UNIVERSITY OF ESWATINI
Faculty of Health Sciences
Department of Environmental Health Science

BACHELOR OF SCIENCE IN:
- ENVIRONMENTAL MANAGEMENT AND WATER RESOURCES;
-ENVIRONMENTAL HEALTH SCIENCE

MAIN EXAMINATION PAPER DECEMBER 2019

TITLE OF PAPER	: WATER TREATMENT
COURSE CODE	: EHS 429
DURATION	: 2 HOURS
MARKS	: 100

INSTRUCTIONS

READ THE QUESTIONS & INSTRUCTIONS CAREFULLY

THERE ARE FIVE QUESTIONS IN THIS EXAM

ANSWER ANY FOUR QUESTIONS

EACH QUESTION CARRIES 25 MARKS.

WRITE NEATLY & CLEARLY

NO PAPER SHOULD BE BROUGHT INTO THE EXAMINATION ROOM.

BEGIN EACH QUESTION ON A SEPARATE SHEET OF PAPER.

DO NOT OPEN THIS QUESTION PAPER UNTIL PERMISSION IS GRANTED BY THE INVIGILATOR.

QUESTION ONE (5 marks each)

A threshold odour test was conducted on water containing 2-4 Dichlorophenol ($Cl_2C_6H_3OH$). It is known that this chemical has a threshold odour value of 40 µg/L. During the odour test, it was found out that 2 successive dilutions at a ratio of 25:175 of the sample with odour-free water were made after which 40 mL was taken from the final dilution and mixed once again with 160 mL odour free water to give 200 mL total volume and give the just detectable odour. Determine

1A. The Threshold odour number (TON) (5 marks)

1B. The Odour Intensity Index (5 marks)

1C. The concentration of 2-4 Dichlorophenol present in the original sample (5 marks)

1D. Consider the following two different types of reactions:

$$(i) \qquad \frac{C}{C_0} = e^{-kt}$$

$$(ii) \qquad \frac{C}{C_0} = \frac{1}{1 + kT}$$

State the names of the reactors and indicate which of the two reactors has the fastest rate of reaction.

1E. List the six sequential steps that occur in a typical heterogeneous chemical reaction.

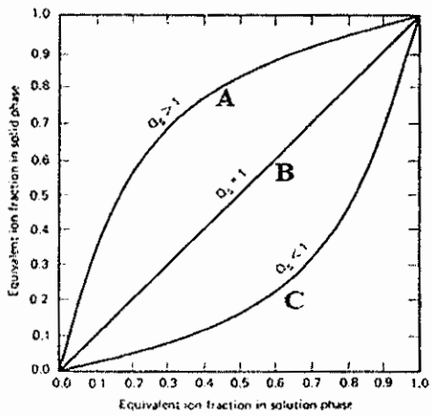
QUESTION TWO (5 marks each)

2A. An ion exchange resin that weighs 200 kg is employed for the removal of calcium from a given hard water. the concentration of calcium in the raw water to be treated is 400 mg/L. The ion exchange resin treats the water so that the treated water contains only 20 mg/L of Calcium. If a total of 60,000 liters water were treated, what will be the ion exchange resin capacity?

2B. State the advantages and disadvantages of ion exchange process compared to that of chemical precipitation involving lime-soda softening for water treatment involving the removal of hardness causing calcium and magnesium ions.

2C. Write a chemical reaction equation for ion exchange resin R involving the exchange of Cation A+ from the ion exchanger and that of ion B^{n+} from the water flowing through the ion exchanger. In addition state the equilibrium expression for i) selectivity coefficient and ii) selectivity quotient

2D. The diagram below shows the selectivity quotient data for a given ion exchange media against three different ions labeled A, B and C in the diagram. Evaluate the suitability of this ion exchanger media for removing the ions A, B and C.



2E. Describe the characteristics, advantages and disadvantages of mixed bed ion exchangers.

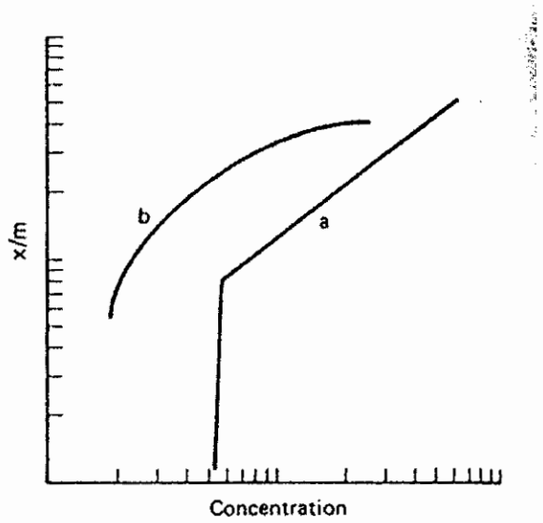
QUESTION THREE (5 marks each)

3A. List advantages of fixed column activated carbon systems over powdered activated carbon systems.

