16/05/2025 TE CHEMICAL SEM-VI C-SCHEME CRE-II QP CODE: 10086006

(3 Hours) **[Total: 80]**

N.B. : (1) Question No. 1 is compulsory.

(2) Solve any three questions from the remaining questions.

(3) Assume suitable data wherever necessary.

Q 1. Answer the following questions: **(20)**

(a) Write a short note on the Shrinking core model and the Progressive conversion model..
(b) What are the first, second and third moments of RTD.
(c) What is the significance of Hatta number in fluid fluid reactions?
(d) Write a short note on the Fluidised bed reactor.

Q.2.(a) Derive the Langmuir-Hinshelwood type of rate equation for the reaction –

$$A + B \rightleftharpoons R + S$$

Where the adsorption of B is rate rate-controlling step. **(10)**

(b) Calculate the time required to burn to completion spherical particles of graphite (radius 12 mm, bulk density 2.4 g/cc) in a 14 % oxygen stream at 900°C and 1 atm. Assume the gas film resistance to be negligible. Surface reaction rate constant, k" = 25 cm/s. **(10)**

Q.3. (a) Develop a conversion time relationship for shrinking spherical particles when resistance through the gas film is controlling. **(10)**

(b)Explain in detail the contacting patterns in fluid-fluid reactions. **(10)**

Q.4. a) The data given below represent a continuous response to a pulse input into a closed vessel, which is to be used as a chemical reactor. Calculate the mean residence time of fluid in the vessel. Tabulate & construct E Curve. **(10)**

t, min	0	5	10	15	20	25	30	35
C_{Pulse} g/l (tracer output concentration)	0	3	5	5	4	2	1	0

(b) Spherical solid particles containing 'B' are roasted at a constant temperature in an oven with a constant gas composition. Solids are converted to give a firm non non-flaking product according to the Shrinking core model (SCM). From the following conversion data, determine the rate-controlling mechanism for the transformation of solid. **(10)**

Data:

d_p,mm	X_B	t,s
2	**0.875**	**1**
1	**1**	**1**

Q.5. (a) The catalytic reaction A → 3R is run in a packed bed reactor at 3.5 atm & 115^0C. It is desired to treat 1500 mol/hr of pure A at 3.5 atm to a 32 % conversion. the following rate concentration data are available:

C_A, Mol/l	0.04	0.06	0.075	0.09
$-r_A$, mol A/(h.kg catalyst)	3.5	5.7	7.2	8.8

Determine the amount of catalyst needed in a packed bed reactor. **(10)**

(b) Write short notes on Packed Bed and Trickling Bed Reactor **(10)**

Q.6. Answer the following questions. (**Any four**): **(20)**

a) Write a short note on the Tanks in Series model

b) Draw the kinetic regime for i) slow reactions, no mass transfer resistance.
ii) Instantaneous reaction with low C_B

c) Differentiate between Physical adsorption & Chemical adsorption.

d) Differentiate true density, apparent density and bulk density

e) Explain the Pulse input experiment for RTD measurement

(3 Hours) **Total Marks: 80**

N.B.: 1. Question **No.1** is **compulsory.**

2. Attempt any **three** questions out of the remaining **five** questions.

3. Assume **suitable** data wherever **required.**

4. **Figures** to the **right** indicates **full** marks.

Q.1] Solve any four [20]

(a) Discuss in brief the binodal solubility curve.

(b) In distillation derive the q-line equation.

(c) Explain in detail the Freundlich Adsorption Isotherm

(d) Explain the principle of leaching. Also write the applications of leaching operation.

(e) Write the different types of membrane processes. Also write the applications of membrane processes.

(f) Explain various methods of super saturation.

Q.2] (a) A liquid mixture of benzene and toluene is being distilled in a fractionating column at 101.3 kPa pressure. The feed of 100 kmole/h is liquid and it contains 45 mole% benzene (A) and 55 mole% toluene (B) and enters at 327.6 K. A distillate containing 95 mole% benzene and 5 mole% toluene and a bottoms containing 10 mole% benzene and 90 mole% toluene are to be obtained. The amount of liquid is fed back to the column at the top is 4 times the distillate product. The average heat capacity of the feed is 159 kJ/kgmole K and the average latent heat 32099 kJ/kgmoles.Calculate, 12

i. The kgmoles per hour distillate, kgmole per hour bottoms

ii. No. of theoretical stages at the operating reflux.

iii. The minimum no. of theoretical stages required at total reflux

iv. If the actual no. of stage is 10, what is the overall efficiency increased at operating condition compared to the condition of total reflux?

