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 FEBRUARY 2021

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)

1A. List the factors that decrease the rate of film diffusion in ion exchangers.

1B. How do you describe the variation of the selectivity of ion exchange resins among ions of the same valance?

1C. Which of the following statements is/are true about ion exchange process for water treatment?

a. Ion exchange is an adsorption process
b. Ion exchange is an absorption process
c. Ion exchange is more favoured for the removal of inorganic compounds rather than organic compounds.
d. Strong cation exchangers have sharp break-through curve
e. Weak cation exchangers have sharp break through curve

1D. Describe the characteristics, advantages and disadvantages of mixed bed ion exchangers.

1E. A bimolecular reaction $A + B \rightarrow P$ is 10% complete in 10 minutes. If the initial concentration of A and B is equal to 1 mole/L, determine the reaction rate constant and how long it will take for the reaction to be 90% complete.

QUESTION TWO (5 marks each)

2A. How do you characterize the adsorption molecules on activated carbon when the solution contains salts compared to the adsorption of the same molecules on activated carbon when the solution does not contain salt?

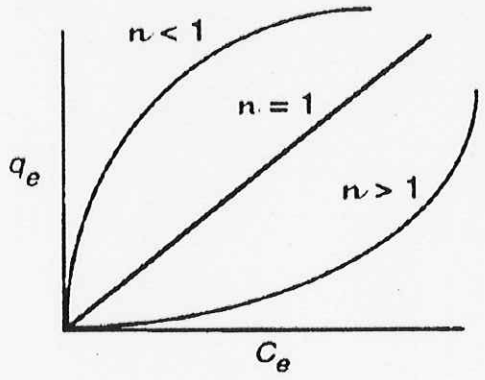
2B. Compare i) physical adsorption and chemical adsorption in terms of:

i. Nature and strength of adsorption
ii. Degree of specificity
iii. Reversible nature of the reaction (regeneration)
iv. Layer formation
v. Isotherm modeling formula(Freundlich or Langmuir)

2C. State the three distinct steps (process) that must take place for adsorbate material to get adsorbed onto activated carbon. State which of these steps process are the rate determining steps for i) granular activated carbon and ii) batch process using powdered activated carbon.

2D. Three different Freundlich isotherms are shown in the figure below. Answer the following questions:

i. Which of the three corves superior performance at low pollutant concentrations? Rank their performance 1st, 2nd, 3rd.
ii. Which of the three curves show superior performance at very high pollutant concentrations, rank their performance (1st, 2nd, 3rd).
iii. How do you determine if a given pollutant present in water is adsorbed according to one of the three adsorption curves?



$$q_e = K_F C_e^{1/n}$$

2E. Describe the three important phases of the production of activated carbon.

QUESTION THREE (Marks are indicated for each question)

3A. For each of the experimental cases described in the table below, Calculate the apparent odour synergism between two compounds A and B. .....[10 marks]

	Compound A	Compound B	Olfactile added total	Olfactle found in mixture
Olfactile added				
Case I	0.3	0.5	0.8	1.0
Case II	0.5	0.3	0.8	0.8
Case III	0.8	0.75	1.55	1.0

3B. Determine the Threshold odour number (TON) and the Odour Intensity Index (OII) for a sample water when the number of 25:175 dilutions made was 3 times after which a 70 mL of the diluted sample was transferred to the 200 mL flask to achieve the just detectable odour. .....[10 marks]

3C. Looking at the solubility diagrams of iron shown in Figure Q3-1 below, discuss the influence the presence of significant amount of alkalinity on the solubility of iron and the implication on water treatment for the removal of iron .....[5 Marks]

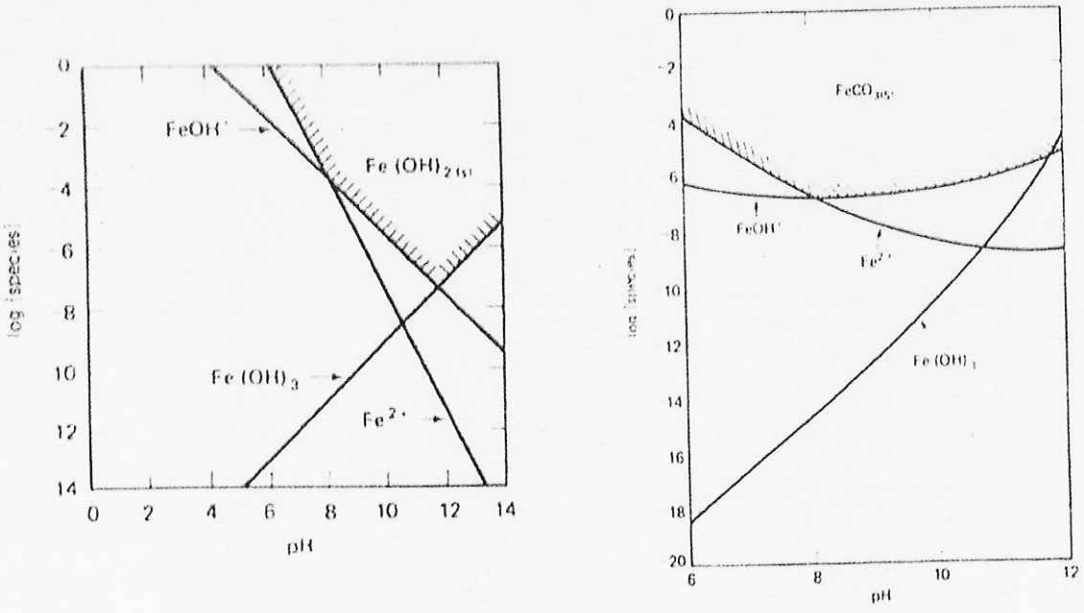


Figure Q3-1: Solubility of iron diagram for OH^- controlled and carbonate controlled precipitation of iron

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	2534	
Ca^{++}	mg/L	549	40.1
Mg^{++}	mg/L	169	24.3
Na^{+}	mg/L	313	23
K^{+}	mg/L	42	39.1
HCO_3^{-}	mg/L	1689	61
$SO_4^{=}$	mg/L	1014	96.1
Cl^{-}	mg/L	211	35.5
$H_2CO_3^{*}$	mg/L	169	62
pH	pH units	7,56	

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. In terms of hydrophobicity what characteristics of membranes are desirable to avoid fouling of membranes?

5C. A membrane module contains 6000 fibers. The fibers are 1.2 m long with an outside diameter of 1.8 mm and inside diameter of 0.8 mm. Calculate the flux necessary to produce a flow of 2500 liter/hour if flow is:

i. outside in

ii. Inside out

5D. Compare the advantages and disadvantages of:

i. Inside-out membrane operation and (2 and ½ marks)

ii. Outside-in membrane operations (2 and ½ marks)

5E. Compare the osmotic pressures created by equal concentration (100 mg/L) of NaCl and $CaCl_2$. Explain the reason for the difference in the osmotic pressures created by these minerals concentrations.