Stoichiometry of Electrolysis

Michael Faraday did extensive research into the relationship between electricity and chemical reactions. He noted that the amount of product formed at each electrode was directly proportional to the amount of charge flowing through the electrolysis cell. This is called Faraday's Law.

1. The amount of charge (coulombs, C) flowing through a cell is determined by the amount of current (amperage, A) and the amount of time in seconds the current flows. Mathematically:

$$\text{Charge} = \text{current} \times \text{time} \qquad \text{so} \qquad 1\ \text{C} = 1\ \text{A} * \text{s}$$

2. The proportionality constant relating charge to the amount of chemical change was named the Faraday in honor of the work he did. One Faraday (F) corresponds to the charge carried by 1 mole of electrons.

$$1\,F = \frac{96,500\ \text{C}}{1\ \text{mole e}^-} \quad \text{(to 3 sig. figs.)}$$

3. Using Faraday's Law:
Example: Using a current of 4.75 A, how many minutes would it take to plate 12.0g of copper onto a sculpture from a copper (II) sulfate solution?

(a) Write the appropriate half-cell reaction. Copper (II) sulfate's formula is $CuSO_4$ so copper is in the 2+ oxidation state originally and will be plated out as Cu metal with 0 oxidation state.

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

Thus, for every 1 mole of copper plated, 2 moles of electrons are exchanged.

(b) Determine the moles of electrons required using stoichiometric ratios.

$$\text{moles of e}^- = (12.0\text{g Cu}) \left(\frac{1\ \text{mole Cu}}{63.55\text{g Cu}}\right)\left(\frac{2\ \text{mole e}^-}{1\ \text{mole Cu}}\right) = 0.378\ \text{mole e}^-$$

(c) Relate moles of electrons to charge using Faraday's constant.

$$\text{amount of charge} = (0.378\ \text{mole e}^-)\left(\frac{96,500\ \text{C}}{1\ \text{mole e}^-}\right) = 3.64 \times 10^4\ \text{C}$$

(d) Finally, the amount of charge and be related to current and time using C = A*s.

$$3.64 \times 10^4\ \text{C} = 4.75\ \text{A} * \text{time (s)}$$

$$\text{time} = 7.67 \times 10^3\ \text{s}\left(\frac{1\ \text{minute}}{60\ \text{s}}\right) = 128\ \text{minutes}$$

(e) Try working the problem in reverse: If a current of 4.75 A is run for 128 minutes, how many grams of copper metal can be plated on the sculpture from a copper (II) sulfate solution?