UNIVERSITY OF RUHUNA
BACHELOR OF SCIENCE SPECIAL DEGREE (LEVELI) SEMESTER (II)
EXAMINATIONS DECEMBER 2016

SUBJECT: Chemistry

COURSE UNIT:CHE 4252 **Time :Two (02) hours**

Answer **All** questions.

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1. Answer **all** parts.

(a) (i) What are the major steps involved in a conventional municipal water treatment process? State the importance of each step.

(12 marks)

(ii) During a heavy rainy season high levels of Fe^{2+} and total suspended solids (TSS) have been found in raw water supplying to a municipal water treatment plant. Giving relevant chemistry discuss how above parameters could be reduced in the municipal water treatment process.

(13 marks)

(b) (i) Biochemical oxygen demand and chemical oxygen demand are used to determine organic pollution levels. Briefly discuss pros and cons of the above two methods.

(12 marks)

(ii) BOD_5 and COD values of three different waste water samples are given below.

Waste water sample	**BOD_5** ($mg\ L^{-1}$)	**COD** ($mg\ L^{-1}$)
A	240	300
B	100	500
C	120	360

Giving reasons identify the most easily biodegradable waste water sample.

(13 marks)

(iii) When atmospheric oxygen was in equilibrium with dissolved oxygen in the surface water, the partial pressure of $O_{2(g)}$ was 0.16 atm and dissolved oxygen content was 6.87×10^{-4} mol L^{-1}. Calculate the dissolved oxygen content in the surface water, when the partial pressure of $O_{2(g)}$ in equilibrium with dissolved oxygen has dropped to 0.03 atm while the temperature is constant.

(15 marks)

(c) Nitrogen is present in water in several forms and three of the relevant processes are given below.

(I) $2NO_3^-{}_{(aq)} + 12H^+{}_{(aq)} + 10e \leftrightarrow N_{2(g)} + 6H_2O_{(\ell)}$ $E^o=1.24$ V

(II) $NO_3^-{}_{(aq)} + 2H^+{}_{(aq)} + 2e \leftrightarrow NO_2^-{}_{(aq)} + H_2O_{(\ell)}$ $E^o=0.836$ V

(III) $NO_2^-{}_{(aq)} + 8H^+{}_{(aq)} + 6e \leftrightarrow NH_4^+(aq) + 2H_2O_{(\ell)}$ $E^0=0.89$ V

(i) Calculate the pE^o for each of the above processes and identify the process occurring at the strongest oxidizing condition.

(15 marks)

(ii) Calculate the pE of water when the pH is 6 and the concentration of $NO_3^-{}_{(aq)}$ is 100 times of $NO_2^-{}_{(aq)}$.

(10 marks)

(d) The HCO_3^- content in a ground water sample is 300 mg L^{-1} and the total amount of CO_3^{2-} and HCO_3^- in that water sample is 411 mg L^{-1}. Determine the total carbonate alkalinity as $CaCO_3$ mg L^{-1}.

***Note**: total carbonate alkalinity = carbonate alkalinity (as $CaCO_3$ mg L^{-1}) + bicarbonate alkalinity (as $CaCO_3$ mg L^{-1})*

(10 marks)

2. Answer **all** parts.

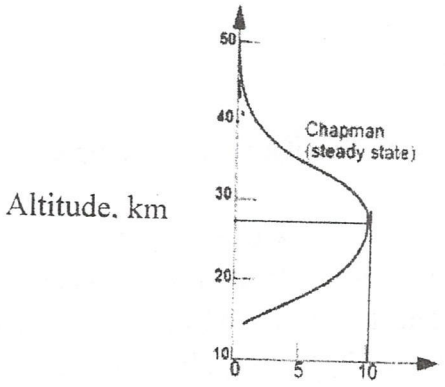
(a) Briefly explain the following.

(i) "Despite the fact that ozone depleting substances are present throughout the stratosphere, ozone hole has appeared over Antarctica". (12 marks)

(ii) Human activities can affect the concentration of OH radicals in the atmosphere.

(10 marks)

(b) Following figure shows the variation of O_3 concentration with the altitude predicted by the Chapman mechanism.



(i) Calculate the mixing ratio of O_3 at the maximum of the curve where the pressure and temperature are 35 hPa and 200 K.

