Solutions for Assignment 4 Part Two: Fuel Cells

Question 1.

Find the FALSE statement in the following:
*To charge a Lead Acid Battery, the positive pole of the direct current source should be connected to the battery terminal with sign "+". Accordingly, the negative pole of the DC source should be connected to the battery terminal with sign "-". During the charging, the reduction of lead sulfate to "spongy" metallic lead occurs as the cathodic process. In the anodic process, lead sulfate transforms to lead dioxide. Charging is completed when the voltage between terminals reaches a maximum value (2.06V*****n*** *when circuit is discontinued, where* ***n*** *is the number of cells in the battery), the sulfuric acid concentration drops to minimum (about 36%) and oxygen evolution occurs on the anode. In order to avoid hydrogen evolution and the formation of a highly explosive gaseous mixture, the capacity of the negative electrode is slightly higher than the positive electrode. As a result, when oxygen evolution starts on PbO_2, the negative electrode is not charged completely and oxygen diffuses through the electrolyte to be reduced on the cathode. This helps to maintain pressure inside the battery. However, after a long-time of lead-acid battery overcharging, the evolution of hydrogen (on negative electrode) and oxygen (on positive electrode) results in the formation of an explosive mixture of gases.*

Solution for question 1.

In accordance with total reaction is Lead Acid Battery:

$$PbO_2 + Pb + H_2SO_4 \underset{\text{charge}}{\overset{\text{discharge}}{\rightleftharpoons}} 2PbSO_4 + 2H_2O$$

concentration of sulfuric acid is increasing during the charging process. Therefore the sentence "Charging is completed when the voltage between terminals reaches a maximum value (2.06V***n** when circuit is discontinued, where **n** is the number of cells in the battery), the sulfuric acid concentration **drops to minimum** (about 36%) and oxygen evolution occurs on the anode" should be "Charging is completed when the voltage between terminals reaches a maximum value (2.06V***n** when circuit is discontinued, where **n** is the number of cells in the battery), the sulfuric acid concentration **reaches the maximum** (about 36%) and oxygen evolution occurs on the anode".

Question 2.

An experimental Direct Methanol Fuel Cell (single sell) is powered by a 2 molar methanol solution with a flow rate 0.8 $L \cdot h^{-1}$. The cell gives 0.9 V voltage at a current of 1A. What is the concentration of methanol in the out-coming flow if anode power density is 100 mW cm^{-2} and the methanol crossover rate is 300 mA cm^{-2}? Change in the water concentration can be neglected.

Solution for question 1.

The electrode area is:

$\boldsymbol{S}$ = power / power density = $\boldsymbol{IU/w}$ = 1A * 0.9 V / 0.1 W cm^{-2} = 9 cm^2

The number of methanol moles spend on the electrochemical process per hour:

$\boldsymbol{n_1} = \boldsymbol{It/nF}$ = (1 A * 3600 s) / (6 * 96500 C mol^{-1}) = 0.0062 mol h^{-1}

The number of methanol moles passed by cross-over per hour:

$\boldsymbol{n_2} = \boldsymbol{j_{cros}St/nF}$ = 0.3 A cm^{-2} * 9 cm^2 * 3600 s /(6 * 96500 C mol^{-1}) = 0.017 mol h^{-1}

Incoming amount of methanol per hour:

$\boldsymbol{N_{incom}} = \boldsymbol{C}$ * ***flow rate*** = 2 mol L^{-1} * 0.8 L h^{-1} = 1.6 mol h^{-1}

Outcoming amount of methanol per hour:

$\boldsymbol{N_{outcom}} = \boldsymbol{N_{incom}} - \boldsymbol{n_1} - \boldsymbol{n_2}$ = 1.6 mol h^{-1} - 0.017 mol h^{-1} - 0.0062 mol h^{-1} = 1.5768 mol h^{-1}

Concentration of methanol in the out-coming flow:

$\boldsymbol{C_{outcom}} = \boldsymbol{N_{outcom}}$ / ***flow rate*** = 1.5768 mol h^{-1}/ 0.8 L h^{-1} = 1.971 mol L^{-1}