NATIONAL UNIVERSITY OF SCIENCE AND TECHNOLOGY

FACULTY OF INDUSTRIAL TECHNOLOGY

DEPARTMENT OF CHEMICAL ENGINEERING

Separation Processes 1B

TCE 3204

Final Examination Paper

March 2025

This examination paper consists of 4 pages

Time Allowed: 3 hours

Total Marks: 100

Special Requirements: Periodic table

INSTRUCTIONS

1. Answer **Question A1** and **any other three (3)** questions
2. Each question carries 25 marks
3. Use of calculators is permissible

MARK ALLOCATION

QUESTION	MARKS
A1	**25**
B1	**25**
B2	**25**
B3	**25**
B4	**25**
TOTAL ATTAINABLE	**100**

SECTION A

Answer all questions

QUESTION A1

a) What is the importance of separation processes in chemical and biochemical industries? **[8]**

b) What is fouling in membrane separation processes, and what methods can be used to prevent it? **[5]**

c) Compare and contrast between chemisorption and physisorption **[6]**

d) In 1916, Irving Langmuir derived the simplest equation for adsorption under dynamic equilibrium conditions. State the assumptions Langmuir made in order to simplify his analysis. **[6]**

SECTION B

Answer any 3 questions

QUESTION B1

a) State and describe the advantages and disadvantages of membrane filtration **[5]**

b) Describe and explain two mechanisms by which material transfer from the liquid phase to the solid phase in crystallisation. **[5]**

c) Name and explain the classifications of fouling in RO and explain how these can be managed. **[6]**

d) Most crystallizers are classified based on how supersaturation is obtained. Describe and explain any 3 types of crystallizers. **[9]**

QUESTION B2

a) Differentiate between absorption and adsorption. **[6]**

b) Fouling can occur in both reverse osmosis (RO) and ultrafiltration (UF) although it's often worse in UF since dirtier streams are often processed. What is fouling? **[2]**

c) Membranes can be synthesized from a different variety of polymers. Describe and explain these three broad classes of polymers. **[9]**

d) A silicon rubber membrane is being used to separate O_2 from N_2. The membrane is perfectly mixed and inlets gas is 21 mole% O_2. We desire a permeate product which is 27 mole% O_2. The membrane has a selectivity of $\alpha_{AB} = p_A/p_B = 2.1$. Pressure ratio is $P_L/P_H = 0.35$. Treat the gases as ideal gases. What cut θ must be used? **[8]**

QUESTION B3

a) What is meant by ion exchange? Describe how the process occurs. **[5]**

b) Describe how high performance-liquid chromatography works and give examples of where it can be used. **[5]**

d) You have been tasked with designing a water treatment process for your community. The water source has been characterised, and you need to ensure that the treated water meets environmental standards for safe consumption and ecological protection.

Water Characteristics

The following table summarizes the characteristics of the raw water sourced from the local river:

Water Characteristic	Measured Value	Environmental Standard Limit
pH	6.5	6.5 - 8.5
Turbidity (NTU)	15	< 5
Total Dissolved Solids (TDS) (mg/L)	800	< 500
E. coli (CFU/100 mL)	200	0
Nitrate (NO3-) (mg/L)	10	< 10

1. Based on the above characteristics, outline a series of steps necessary for treating this water to meet environmental standards.
2. Justify each step in your treatment process and the mechanism of separation and how it addresses specific contaminants or characteristics that exceed the environmental limits.

[10]

QUESTION B4

a) Why is mass transfer a major factor in separation processes? **[5]**

b) Explain how polarization occurs in electrodialysis and reverse osmosis. **[8]**

c) In a cooling crystallizer used to crystallise sodium acetate from a salt liquid solution, water is also removed by evaporation after cooling at 0°C. The feed is initially saturated at 80°C and cooled to 0°C. If we initially dissolve the anhydrous salt in 100kg/hr of H_2O, how many crystals are collected. **[12]**

Table 2: Solubilities of 1 selected compound adapted from Mullin(1972), grams anhydrous compound per 100g of water

		Solubility °C								
Compound	Formula	0	10	20	30	40	60	80	100	Stable hydrate 0-25°C

Sodium Acetate	$NaC_2H_3O_2$	36.3	40.8	47	54.5	65.5	139	153	170	3

(END OF PAPER)

