ESS 312 Geochemistry

Lab / Problem set #1

Two lab periods and/or homework. Due one week after the second lab period.

Post-Spring Break Limbering-Up Exercises

For the following, any required data not found in the problem are in the Appendices to McSween (or other references, or reputable sources on the Web). State assumed values. Show units in calculations. Use correct number of significant figures.

1. What is the formula and formula-weight in grams of the following minerals?
    a) quartz, b) albite, c) microcline, d) enstatite, e) diopside

2. For each of the above minerals, calculate the weight % that is composed of each of the following oxides:
    Na_2O, MgO, Al_2O_3, SiO_2, K_2O, CaO, FeO

3. Below are concentration data for six unknown mineral separates (presented in weight %).
Calculate the molecular proportions of the oxides, give the mineral formula and name.

a) SiO_2 = 59.45	Al_2O_3 = 25.21	Na_2O = 15.34
b) SiO2 = 55.07	Al_2O_3 = 23.35	K_2O = 21.58
c) SiO_2 = 43.20	Al_2O_3 = 36.64	CaO = 20.16
d) SiO_2 = 59.84	MgO = 40.16	
e) SiO_2 = 48.44	CaO = 22.60	FeO = 28.98

4. a) Seismic data are consistent with the presence of 7.4% (by weight) Ni in the Earth's core.
        How many grams of Ni are in the core? How many moles?
    b) The volume of the Earth's crust is $1.02 \times 10^{10} km^3$; mean crustal density is $2.8 g/cm^3$; and mean concentration of Ni in the crust is 75 parts per million (ppm) by weight. How many grams of Ni are in the Earth's crust?
    c) The mantle has 0.20 weight % NiO. How many grams of Ni are in the Earth's mantle?
    d) What fraction of the Earth's Ni is in the core, mantle and crust? Suggest possible reasons for the calculated differences in distribution of Ni in the core, mantle and crust.

    The mass of the Earth is 5.97×10^{27} g; The mass of the core is: 1.94×10^{27} g; The mass of the mantle is: 4.02×10^{27} g. You have to compute the mass of the crust as part of question (b) above.

5. To build a Lincoln Navigator requires 23kg of Cu, 12kg of Pb, and 23kg of Zn.

    a) A typical porphyry copper deposit has an ore grade of 0.5% Cu (i.e. 0.005 g Cu per g of ore mined). With a metal recovery efficiency of 85%, how much total ore must be mined to get the Cu for each Lincoln?

b) Pure metals are commonly recovered from sulfide ores by successive processes of roasting in air (oxidation), dissolution in sulfuric acid and electrolysis (reduction). Consider the starting ore mineral sphalerite (ZnS). Write balanced chemical reactions for: (i) the oxidation of sphalerite with O_2 to produce zinc oxide. Note that the gas produced in this reaction is actually SO_3. (ii) Dissolution of the gas produced in reaction (i) to form sulfuric acid, (iii) dissolution of zinc oxide in sulfuric acid to form an ionic sulfate solution, and (iv) the reduction and oxidation processes that occur during electrolysis of a zinc sulfate solution (note: the oxidation reaction that takes place at the anode may not be obvious. It doesn't actually involve the sulfate ions ...).

c) In the roasting of sulfide ores, SO_2 is converted to SO_3 which in turn reacts with water in the atmosphere to form sulfuric acid. How many moles of sulfuric acid are generated per Lincoln Navigator? How many grams?

In addition to sphalerite (ZnS), for which you've already written the reaction, assume that the copper is derived from chalcopyrite ($CuFeS_2$) and the lead from galena (PbS).

6. For some elements such as phosphorus, human activity has strongly perturbed the natural cycle. Consider the case of a lake which (for simplicity) we will assume contained no dissolved phosphorus initially. Farming moved into the valley and run-off from the use of fertilizer added considerable quantities of P to the lake. This induced the growth of plants that removed dissolved P from lake water. The P is removed in proportion to how much is in the lake. In this case, every year the plants remove 15% of the P that is present. This system can be described by the following equation:

$$P = \frac{R}{\lambda}(1 - e^{-\lambda t})$$

where P = mass of phosphorus atoms at time t, R = rate of addition of phosphorus (assumed to be 1000 kg/yr), λ = fraction of P removed every year (assumed to be 0.15 yr^{-1}) and t = time (yr)

a) Produce a graph showing the change in mass of P in the lake over the first 35 years.

b) To within 1%, how much time is required for the P content to become constant?

c) What is the rate of increase of P mass at 1, 10 and 20 years after farming starts? Write an equation that describes the *rate* of increase of phosphorus as a function of time.

7. The solubility of SiO_2 in water depends on pH. From pH = 2 to pH = 11 the solubility of SiO_2 in millimoles/liter is roughly:

$$SiO_2(\text{millimol/l}) = 3.8 - 2.6 \, pH + 0.6 \, pH^2 - 0.03 \, pH^3.$$

a) Now we can measure the pH of a solution and with this equation determine the concentration of SiO_2. But we have an error in our pH measurements of ± 0.3 units.

Roughly, plot a graph of solubility *vs* pH to show qualitatively that the error in determining solubility varies depending on the pH of the system, even though our pH measurements have constant error.

b) Write an equation that gives the error in calculated solubility at any pH for this curve.

8. A stream in Nevada dissolves evaporites (predominantly halite) and transports the dissolved salt into a closed, slowly evaporating basin. The flux of evaporites into this basin is not continuous, but varies sinusoidally with a period of 100 years; i.e., over 100 years the flux goes from the average flux through a maximum, then through a minimum and back to the average flux. The average flux is 3,000 metric tons/year. The flux varies by ±150 tons/year from average to maximum and minimum, during each 100 year cycle. Given these conditions, the flux (Q) of halite as a function of time (T) is given by:

$$Q(T) = 3,000 + 150 * \sin(T * \pi/50)$$

a) Explain the origin of each of the constants (3000; 150 and $\pi/50$) in the equation above.

b) Calculate the integrated amount of halite (in metric tonnes) added to this lake for the 500 years following the time at which it first becomes a closed basin. Note – there is a simple way, and a more complicated way, to arrive at the answer.

c) Calculate the amount of halite (in metric tons) added to the lake after only 250 years. Why is this value not exactly one-half of the amount added after 500 years?

d) After adding approximately 26.5 g of halite to 1000 g of water, the solution is saturated with halite. If you assume constant volume of 151 cubic kilometers for the lake volume, how many years will it take for the lake to become saturated with halite? (Hint: Calculate the mass of water in the basin assuming a density of 1000 kg/m^3).