B10 · Faraday's law

Student notes - follow the slides, fill the blanks, work the questions

Goals: Find the charge from current and time, with the time in seconds. Use the Faraday constant and a half-reaction to find moles of metal. Find the mass deposited, or the time needed, in an electrolysis.

Name: _____ Date: _____

Slide 1 of 8 · Current is charge per second

Electric charge is measured in _____, C. Current, I, is the charge that passes a point every _____.

Current is measured in _____, A. One ampere means _____ each second.

Charge equals current times time: q = _____. Here q is the charge in coulombs, I is the current in amperes and t is the time in _____.

If the time is in minutes or hours, change it to seconds first. 1 min = _____ s and 1 h = _____ s.

Example. A current of 4.00 A runs through an electrolytic cell for 5.00 minutes. How much charge moves, in coulombs?

Work:

Answer: _____

Try it. A current of 2.50 A runs through an electrolytic cell for 12.0 minutes. How much charge moves, in coulombs?

Work:

Answer: _____

Slide 2 of 8 · Charge to moles of electrons

One mole of electrons carries _____. This is the _____, F, printed in the Data Booklet on p. 3.

F = 9.65 × 10^4 C/mol e^-. The unit says coulombs for _____ of electrons.

To change coulombs to moles of electrons, _____ by F: $n(e^-)$ = _____. Here $n(e^-)$ is the moles of electrons and q is the charge.

Coulombs divided by coulombs per mole leaves _____. A small charge should give a _____ number of moles.

Example. A charge of 1500 C moves through a cell. How many moles of electrons is that? Use F = 9.65 × 10^4 C/mol e^-.

Work:

Answer: _____

Try it. A charge of 4.80 × 10^3 C moves through a cell. How many moles of electrons is that? Use F = 9.65 × 10^4 C/mol e^-.

Work:

Answer: _____

Slide 3 of 8 · Electrons to moles of metal

The coefficient of e^- in the reduction half-reaction gives the mole ratio. In $Cu^{2+} + 2e^- \rightarrow Cu$, _____ mol of electrons make _____ mol of copper.

So $n(Cu) = n(e^-)$ _____. Here n(Cu) is the moles of copper.

For silver, $Ag^+ + e^- \rightarrow Ag$, the ratio is _____. For aluminium, $Al^{3+} + 3e^- \rightarrow Al$, divide by _____.

The ratio is set by the _____. Write the half-reaction every time and never guess the ratio.

Example. A cell supplies 0.0155 mol of electrons to the cathode, where $Cu^{2+} + 2e^- \rightarrow Cu$. How many moles of copper form?

Work:

Answer: _____

Try it. A cell supplies 0.0450 mol of electrons to the cathode, where $Al^{3+} + 3e^- \rightarrow Al$. How many moles of aluminium form?

Work:

Answer: _____

Slide 4 of 8 · The full chain to a mass

The Faraday chain is: current and time give _____, charge gives _____, the half-reaction gives moles of metal, and molar mass gives mass.

First change the time to seconds and find q = It. Then n(e^-) = _____. Then divide by the _____ to find n(metal).

Finally m = _____. Here n is the moles of metal and M is the molar mass in _____, from the periodic table.

The chain as one formula is m = (I × t × M) ÷ (z × F). Here z is the _____ in the half-reaction, and t is in _____.

Example. Zinc is plated from Zn^{2+} solution by a current of 2.50 A for 25.0 minutes. What mass of zinc forms at the cathode? M(Zn) = 65.41 g/mol.

Work:

Answer: _____

Try it. Copper is plated from Cu^{2+} solution by a current of 3.00 A for 30.0 minutes. What mass of copper forms at the cathode? M(Cu) = 63.55 g/mol.

Work:

Answer: _____

Slide 5 of 8 · Method: how to find a mass from current and time

Step 1. Change the time to _____. Multiply minutes by 60.

Step 2. Find the charge: q = _____.

Step 3. Find the moles of electrons: $n(e^-) = q \div$ _____, with $F = 9.65 \times 10^4$ C/mol e^-.

Step 4. Use the _____ ratio to find the moles of the substance.

Step 5. Find the mass: m = _____.

Step 6. Round _____, at the end, to three significant digits.

Example. Use the method on 2.50 A for 25.0 minutes plating zinc from Zn^{2+} solution. Find the mass of zinc.

Work:

Answer: _____

Try it. Use the method on 1.50 A for 20.0 minutes plating silver from Ag^+ solution. M(Ag) = 107.87 g/mol. Find the mass of silver.

