2017 Fall, 4582-608 (WCU Program)
Electrochemical Energy Engineering, 전기화학에너지공학

Make-up/Homework #1 (60 points)
(due: September 25(Mon), before lecture)

1. Consider a portable 20 cm^2 active area fuel cell operating steadily at 0.75 V, 0.6 A/cm^2. The fuel utilization efficiency is 50%, and the cathode stoichiometry is 2.3. The fuel cell is expected to run for three days before being recharged. The cathode operates on ambient air, and the anode runs off of compressed hydrogen gas.
(a) Determine the volume of the hydrogen fuel tank required if it is stored as a compressed gas at 200 atm(20.26 MPa), 298 K.
(b) How large would a pure oxygen container be if it was used to provide the oxidizer? Consider 200 atm(20.26 MPa) storage pressure and 298 K average ambient temperature.

2. Determine the theoretical open circuit voltage of the following fuel cells and determine which reactant would be oxidizer and which would be the fuel for a galvanic reaction.
(a) Oxygen and hydrogen gas
(b) Lithium and oxygen gas
(c) Magnesium and oxygen gas

3. Determine the minimum theoretical open circuit voltage that would be required to generate hydrogen peroxide, H_2O_2, with hydrogen gas and air.

4. Consider a 300 plate fuel cell stack with 150 cm^2 active area per plate:
(a) For an anode and a cathode stoichiometry of 1.4 and 2.5, respectively, determine the mass flow rate of hydrogen and air into the fuel cell per ampere of current.
(b) If the nominal operating point is an average of 0.6 V per plate with 1.2 A/cm^2, determine the stack voltage and electrical power output.
(c) How much total electrical work at 0.6 V per plate could be performed with a storage tank containing 5 kg of hydrogen and limitless air? How much more output could be achieved if the unused fuel were recycled so that the effective fuel utilization became 100%.
(d) Determine how many plates the fuel cell would have to have at 0.6 V per plate, 1.2 A/cm^2, to generate 150 horsepower for an automotive application. (1 horsepower = 746 W)

5. A given fuel cell has continuous 150 A DC, an operating voltage of 0.55 V, and an overall internal resistance of 3 mΩ at 1.4 A/cm^2 current density. Calculate
(a) The potential loss from ohmic resistance, in volts, at this condition.
(b) The total electrical work produced in 2 h.
(c) The rate of ohmic heat dissipation from the cell in watts.

6. Consider a direct methanol fuel cell with a liquid methanol and water solution in the anode and an air cathode. The anode electrochemical oxidation reaction is

$$CH_3OH + H_2O \rightarrow 6H^+ + 6e^- + CO_2$$

The basic cathode electrochemical reduction reaction is

$$O_2 + 4e^- + 4H^+ \rightarrow 2H_2O$$

The balanced overall electrochemical reaction is

$$CH_3OH + 2/3O_2 \rightarrow 2H_2O + CO_2$$

Where methanol density is 700 kg/m^3 and methanol molecular weight is 32 g/mol.

(a) Calculate the minimum volume (in cubic centimeters) of a pure methanol fuel tank required to run a soldier’s uniform equipment for three days. The nominal power is 20 W. There are 10 cells in the stack in series and the total stack voltage is 5 V.
(b) What is the molar rate of water consumption at the anode?
(c) What is the molar rate of water production at the cathode?
(d) What is the net molar rate of water production per mole of methanol for the cell?
(e) What is the minimum molar rate of air required for reaction?