



UNIVERSITY OF KELANIYA - SRI LANKA  
FACULTY OF SCIENCE

Bachelor of Science Honours Degree Examination – November 2023  
Academic Year 2021/2022– Semester I  
CHEMISTRY

APCH 21663 - Atmospheric Chemistry, Aquatic Chemistry and Pollution Analysis

Number of Questions: Five (05)

Time: Two and a half (2 1/2) hours

Number of pages: Five (05)

Answer all questions.

(1). Answer all parts.

(A) The pH of a wastewater sample was above 8.5. Three aliquots of the water sample, each of 100.00 mL were titrated with  $0.01 \text{ mol dm}^{-3} \text{HCl}$  acid. The average volume of the acid required to reach the phenolphthalein endpoint was 25.50 mL. Thereafter methyl orange indicator was added to each of the already titrated water samples and titrations were carried out with the same acid and the average volume of the acid required to reach the methyl orange endpoint was 5.00 mL.

(i) ( $\alpha$ ) Write down the neutralization reactions expected to occur in the first titration.

( $\beta$ ) Calculate the phenolphthalein alkalinity of the water in terms of *of  $\text{CaCO}_3$* .

(ii) ( $\alpha$ ) Write down the neutralization reactions expected occur in the second titration

( $\beta$ ) Calculate the methyl orange alkalinity of the water sample in terms of *mg of  $\text{CaCO}_3$* .

(25 marks)

(B) The volume percentage of oxygen in air is 20.95. This oxygen dissolves in surface waters exposed to the atmosphere.

Calculate,

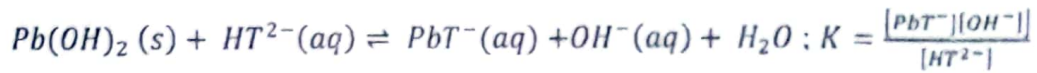
(i) the concentration of dissolved oxygen in water exposed to air at  $25^\circ\text{C}$ . The Henry's law constant for dissolution of oxygen in water and the saturated pressure of water at  $25^\circ\text{C}$  are  $1.3 \times 10^{-3} \text{ atm M}^{-1}$  and  $0.013 \text{ atm}$  respectively.

(ii) the weight of organic matter in 1 liter that consumes the dissolved oxygen in 1 liter of the water completely under the above condition (Relative atomic weights  $\text{C}=12$ ,  $\text{H}=1$  and  $\text{O}=16$ ).

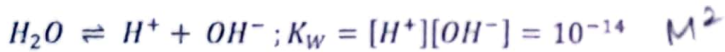
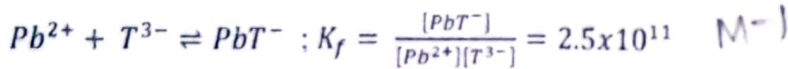
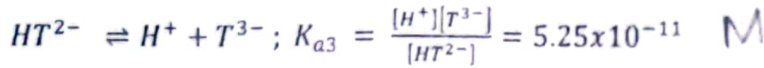
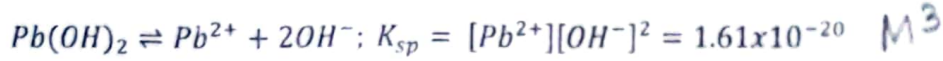
Hint:  $\{\text{CH}_2\text{O}\} + \text{O}_2 \rightarrow \text{CO}_2 + \text{H}_2\text{O}$

(35 marks)

- (C) Solubilization of  $Pb(OH)_2(s)$  at pH 8, via complexation with  $HT^{2-}$ , the dissolved species of  $H_3T$ , a cleaning agent present in waste waters can be represented by the following equilibrium.



Taking into consideration of the following equilibria also existing in the above waters.



