APS 104S Midterm 2 March 20, 2008 [1 hour and 50 minutes]
Physical Chemistry Portion

Problem 1 [23 marks total]

Consider an ideal gas with heat capacities, $C_{p,m} = 5/2$ R, $C_{v,m} = 3/2$ R. Initially the gas is at high temperature and pressure, and we wish to extract work by allowing the gas to expand in a piston/cylinder assembly connected to mechanical machinery. The ambient environment is at 1 bar and 20 °C The initial pressure P_1 of the gas is 20 bar. The final temperature T_2 is 500 °C, and the final pressure P_2 is 1 bar.

[17 marks] (a) If the expansion occurs adiabatically and reversibly, find (i) ΔS of the gas, (ii) T_1, and (iii) work **done by** the gas on the surroundings (i.e. the work we can extract from the expansion process).

[3 marks] (b) Now consider a situation where T_1, P_1, T_2 and P_2 are the same as in part (A), but the expansion process occurs irreversibly. (i) Is the work extracted more or less than in part (A)? (ii) Explain your answer briefly.

[3 marks] (c) Can we extract any more work out of the gas at the end of the process described (when the gas is at $T_2 = 500$ °C and $P_2 = 1$ bar)? Explain.

Problem 2 [15 marks]

The triple point of iodine I_2 occurs at 112.9 °C and 11.57 kPa. The enthlapy of vaporization for iodine is 47.17 kJ/mol. Find the boiling point of iodine at 1 bar.

Problem 3 [12 marks total]

Provide short answers for the following questions.

[4 marks] (a) Sketch a typical phase diagram of a pure substance on a pressure vs temperature graph showing the solid (S), liquid (L), and vapor (V) regions. Also indicate on the graph the triple point (t_p), and the critical point (t_c).

[4 marks] (b) Consider a process in which a liquid system is cooled, so ΔS of the system is negative. Since entropy decreases, is this process a violation of the second law? Explain.

Problem 3, continued

[4] (c) Consider the phase diagram of H_2O shown where I through XI are different forms of solid ice.

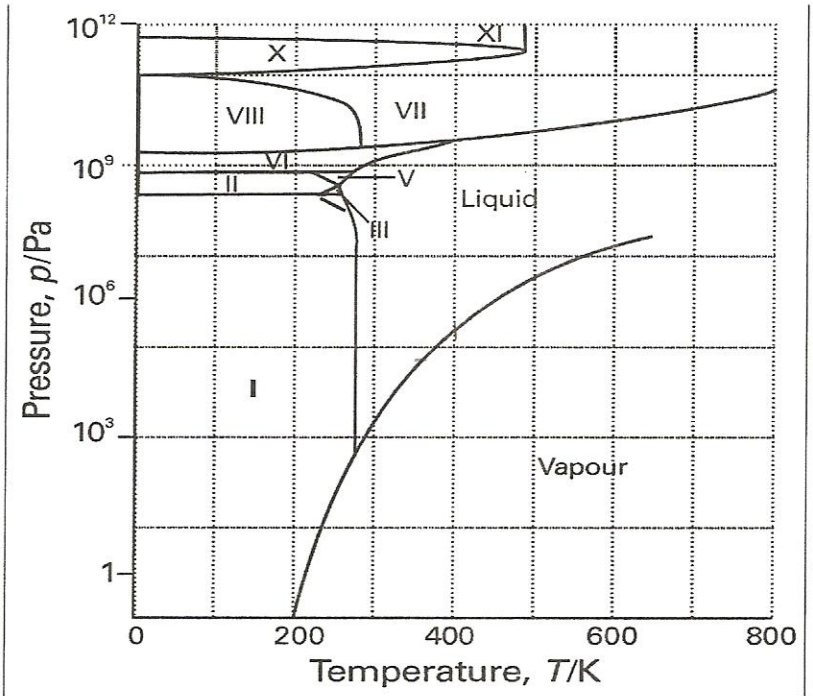

Figure 4-5
Atkins Physical Chemistry, Eighth Edition

- Explain what happens at 10^6 Pa as you increase temperature from 0 K to 600 K.
- Third degree burns can occur when skin contacts objects at 60 °C or higher for 5 seconds or longer. Can you get burned by ice? If so, which forms of ice?