IUPAC Periodic Table of the Elements

1																	18
1 **H** hydrogen 1.0080 ± 0.0002	2		Key:									13	14	15	16	17	2 **He** helium 4.0026 ± 0.0001
3 **Li** lithium 6.94 ± 0.06	4 **Be** beryllium 9.0122 ± 0.0001		atomic number **Symbol** name abridged standard atomic weight									5 **B** boron 10.81 ± 0.02	6 **C** carbon 12.011 ± 0.002	7 **N** nitrogen 14.007 ± 0.001	8 **O** oxygen 15.999 ± 0.001	9 **F** fluorine 18.998 ± 0.001	10 **Ne** neon 20.180 ± 0.001
11 **Na** sodium 22.990 ± 0.001	12 **Mg** magnesium 24.305 ± 0.002	3	4	5	6	7	8	9	10	11	12	13 **Al** aluminium 26.982 ± 0.001	14 **Si** silicon 28.085 ± 0.001	15 **P** phosphorus 30.974 ± 0.001	16 **S** sulfur 32.06 ± 0.02	17 **Cl** chlorine 35.45 ± 0.01	18 **Ar** argon 39.95 ± 0.16
19 **K** potassium 39.098 ± 0.001	20 **Ca** calcium 40.078 ± 0.004	21 **Sc** scandium 44.956 ± 0.001	22 **Ti** titanium 47.867 ± 0.001	23 **V** vanadium 50.942 ± 0.001	24 **Cr** chromium 51.996 ± 0.001	25 **Mn** manganese 54.938 ± 0.001	26 **Fe** iron 55.845 ± 0.002	27 **Co** cobalt 58.933 ± 0.001	28 **Ni** nickel 58.693 ± 0.001	29 **Cu** copper 63.546 ± 0.003	30 **Zn** zinc 65.38 ± 0.02	31 **Ga** gallium 69.723 ± 0.001	32 **Ge** germanium 72.630 ± 0.008	33 **As** arsenic 74.922 ± 0.001	34 **Se** selenium 78.971 ± 0.008	35 **Br** bromine 79.904 ± 0.003	36 **Kr** krypton 83.798 ± 0.002
37 **Rb** rubidium 85.468 ± 0.001	38 **Sr** strontium 87.62 ± 0.01	39 **Y** yttrium 88.906 ± 0.001	40 **Zr** zirconium 91.224 ± 0.002	41 **Nb** niobium 92.906 ± 0.001	42 **Mo** molybdenum 95.95 ± 0.01	43 **Tc** technetium [97]	44 **Ru** ruthenium 101.07 ± 0.02	45 **Rh** rhodium 102.91 ± 0.01	46 **Pd** palladium 106.42 ± 0.01	47 **Ag** silver 107.87 ± 0.01	48 **Cd** cadmium 112.41 ± 0.01	49 **In** indium 114.82 ± 0.01	50 **Sn** tin 118.71 ± 0.01	51 **Sb** antimony 121.76 ± 0.01	52 **Te** tellurium 127.60 ± 0.03	53 **I** iodine 126.90 ± 0.01	54 **Xe** xenon 131.29 ± 0.01
55 **Cs** caesium 132.91 ± 0.01	56 **Ba** barium 137.33 ± 0.01	57-71 lanthanoids	72 **Hf** hafnium 178.49 ± 0.01	73 **Ta** tantalum 180.95 ± 0.01	74 **W** tungsten 183.84 ± 0.01	75 **Re** rhenium 186.21 ± 0.01	76 **Os** osmium 190.23 ± 0.03	77 **Ir** iridium 192.22 ± 0.01	78 **Pt** platinum 195.08 ± 0.02	79 **Au** gold 196.97 ± 0.01	80 **Hg** mercury 200.59 ± 0.01	81 **Tl** thallium 204.38 ± 0.01	82 **Pb** lead 207.2 ± 1.1	83 **Bi** bismuth 208.98 ± 0.01	84 **Po** polonium [209]	85 **At** astatine [210]	86 **Rn** radon [222]
87 **Fr** francium [223]	88 **Ra** radium [226]	89-103 actinoids	104 **Rf** rutherfordium [267]	105 **Db** dubnium [268]	106 **Sg** seaborgium [269]	107 **Bh** bohrium [270]	108 **Hs** hassium [269]	109 **Mt** meitnerium [277]	110 **Ds** darmstadtium [281]	111 **Rg** roentgenium [282]	112 **Cn** copernicium [285]	113 **Nh** nihonium [286]	114 **Fl** flerovium [290]	115 **Mc** moscovium [290]	116 **Lv** livermorium [293]	117 **Ts** tennessine [294]	118 **Og** oganesson [294]

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57 **La** lanthanum 138.91 ± 0.01	58 **Ce** cerium 140.12 ± 0.01	59 **Pr** praseodymium 140.91 ± 0.01	60 **Nd** neodymium 144.24 ± 0.01	61 **Pm** promethium [145]	62 **Sm** samarium 150.36 ± 0.02	63 **Eu** europium 151.96 ± 0.01	64 **Gd** gadolinium 157.25 ± 0.03	65 **Tb** terbium 158.93 ± 0.01	66 **Dy** dysprosium 162.50 ± 0.01	67 **Ho** holmium 164.93 ± 0.01	68 **Er** erbium 167.26 ± 0.01	69 **Tm** thulium 168.93 ± 0.01	70 **Yb** ytterbium 173.05 ± 0.02	71 **Lu** lutetium 174.97 ± 0.01
89 **Ac** actinium [227]	90 **Th** thorium 232.04 ± 0.01	91 **Pa** protactinium 231.04 ± 0.01	92 **U** uranium 238.03 ± 0.01	93 **Np** neptunium [237]	94 **Pu** plutonium [244]	95 **Am** americium [243]	96 **Cm** curium [247]	97 **Bk** berkelium [247]	98 **Cf** californium [251]	99 **Es** einsteinium [252]	100 **Fm** fermium [257]	101 **Md** mendelevium [258]	102 **No** nobelium [259]	103 **Lr** lawrencium [262]

For notes and updates to this table, see www.iupac.org. This version is dated 4 May 2022.