

Q1/ a) $\alpha_{\text{NiOH}^+} = \frac{[\text{NiOH}^+]}{[\text{Ni}^{2+}] + [\text{NiOH}^+] + [\text{Ni}(\text{OH})_2]}$

≈ 0.33 at $\text{pH} = 9.5$

where $[\text{Ni}^{2+}] = [\text{NiOH}^+] = [\text{Ni}(\text{OH})_2]$



since $[\text{Ni}^{2+}] > [\text{NiOH}^+]$ at all pH's

$[\text{NiOH}^+]$ is more acidic than $[\text{Ni}^{2+}]$
and therefore never dominates on
pH speciation diagram.

Q2/ $\Omega_{\text{CaCO}_3} = \frac{Q_{\text{sp}}}{K_{\text{sp}}} = \frac{[\text{Ca}^{2+}][\text{CO}_3^{2-}]}{K_{\text{sp}}}$

where $[\text{CO}_3^{2-}]_T = [\text{CO}_2(\text{aq})] + [\text{HCO}_3^-] + [\text{CO}_3^{2-}]$

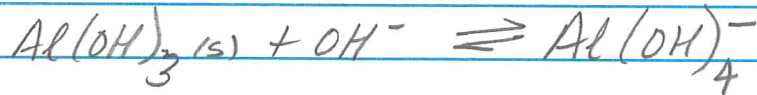
and $[\text{alk}]_T = [\text{HCO}_3^-] + 2[\text{CO}_3^{2-}] + [\text{OH}^-] \approx [\text{HCO}_3^-]$

$\therefore [\text{CO}_3^{2-}] = [\text{CO}_3^{2-}]_T - [\text{CO}_2(\text{aq})] - [\text{HCO}_3^-]$

$= [\text{CO}_3^{2-}]_T - K_H P_{\text{CO}_2} - [\text{alk}]_T$

$\therefore \Omega_{\text{CaCO}_3} = \frac{[\text{Ca}^{2+}] \left([\text{CO}_3^{2-}]_T - K_H P_{\text{CO}_2} - [\text{alk}]_T \right)}{K_{\text{sp}}}$

Q3/ Solubility at pH = 9.00



$$K_{f4} = \frac{[\text{Al(OH)}_4^-]}{[\text{OH}^-]} = 0.89$$

$$\therefore [\text{Al(OH)}_4^-] = (0.89)(1.00 \times 10^{-5})$$

$$= 8.9 \times 10^{-6} \text{ M}$$

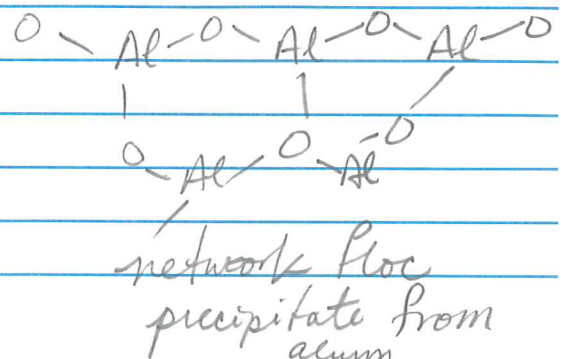
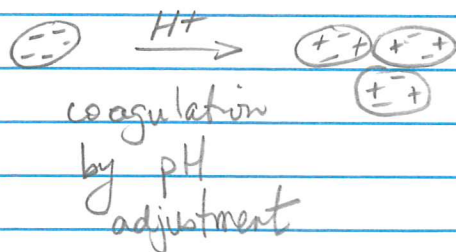
$$\text{Conc. in solution} = \left(8.9 \times 10^{-6} \frac{\text{mol}}{\text{L}} \right) \left(\frac{26.98 \text{ g}}{\text{mol}} \right) \left(\frac{10^3 \text{ mg}}{\text{g}} \right)$$

ppm Al

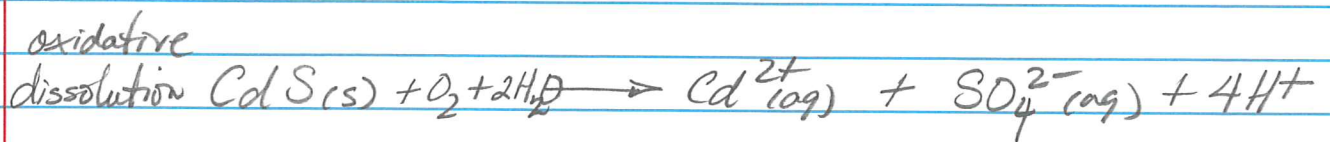
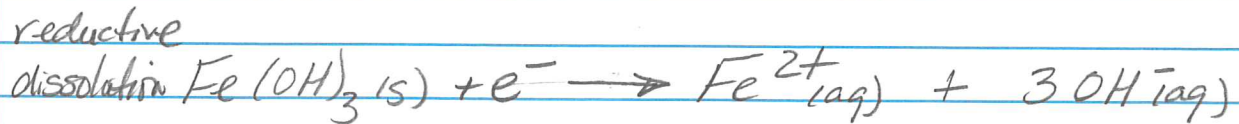
$$= 0.24 \text{ mg/L} = 0.24 \text{ ppm Al}$$