The equilibrium data:

Temp.(K)	353.3	358.2	363.2	366.7	373.2	378.2	383.8
x_A (mole fraction)	1.000	0.780	0.580	0.450	0.258	0.13	0
y_A(mole fraction)	1.000	0.900	0.777	0.657	0.456	0.261	0

(b) Discuss the single stage leaching and derive the relations for N_{M_1} and y_{M_1}. 08

Q.3] (a) If 100kg of solution of acetic acid (C) and water (A) containing 30% acid is to be extracted three times with isopropyl ether (B) at 20ºC,using 40kg of solvent in each stage, determine the quantities and compositions of the various streams. How much solvent would be required if the same final raffinate concentration were to be obtained with one stage? The equilibrium data at 20ºC is given below. 12

Water Layer			Isopropyl Ether layer		
Wt % Acetic acid, 100x	Water	Isopropyl ether	Acetic acid, 100y*	Water	Isopropyl ether
0.69	98.1	1.2	0.18	0.5	99.3
1.41	97.1	1.5	0.37	0.7	98.9
2.89	95.5	1.6	0.79	0.8	98.4
6.42	91.7	1.9	1.93	1.0	97.1
13.30	84.4	2.3	4.82	1.9	93.3
25.50	71.1	3.4	11.40	3.9	84.7
36.70	58.9	4.4	21.60	6.9	71.5
44.30	45.1	10.6	31.10	10.8	58.1
46.40	37.1	16.5	36.20	15.1	48.7

(b) Explain minimum boiling azeotrope and maximum boiling azeotrope. 8

Q.4] (a) 360 kg/hr of halibut liver is to be extracted in a counter current cascade with ether to recover oil. The ether which has been used partially contains 2.5 % oil. The fresh liver contains 25 % oil and is to be extracted to composition 2 % (on solvent free basis). 250 kg/hr of solvent is to be used. 12

i) What percentage of oil entering the liver is recovered in the extract?

ii) How many equilibrium stages are required?

The equilibrium data is given in the following table:

$kg\ oil/kg\ solution$	0	0.1	0.2	0.3	0.4	0.5	0.6
$kg\ solution\ /kg\ exhausted\ liver$	0.288	0.368	0.44	0.51	0.6	0.71	0.87

(b) Discuss the terms i) Reflux ratio, ii) Optimum reflux ratio (iii) Minimum reflux ratio. 8

Q.5] (a) A salt solution weighing 10000 kg with 30 % Na2CO3 is cooled to 293 K. the salt crystallizes as the decahydrate. What will be the yield of Na2CO3.10H2O crystals if the solubility is 21.5 kg anhydrous Na2CO3/100 kg of total water? 10

Do this for the following cases-

a. Assume that no water is evaporated

b. Assume that 3 % of the total weight of the solution is lost by evaporation of water in cooling.

(b) A batch of water containing residual chlorine at a concentration of 12 ppm is to be treated with activated carbon at 25°C to reduce the chlorine concentration to 0.5 ppm. Estimate the minimum mass of carbon per unit volume of water which can be used. 10

The equilibrium distribution coefficient = c*/X = 0.8 (kg Cl_2/m^3 liquid)/(kg Cl_2/kg Carbon).

Q.6] Solve any four. 20

(a) Derive operating line equation for flash distillation.

(b) Write short note on steam distillation.

(c) Write short note on reverse osmosis.

(d) Explain factors involved in choice of solvent in extraction

(e) Explain in brief Ion exchange process.

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Time: 3 Hours **Marks: 80**

N.B. 1 Question number ONE is compulsory
2 Attempt any THREE questions out of remaining FIVE
3 Figure to right indicate full marks

01. Write short notes on (any four) **20**

(a) Environmental legislation and regulations.

(b) Oxygen Sag Curve

(c) Classification of hazardous waste based on material properties.

