Totally Epic AP Chem Review: Electrolytic Cells!

Electrolytic Cells: You have the *power!*

Electrolytic cells: thermodynamically unfavorable, therefore + ΔG° and − $\cancel{\Delta}E^\circ$

- Since an electrolytic cell is NOT spontaneous, it will undergo a redox reaction only if current is applied!

Electrolysis: using electrical energy to break a compound apart (separate elements from compounds)

Electrorefining: Purification of metals through electrolysis

- The anode is the impure metal (ore) to be purified.
- The cathode is where the pure metal will be deposited (made of a thin sheet of the pure metal).
- The electrolyte (solution) contains the cation of the metal to be purified.

Electroplating: Applying a thin layer of an expensive metal onto a less expensive one for structural or cosmetic reasons

- The object to be plated is the cathode ← fat cat!.
- The electrolyte (solution) contains the cation of the metal to be plated on the object.
- The best anode is made of the metal to be plated onto the object

Differences between Galvanic/Voltaic Cells and Electrolytic Cells

Galvanic/ Voltaic Cells	Electrolytic Cells
− ΔG, + E°_{cell}, K > 1	+ ΔG, − E°_{cell}, K < 1
Thermodynamically favorable	Thermodynamically Unfavorable
spontaneous in the forward direction	spontaneous in the reverse direction
Separated into two half cells to generate electricity	Usually occurs in a single container (but can be set up in two containers)
Is a battery (turns chemical energy into electrical energy)	Needs a battery (turns electrical energy into chemical energy)
Often electrodes made of metal used in half-reactions	Usually use inert electrodes (such as Pt or graphite)
Electrons supplied by species being oxidized	Electrons supplied by external battery at cathode
Cathode +, Anode −	Anode +, Cathode −

EPA: Electrolytic = positive anode

Note: In electrolytic cells, **An Ox** and **Red Cat** still work (yay!)

Quantitative Electrolysis: In an electrolytic cell, the amount of product made is related to the number of electrons transferred. Essentially, the electrons are a reactant. To solve, use the formula for current from the periodic table and follow the following steps:

$q = I(t)$	→	$q / F = \text{mol } e^-$	→	Use the appropriate half-reaction to determine the moles of the metal formed.	→	Use molar mass to convert from moles to grams of metal.
I = current (amperes, A) q = charge (coulombs, C) t = time (sec)						
Rearrange the formula to solve for charge (q) in Coulombs. BE SURE t is in SECONDS!		F = 96, 485 C/mol e^-		For example, $Au^{3+}(aq) + 3e^- \rightarrow Au(s)$ For every 3 moles of electrons gained, 1 mole of solid gold forms.		

☆ 1 Amp = 1 C/s

Example: Gold can be plated out of a solution containing Au^{3+} according to the half-reaction:

$$Au^{3+}(aq) + 3\,e^- \rightarrow Au(s)$$

What mass of gold (in grams) is plated by a 25-minute flow of 5.5 A current?

Solution: $$\boxed{25\ \cancel{\text{min}} \times \frac{60\ \cancel{\text{s}}}{1\ \cancel{\text{min}}}} \times \frac{5.5\ \cancel{\text{C}}}{1\ \cancel{\text{s}}} \times \frac{1\ \cancel{\text{mol e}^-}}{96{,}485\ \cancel{\text{C}}} \times \frac{1\ \cancel{\text{mol Au}}}{3\ \cancel{\text{mol e}^-}} \times \frac{196.97\text{ g Au}}{1\ \cancel{\text{mol Au}}} = 5.6\text{ g Au}$$

$$\text{time (se)} \times \text{current (Amp)} \times \frac{1}{F} \times \frac{\text{solid metal}}{\text{mol } e^-} \times \text{molar mass (g/mol)}$$

You will need to be able to do two basic calculations for quantitative electrolysis:

1. Given time (sec) and current (A), calculate mass (g).
2. Given mass (g) and current (A), calculate time required (sec).