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APS104S – Midterm Exam, March 20, 2008
Materials Science Portion

Total marks for all questions: 19

1. Fe undergoes an allotropic phase transformation from BCC to FCC when the temperature is increased above 912 °C. The lattice parameter of BCC Fe is 0.2866 nm, the lattice parameter of FCC Fe is 0.3571 nm, and the molar mass of Fe is 55.847 g/mol.

   a) Calculate the theoretical density of Fe in both the FCC and BCC forms. (2 marks)

   b) What is the atomic radius of Fe in the BCC form and the FCC form? (2 marks)

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2. The nickel aluminides are an important class of high temperature stable materials. For the Al-Ni phase diagram shown below, determine the following (note that the composition in weight percent is given on the top x-axis):

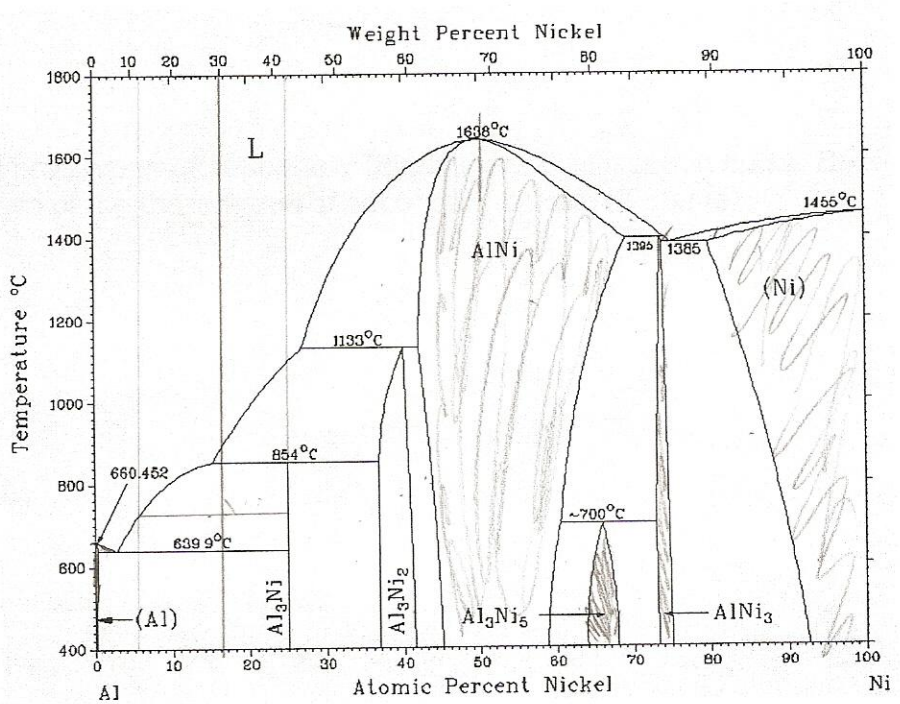
a) List all the phases present in the Al-Ni phase diagram. (1 mark)

b) How many two-phase regions are present? (1 mark)

c) What is the invariant reaction occurring at 50 atomic % Ni? (1 mark)

d) What is the invariant reaction occurring at 639.9°C? (1 mark)

e) What is the invariant reaction occurring at 1133°C? (1 mark)



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3. Use the Al-Ni phase diagram from the previous page to answer the following. A 500g sample with an overall chemical composition of 30 weight percent Ni is held at 700°C until equilibrium is attained.

   a) What is the chemical composition of the liquid and the solid? (2 marks)

   b) How many grams of solid are present? (2 marks)

4. Three types of secondary bonds were discussed in class. *Briefly* explain two of the three types of secondary bonds. (2 marks)

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5. If the potential energy as a function of interatomic spacing is given by the following expression:

$$E = -\frac{A}{r} + \frac{B}{r^n}$$

where A = 2.38 eV nm, $B = 1.88 \times 10^{-5}$ eV nm^{10}, and n = 10, what is the equilibrium spacing between the two atoms? (4 marks)