Birla Institute of Technology and Science, Pilani
Semester I Session: 2022-2023
CHE F313 Separation Process-II
Comprehensive Examination

Date: 30/12/2022 **Full Marks: 120**
Time: 9.00 am-12.00 pm

Part A-Closed Book **Full Marks: 60**
(Time: 90 Minutes)

Instructions: **Write your name and ID clearly on the answer sheet. *Answer all parts of a question together. *State and justify if you make any assumptions. *Clearly write the nomenclature used. *Your answers must include appropriate units. *Clearly mention the question number. *Be to the point and specific. * Textbook/printed lecture notes are only allowed as a reference material in open book part. *No other material is allowed. * No exchange of calculator is allowed. *Timings for closed book part can be (+/-) 10 minutes. *Once, you return the answer script for part A, part B answer script will be given to you*

1. A filter (preferably, a leaf filter) having 1.5 m^2 of filtration surface is operated under constant gauge pressure of 2.5 bar. Equation governing the filtration process is given as: $\frac{dt}{dv} = 50V + 80$ (s/m^3). Time for dumping and reassembling the filter cake is 1.5 hours. Assume that the rate of washing is equal to the final rate of filtration. Estimate (a) time required for washing the cake formed at the end of 1 hour of filtration, under the same pressure, using 5000 liters of wash water; (b) Number of times, the overall cycle can operate in a day, if volume of filtrate is equal to volume of wash water. **[5+5=10]**

2. A silty soil containing 20 percent moisture was mixed in a large mixer with 50 wt.% of a tracer. After 5 min of mixing, random samples were taken from the mix and analyzed calorimetrically for tracer material. The measured concentrations in the sample were in weight percent tracer and can be presented as follows: 10.8, 8.5, 7.5, 10.2, 11.1, 10, 12, 9.7, 9.2, 10.8, 11, 13. Calculate the mixing index and the standard deviation. You may use the following formula: $\sigma_0 = \sqrt{\mu(1-\mu)}$; $I_p = \frac{\sigma_0}{s} = \sqrt{\frac{(N-1)\mu(1-\mu)}{\sum_{i=1}^{N} x_i^2 - \bar{x}\sum_{i=1}^{N} x_i}}$ **[5+5=10]**

3. A wet solid is contained in a tray and must be dried from 35 to 10% moisture content, using air at constant conditions. Usually, the time required for drying is 6 hours. Experiments done previously, revealed that the critical and equilibrium moisture content of the wet solid was 17% and 5%, respectively. Assume there is no preheat period and the drying pattern depicts constant rate followed by falling rate period. Determine for the stated conditions, the drying time (in hours), if initial moisture content is 45% and a final moisture of 6% is desired. All moisture contents are on a dry basis. **[10]**

4. Urea is to be crystallized from an aqueous solution that is 90% saturated at 100^0C. If 90% of urea is to be crystallized in an anhydrous form and the final solution temperature is to be 30^0C, what percentage fraction of the total water must be evaporated? Take solubility of urea in water at 100^0C and 30^0C to be 730 and 135 g/100 g water, respectively. Molecular weight of urea is 61 g/mol. You may take a basis of 100 kg. **[10]**

5. Water contains 100 mg/l Ca^{2+} ions initially. This water must be treated using 10% of a polystyrene-based resin, which is in Na^+ form. It can remove 96% of present calcium ions. The resin is expected to have an exchange capacity of 2 eq./liter. Calculate the amount of resin (in whole numbers, having no significant digits of decimal places) required to treat 8 m^3 of the water. Equilibrium constants for Ca^{2+} and Na^+ ions are 5.2 and 2, respectively. Atomic weight of calcium is 40, while that of sodium is 23. You may use the following equation: $\frac{y_D}{(1-y_D)^2} = K\frac{\overline{C_e}}{C_e}\frac{x_D}{(1-x_D)^2}$ **[10]**

6. Write in short with proper mathematical equations (wherever possible) about the following items: (a) Langmuir isotherm; (b) Various chromatography techniques in a tabular form; (c) Various membranes and their pore size range in a schematic; (d) Crystal geometries (having proper schematics) (e) Steps in mass transfer process during fixed bed adsorption **[2×5=10]**

Part B-Open Book **Full Marks: 60**
(Time: 90 Minutes)

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7. A grinder having an efficiency of 8% handles 15 tonnes per hour of an ore (siliceous in nature). The specific gravity of the ore and work index of the ore is 2.65 and 13.57 kWh/tonne, respectively. The size analysis of feed and the product is mentioned below:

Screen Size (mm)	*Feed Mass Fraction*	*Product Mass Fraction*
-3.327+2.362	0.143	0.0
-2.362+1.651	0.211	0.0
-1.651+1.168	0.230	0.0
-1.168+0.833	0.186	0.098
-0.833+0.589	0.120	0.234
-0.589+0.417	0.076	0.277
-0.417+0.295	0.034	0.149
-0.295+0.208	0.0	0.101
-0.208+0.147	0.0	0.068
-0.147+0.104	0.0	0.044
-0.104	0.0	0.029

The cost of the grinder is 50000 INR. It operates 24 hours daily for 300 days/year. Its maintenance, overhead and the replacement cost is approximately 50% of the power cost. Industrial electricity cost can be assumed to be 1 INR per kWh. The grinder is depreciating on a straight-line basis for 10 years (*i.e., annual depreciation cost=cost of grinder/number of years*). Estimate the annual processing cost of the ore in lakhs INR. (*Hint: Use cumulative mass fraction followed by an appropriate law of size reduction*). **[20]**

8. Decolorization of a sample waste oil (density- 950 kg/m^3) is done by adsorption, using a special type of clay. Equilibrium data governing the removal process is given by the following relationship: $Y=4.2\times10^{-4}X^*$. Here, Y is the number of color units per kg of oil, while X^* is the number of color units per kg of clay in equilibrium. 2000 kg of waste oil must be treated, containing an initial color concentration of 60 units. It is desired to reduce this concentration to 1 color unit. Adsorbent's effective surface area is 25 m^2/kg and surface mass transfer coefficient is 5.2×10^{-6} m/s (on solid phase concentration basis). Estimate (a) minimum quantity of adsorbent required (in kg) and (b) required contact time (in min), if, 1.5 times the minimum amount of adsorbent is used. (*Hint: Formulate an unsteady state mass balance for part b*) **[10+10=20]**

9. A liquid containing dilute solute A at a concentration $c_1=5\times10^{-2}$ kg mol/m^3 is flowing rapidly past a dialysis grade membrane of thickness $L=5.0\times10^{-5}$ m. The distribution coefficient $K'=2$ and $D_{AB}=8.0\times10^{-11}$ m^2/s in the membrane. The solute diffuses through the membrane and its concentration on the other side is $c_2=1\times10^{-2}$ kg mol/m^3. Mass-transfer coefficient k_{c1} is large and can be considered as infinite, and $k_{c2}=1.5\times10^{-5}$ m/s. (a) Calculate the steady-state flux N_A (in kgmol/m^2.s) and make a sketch. (b) Calculate the concentrations at the membrane interface. *(Hint: Effective diffusivity is distribution coefficient times binary diffusivity; distribution coefficient is equal to the ratio of concentration at the interface)* **[10+10=20]**

All the Best 👍 and Happy New Year