Q4/a)

i) coagulation and flocculation are both used to clarify water by removing colloidal solids. Coagulation occurs by reducing ~~sa~~ repulsive forces arising from surface charge. Flocculation occurs by forming a flocculate precipitate which settles slowing attracting and trapping colloidal material.



ii) reductive dissolution and oxidative dissolution occur when a change in oxidation state results in a solid dissolving. Significant in that adsorbates will be released to solution as solid dissolves.



iii) K_{ow} and BCF relate to hydrophobic character of a contaminant

$$K_{ow} = \frac{[X(\text{octanol})]}{[X(\text{aq})]}$$

measured by difference in solubility in n-octanol relative to water

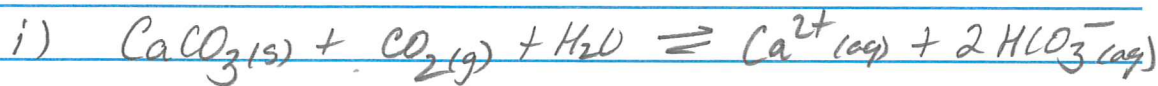
$$\text{BCF} = \frac{[X(\text{organism})]}{[X(\text{aq})]}$$

measured by relative concentration in aquatic organism versus in water

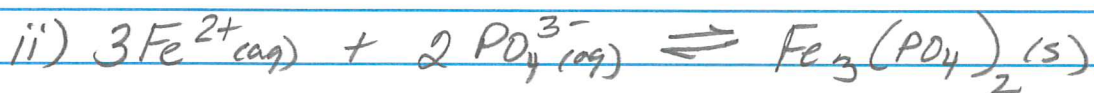
Generally, higher K_{ow} leads to higher BCF

$$\log K_{ow} = a \log \text{BCF} + b$$

4 b)



high P_{CO_2} will lead to equilibrium shifting to RIGHT, thus more $\text{CaCO}_3(s)$ will dissolve.



as pH increases the conc. of PO_4^{3-} increases, resulting in more precipitation of $\text{Fe}_3(\text{PO}_4)_2(s)$



hexameta phosphate forms strong complex with calcium ion, thus effectively removing Ca^{2+} from solution and more calcium stearate dissolves.

Q5/

mass CH_2O to consume $\text{O}_2(\text{aq})$ in saturated solution at 25°C



$$K_H = 1.3 \times 10^{-8} \text{ M Pa}^{-1} \quad \text{at } P_{\text{O}_2} = 0.2095 \text{ atm} \\ \times \frac{101,300 \text{ Pa}}{\text{atm}}$$

$$\therefore [\text{O}_2(\text{aq})] = K_H \cdot P_{\text{O}_2} = 21.2 \times 10^4 \text{ Pa}$$

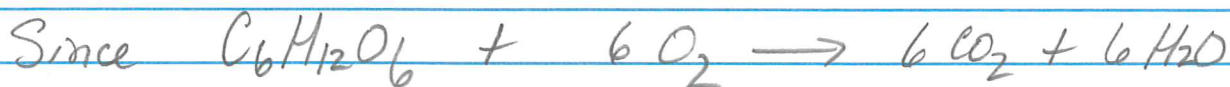
$$= \left(\frac{1.3 \times 10^{-8} \text{ M}}{\text{Pa}} \right) (21.2 \times 10^4 \text{ Pa})$$

$$= 2.76 \times 10^{-4} \text{ M}$$

So #mols of CH_2O consumed in one liter
 $= 2.76 \times 10^{-4} \text{ mol}$

$$\text{mass} = (2.76 \times 10^{-4} \text{ mol}) (30.0 \text{ g/mol})$$

$$= 8.28 \times 10^{-3} \text{ g} \quad \text{or} \quad 8.28 \text{ mg}$$



therefore #mols of $\text{C}_6\text{H}_{12}\text{O}_6$ is $\frac{1}{6}$ th
of #mols O_2 , but molar mass is $6 \times$ greater

$$\therefore 8.28 \text{ mg of } \text{C}_6\text{H}_{12}\text{O}_6$$

Q6/



$$K_f' = \frac{[\text{Ca-FAco}_2^-]}{[\text{Ca}^{2+}]_f [\text{FAco}_2^-]_f} = 1.0 \times 10^3$$

$$[\text{Ca}^{2+}]_T = 1.0 \times 10^{-3} \frac{\text{mol}}{\text{L}} = [\text{Ca}^{2+}]_f + [\text{Ca-FAco}_2^-]$$

$$[\text{FAco}_2^-]_T = 500 \frac{\mu\text{g}}{\text{L}} \times 5.0 \times 10^{-3} \frac{\text{mol}}{\text{g}} \times \frac{1 \text{ g}}{10^6 \mu\text{g}}$$
$$= 2.5 \times 10^{-6} \text{ mol/L}$$

$$= [\text{FAco}_2^-]_f + [\text{Ca-FAco}_2^-]$$

$$K_f' = \frac{x}{(1.0 \times 10^{-3} - x)(2.5 \times 10^{-6} - x)}, \text{ where } x \text{ represents } [\text{Ca-FAco}_2^-]$$