Of course, there are endless variations of these two calculation types we can give you! ☺

Quick Trick to remember the order of steps to calculate mass of a metal produced (given time and current):

Are you SAFe? MMM.

$$\text{Sec} \times \text{Amp} \times \frac{\text{mol } e^-}{F} \times \frac{\text{mol}}{\text{mol } e^-} \times \text{molar mass}$$

Practice:

1. How long must a current of 5.00 A be applied to a solution of Ag^+ to produce 10.5 g silver metal?

$$10.5\text{ g Ag} \times \frac{1\text{ mol Ag}}{107.87\text{ g Ag}} \times \frac{1\text{ mol } e^-}{1\text{ mol Ag}} \times \frac{96{,}485\text{ C}}{1\text{ mol } e^-} \times \frac{1\text{ s}}{5.00\text{ C}} = \boxed{1{,}880\text{ Sec}}$$

2. Copper may be used for electroplating, with a half-reaction of $Cu^{2+} + 2\,e^- \rightarrow Cu(s)$.

   a. If a current of 10.0 amp is applied to a Cu^{2+} solution for 60.0 minutes, what mass of copper will be plated out?

$$60.0\text{ min} \times \frac{60\text{ s}}{1\text{ min}} \times \frac{10.0\text{ C}}{1\text{ s}} \times \frac{1\text{ mol }e^-}{96{,}485\text{ C}} \times \frac{1\text{ mol Cu}}{2\text{ mol }e^-} \times \frac{63.55\text{ g Cu}}{1\text{ mol Cu}} = \boxed{11.9\text{ g Cu}}$$

   b. How many moles of electrons must be transferred in this reaction to produce 5.16 g of copper metal?

$$5.16\text{ g Cu} \times \frac{1\text{ mol Cu}}{63.55\text{ g Cu}} \times \frac{2\text{ mol }e^-}{1\text{ mol Cu}} = \boxed{0.162\text{ mol }e^-}$$

3. In an electrolytic cell, Cu(s) is produced by the electrolysis of $CuSO_4(aq)$. Calculate the maximum mass of Cu(s) that can be deposited by a direct current of 100. amperes passed through 1.50 L of 2.00 M $CuSO_4(aq)$ for a period of 1.00 hour.

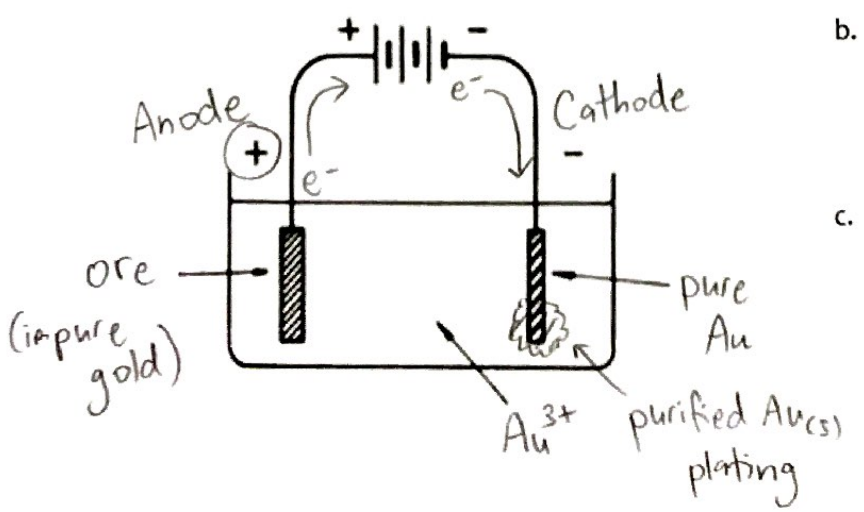
$1.50\text{ L} \times 2.00\text{ M} = 3.00\text{ mol } CuSO_4$ enough! won't run out ☺

$$1.00\text{ h} \times \frac{60\text{ min}}{1\text{ h}} \times \frac{60\text{ s}}{1\text{ min}} \times \frac{100.\text{ C}}{1\text{ s}} \times \frac{1\text{ mol }e^-}{96{,}485\text{ C}} \times \frac{1\text{ mol Cu}}{2\text{ mol }e^-} = 1.87\text{ mol}$$

$$1.87\text{ mol Cu} \times \frac{63.55\text{ g Cu}}{1\text{ mol Cu}} = \boxed{119\text{ g }Cu_{(s)}}$$

4. Gold ore, when discovered in nature, often contains impurities. If a sample of gold ore contains some silver impurity, the ore can be purified by electrolysis. (Assume Au(s) will form a $Au^{3+}(aq)$ cation.)

   a. On the diagram below, identify the anode (and what it's made of), the cathode (and what it's made of), and the direction of electron flow.



   b. Where will the purified gold be found?

   on the cathode

   c. What might be a possible electrolyte for use in this solution?

   $Au(NO_3)_3\,(aq)$

   100% soluble, contains Au^{3+}