INDIAN INSTITUTE OF TECHNOLOGY KHARAGPUR
Mid-Autumn Semester Examination 2022-23

Date of Examination: 20.09.2022 **Session: FN** **Duration: 2 hrs** **Full Marks: 30**

Subject No. : CH31010_ **Subject : Mass Transfer 2**

Department/Center/School: Chemical Engineering

Specific charts, graph paper, log book etc., required: Graph Paper

Special Instructions (if any): *Please write answers in brief and to the point, with logical arguments. Avoid extended descriptions.*
Make suitable assumptions as necessary, and provide justifications for the same in case you think any data is missing

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Part A

Specific Instruction:
Part marking to the solution of a question will be considered only when it is partially correct, not for partially incorrect/ illogical attempts.

1. **Answer the following questions:**

(a) **What is the fundamental difference between the film theory and penetration theory, in diffusive mass transport.** [1]

(b) **Show that the Fick's law of diffusion is a specific case of the generalised multi-component diffusion theory.**

The Stefan's law of multicomponent diffusion is $-\frac{\partial c_i}{\partial z} = \sum_{j=1}^{n-1} \frac{1}{c_T D_{ij}} (c_j N_i - c_i N_j)$ [2]

(c) **Explain the thermodynamic and operational factors which influences the quality and performance of the polymeric membrane produced using the non-solvent induced phase separation technique.** [1]

(d) **In the case of a developing (spatially) mass transfer boundary layer over the membrane surface in a cross-flow type configuration, using the scaling analysis show that the permeate flux,** $v_w \propto \frac{1}{x^{1/3}}$, **where** x **is the leading axial distance from the edge (inlet) of the membrane channel.** [3]

(e) **What are the important underlying assumptions in the multicomponent Langmuir adsorption isotherm model?** [2]

2. Explain how you will determine the gel layer concentration in a (gel-controlling) membrane separation process (for e.g., microfiltration). Please base your answer with mathematical analysis (or derivations) supported by logical arguments and following practical considerations. [3]

3. An adsorption study is set up in laboratory by adding a known amount of activated carbon (AC) to six flasks which contain 200 mL of an industrial waste containing Alachlor (pesticide). An additional flask containing 200 mL of waste but no carbon is run as a blank. The details of the different flask conditions are tabulated below (P.T.O):

(a) Plot the Langmuir isotherm and determine the values of the constants. You may use the linear regression technique. The Langmuir isotherm relation is given as $q_e = \frac{q_0 K C_e}{1 + K C_e}$ where q_0 and K are the constants to be determined.

(b) Estimate the amount of adsorbent (carbon) required to reduce the final Alachlor concentration in the waste solution below 1 mg/L, at equilibrium. **(2+1=3)**

Flask No.	Mass of AC (mg)	Volume in flask (mL)	Equilibrium Alachlor concentration (mg/L)
1	804	200	4.7
2	668	200	7.0
3	512	200	9.3
4	393	200	16.6
5	313	200	32.5
6	238	200	62.8
7	0	200	250

Part B

Specific Instructions for part B:

Detach the Triangular Graph paper attached with question paper and attach it with the answer sheet. No marks will be given for the relevant question if graph paper is not attached.

4. The following equilibrium data is given.

x	Fraction of B	y	Fraction of B
0	0.09	0	0.90
0.06	0.07	0.12	0.80
0.12	0.07	0.27	0.65
0.20	0.08	0.34	0.57
0.26	0.10	0.40	0.50
0.32	0.11	0.45	0.41
0.37	0.13	0.48	0.31

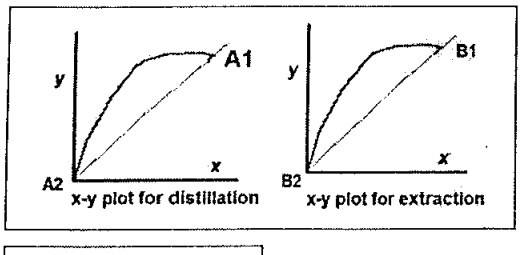
a) Draw the phase diagram on the given triangular graph paper.

b) Find out the coordinate of the Plate point. Mark it on the graph.