Work:

Answer: _____

Slide 6 of 8 · Your turn: silver

Hours must be changed to seconds in two steps: 1.00 h = _____ min = _____ s.

Charge: q = It = 0.500 A × 3600 s = _____. Then n(e^-) = q ÷ F = _____ mol.

In $Ag^+ + e^- \rightarrow Ag$ the ratio is _____, so n(Ag) = n(e^-). Show this step even when the ratio is 1 to 1.

Finally m = n × M = 0.01865 mol × _____. Check that the units give grams: mol × g/mol leaves _____.

Example. A silver nitrate solution carries 0.500 A for 1.00 hour. The half-reaction is $Ag^+ + e^- \rightarrow Ag$. What mass of silver forms at the cathode? M(Ag) = 107.87 g/mol.

Work:

Answer: _____

Try it. A copper(II) sulfate solution carries 0.750 A for 45.0 minutes. The half-reaction is $Cu^{2+} + 2e^- \rightarrow Cu$. What mass of copper forms at the cathode? M(Cu) = 63.55 g/mol.

Work:

Answer: _____

Slide 7 of 8 · Running the chain backward

To run the chain backward, start at the given _____ and find moles with n = _____. Here m is the mass in grams and M is the molar mass.

Go from metal to electrons by _____ by the coefficient of e^-. For $Al^{3+} + 3e^- \rightarrow Al$, $n(e^-)$ = _____ × n(Al).

Change moles of electrons to charge by multiplying by _____. Then find the time with t = _____.

Coulombs divided by amperes leaves _____. Divide by _____ for minutes if the question asks for minutes.

Example. We want 1.00 g of aluminium from Al^{3+} using a steady current of 5.00 A. How long must the current run, in seconds and in minutes? M(Al) = 26.98 g/mol.

Work:

Answer: _____

Try it. We want 1.50 g of zinc from Zn^{2+} using a steady current of 3.00 A. How long must the current run, in minutes? M(Zn) = 65.41 g/mol.

Work:

Answer: _____

Slide 8 of 8 · What the calculation assumes

The calculation assumes _____ the charge makes the wanted metal. In real cells some charge goes to _____, so a little less metal forms.

Mass deposited is the mass the cathode _____: the final mass _____ the starting mass.

The same chain also works in a _____ cell. The electrons in the wire come from the _____ half-reaction.

In a zinc and copper cell, $Zn \rightarrow Zn^{2+}$ + _____ and $Cu^{2+} + 2e^{-} \rightarrow$ _____. The same electrons do both jobs.

Example. A cathode has a mass of 31.40 g before plating and 32.15 g after plating. What is the mass deposited? What does the calculation assume about the charge?

Work:

Answer: _____

Try it. In a zinc and copper voltaic cell, 0.0200 mol of electrons pass through the wire. How many moles of zinc are oxidized at the anode, and how many moles of copper deposit on the cathode?

Work:

Answer: _____

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Faraday's law | Questions 1-2 of 7

1. Given a current of 4.00 A for 30.0 minutes. Find the charge that moves, in coulombs.

Work:

Final answer (with unit): _____

2. Given a charge of 7.20×10^{3} C. Find the moles of electrons, using $F = 9.65 \times 10^{4}$ C/mol e^{-}.

Work:

Final answer (with unit): _____

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3. Given 0.0746 mol of electrons and the half-reaction $Cu^{2+} + 2e^- \rightarrow Cu$. Find the moles of copper formed and the mass (M = 63.55 g/mol).

Work:

Final answer (with unit): _____

4. Given 2.00 A for 45.0 minutes and the half-reaction $Zn^{2+} + 2e^- \rightarrow Zn$ (M = 65.41 g/mol). Find the mass of zinc deposited.

Work:

Final answer (with unit): _____

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5. Given 1.50 A for 2.00 hours and $Ag^+ + e^- \rightarrow Ag$ (M = 107.87 g/mol). Find the mass of silver deposited.

Work:

Final answer (with unit): _____

6. Given that 2.00 g of copper must form from Cu^{2+} at a steady 2.50 A (M = 63.55 g/mol). Find the time needed in minutes.

Work:

Final answer (with unit): _____

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7. Challenge: Given two electrolytic cells joined in a row, so the same current passes through both. One cell plates silver ($Ag^{+} + e^{-} \rightarrow Ag$, M = 107.87 g/mol). The other plates copper ($Cu^{2+} + 2e^{-} \rightarrow Cu$, M = 63.55 g/mol). The current is 1.25 A for 20.0 minutes. Find the mass of each metal deposited, in grams. Use $F = 9.65 \times 10^{4}$ C/mol e^{-}.

Work:

Final answer (with unit): _____