(i) Prove,  $K = \frac{K_{sp}K_{a3}K_f}{K_w}$  (20 marks)

(ii) Calculate  $K$  for 25 °C (10 marks)

(iii) Calculate the concentration of  $PbT^-$  in waste water at pH 8 when

$$[HT^{2-}] = 10^{-4} \text{ mol dm}^{-3}$$

(40 marks)

## (2). Answer all parts.

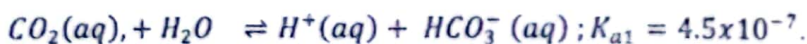
(A) Provide a short account on pollution caused by each of the following industries operating in Sri Lanka. (Note: the description should cover the type of major pollutants, their ways of transportation to surface & ground waters and the adverse effects on flora and fauna)

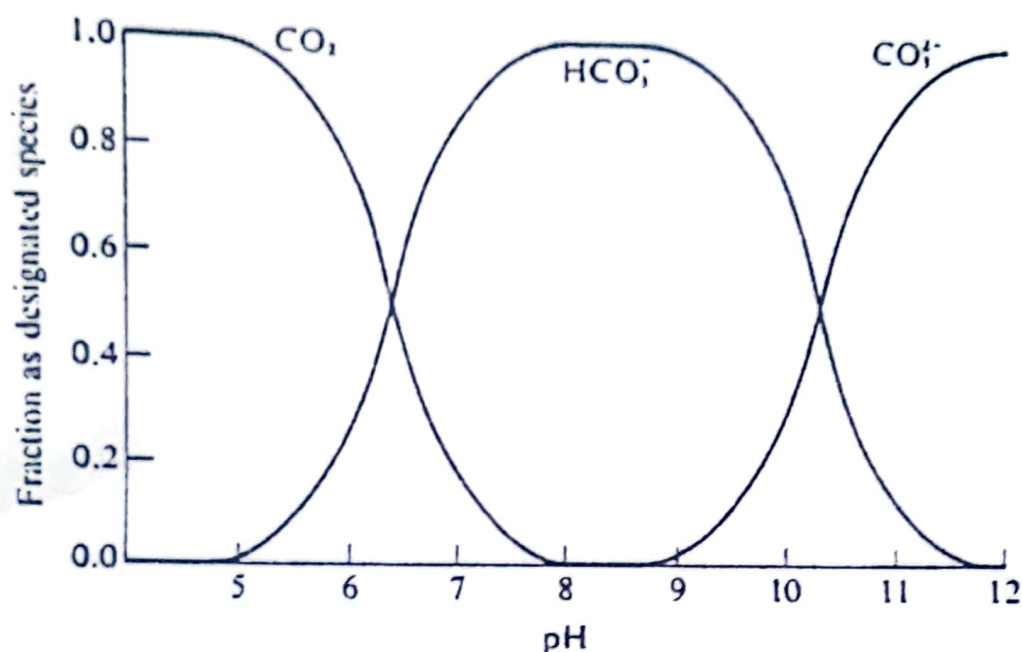
- Rubber industry.
- Textile manufacturing industry.
- Leather industry
- Food and food processing industry
- Paper & pulp industry

(25 marks)

(B) The total inorganic carbon concentration,  $[TIC]$  of a lake water is 4.2 mM. If the pH and the temperature of the water are 8.8 and 25 °C respectively, calculate the concentrations of  $CO_2(aq)$ ,  $HCO_3^-(aq)$  and  $CO_3^{2-}(aq)$  in the lake water.

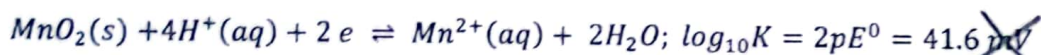
$$[TIC] = [CO_2(aq)] + [HCO_3^-(aq)] + [CO_3^{2-}(aq)].$$





(30 marks)

- (C) A sample of normal sea water and a sample of water from the Black sea gave redox potentials,  $E_h$  of +125.8 and -4.0 mV respectively. The following redox chemical equilibrium exists between solid  $MnO_2(s)$  and aqueous  $Mn^{2+}(aq)$  dominantly in both sea environments.



- Write down a mathematical expression for the equilibrium constant  $K$ , for the above equilibrium taking into account the number of moles of electrons participated in the reaction.
- Obtain an expression for  $\log_{10}[Mn^{2+}]$  using the expression you wrote for step (i) above.
- Using the expression obtained in step (ii) above, calculate the concentration of  $Mn^{2+}$  for  $\alpha$  normal sea water and  $\beta$  water in Black sea.
- State which seawater is more oxidizing and which seawater is more reducing comparing both the concentrations of  $Mn^{2+}$  ions and  $E_h$  values of both seawaters. Hint:  $\log_{10}K = n E_h^0$

(45 marks)



**(3). Answer all parts.**

(A)(i). Briefly explain the following terms.