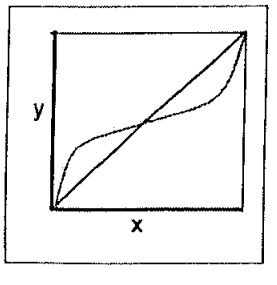
c) 30 Kg of a pure solvent is mixed with certain amount of feed in a **single stage** batch extractor, with initial solute concentration of 25%. The final Raffinate contains 16% solute. Calculate the amount of Feed used, and also the amounts of Extract and Raffinate produced. **(2+1+4=7)**

5. Find out the number of stages (with appropriate construction) required for the counter flow extraction, for which x_F, x_R, y_E and y_S are shown on the graph paper given in the next sheet. The mass balance and the logic of your calculation must be written in the answer script. **(2+2=4)**

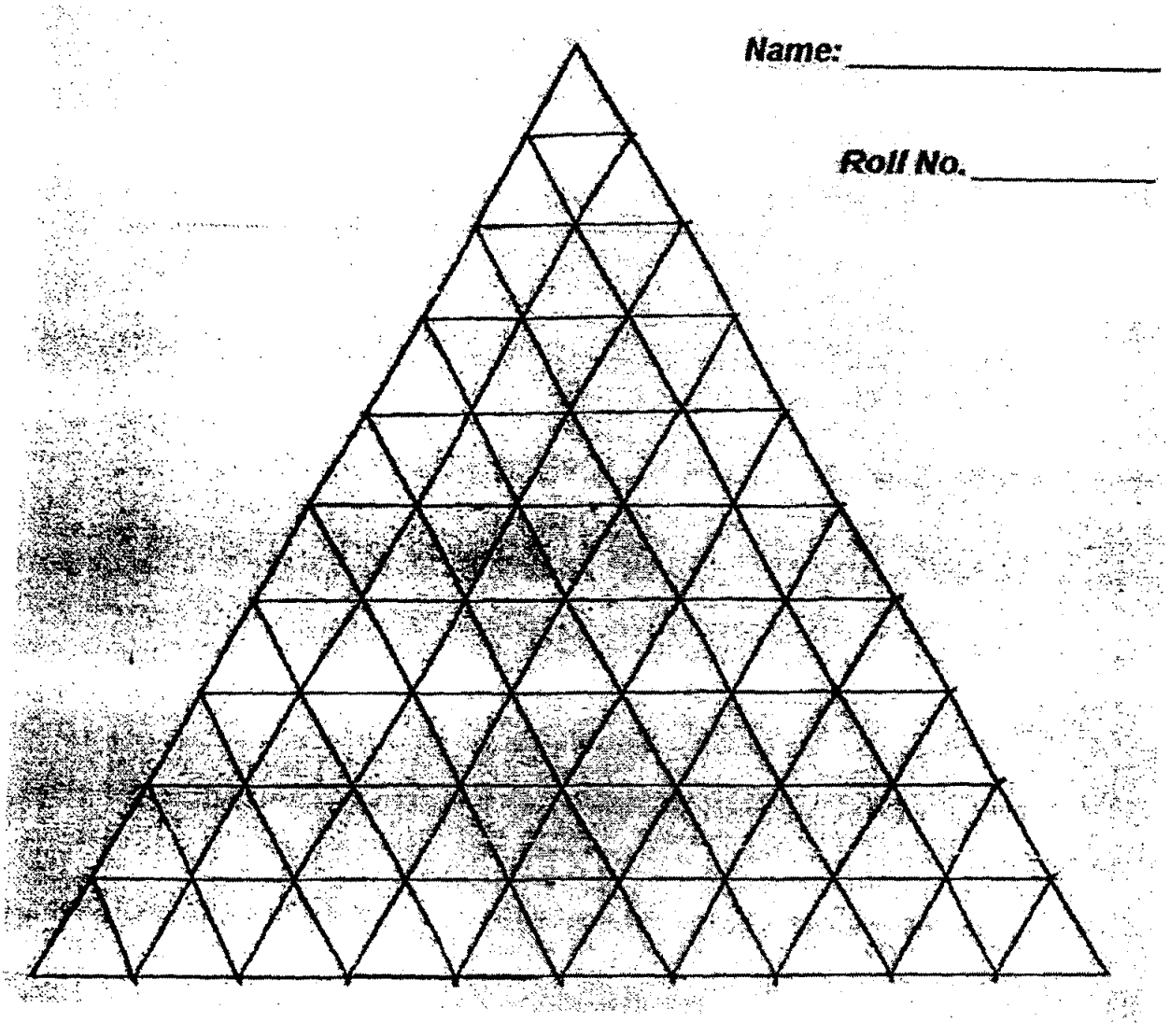
6. Discuss the similarities and dissimilarities between the following two graphs, specifically with respect to i) coordinates of A1 and B1; ii) Coordinates of A2 and B2; iii) nature of the equilibrium and iv) anything else. **(2)**



7. The x-y plot for a system (x and y have their usual meaning in the context of extraction) is shown in the adjacent figure. Draw qualitatively the phase diagram on a triangular plot. **(2)**



Graph paper for question number 4.



Graph paper for question number 5