

Fuel Cell Science and Technology

Midterm Exam

2009 Apr 23 16:00~17:15

Useful constants:

$$F=96500 \text{ C/mole}$$

$$N_0 = 6.02 \times 10^{23} / \text{mol}$$

$$e = 1.6 \times 10^{-19} \text{ C/electron}$$

$$R = 8.314 \text{ J/K mol}$$

$$k = 1.38 \text{ J/K}$$

$$0^\circ\text{C} = 273.15\text{K}$$

1. [30 pts] Explain following terms.

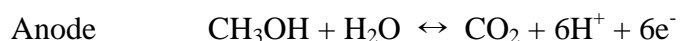
- a) Faraday number
- b) Triple phase boundary
- c) Gibbs free energy
- d) Concentration cell
- e) Exchange current density
- f) MEA
- g) Mixed ionic conductor
- h) Activation energy in catalyst
- i) Activation energy in electrolyte
- j) Standard electrode potential

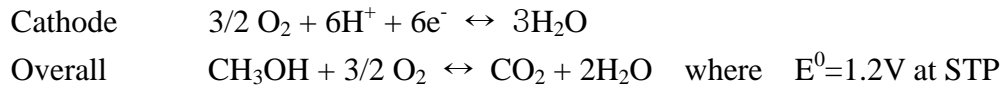
2. [15 pts] Consider an ideal cubic structure composed of 1000 atoms, say 10 atoms X 10 atoms X 10 atoms. In a certain state, the cubic structure loses any of 2 atoms in it. Calculate the approximate value entropy of the cubic structure in this state.

3. [15 pts] Commonly, Butler-Volmer equation is simplified to “Linearized BV equation” or “Tafel equation”. Which equation will you use for a) hydrogen oxidation and b) oxygen reduction? Explain why.

4. [40 pts]

(a) [5 pts] We know a direct methanol fuel cell (DMFC) have following reaction.





The main problem of a DMFC is the methanol crossover and high activation overvoltage of methanol fuel. For these reason, typical DMFC use diluted (with water) methanol fuel. If a DMFC uses methanol of 1/20 concentration of the above reaction, find the output voltage of such cell. Assume all the other conditions are same.

(b) [10 pts] Now, we use formic acid (CHOOH) as fuel instead of methanol. Formic acid reduces the crossover and activation overvoltage. Write down the anode, the cathode and overall electrochemical reactions. Find the voltage of the reaction at STP using standard electrode potential.

(c) [10 pts] A fuel cell operates at 0.5V, 2A. Fuel stoichiometry number is 1.2. For above 2 cases, calculate how much heat the fuel cell will generate for methanol fuel and formic acid fuel. (Use reaction enthalpy for methanol as -700kJ/mol and formic acid as -300kJ/mol). What is the efficiency of the cell for each case?

(d) [20 pts] Accidentally, we mixed the formic acid and methanol diluted in water. This mixed fuel has 1:1 mole ratio of formic acid and methanol. Now, we provide this mixture at a *constant rate* to the fuel cell. The total fuel in the mixture can generate up to 1A. Assuming the reaction of formic acid is much faster than methanol, sketch an IV curve for this fuel cell including as much detail as possible. Ignore activation and ohmic overvoltage for your sketch.