AP Chemistry problem set

1) The normal boiling and freezing points of argon are 87.3 K and 84.0 K, respectively. The triple point is at 82.7 K and 0.68 atmosphere.

(a) Use the data above to draw a phase diagram for argon. Label the axes and label the regions in which the solid, liquid and gas phases are stable. On the phase diagram, show the position of the normal boiling point.

(b) Describe any changes that can be observed in a sample of solid argon when the temperature is increased from 40 K to 160 K at a constant pressure of 0.50 atmospheres.

(c) Describe any changes that can be observed in a sample of liquid argon when the pressure is reduced from 10 atmospheres to 1 atmosphere at a constant temperature of 100 K, which is well below the critical temperature.

(d) Does the liquid phase of argon have a density greater than, equal to, or less than the density of the solid phase? Explain your answer, using information given in the introduction to this question.

2) A 0.472 g sample of an alloy (a misture of two metals) of tin and bismuth is dissolved in sulfuric acid to produce tin(II) and bismuth(III) ions. This solution is diluted to the mark in a 100 mL volumetric flask and 25.00 mL aliquots (equal portions) are titrated with a 0.0107 M solution of KMnO4, forming tin(IV) and manganese(II) ions. (The bismuth ions are unaffected during this titration.)

a. Write a balanced equation for the reaction of the MnO_4- ion with Sn(II) in acid solution.

b. If an average titration requires 15.61 mL of the MnO_4- solution, calculate the number of moles of MnO_4- used in an average titration.

c. Determine the percentage of tin in the alloy. Ans: 42%

3) Liquid hydrazine, N_2H_4, is sometimes used as a rocket propellant.

a. Write an equation for the formation of hydrazine from its elements and use the combustion equations below to derive an equation in which $\Delta H_f°$ for liquid hydrazine is expressed in terms of ΔH_1, ΔH_2 and ΔH_3.

$$\tfrac{1}{2} N_2(g) + O_2(g) \longrightarrow NO_2(g) \qquad \Delta H_1$$

$$H_2(g) + \tfrac{1}{2} O_2(g) \longrightarrow H_2O(g) \qquad \Delta H_2$$

$$N_2H_4(g) + 3O_2(g) \longrightarrow 2NO_2(g) + 2H_2O(g) \qquad \Delta H_3$$

b. In a rocket, liquid hydrazine is reacted with liquid hydrogen peroxide to produce nitrogen and water vapor. Write a balanced equation for this reaction.

c. Calculate $\Delta H_{rxn}°$ for the reaction represented in 2b.

$\Delta H_f°$ kJ/mol
$N_2H_4(l)$ 50.6
$H_2O_2(l)$ –187.8
$H_2O(g)$ –285.8

d. Calculate $\Delta H_{rxn}°$ for the reaction in 3b using bond dissociation energies.
Bond Dissociation Energy kJ/mol
N–N 167 O–O 142
N=N 418 O=O 494
N≡N 942 O–H 459
N-H 386

e. Which value of ΔHrxn° (that calculated in part c or part d) is likely to be more accurate? Justify your answer.

f. Calculate the maximum temperature of the combustion gases if all the energy generated in the reaction goes into raising the temperature of those gases. [The heat capacities of $N_2(g)$ and $H_2O(g)$ are 29.1 J/(mol**.**°C) and 33.6 J/(mol**.**°C), respectively.]

4) A certain compound contains only C, H, and N. Combustion of 0.125 g of this compound produces 0.172 g of H_2O and 0.279 g of CO_2.
a. Calculate the number of moles of CO_2 and H_2O.

b. Find the mass percentages of C, H, and N and the empirical formula of this compound.

c. Assume the empirical formula is also the molecular formula. Draw structural formulas for the four different isomers that are possible for a compound with this formula.

d. The four compounds have boiling points that range from 3 °C to 48 °C. Identify the isomers that you would expect to exhibit the lowest and highest boiling points. Explain your reasoning in terms of the intermolecular forces involved.