Assignment #6

PHYS-410
Fall 2013
Mr. Scofield

Announcements

Reading

this next week you will stay in Chapter 5. Review Sections 1-3. Skim through the rest of the chapter, reading portions that interest you. (I'll select a few topics to highlight in lecture.)

Homework Problems (from Schroeder, unless otherwise specified)

Your solutions to the problems below are due at the beginning of class, Friday, Nov. 1.

6.01 Compare the data on Pg. 167 for the liquid/vapor boundary of water to the predictions of the Clausius-Clapeyron equation at, say, T = 50ºC. (More specifically, graph the p vs T data next to the theoretical prediction of the C-C equation, assuming an ideal gas for the vapor, and using data at T = 50ºC for finding p_0 and L.) Comment on the level of agreement.

6.02 Derive Sievert's Law, that the concentration of dissolved H atoms in a metal is proportional to the square-root of the H_2(g) pressure. Key here is that you have the chemical equation $H_2 \to 2H$, where the H atoms are dissolved in the solid.

6.03 In Chapter 5 Schroeder goes through a calculation of the maximum theoretical efficiency for a hydrogen fuel cell. This efficiency is defined to be the ratio of the change in Gibbs Free energy divided by the change in Enthalpy, namely $\eta \equiv \Delta G / \Delta H$.
Your task is to repeat this calculation, but for a different fuel cell, namely, the carbon/carbon-dioxide fuel cell that utilizes the reaction $C + O_2(g) \to CO_2(g)$. On the surface your answer may be surprising. Explain how it is possible to achieve "efficiencies" greater than 100%.

6.04 **Problem 5.4.** In a hydrogen fuel cell, the steps of the chemical reaction are

$$\text{at} - \text{electrode:} \quad H_2 + 2OH^- \longrightarrow 2H_2O + 2e^-;$$
$$\text{at} + \text{electrode:} \quad \tfrac{1}{2}O_2 + H_2O + 2e^- \longrightarrow 2OH^-.$$

Calculate the voltage of the cell. What is the minimum voltage required for electrolysis of water? Explain briefly.

6.05

Problem 5.5. Consider a fuel cell that uses methane ("natural gas") as fuel. The reaction is

$$CH_4 + 2O_2 \longrightarrow 2H_2O + CO_2.$$

(a) Use the data at the back of this book to determine the values of ΔH and ΔG for this reaction, for one mole of methane. Assume that the reaction takes place at room temperature and atmospheric pressure.

(b) Assuming ideal performance, how much electrical work can you get out of

(c) How much waste heat is produced, for each mole of methane fuel?

(d) The steps of this reaction are

$$\text{at} - \text{electrode:} \quad CH_4 + 2H_2O \longrightarrow CO_2 + 8H^+ + 8e^-;$$
$$\text{at} + \text{electrode:} \quad 2O_2 + 8H^+ + 8e^- \longrightarrow 4H_2O.$$

What is the voltage of the cell?

6.06

Problem 5.11. Suppose that a hydrogen fuel cell, as described in the text, is to be operated at 75°C and atmospheric pressure. We wish to estimate the maximum electrical work done by the cell, using only the room-temperature data at the back of this book. It is convenient to first establish a zero-point for each of the three substances, H_2, O_2, and H_2O. Let us take G for both H_2 and O_2 to be zero at 25°C, so that G for a mole of H_2O is -237 kJ at 25°C.

(a) Using these conventions, estimate the Gibbs free energy of a mole of H_2 at 75°C. Repeat for O_2 and H_2O.

(b) Using the results of part (a), calculate the maximum electrical work done by the cell at 75°C, for one mole of hydrogen fuel. Compare to the ideal performance of the cell at 25°C.

6.07

Problem 5.32. The density of ice is 917 kg/m^3.

(a) Use the Clausius-Clapeyron relation to explain why the slope of the phase boundary between water and ice is negative.

(b) How much pressure would you have to put on an ice cube to make it melt at -1°C?

(c) Approximately how deep under a glacier would you have to be before the weight of the ice above gives the pressure you found in part (b)? (Note that the pressure can be greater at some locations, as where the glacier flows over a protruding rock.)

(d) Make a rough estimate of the pressure under the blade of an ice skate, and calculate the melting temperature of ice at this pressure. Some authors have claimed that skaters glide with very little friction because the increased pressure under the blade melts the ice to create a thin layer of water. What do you think of this explanation?