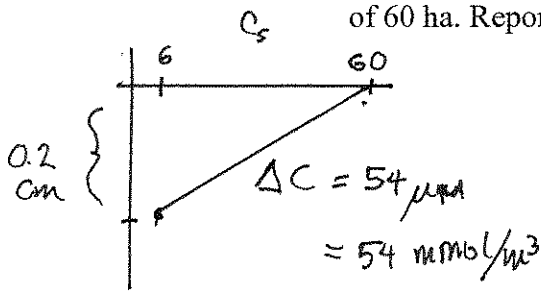


Note: Write out your calculations clearly in the space provided and place your final answer in a box. If a calculation is needed and you do not support your answer with written calculations, you will receive no credit, even if you write the correct answer in the box. Also be sure your answer matches the UNITS requested.

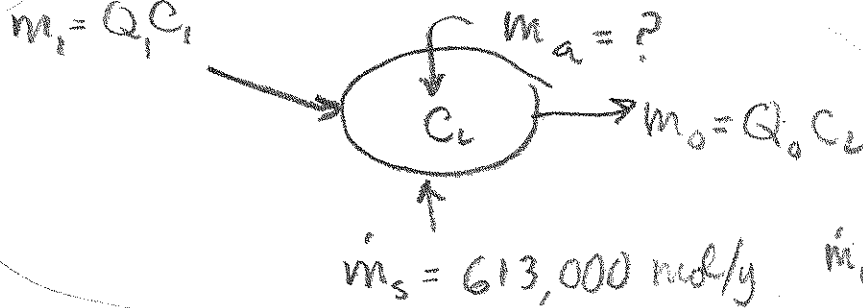
1. [20 pts] A lake has a seasonally averaged sulfate concentration of 60 μM at the sediment-water interface but only 6 μM at a depth of 0.20 cm below the interface. (Presumably sulfate is being removed by anaerobic sulfate-reducing bacteria.)

- a. How much sulfate can be removed each year from this lake by diffusion into the sediment? Assume an effective diffusion coefficient of $1.2 \times 10^{-9} \text{ m}^2/\text{s}$ and a lake area of 60 ha. Report in moles/yr.



$$\begin{aligned} \dot{m} &= JA = [600,000 \text{ m}^2] \cdot (1.2 \times 10^{-9} \frac{\text{m}^2}{\text{s}}) \left(\frac{54 \text{ mmol}}{0.002 \text{ m}^3 \cdot \text{m}} \right) \\ &= (19.4 \text{ mmol/s}) (86,400 \text{ s/d}) (365 \text{ d/y}) (10^{-3}) \\ &= \boxed{613,000 \text{ mol/y} = 6.13 \times 10^5 \frac{\text{mol}}{\text{y}}} \end{aligned}$$

- b. The lake has an inflow of $6.0 \times 10^6 \text{ m}^3/\text{yr}$ and the sulfate concentration in that inflow is 62 μM . Outflow is $5.5 \times 10^6 \text{ m}^3/\text{yr}$ and the sulfate concentration in that inflow is 60 μM . If the only other source of sulfate input or loss is atmospheric deposition (dust and rainfall), estimate the annual atmospheric input of sulfate into the lake. Report in moles/yr. Assume the lake is well mixed and has no seasonal stratification.



$$m_i - m_o + m_s + m_a = 0$$

$$-m_a = (372,000) - (330,000) - (613,000)$$

$$\boxed{m_a = +571,000 \frac{\text{mol}}{\text{y}}}$$

$$\boxed{5.7 \times 10^5 \text{ mol/y}} \quad 1$$

$$\begin{aligned} m_i &= (6 \times 10^6 \frac{\text{m}^3}{\text{y}}) (62 \times 10^{-3} \frac{\text{mol}}{\text{m}^3}) \\ &= 372,000 \end{aligned}$$

$$\begin{aligned} m_o &= (5.5 \times 10^6 \frac{\text{m}^3}{\text{y}}) (60 \times 10^{-3} \frac{\text{mol}}{\text{m}^3}) \\ &= -330,000 \end{aligned}$$

$$m_s = -613,000 \frac{\text{mol}}{\text{y}}$$

Q.3. Actual solution for 2nd order decay



$$R = k'[A][B] \text{ and } A_0 = B_0$$

SOL'N:

$$\frac{1}{[A]_t} - \frac{1}{[A]_0} = k' t$$

where $[A]_t$ = conc. at time t
 $[A]_0$ = initial conc.