(20 marks)

(ii) The experimental mixing ratio of O_3 at the altitude 25 km is 4340 ppbv. Compare the experimental mixing ratio of O_3 with the answer to the above (i) and give reasons for any difference between the two values.

(10 marks)

(c) (i) Briefly explain the difference between the box model and the puff model used in atmospheric chemistry.

(04 marks)

(ii) Consider an air plume containing a chemical species **X**. The production and loss rates of **X** inside the puff may include the contributions from the processes emissions (***E***), deposition (***D***), chemical production (***P***) and chemical loss (***L***).

(I) Identify sources and sinks of **X** in the puff.

(04 marks)

(II) Write down the mass balance equation for the change in concentration of **X** with time, in the puff.

(05 marks)

(iii) Waste management plant located at Matara area emits CH_4 gas to the atmosphere. This CH_4 gas is removed from the atmosphere only by oxidation by OH radicals with rate,

$-\frac{d[CH_4]}{dt} = k[CH_4][OH^{\cdot}]$ where rate constant k is in units of cm^3 $molecules^{-1}$ s^{-1}.

The puff travels while diluting with air and the dilution rate constant is k_d (s^{-1}) along the wind direction. Write the mass balance equation for the diluting puff assuming that background concentration of the CH_4 gas is zero and there are no sources within the puff.

(10 marks)

(iv) A research group sets up an observation site at a distance x, downwind of the waste management site mentioned in c(iii) and measures the concentration of CH_4 gas. The air parcel containing CH_4 gas transports with a fixed wind speed U while diluting with background air with a dilution rate constant k_d (s^{-1}). Show that the concentration of the gas CH_4, measured at the above observation site is given by

$$[CH_4] = C_S \, e^{\frac{-(k\,[OH]+k_d)x}{U}}$$

Note – CH_4 gas has no other sources and that background concentration is negligible.

$[CH_4]$ - Concentration of CH_4 measured at the above observation site.

Cs - Concentration of CH_4 gas at the waste management plant.

Units of [OH] is molecules cm^{-3}

(25 marks)

(03) Answer **all** parts

(a) (i) What is the definition of biomolecules in soil? (06 marks)
(ii) What is siderophore? (06 marks)
(iii) What are the main functional groups present in siderophores? (10 marks)

(b) (i) The relationship between the hydrophobic effect and water solubility of uncharged organic molecules can be quantified by two important properties of uncharged organic molecules: what are these properties?

(10 marks)

(ii) Give the formula for the Chiou distribution coefficient (K_{oc}) which explains the relationship between the hydrophobic interaction and water solubility of uncharged molecules. State all the terms used in the above formula.

(08 marks)

(c) Following table shows water solubilities (S_w) of two groups of organic pollutants PCB and PAH known to contaminate soils. Chiou distribution coefficient of PCB follows the equation $\text{Log } K_{oc} = -1.01 \log S_w + 1.91$ and PAH follows $\text{Log } K_{oc} = -1.01 \log S_w + 1.12$ where S_w is the solubility of above pollutants in water.

Pollutant (PCB)	S_w (g m^{-3})	Pollutant (PAH)	S_w (g m^{-3})
Chlorobenzene	484	Naphthalene	112
1,4-Dichlorobenzene	83	Phenanthrene	6.2
1,3,5-Trichlorobenzene	5.3	Anthracene	2.2

(i) Use these data to calculate the Chiou distribution coefficient (L kg^{-1}oc) for each pollutant.

(ii) Using the chemical structures of the pollutants, explain the differences in log K_{oc} among them.

(iii) Based on the above results, discuss the relationship between water solubility of nonpolar organic pollutants and partitioning of those compounds into soil humus.

(28 marks)

(d) The desorption of PAHs from river sediments has been observed to follow an exponential time dependence

$$n(t) = n_0 \exp(-k_{des}t)$$

Where n_0 is an initial value of the amount adsorbed per unit mass of sediments and k_{des} is the rate coefficient for the desorption process. Studies with the PAH given in the above table have shown that the value of k_{des} follows the equation given below.

$$\log k_{des} = -0.98 \log K_{oc} - 0.104$$

Where k_{des} is in units of day^{-1}. Calculate the half life for each of the PAHs listed in the table and explain the trend.

(32 marks)

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