

Solution 10:

1). Assume that the reaction $\text{CaCO}_3 + \text{CO}_2 + \text{H}_2\text{O} = \text{Ca}^{2+} + 2\text{HCO}_3^-$ is at equilibrium at 1 km depth (about 3 bars pressure) in the hydrothermal spring system in the Yellowstone Nation 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.

Decompression occurs, i.e. loss of CO_2 . The reaction goes to left. Calcite precipitates.

b). What will happen if the fluid is diluted near the surface by shallow level groundwater that is nearly pure H_2O ?

H_2O is added, so the reaction goes to right. Calcite dissolves.

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)?

HCO_3^- is added, so the reaction goes to left. Calcite precipitates.

2.) (Problem #1 from book)

$T = 10^\circ\text{C}$, $\delta^{18}\text{O}_l = -10.0\text{‰}$, $\alpha_v^l = 1.0105$, $\delta^{18}\text{O}_v = ?$.

$$\begin{aligned}\alpha_{b}^a &= (\delta^{18}\text{O}_a + 10^3) / (\delta^{18}\text{O}_b + 10^3) \\ \alpha_v^l &= (\delta^{18}\text{O}_l + 10^3) / (\delta^{18}\text{O}_v + 10^3) \\ \delta^{18}\text{O}_v &= (\delta^{18}\text{O}_l + 10^3) / \alpha_v^l - 10^3 \\ &= (-10.0\text{‰} + 10^3) / 1.0105 - 10^3 \\ &= -20.3\text{‰}\end{aligned}$$

3.) (Problem #4 from book)

$\alpha_v^l(D) = 1.074$, $f = 0.45$, $\delta D_v^0 = -94.8\text{‰}$, $\delta D_v = ?$.

$$\begin{aligned}R_v &= R_v^0 * f^{-1}, R_v / R_v^0 = (\delta D_v + 10^3) / (\delta D_v^0 + 10^3) \\ \delta D_v &= (\delta D_v^0 + 10^3) * f^{-1} - 10^3 \\ &= (-94.8 + 10^3) * 0.45^{(1.074 - 1)} - 10^3 \\ &= -146.7\text{‰}\end{aligned}$$

4.) (Problem #8 from book)

$\delta D_w = -175\text{‰}$, $\delta^{18}\text{O}_c = 10.0\text{‰}$, $T = ?$.

I, calculate $\delta^{18}\text{O}_w$.

$$\delta D_w = 8 * \delta^{18}\text{O}_w + 10$$

$$\delta^{18}\text{O}_w = (\delta\text{D}_w - 10) / 8 = (-175 - 10) / 8 = -23.1\text{‰}$$

II. calculate the fractionation factor between water and calcite.

$$\begin{aligned}\alpha_w^c &= (\delta^{18}\text{O}_c + 10^3) / (\delta^{18}\text{O}_w + 10^3) \\ &= (10.0 + 1000) / (-23.1 + 1000) \\ &= 1.0339\end{aligned}$$

III. calculate the temperature of deposition.

$$\begin{aligned}10^3 \ln(\alpha_w^c) &= 2.78 * 10^6 / T^2 - 2.89 \\ T^2 &= 2.78 * 10^6 / (10^3 \ln(\alpha_w^c) + 2.89) \\ T^2 &= 76736.1 \\ T &= 277.01 \text{ K} = 3.86^\circ\text{C}\end{aligned}$$

5.) The $\delta^{18}\text{O}$ values of H₂O in fluid inclusions in calcite or quartz cannot be used to determine the temperature of formation of these minerals because the oxygen in the water will re-equilibrate with the oxygen in the minerals as they warm and cool. δD can be used to calculate the original $\delta^{18}\text{O}$ of the fluid inclusion because there is no hydrogen in either calcite or quartz for the water's hydrogen to equilibrate with.

6.) In minerals, the strength of the cation-O bond controls the $^{18}\text{O}/^{16}\text{O}$ ratio. Stronger cation to oxygen bonds tend to concentrate ^{18}O . Quartz contains only Si-O bonds, while K-spar contains both Si-O and Al-O bonds. Since $\delta^{18}\text{O}$ in quartz is higher than $\delta^{18}\text{O}$ in K-spar, the Si-O bond must be stronger than the Al-O bond.

7.)

$$\begin{aligned}\Delta\delta^{18}\text{O}_c &= \delta^{18}\text{O}_c^{\text{present}} - \delta^{18}\text{O}_c^{\text{LGM}} = -1.8\text{‰} \\ \Delta\delta^{18}\text{O}_w &= \delta^{18}\text{O}_w^{\text{present}} - \delta^{18}\text{O}_w^{\text{LGM}} = -1.0\text{‰} \\ d\delta^{18}\text{O} / dT &= -0.22\text{‰} / ^\circ\text{C} \text{ at constant } \delta^{18}\text{O}_w\end{aligned}$$

I, Subtract of the change of $\delta^{18}\text{O}$ in the seawater.

$$\Delta\delta^{18}\text{O}_{c-T} = -0.8\text{‰}$$

This is the portion of the $\delta^{18}\text{O}_c$ change that is controlled by temperature.

II, Calculate the temperature change.

$$\begin{aligned}dT &= d\delta^{18}\text{O} / (-0.22\text{‰} / ^\circ\text{C}) \\ &= (-0.8 \text{‰} / -0.22\text{‰} / ^\circ\text{C}) \\ &= 3.6^\circ\text{C}\end{aligned}$$

Therefore, based on this foram data, it is about 3.6°C warmer today than it was during the last glacial maximum.