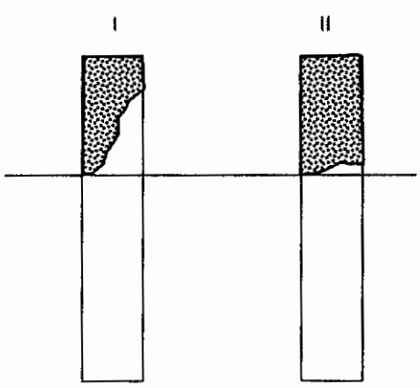
3B. List the following organic compounds from the highest affinity for adsorption onto activated carbon to the lowest affinity. The characteristics of the compounds are provided below.

Compound	Molecular weight	Polarity
Butyl amine	73.1	Low polarity
Formaldehyde	30	High polarity
Benzene	78.1	Very low polarity
Methanol	32	Very high polarity
Phenol	94	Very low polarity

3C. Characterize the adsorption isotherms labeled a and b shown in the figure below.



3D. Two types of interfaces of the saturated zone for a given activated adsorption process are shown in the figure below labeled types I and type II. Compare the efficiency of adsorption and the characteristics of breakthrough curve for these two types of adsorption processes.



3E. Describe in <u>sufficient detail</u> the three important phases of the production of activated carbon.

QUESTION FOUR (5 marks each)

The table below shows the results of water quality analysis of a sample of raw water intended for potable water treatment. Using the data provided in the table as well as the chemical equations and equilibrium constants shown in the following page, answer the following questions.

4A. Check the water quality analysis results for consistency and suggest if the analysis results are acceptable.

4B. Calculate the bicarbonate and permanent hardness in mg/L of $CaCO_3$

4C. Draw the ion bar chart of the raw water in meq/L

4D. Calculate the lime (in mg/L as $CaCO_3$) required to soften this water using excess lime treatment method.

4E. Calculate the soda ash required (in mg/L as $CaCO_3$).

Parameter	Unit	Concentration (mg/L)	Molecular weight
TDS	mg/L	65	
Ca^{++}	mg/L	14	40.1
Mg^{++}	mg/L	4	24.3
Na^{+}	mg/L	8	23
K^{+}	mg/L	1	39.1
HCO_3^{-}	mg/L	43	61
$SO_4^{=}$	mg/L	26	96.1
Cl^{-}	mg/L	5	35.5
$H_2CO_3^{*}$	mg/L	4	62
pH	pH units	7.16	

Chemical equations and equilibrium constants

a. Neutralisation of carbonic acid:

$$CO_2 + Ca(OH)_2 \leftrightarrow CaCO_{3(s)} + H_2O$$

b. Precipitation of carbonate hardness due to calcium

$$Ca(HCO_3)_2 + Ca(OH)_2 \leftrightarrow 2CaCO_3 + 2H_2O$$

c. Precipitation of carbonate hardness due to magnesium

$$Mg(HCO_3)_2 + 2Ca(OH)_2 \leftrightarrow 2CaCO_{3(s)} + Mg(OH)_2 + 2H_2O$$

d. Removal of non-carbonate hardness due to calcium

$$CaSO_4 + Na_2CO_3 \leftrightarrow CaCO_3(s) + Na_2SO_4$$

$$CaCl_2 + Na_2CO_3 \leftrightarrow CaCO_3(s) + 2NaCl$$

e. Removal of non-carbonate hardness due to magnesium

$$MgSO_4 + Ca(OH)_2 + Na_2CO_3 \leftrightarrow Mg(OH)_2 + CaCO_3(s) + Na_2SO_4$$

f. Equilibrium constant for the dissociation of bicarbonate into hydrogen and carbonate ions:

$$10^{-10.33} = \frac{[H^+][CO_3{}^{2-}]}{[HCO_3{}^-]}$$

g. The ion product of water

$$[H^+]\,[OH^-] = 10^{-14}$$

QUESTION FIVE (5 marks each)

5A. Define the following terms: i) Permeate ii) retentate iii) permeator iv) concentration polarization v) solute rejection.

5B. Compare the rejection rates of micro membrane filters and ultra-membrane filters against:

i. Giardia lamia cysts
ii. bacteria
iii. viruses

5C. List the pretreatment and post treatment requirements of reverse osmosis plants.

5D. A membrane module contains 8000 fibers. The fibers are 1.2 m long with a thickness of 0.525 mm and inside diameter of 0.75 mm. calculate the flux necessary to produce a flow of 2500 lit/hr from the module if flow is from outside- in.

5E. Characterize the following types of adsorption:

i. Physical adsorption
ii. Chemical adsorption

(Note: this question (5E) is related to activated carbon adsorption and NOT to membrane filtration)