Birla Institute of Technology and Science, Pilani
Semester I Session: 2023-24
CHE F313 Separation Process-II
Comprehensive Examination

Date: 11/12/2023 (9.00 am-12.00 pm) **Full Marks: 120**

Part A-Closed Book **Full Marks: 70**
(Time: 120 Minutes)

Instructions: **Write your name and ID clearly on the answer sheet. *Answer all parts of a question together by mentioning the question number. *State and justify if you make any assumptions. *Clearly explain the nomenclature used. *Your answers must include appropriate units. *Be to the point and specific. * Textbook/Printed lecture/Handwritten notes are only allowed as reference material in open book part. * No exchange of calculators is allowed. *Once, you return the answer script for part A, part B answer script will be provided to you*

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1. A wastewater solution having a volume of 3 m^3 contains 0.4 kg phenol/m^3 of solution. This solution is mixed thoroughly in a batch process with 2 kg of granular activated carbon until equilibrium is reached. Equilibrium data provides a relation: $q=0.1c^2$, where q is kg of phenol adsorbed/kg of carbon and c is kg of phenol/m^3 of solution. Using the information provided, calculate the final equilibrium concentration (in kg/m^3) and the percentage phenol extracted by analytical method. **[5]**

2. Estimate the maximum product size obtained by reducing the size of a rock feed (70 cm size), using a double roll crusher which have rolls of 150 cm diameter and 50 cm width face. Coefficient of friction can be assumed to be 0.3. Compare your result if the coefficient of friction is 0.5. **[5]**

3. Block of wet laundry soap (approximate weight: 10 kg) has an initial moisture content of 25 wt.% on a dry basis. These soaps were then dried with air in a tunnel dryer at atmospheric pressure. During this operation, soaps were brought to equilibrium with air at 25^0C having a relative humidity of 20%. Equilibrium moisture content of soap at 20% relative humidity and 25^0C is observed as 0.04 (kg of moisture/kg of dry soap). Determine the amount of moisture (in kg) evaporated per kg of soap. **[10]**

4. A chromatographic column is utilized for analysis of two organic solvents, acetone (A) and acetonitrile (B). Length of the column has been observed to be 35 cm, while the mobile phase velocity is 0.2 cm/s. Capacity factors for acetone is 8.5 while that for acetonitrile is 7. It may also be noted that the peak width at the base of acetone is 170 s. Calculate the following parameters for analysis: (a) difference in retention times of acetone and acetonitrile; (b) selectivity; (c) height of theoretical plate; (d) plate height of the column for separation of the mixture and (e) resolution between the peaks. **[5×2=10]**

5. Write briefly about the following items with proper mathematical equations (wherever possible): (i) Rittinger's Law; (ii) Terminal velocity in different regimes of Reynolds number; (iii) McCabe "ΔL" Law; (iv) Permeability of a gas in polymers (v) Molar selectivity coefficient of ion exchange resins **[5×2=10]**

6. A waste stream of contaminant in liquid was adsorbed by activated carbon particles in a packed bed, having a diameter of 4 cm and length of 15 cm, containing 80 g of carbon. The inlet stream having a concentration C_o of 500 mg/l and a density of 0.00115 g/cm^3 entered the bed at a flow rate of 800 cm^3/s. Data in the table provided below gives the concentrations of the breakthrough curve. The break-point concentration is set at $\frac{C}{C_0} = 0.01$ and the exhaustion point is set at $\frac{C}{C_0} = 0.9$

t (h)	$\frac{C}{C_0}$	*t (h)*	$\frac{C}{C_0}$	*t (h)*	$\frac{C}{C_0}$
0	0	5	0.396	6.8	0.933
3	0	5.5	0.658	7	0.933
3.5	0.002	6	0.903		
4	0.030	6.2	0.933		
4.5	0.155	6.5	0.975		

Determine the (a) break-point time and exhaustion time, (b) the fraction of total capacity used up to the break point, (c) the length of the used and unused bed, (d) saturation loading capacity of the carbon. (e) If the break-point time required for a newly fabricated column becomes 5 hours, what will its new total length required? Use the graph paper provided. **[5×3=15]**

