Example Exam Question (Fall 1996)
ERS 100

Note: This exam question was slightly altered, since the original question was not set up correct. Assume that the precipitation of $CaSO_4$ occurs at exactly the end of the river…

1)
In a 240-km reach of a 2-m wide river flowing in a well defined channel from the high to low desert regions of New Mexico, the river water quality changes from a $CaCO_3$ to predominantly NaCl-$MgSO_4$ type water. During a 14-day long snowmelt period at the headwaters of this reach, the flowrate is 1.2 m^3/sec and the Ca concentration is 15 mg/L. Assuming that there are no water diversions, that river seepage is negligible, and that $CaCO_3$ precipitation is negligible as compared to $CaSO_4$ precipitation due to CO_2 limits, estimate the net river evaporation (cm/day) during the snowmelt period. What is the flowrate (m^3/sec) at the end of the reach? (M.W. Ca = 40 g/mole, C = 12 g/mole, O = 16 g/mole and S = 32 g/mole).

Solution

We can calculate the concentration of Ca at the end of the river, because we know it precipitates there according the following reaction:

$$Ca^{2+} + SO_4^{2-} \Leftrightarrow CaSO_4\,(s)$$

From table 10.13 in the book, we find that

$$K_{SO} = 2.57 * 10^{-5}\ [\text{liters}^2/\text{moles}^2]$$

$$K_{SO} = [Ca]*[SO_4]$$

Thus,

$$[Ca] = 5.07*10^{-3}\ \text{moles/L}$$

To rewrite this in the same units as our initial concentration, multiply by the Molecular Weight:

$$5.07*10^{-3} * 40\ \text{g/mole} = 0.203\ \text{g/L} = 203\ \text{mg/L}$$

In between the beginning and the end of the river, the concentration of [Ca] changes from 15 mg/L to 203 mg/L.

Since there are no water losses in the river other than evaporation, and since evaporation only removes water from the river and not salts, we can assume that this increase of [Ca] is caused by evaporation.

To calculate the outflow of the river, we can set up a mass balance for Calcium:

$Vol[Ca]^{IN} = Vol[Ca]^{OUT}$ since there are no sinks or sources in the river.

$Q^{in} * \Delta t * [Ca]^{IN} = Q^{out} * \Delta t * [Ca]^{OUT}$

$Q^{out} = [Ca]^{IN}/[Ca]^{OUT} * Q^{in}$

$Q^{out} = 88.8$ L/s

[THIS IS ANSWER TO QUESTION 2]

To calculate the evaporation, set up a water balance

$\Delta t * Q^{in} = \Delta t * Q^{out} + E$

$E = 1.34 * 10^6\ m^3$ for 14 days

Evap is required in cm/day, hence we need to divide by area of the river (240 km x 2 m)

E = 2.8 m for 14 days

E = 20 cm per day

THIS VALUE IS THE CORRECT ANSWER, BUT DOES NOT MAKE ANY REAL WORLD SENSE…

Keep in mind what the method is.
1) Determine concentrations
2) Determine mass balance of solids
3) Determine corresponding mass balance for water