or the cathode of the cell?

   b. Write the half reaction that occurs as the metals are collected on the electrode.

   Experiment A electrode:

   Experiment B electrode:

2. Consider Experiment A of Model 1.

   a. Identify each of the following variables:

   Independent Dependent Controlled

   b. Describe the relationship between the independent and dependent variable in this experiment. Linear? Inverse? Exponential? Logarithmic? Justify your answer.

3. When the time and electrical current were identical in Experiments A and B, was the same mass of metal collected? Support your answer with evidence from Model 1.

4. For each trial of Experiments A and B, calculate the moles of metal collected. Add these data points to Model 1 by adding a column to each of the tables. Divide the work among group members.

5. When the time and electrical current were identical in Experiments A and B, was the same amount of metal, in moles, collected? Support your answer with evidence from Model 1.

Model 2 – A New Variable

Experiment C

Trial	Run Time (hrs)	Current (Amperes)	Ag Collected (mole)
1	1.00	1.00	0.037
2	1.00	2.00	0.075
3	1.00	3.00	0.112
4	1.00	4.00	0.149
5	1.00	5.00	0.187
6	1.00	6.00	0.224

6. Consider Experiment C of Model 2.

   a. Identify each of the following variables.

   Independent Dependent Controlled

b. Describe the relationship between the independent and dependent variable in this experiment. Linear? Inverse? Exponential? Logarithmic? Justify your answer.

7. Did any of the trials in Experiment C result in the same number of moles of metal being collected as that in Experiments A and B? If yes, list the time and current conditions for those that produced the same amounts of metal.

Read This!

Electrical current, a measure of the rate of electrons moving through a wire, can be thought of as water in a river passing a defined point. Electrical current is measured in Amperes. One amp is equal to one coulomb (unit of charge) per second. More coulombs (charge) will therefore move through a wire in an hour than in a minute at a given current. Similarly, more river water will move past a bridge in an hour than in a minute at a given current. As the magnitude of the current increases, more water (or charge) will pass a bridge (or move through a circuit) than at smaller currents in a given time span.

8. Discuss with your group how the total charge might be calculated for each of the trials in Experiment C. Propose an equation for finding total charge of an electrolytic cell using the variables t for time, q for charge and I for current. *Hint:* Consider the base units of a Coulomb.

9. Do the trials in Experiments A and C that produced the same number of moles of metal have the same total charge?

10. The experiment was done two more times:

Experiment D

Trial	Run Time (hrs)	Current (Amperes)	Moles Zn
1	1.00	2.00	0.037
2	2.00	2.00	0.075
3	3.00	2.00	0.112
4	4.00	2.00	0.149
5	5.00	2.00	0.187

Experiment E

Trial	Run Time (hrs)	Current (Amperes)	Moles Al
1	1.00	2.00	0.025
2	2.00	2.00	0.050
3	3.00	2.00	0.075
4	4.00	2.00	0.100
5	5.00	2.00	0.124

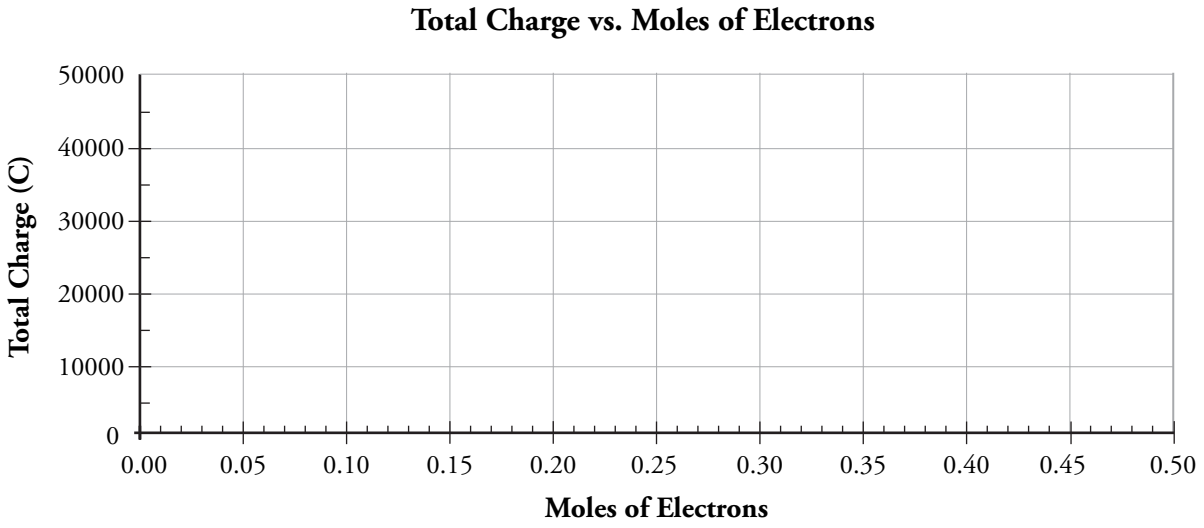
a. Write the half reaction that occurs at the electrode as these metals are collected.

b. Compare the moles of metal collected in Experiments D and E with the moles of metal collected in Experiments A and B under the same conditions of time and electrical current. Was the same number of moles of metal collected when conditions were equal? Justify your answer with data from the four experiments.

11. Consider the number of electrons that are needed to reduce the molten ions in Experiments A–E to neutral atoms. Explain why the trials which have the same amount of total charge going through the cell produce different numbers of moles of metal when the charges on the ions are different.

STOP

Model 3 – Faraday's Constant



12. Calculate the total charge for each of the trials in Experiments A and C. Graph the data from Experiments A and C in Model 3.

13. Calculate the slope of the trend line for the graph in Model 3, including units. This ratio of total charge to moles of electrons is called **Faraday's constant**.

14. How many moles of electrons would be moved through the electrolytic cell if it ran for 45.0 minutes at a constant current of 3.85 Amperes?

15. How many moles of solid copper could be produced by electrolysis of molten $CuSO_4$ under the conditions in Question 14?

16. Molten aluminum hydroxide is electrolyzed for 8.00 hours at 4.27 Amperes. Calculate the mass of aluminum metal that will be produced.

Extension Questions

Model 4 – Electrolysis of Aqueous Solutions

Experiment F

Trial	[$AgNO_3$] (M)	Run Time (hrs)	Current (Amperes)	Ag Collected (mole)
1	0.20	1.00	3.00	0.11
2	0.40	1.00	3.00	0.11
3	0.60	1.00	3.00	0.11
4	0.80	1.00	3.00	0.11
5	1.00	1.00	3.00	0.11

17. Consider Experiment F in Model 4.

    a. Identify each of the following variables:

    Independent Dependent Controlled

    b. Describe the relationship between the independent and dependent variable in this experiment. Linear? Inverse? Exponential? Logarithmic? Justify your answer.

18. Propose an atomic level explanation for the data in Experiment F.

19. What is the minimum voltage needed for Trial 5 of Experiment F to work?