2019_1**2_10**

Fall 2019, Ceramics (5000/4000 level course)

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HW-TakeHomeExam-3 Electrochemistry

Please submit your solutions on Monday, December 16, 2019

This take-home carries 25% of the grade. All questions carry equal weight.

1. Within one-page draw and/or write *three* iconic sketches and/or equations which you feel embody the subject matter we discussed in class during this third phase of the course with a focus on Fuel Cells and Li+ Batteries. Explain each "object" in two lines of text.

2. The application of the Nernst equation to a fuel cell is as follows

$$\Delta V_N = \frac{RT}{4F} \ell n \frac{p_{O_2}^{Cathode}}{p_{O_2}^{Anode}} \qquad (1)$$

(i) Give a complete derivation for Eq. (1), clearly stating the assumptions in your analysis. Please show that the units in Eq. (1) are in balance

(ii) Show that Eq. (1) is consistent with the equation $\Delta V_N = \frac{\Delta G_{Janaf}}{4F}$ where ΔG_{Janaf} is the free energy for the reaction $2H_2 + O_2 = 2H_2O$ where hydrogen and water vapor are in their standard states.

3. Draw an equivalent circuit for a fuel cell showing the Nernst Voltage, the electrolyte resistance, and the electrical (resistive) load on the cell. The current drawn from the fuel cell depends on the magnitude of the resistive load, which can vary. Show that the power drawn from the fuel cell goes through a maximum as the current is increased, and that the position and the magnitude of the maximum is related to the resistance of the electrolyte. Sketch two curves, relative to one another, one for a lower and the other for a higher value of the electrolyte resistance.

4. In Q.3 it is assumed that the charge transfer resistance at the anode and the cathode interfaces is negligible in comparison to the

ionic transport resistance of the electrolyte. Now, let us assume that the charge transfer resistance produces a sharp voltage drop at each of the two electrode-electrolyte interfaces and that this voltage drop is equal to one-tenth of the Nernst Potential difference. The electrolyte resistance remains unchanged. Sketch two power vs. current density curves, one with and the other without the charge transfer resistance. Show the relative change in the position and the magnitude of the maximum in the power vs. current curve for these two considerations. Explain your answer in a few words.

5. Make a hand drawn sketch (a straight line) for an Arrhenius plot that follows this equation

$$\frac{D}{D_o} = e^{-\frac{Q}{RT(K)}} \qquad (2)$$

Assume that Q=83.1 $kJmol^{-1}$. The gas constant R=8.31 $Jmol^{-1}K^{-1}$.

(i) Calculate by hand the (approximate) value for D/D_o when T = 1000 K. Remember that $\ln_e(10) = 2.3$.

(ii) Draw by hand a graph where the y-axis is $\log_{10}\left(\frac{D}{D_o}\right)$, and the x-axis is in units of $\frac{1000}{T(K)}$.

(iii) Calculate $\Delta\left(\frac{1000}{T(K)}\right)$, that is the change in the value of the quantity within the brackets that would produce a change of two orders of magnitude in D/D_o. Now create a scale along the y-axis and the x-axis that can suitably display the Arrhenius plot. Now draw the line on the graph that is consistent with Eq. (2).

6. Draw a comparison between a fuel cell and a lithium ion battery in the form of a table with three columns. List the subtopic in the first column and then the attributes of this topic with reference to fuel cells and lithium ion batteries in the second and the third columns. You many include text, equations and/or sketches within the cells. Choose three topics and describe then in this table which is contained within one page (for example one topic could be the “source of energy”).