← The missing piece

Substitute $[A]_t = 0.2 [10 \text{ mM}]$ ("20% of initial value")

$$\frac{1}{2 \text{ mM}} - \frac{1}{10 \text{ mM}} = (180 \text{ mM}^{-1} \text{ h}^{-1}) t$$

$$0.5 - 0.1 \text{ mM}^{-1} = (180 \text{ mM}^{-1} \text{ h}^{-1}) t$$

$$t = \frac{0.4 \text{ mM}^{-1}}{180 \text{ mM}^{-1} \text{ h}^{-1}} = 0.02 \text{ h} = \boxed{80 \text{ s}}$$

yep, Disappears pretty fast (minutes)

4. True story. In the 1970s, large amounts of waste products from the production of Agent Orange herbicide were disposed of in shallow trenches near Alkali Lake in South Central Oregon. (The Agent Orange was produced in Portland for use in the Vietnam War.) A principal toxic contaminant at the site was pentachlorophenol (commonly called "penta"). Although the site has been covered over with gravel, most of the pentachlorophenol is still in the ground. Let us assume that pure NAPL pentachlorophenol has seeped through groundwater from the disposal site and is pooled in small quantities on the bottom of Alkali Lake. Because of the wet spring in 2014, Alkali Lake actually has water in it (in dry years it is a dry desert playa). **Question:** What is the maximum possible concentration of penta in the air above the surface of the lake?

$$C_{\max}^w = \text{Solubility limit} = 14 \text{ mg/L (Table 1-2)}$$

$$C_a = HC_w = (1.5 \times 10^{-4})(14 \text{ mg/L})$$

$$= \boxed{2.1 \times 10^{-3} \text{ mg/L}} = \boxed{2.1 \text{ } \mu\text{g/L}}$$

5. The hypolimnion of a pond is anoxic in late summer and contains total sulfide ($= [\text{H}_2\text{S}] + [\text{HS}^-] + [\text{S}^{2-}]$) at a concentration of 10 mM. The hypolimnetic water is quite alkaline and has a pH = 9.3. If the sediments are contaminated with cadmium, what is the solubility of Cd^{2+} in the hypolimnion water in units of mol/L? Neglect activity correction and hydrolysis reactions.

$$K_{sp} = [\text{Cd}^{2+}][\text{S}^{2-}] = 10^{-27.0}$$

$$S_T = 1 \times 10^{-2} \text{ M} \quad \text{For } \text{H}_2\text{S}: pK_{a1} = 7.0 \bullet$$

Hence at pH 9.3

$$pK_{a2} = 13.9 \bullet$$

almost all sulfide is $[\text{HS}^-]$

$$[\text{HS}^-] \approx S_T = 10^{-2.0} \text{ M} \rightarrow$$

$$\frac{[\text{S}^{2-}][\text{H}^+]}{[\text{HS}^-]} = 10^{-13.9}$$

$$\therefore [\text{S}^{2-}] = \frac{10^{-13.9}}{10^{-9.3}} \cdot 10^{-2.0} = 10^{-6.6} \text{ M}$$

$$[\text{Cd}^{2+}] = \frac{10^{-27.0}}{10^{-6.6}} = \boxed{10^{-20.4} \text{ M}} = \underline{4.5 \times 10^{-19} \text{ g/L}}$$

VERY SMALL!

6. Match up the following
[10 pts]

- | | | |
|---------------------------|----------|--|
| a. Hydrophobic | <u>i</u> | Laminar interfacial layer |
| b. Mass action law | <u>j</u> | Overall charge of the solution |
| c. AVS | <u>g</u> | Pure phase |
| d. Temperature correction | <u>f</u> | Ionic strength |
| e. Catalyst | <u>h</u> | Reaeration coefficient times depth |
| f. Activity correction | <u>e</u> | Unchanged after going through reaction |
| g. NAPL | <u>a</u> | Nonpolar |
| h. Piston velocity | <u>b</u> | Reaction quotient at equilibrium |
| i. Thin-film model | <u>d</u> | Arrhenius equation |
| j. Electroneutrality | <u>c</u> | Amorphous iron sulfide |