Faraday’s Law

The basis for electrochemical theory and technology are Faraday’s laws of electrolysis which formed a crucial link between chemistry and electricity. These laws are called in honor of Michael Faraday (1791-1867) who formulated them during 1833 and 1834:

1. The amount of chemical change produced by electrolysis is proportional to the total amount of charge passed through the cell.

2. The amount of chemical change produced is proportional to the equivalent weight of the substance undergoing chemical change.

\[ W = \frac{ItA}{zF} \]

- \( W \) = weight in grams of the compound undergoing electrolysis
- \( I \) = current in amperes; \( A \) = atomic weight
- \( t \) = elapsed time of electrolysis in seconds
- \( z \) = number of charges involved in the elementary reaction
- \( F \) = Faraday’s constant, 96,493.5 coulombs/equivalent

For engineering purposes, the value of the Faraday will be rounded off to 96,500 coulombs/equivalent.

Example Problem #1:

Calculate the daily aluminum production of a 150,000 ampere aluminum cell which operates at a current efficiency of 89%. The cell reaction is

\[ 2Al_2O_3 + 3 C = 4 Al + 3 CO_2 \]

Answer:

\[ W = \varepsilon_c \left( \frac{ItA}{zF} \right) \]

\[ = 0.89 \left( \frac{1.5 \times 10^5 A \times 24 \times 60 \times 60 \text{ sec}}{3 \text{ eq mol}} \right) \left( \frac{26.985 \text{ gm}}{\text{ mol eq}} \right) \left( \frac{96,500 \text{ A sec}}{\text{ day}} \right) \text{ day} = 1.08 \times 10^6 \text{ gm day} \text{ or } 1.18 \text{ ton day} \]
Example Problem #2

The electrolysis of water at high pressure is used to produce hydrogen and oxygen of very high purity. For a cell voltage of 1.78V, what is the power consumption in kw-hrs per cubic meter of hydrogen gas at standard conditions of temperature and pressure?

Answer:

\[ 1 \text{m}^3 \text{ of } H_2 \text{ @ STP} = \left(1 \text{m}^3 \right) \left(100 \frac{\text{cm}}{\text{m}}\right)^3 / \left(22.414 \frac{\text{lit}}{\text{gmol}}\right) \left(10^3 \frac{\text{cm}^3}{\text{lit}}\right) = 44.615 \text{ gmol} \]

Faradays Law → \( \left(44.615 \frac{\text{gmol}}{\text{m}^3}\right) \left(96,500 \frac{\text{coul}}{\text{gmol}}\right) \left(2 \frac{\text{gmol}}{\text{eq}}\right) = 8.61 \times 10^6 \frac{\text{coul}}{\text{m}^3} \)

Since Power Current X Voltage:

\[ \frac{\left(8.61 \times 10^6 \frac{\text{coul}}{\text{m}^3}\right) \left(1.78\text{V}\right)}{\left(3600 \frac{\text{sec}}{\text{hr}}\right) \left(10^3 \frac{\text{watt}}{\text{kW}}\right)} = 4.26 \frac{\text{kw-hr}}{\text{m}^3 @ \text{STP}} \]