

**Question 1**

- (a) State the meaning of saturation index of a system.
- (b) A spring water sample was obtained from Spring Valley, Baddulla. The water had a calcium ion activity of  $10^{-3.04}$  and carbonate activity of  $10^{-5.56}$ . The  $\text{CaCO}_3$  solubility free energy is shown as  $\Delta G_r^0 = 47.8 \text{ kJ/mol}$ . Is the in equilibrium with calcite, if not is calcite tending to dissolve or precipitate?
- (c) Water is in equilibrium with calcite in an open environment. Explain all relevant chemical reactions that can occur.
- (d) Prove that the proton activity of the water sample stated in Section (c) is given by  $a_{\text{H}^+}^3 = \frac{p_{\text{CO}_2}^2 K_1^2 K_2^2}{2K_{\text{calcite}}}$ . State all assumptions made.

**Question 2**

- (a) Prove that the buffer capacity of distilled water is  $2.303([H^+] + [OH^-])$ .
- (b) What is the minimum buffer capacity value that a natural system can obtain at  $25^\circ\text{C}$ .
- (c) Explain the meaning of closed  $\text{CO}_2$  - water system. Write all chemical reactions needed for different carbonate species estimation.
- (d) Prove that for a closed  $\text{CO}_2$  -  $\text{H}_2\text{O}$  system that

$$[\text{HCO}_3^-] = \frac{C_T}{\frac{[H^+]}{K_1} + 1 + \frac{K_2}{[H^+]}}$$

where  $C_T$  is the total concentration of all carbon species and  $K_1$  and  $K_2$  are mass action coefficients of  $\text{H}_2\text{CO}_3$  dissociation.

**Question 3**

- (a) Discuss the similarities between acid - base and redox processes.
- (b) Why are Eh values that are determined by reading the potential of a Pt electrode versus a reference electrode generally are not meaningful?
- (c) Write down the half redox reaction involving  $\text{NO}_3^-$  into  $\text{NH}_4^+$ . If the concentrations of  $\text{NO}_3^-$  and  $\text{NH}_4^+$  are  $10^{-5} \text{ M}$  and  $10^{-3} \text{ M}$  respectively at PH of 8. Calculate the pe and Eh of the system at  $25^\circ\text{C}$  ( $G_{\text{H}_2\text{O}}^0 = -237.1 \frac{\text{kJ}}{\text{mol}}$ ;  $G_{\text{HH}^+}^0 = -79.4 \text{ kJ/mol}$ ;  $G_{\text{NO}_3^-}^0 = -110.8 \text{ kJ/mol}$ )
- (d) Draw the redox ladder when using following species in water. Assume organic carbon is the electron donor. Oxygen, nitrate,  $\text{Fe}^{2+}$ ,  $\text{Mn}^{2+}$ ,  $\text{SO}_4^{2-}$ ,  $\text{S}^{2-}$ , and  $\text{CH}_4$ .



**Question 4**

(a) The Gouy-Chapman model is shown below. Identify all terms therein

$$\sigma = \frac{2k_B T \epsilon_0 \epsilon \kappa}{q} \sinh\left(\frac{q\psi_D}{2k_B T}\right)$$

- (b) Draw a schematic diagram of basic Stern layer model labeling all layers.
- (c) Develop a graph that shows how the thickness of double layer, varies over the range of ionic strength,  $I = 0.001$  to  $0.1$  M. At what ionic strength does the double layer essentially cease being a "diffused layer"? (Hint:  $\kappa^{-1} = 2.8 \times 10^{-8} \times I^{1/2}$ ).
- (d) Discuss the uses of double layer concepts as applied to water treatment processes.

**Question 5**

(a) State five members of POPs family. How these compounds are introduced to aquatic systems.

A certain soil has a bulk density of  $1.28 \text{ g cm}^{-3}$  and an organic carbon content of 1%. The porosity of the soil is 30%, of which 50% is occupied by water and 50% by air.  $K_H = 0.22$ ;  $K_{ow} = 134.90$ .

(b) Calculate  $K_d$  value using the empirical relationship given below:

$$K_d = 0.6 f_{oc} K_{ow}$$

- (c) Assume the concentration of benzene in water is  $C_w$ . Calculate the benzene mass in the soil, water and air in terms of  $C_w$ .
- (d) Find the percentages of benzene contained within the soil, liquid and gas phases.

