

**GG325 -- PRINCIPLES OF GEOCHEMISTRY**  
**Homework set #3 - Due on Wednesday 11/11**

**1. The oceans**

**a.** The annual input of  $\text{SO}_4^{2-}$  into the oceans by rivers is estimated to be  $3 \times 10^{12}$  mole/yr. If  $\text{SO}_4^{2-}$  were at a steady-state concentration in sea water and the only significant sulfate input to the oceans were the river flux, what would the residence time of  $\text{SO}_4^{2-}$  in the oceans be? The mass of the oceans is  $1.4 \times 10^{24}$  g and the  $\text{SO}_4^{2-}$  concentration in the oceans is 0.028 mol/kg

**b.** If there were no  $\text{SO}_4^{2-}$  flux out of the oceans to balance the above input flux, so that its concentration was constantly building up due to the river flux, how long would it take to increase the  $\text{SO}_4^{2-}$  concentration by 15%

**2. Hydrosphere composition**

**a.** What is the Alkalinity of seawater of the following composition:

$\text{Na}^+$	0.481 M	$\text{Cl}^-$	0.560 M
$\text{Mg}^{2+}$	0.0544 M	$\text{SO}_4^{2-}$	0.0283 M
$\text{Ca}^{2+}$	0.011 M	$\text{HCO}_3^-$	0.00238 M
$\text{K}^+$	0.011 M		

**b.** write the charge balance equation for this solution and substitute in the numbers above. Is this solution balanced? If not, what other ion(s) that are not listed might be present in seawater to help balance the charge?

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**3 Weathering**

A sediment has a CEC of 70 meq/100 g. The following exchangeable cations make up the CEC: Ca<sup>2+</sup>, Mg<sup>2+</sup>, Na<sup>+</sup>, K<sup>+</sup> and H<sup>+</sup>. The first 4 were measured at concentrations of 19, 5.9, 4.1 and 1.2 meq/100g, respectively. What is the ECS of H<sup>+</sup> on this sediment?

**4. Soils**

a. Name 2 chemicals (or minerals) that precipitate from soil water as the pH changes

b. what is the name of the soil zone where the precipitation occurs?

**5. Paleoclimate**

The equilibrium temperature dependent law for O isotope fractionation between water (H<sub>2</sub>O, described by  $\delta_w$ ) and calcite (CaCO<sub>3</sub>, described by  $\delta_c$ ) and is:

$$T (^{\circ}\text{C}) = 16.0 - 4.14 (\delta_{c(\text{PDB})} - \delta_{w(\text{PDB})}) + 0.13 (\delta_{c(\text{PDB})} - \delta_{w(\text{PDB})})^2$$

However, the observed fractionation of oxygen isotopes between seawater and their calcareous shells for many planktonic foraminifera (described by  $\delta_f$ ) follows a different but similar temperature dependent law:

$$T (^{\circ}\text{C}) = 16.5 - 4.3 (\delta_{f(\text{PDB})} - \delta_{w(\text{PDB})}) + 0.14 (\delta_{f(\text{PDB})} - \delta_{w(\text{PDB})})^2$$

in both of the above equations, all  $\delta$ 's are on the PDB scale and refer to <sup>18</sup>O/<sup>16</sup>O ratios [from Berger and Gardner, Journal of Foraminiferal Research, vol. 5, p 102-113 (1975)].

To solve problems using either equation, you will need to use the quadratic formula.

The general form for  $ax^2 + bx + c = 0$  is

$$x = \frac{-b \pm (b^2 - 4ac)^{1/2}}{2a}$$

2a

*(Remember, there are 2 roots when you use this equation; in our case, only 1 will "make sense" -i.e., will have a reasonable  $\delta^{18}\text{O}$  value, and thus be the correct answer)*

**5a.** Explain why these organisms do not follow the chemical equilibrium rate law

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**5b.** Assume that equatorial seawater today has  $\delta_{w(\text{SMOW})} = 0\text{‰}$  and mean surface temperature =  $28^{\circ}\text{C}$ . What would  $\delta_{f(\text{PDB})}$  be in foram shells formed in this locations?

**5c.** Let's say that in the worst case scenario for anthropogenically induced greenhouse warming the sea level temperature at the equator increases by  $1^{\circ}\text{C}$ . What would  $\delta_{f(\text{PDB})}$  be in foram shells growing there assuming that  $\delta_{w(\text{SMOW})} = 0\text{‰}$  (i.e., the same as in 5b)?

**5d.** Now let's say that during this temperature shift, 10% of the volume of polar icecaps melt and this water, with  $\delta_{w(\text{SMOW})} = -55\text{‰}$ , is distributed evenly in the top 100m of the oceans. What would  $\delta_{f(\text{PDB})}$  be in foram shells growing there assuming that the only effect is the addition of the isotopically-light melt water (i.e., ignore the temperature change calculated in c)?

*Hint:* The volume of the oceans and polar icecaps are  $1370 \times 10^6 \text{ km}^3$  and  $29 \times 10^6 \text{ km}^3$ , respectively. Assume that the oceans are rectangular in shape with a uniform depth of 4000m. Ice melt adds to the surface ocean to change the oxygen isotopic values. To get the revised  $\delta_{w(\text{SMOW})}$  of seawater, calculate the proportion of oceanic volume in the top 100 m relative to the entire oceans, add the melt water to this to make a "new" expanded top layer of  $(100+x)\text{m}$  depth,  $x$  being that added from melt water. This new  $\delta_{w(\text{SMOW})}$  can be assumed to isotopically shifted equally at all latitudes.