Since $x \ll 2.5 \times 10^{-6} \text{ M}$

$$K_f' = \frac{x}{(1.0 \times 10^{-3})(2.5 \times 10^{-6} - x)} = 1.0 \times 10^3$$

$$x = (2.5 \times 10^{-9} - 1.0 \times 10^{-3} x) 1.0 \times 10^3$$

$$x = 2.5 \times 10^{-6} - x$$

$$2x = 2.5 \times 10^{-6}$$

$$\therefore x = 1.25 \times 10^{-6} \text{ M}$$

$$\alpha_{\text{CaFAco}_2} = \frac{1.25 \times 10^{-6} \text{ M}}{2.5 \times 10^{-6} \text{ M}}$$
$$= 0.50$$

50% FA bound

$$Q7/ \quad 8.8 \text{ ppm } \text{PO}_4\text{-P} \times \frac{1 \text{ mol}}{30.97 \text{ g}} \times \frac{1 \text{ g}}{10^3 \text{ mg}}$$

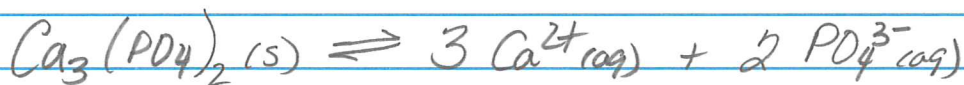
$$[\text{PO}_4^{3-}]_T = 2.84 \times 10^{-4} \frac{\text{mol}}{\text{L}}$$

$$\text{pH} = 9.0$$

$$\therefore [\text{H}^+] = 10^{-9.0} = 1.0 \times 10^{-9} \text{ M}$$

$$[\text{OH}^-] = 1.0 \times 10^{-5} \text{ M}$$

$$[\text{Ca}^{2+}] = 4.7 \times 10^{-3} \text{ M}$$



$$K_{sp} = [\text{Ca}^{2+}]^3 [\text{PO}_4^{3-}]^2 = 1. \times 10^{-24}$$

$$\therefore [\text{PO}_4^{3-}] = \sqrt{\frac{1. \times 10^{-24}}{(4.7 \times 10^{-3})^3}} = 3.1 \times 10^{-9} \text{ M}$$

$$[\text{PO}_4^{3-}]_T = [\text{H}_3\text{PO}_4] + [\text{H}_2\text{PO}_4^-] + [\text{HPO}_4^{2-}] + [\text{PO}_4^{3-}]$$

minor at
pH = 9.0

$$K_{a3} = \frac{[\text{H}^+][\text{PO}_4^{3-}]}{[\text{HPO}_4^{2-}]}$$

$$\therefore [\text{PO}_4^{3-}] \approx 7.4 \times 10^{-6} \text{ M}$$

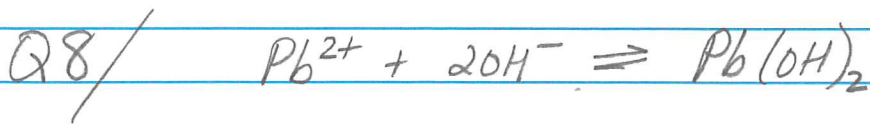
$$\times \frac{30,970 \text{ mg}}{\text{mol}}$$

$$= 0.23 \text{ ppm P}$$

$$\therefore [\text{HPO}_4^{2-}] = \frac{[\text{H}^+][\text{PO}_4^{3-}]}{K_{a3}}$$

$$= \frac{(1.0 \times 10^{-9})(3.1 \times 10^{-9})}{(4.2 \times 10^{-13})}$$

$$= 7.39 \times 10^{-6} \text{ M}$$



$$\beta_2 = \frac{[Pb(OH)_2]}{[Pb^{2+}][OH^-]^2}$$

boundary between $Pb^{2+}/PbOH^+$ occurs when

$$[Pb^{2+}] = [PbOH^+]$$

$$\therefore K_{f1} = \frac{[PbOH^+]}{[Pb^{2+}][OH^-]} = \frac{1}{[OH^-]} \text{ at boundary pH} = 7.5$$

$$\therefore K_{f1} = \frac{1}{10^{-6.5}} = 3.2 \times 10^6$$

Similarly for $PbOH^+/Pb(OH)_2$ boundary at $pH = 9.4$

$$K_{f2} = \frac{[Pb(OH)_2]}{[PbOH^+][OH^-]} = \frac{1}{[OH^-]}$$

$$\therefore K_{f2} = \frac{1}{10^{-4.6}} = 3.9 \times 10^4$$

$$\beta_2 = K_{f1} \cdot K_{f2} = 1.3 \times 10^{11}$$