GEO 2303
April 29, 2008
Due: May 7, 2008

PROBLEM SET #10

1.) Assume that the reaction $CaCO_3 + CO_2 + H_2O = Ca^{2+} + 2HCO_3^-$ is at an equilibrium at 1 km depth (about 3 bars pressure) in the hydrothermal spring system of Yellowstone National Park.

   a.) What will happen as the fluid ascends to the surface (1 bar pressure), assuming there is no change in the temperature of the fluid?
   b.) What will happen if the fluid is diluted near the surface by shallow level groundwater that is nearly pure H_2O?
   c.) What will happen if during the ascent the fluid is mixed with another hydrothermal fluid of different origin containing mainly $NaHCO_3$ (assume $NaHCO_3$ is completely dissociated)?

The following three problems are from Chapter 17 in your text book:

2.) Problem #1

3.) Problem #4

4.) Problem #8

5.) Look at your answer to the previous problem and the example provided. Why do you think the measured $\delta^{18}O$ values of water in fluid inclusions in calcite or quartz cannot be used to determine the temperature of formation of these minerals? (Hint: Even though you can't use directly measured $\delta^{18}O$ values of water in fluid inclusions, you can use direct measurements of δD (D is ^2H) in the fluid inclusions and use the meteoric water line equation to get the $\delta^{18}O$ value. Why δD in the fluid but not $\delta^{18}O$?)

6.) The data in the attached table indicate that different minerals in igneous and metamorphic rocks tend to have different $^{18}O/^{16}O$ ratios. For example, quartz in igneous rocks usually has a higher $\delta^{18}O/^{16}O$ value than K-feldspar. What property of minerals would be important in controlling $^{18}O/^{16}O$ ratios?

7.) If you analyze a foram that formed during the last glacial maximum and one that formed today you will find the $\delta^{18}O$ in today's foram is 1.8‰ lower than the $\delta^{18}O$ of the foram that formed during the last glacial maximum. You can also measure pore fluids from the last glacial maximum and find that the $\delta^{18}O$ of today's seawater is 1‰ lower than the porewater that represents seawater from the last glacial maximum.

   Therefore, you know the change in $\delta^{18}O$ for seawater and for calcite (Forams are little critters that make calcite shells.) What was the temperature change between the last glacial maximum and today?

   HINT: $d\delta^{18}O_{calcite}/dT = -0.22$ ‰/°C for constant $\delta^{18}O_w$.
   Changes in $\delta^{18}O_w$ and $\delta^{18}O_c$ are roughly equal.
   You may assume any additional changes in $\delta^{18}O_c$ are due to temperature.

Table: General range of $^{18}O/^{16}O$ ratios (relative to VSMOW)
(Source: Modified from Taylor, 1967, P109-142)

Material	δ value range (‰)
Meteorites	
Achodrites	4-5
Chondrites	5-6
Carbonaceous chondrites	-1 to +12
Igneous rocks	
Granite pegmatites	7-14
Granites and quartz monzonites	7-9
Basalts and gabbros	6-7
Ultramafic rocks	5-6
Igneous minerals	
Quartz	8.9-10.3
K-feldspar	7.0-9.1
Plagioclase	6.5-9.1
Hornblende	5.9-6.9
Pyroxene	5.5-6.3
Biotite	4.4-6.6
Magnetite	1.0-3.0
Metamorphic rocks	
Marbles	15-27
Pelitic schists	12-18
Quartzites	10-15
Amphibolites	7-13
Metamorphic minerals	
Quartz	8-19
Pagioclase	7-14
Muscovite	6-20
Biotite	4-11
Garnet	4-12
Ilmentie	3-17
Magnetite	6-7
Chlorite	3-9
Sedimentary rocks	
Marine limestones	22-30
Freshwater limestones	18-25
Arkosic sandstones	12-16
Shales	14-19
Cherts and diatomites	28-36
Waters	
Ocean water	-0.5 to +0.5
Temperate fresh water	-10 to -4
Snow and ice	-40 to -20
Meteoric and geothermal waters	-24 to -7