- (a) mixing ratio
- (b) residence time

(10 marks)

(ii) The 24-hour mean concentration of nitrogen dioxide in an industrial city of Sri Lanka is 85 ppb whereas in an urban city of India it is expressed as  $150 \mu\text{g m}^{-3}$ . Which of the above cities is more polluted by nitrogen dioxide? (Assume temperature is  $25^\circ\text{C}$  and pressure is 1 atm in both cities.)

[Relative molecular mass of  $\text{NO}_2$  is 46

Universal gas constant ( $R$ ) =  $8.314 \text{ J K}^{-1} \text{ mol}^{-1}$

1 atm =  $101.325 \text{ kPa} = 101325 \text{ N m}^{-2}$ ]

(25 marks)

(B)(i) What important property do gases, that are eventually transported to the stratosphere have? Explain your answer with an example.

(ii) The S-O bond energy in  $\text{SO}_2$  is  $550 \text{ kJ mol}^{-1}$ . Calculate the maximum wavelength of radiation that is capable of cleaving this bond, and comment on whether photolysis is likely to be an important removal process for  $\text{SO}_2$  in the troposphere.

[Planck's constant ( $h$ ) =  $6.626 \times 10^{-34} \text{ J s}$

Speed of light ( $c$ ) =  $2.998 \times 10^8 \text{ m s}^{-1}$

Avogadro's constant ( $L$ ) =  $6.022 \times 10^{23} \text{ mol}^{-1}$ ]

(25 marks)

(C)(i) Why have "ozone holes" appeared over Antarctica region when ozone-depleting gases are present throughout the stratosphere?

Explain your answer with the relevant chemistry.

(ii) Summarize the roles played by aerosol particles in (i) the chemistry and (ii) the radiative balance of the earth's natural atmosphere.

↳ Albedo forcing

(40 marks)

**(4). Answer all parts.**

(A)(i) Give an account of the chemistry of nitrogen oxides in the troposphere stating the sources and removal mechanisms.

(ii) What strategies have been introduced to control the anthropogenic emission of nitrogen oxides in the troposphere?

(30 marks)

(B) "The chemistry of hydroxyl radicals ( $\text{OH}$ ) in the troposphere is strongly linked to that of ozone ( $\text{O}_3$ ). The primary formation of  $\text{OH}$  is controlled by the solar ultraviolet radiation flux, dependent on the overhead  $\text{O}_3$  column as well as the local  $\text{O}_3$  and water vapour concentrations," - *Atmos. Chem. Phys.*, 4, 2337–2344 (2004).

- (i) Describe how hydroxyl radicals are formed in the atmosphere providing examples where appropriate.
- (ii) What are the major influences on the OH concentration in the troposphere?
- (iii) Show how solar ultraviolet radiation controls these processes.

(35 marks)

- (C)(i) What controls the ozone depletion potential (ODP) of a given molecule? Rank the following molecules in order of increasing ODP:

$\text{CFCl}_3$ ,  $\text{CF}_3\text{Br}$  and  $\text{CHF}_2\text{Cl}$

*Lifetime where in stratosphere breaks down  
No. of halogens.*

- (ii) What do you mean by 'atmospheric reservoir species'? For each of the chemical species listed below, give two examples of reservoir species that occur in the atmosphere. Explain how these species are formed and what contribution they make to the chemistry of the atmosphere.

(α) Chlorine

→  $\text{ClONO}_2$ ,  $\text{HCl}$

(β) Nitrogen

→  $\text{N}_2\text{O}_5$ ,  $\text{HNO}_3$

(35 marks)

**(5). Answer all parts.**

- (A) The National Building Research Organization (NBRO) has warned that the Colombo air quality index (AQI) has increased towards an unhealthy level.

- News report-08 December 2022

- (i) What is the Sri Lanka Air Quality Index (SLAQI)?
- (ii) How is it derived?
- (iii) Why is such an index important in a situation like above.

(20 marks)

- (B)(i) What is the importance of air sampling in environmental science and monitoring?
- (ii) Explain the differences between passive and active air sampling methods and when to use each of these methods.
- (iii) Discuss two different techniques used for collecting air samples in environmental studies?
- (iv) What are the three primary factors that influence the concentration of pollutants or contaminants when taking air samples, and how do these factors impact the accuracy and reliability of air sampling data? Provide examples to illustrate your answer.

(50 marks)

- (C)(i) Describe the purpose of using models in environmental studies.

- (ii) Briefly explain the One-Box model and its limitations.

(30 marks)

END OF PAPER