7. Flow rate of a concentrate from an evaporation system is 2026 kg/h which contains 38 wt.% $MgSO_4$ (M_W: 120) at 77^0C and 138 kPa. It is mixed with 4477 kg/h of a saturated aqueous recycle filtrate of $MgSO_4$ at 30^0C and 138 kPa and sent to a vacuum crystallizer, which is operating at 30^0C and 4 kPa, to produce water vapor and a magma of 20.8 wt.% crystals and 79.2 wt.% saturated solution. The magma is sent to a filter, from which filtrate is recycled. It may be assumed that (a) for saturated filtrate at 30^0C, wt.% of $MgSO_4$ is 28; (b) at 30^0C, magma is 21 wt.% $MgSO_4.7H_2O$ crystals and 79 wt.% of 28 wt.% aqueous $MgSO_4$ liquid. Determine the (a) flow rate of water evaporated (in kg/h) and (b) the maximum crystal production rate (in tons/day: 1 tons=1000 kg) on a dry basis. **[8+7=15]**

Part B-Open Book **Full Marks: 50**
(Time: 60 Minutes)

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1. A dilute solution of solute A in solvent B is passed through a tubular membrane separator, where the feed flows through the tubes. At a certain location, solute concentrations on the feed and permeate sides are 5×10^{-2} kmol/m^3 and 2×10^{-2} kmol/m^3, respectively. The permeance of the membrane for solute A is given by the membrane vendor as 7×10^{-5} m/s. Consider the following assumptions: (i) tube-side Reynolds number=15000; (ii) feed-side solute Schmidt number=500 and (iii) the diffusivity of the feed-side solute is 6.5×10^{-5} cm^2/s and the (iv) inside diameter of the tube is 0.5 cm. Estimate the solute flux through the membrane if the mass-transfer resistance on the permeate side of the membrane is negligible. Comment on your result of solute flux in case of following condition change, i.e., tube-side Reynolds number becoming 25,000; tube inside diameter becoming 0.4 cm and permeate side mass-transfer coefficient becoming 0.06 cm/s. Comment on the concentration polarization for these two cases. You may use the following empirical film-model correlation for turbulent flow: $Sh = \frac{kd_e}{D} = 0.023 \times Re^{0.8} \times Sc^{0.33}$, where, *Sh*=Sherwood number; *Re*=Reynolds number; *Sc*=Schimdt number; d_e=effective diameter of the channel; *D*=diffusivity and *k*=mass transfer coefficient **[10+5+5=20]**

2. A plate and frame filter press with a filtration area of 2 m^2 was used to filter a slurry of 10 wt.% by weight of a calcite paste (specific gravity=2.5) in water. Volume of filtrate collected with time has been recorded as:

Volume of filtrate collected (m^3)	75	150	180	200
Time (min)	10	30	60	100

Volume of filtrate collected with time follows a relation of: $V^2=K_1 t + K_2$, where t is in hours and K_1 and K_2 are constants (for all t > 0). The cake obtained is washed with water equal to 1/10th of the volume of the filtrate delivered per cycle. The rate of washing is 1/5th of the final rate of filtration. Idle time, i.e., the time required for dumping and reassembling the filter press takes 35 minutes. Estimate: (i) washing time (in hours); (ii) volume of the filtrate collected over a time of 45 minutes (in m^3); (iii) optimum cycle time (in hours) and (iv) the maximum output of filtrate per day (in m^3). **[5+5+5+15=30]**

Necessary correlations for closed book part

$$cos\frac{A_N}{2} = \frac{D_1+D_3}{D_1+D_2}\, ; K' = \frac{t_R-t_M}{t_M}; R' = (\frac{\alpha-1}{4})(\frac{K'}{K'+1})\sqrt{N_p}; N_p = 16\left(\frac{t_{R1}}{W_1}\right)^2$$

$$HETP = \frac{\sigma^2 L}{{t_R}^2}; \sigma^2 = \frac{1}{M_0}\int_0^\infty C(t-t_R)^2dt; M_n = \int_0^\infty t^n C dt$$

$$t_T = \int_0^\infty \left(1-\frac{C}{C_0}\right)dt$$

All the best

Advance Wishes for Christmas and New Year
