V25.0109: General Chemistry I: Honors

Problem set #1: due 9/18

Practice problems from Chapter 1: 20,21,26,29,36

Graded problems

1. A given element X has an average relative mass A and three isotopes of relative masses A_1, A_2 and A_3. Let the fractional abundances of these isotopes be p_1, p_2 and p_3. Suppose the mass difference between isotope 2 and isotope 1 is 1.003 (relative mass), with isotope 2 being the heavier than isotope 1, and that the mass difference between isotope 3 and isotope 2 is 1.005 (relative mass), with isotope 3 being heavier than isotope 2. In addition, suppose that isotope 1 is 10 times as abundant as isotope 2 and that isotope 2 and isotope 3 together comprise 15% of the total amount of X. Calculate the value of A *in terms* of the mass of the most abundant isotope of X.

2. Balance the following reactions. You may use any method you like.

   a. $Ca_5(PO_4)_3F + H_2SO_4 + H_2O \longrightarrow Ca(H_2PO_4)_2{\cdot}H_2O + CaSO_4{\cdot}2H_2O + HF$

   b. $Ca_5(PO_4)_3F + SiO_2 + C \longrightarrow CO + CaO{\cdot}\frac{2}{3}SiO_2 + SiF_4 + P_4$

   c. $BrO_3^- + CH_2(COOH)_2 + H^+ \longrightarrow BrCH(COOH)_2 + CO_2 + H_2O$

   Hint: The charge must be balanced as well, which means that the net charge (total positive charge − total negative charge) must be the same on both sides of the reaction.

   d. $NH_4ClO_4 + Al \longrightarrow Al_2O_3 + N_2 + HCl + H_2O$

   e. $CO_2 + NH_4^+ + O_2 \longrightarrow C_5H_7O_2N + NO_2^- + H_2O + H^+$

   Hint: Charge must be balanced as well, meaning that the net total charge must be the same on both sides. Is there more than one solution?

3. Iron (Fe) can be produced from iron oxide (Fe_2O_3) by reaction with carbon-monoxide gas (CO) according to:

$$Fe_2O_3(s) + 3CO(g) \longrightarrow 2Fe(s) + 3CO_2(g)$$

   When 7.56 kg of CO gas are combined with 15.02 kg iron oxide in a furnace, it is observed that 9.54 kg of iron are produced. What is the percentage yield of this reaction?

4. A particle of mass m moving along the x axis is subject to a Hooke's law force $F(x) = -kx$.

   a. Calculate the work needed to move the particle from $x = 0$ to $x = 2$.

   b. Calculate the work needed to move the particle from $x = -2$ to $x = 2$.

   c. Explain the physical reason for the answers to parts a and b.

5. Let r denote the distance between the two atoms in a diatomic molecule AB. A useful expression for the potential energy $V(r)$ stored in the molecule as a function of r is

$$V(r) = D_0 \left(1 - e^{-b(r-r_0)}\right)^2$$

where D_0, b and r_0 are constants.

a. Sketch the plot of $V(r)$ as a function of r. Are there any restrictions on the allowed values of r?

b. Derive an expression for the force F between the two atoms as a function of r and sketch the plot of F vs. r.

c. If the distance between the atoms A and B is initially r_0, determine an expression in terms of D_0, r_0 and b for the work needed to dissociate the molecule, i.e. to move the two atoms to infinite separation.

d. Give a physical intepretation of the parameters D_0, r_0, and b.