(d) Electrostatic precipitator

(e) ISO 14001

02. (a) List the potential methods for disposal of solid waste and discuss any one in detail **10**

In a completely mixed activated sludge system determine: **10**
i) The aeration basin volume
ii) The Hydraulic retention time
iii) The sludge volume wasted daily
iv) The mass of sludge wasted daily
v) The fraction of sludge recycled
vi) The F/M ratio
Given Data:
Population equivalent 50000 (11250 m^3/day)
Influent BOD_5 = 200 mg/L
Effluent BOD_5 is 10 mg/L
Yield Coefficient Y = 0.6
Decay rate k_d = 0.06 d
Assume:
MLSS in aeration basin = 3.5 kg/m^3
MLSS in clarifier sludge = 15 kg/m^3
Mean cell residence time = 10 days

03. (a) Discuss the design criteria for Activated Sludge Process in detail. Derive the necessary derivation for volume of Aeration tank. **10**

(b) What is Plume behavior? Explain different types of plume behavior with a neat diagram. **10**

04. (a) How are air pollutants classified? List the major types of Air pollutants. Briefly explain the dry deposition mechanism and wet precipitation mechanism of nature for removal of particulate matter. **10**

(b) Describe techniques for removal of gaseous pollutants from an effluent stream? **10**

05. (a) What do you understand by inversion? What are the various types of inversion? Explain in detail along with diagram. **10**

(b) Show that the ratio of 2.25 day, 35 ºC BOD to the 5-day 20 ºC BOD is approximately unity **5**

(c) Explain Biological film system with a neat diagram. **5**

06. (a) Explain in brief about Source correction methods for air pollution control. **10**

(b) Explain Nitrification-Denitrification process in detail with a neat diagram and reactions involve in it. **10**

Time: 3 Hours **Total marks: 80**

N.B.: (1) Question No 1 is compulsory
(2) Attempt any three questions out of remaining five questions
(3) Assume suitable data if necessary and indicate it clearly.
(4) Figures to the right indicate full marks.

Q.1. Solve the following (Any four) **20**

a) Discuss different roles & responsibilities of process engineer.
b) Differentiate between Piping and Instrumentation Diagram (P&ID) and Process Flow Diagram (PFD).
c) Discuss significance of different types of trays used in distillation column.
d) Differentiate between physical and functional depreciation.
e) Draw tree diagram showing cash flow in an industrial operation.
f) Explain the various types of costs.

Q.2. a) Find out area of heat exchanger according to the following specifications and calculate its total installed cost (Updated bare module cost) in year 2015. **12**

Heat Exchanger specifications:
Identification: Condenser;
Function: to condense vapors of methanol;
Overall HTC, U= 975.7w/m^2K;
Type: Horizontal fixed tube sheet;
F_p=0.2;
Heat duty= 1250 kW;
Type of flow: Counter current flow;
Tube side specifications: Fluid: Cooling water, T_{in}= 25^0C, T_{out}= 45^0C;
Shell side specifications: Fluid: Methanol, T=80^0C (Constant);
Tube material: Stainless Steel (SS); Shell material: Stainless Steel (SS).

Design Type	**Kettle reboiler**	**U tube**	**Fixed tube sheet**
F_d	1.35	0.80	0.85

Surface area (m^2)	**Shell & Tube material, F_m**	
	Carbon steel (CS) / CS	SS / SS
0-10	1.0	2.50
10-50	1.0	3.10

Equipment type	**Co (Rs.)**	**So (m^2)**	**Range (s) m^2**	**α**	**MF**
Heat exchanger	$25x10^4$	37.18	10-900	0.65	4.12
	$1.5x10^4$	0.51	0.1-10	0.024	183

Cost index (CI)	**Year**
453	2015
128	Base year

b) A tray dryer was purchased in 2020 of the cost of Rs. 55000 has total 10 trays, each tray has size 45 cm x 28 cm, used in food processing unit. Now, production capacity is increased which require 10 trays of size 2m x 2m. Using six tenth rule, what is the expected cost of new dryer in 2023, if cost index in 2020 is 198 & in 2023 is 205? **08**

Q.3. a) Design an absorber for the following feed stream at 10 bar & 300K to recover 90% of the Diethyl ether in the liquid stream. Find the flow rate of solvent required, theoretical number of trays, Flow rates of liquid & vapour streams leaving the absorber & its composition. **15**

Data:

Component	Flow rate (gmole/s)	Vapour pressure (bar)
n-butane	100	3.4503
Di ethyl ether	5	1.09
n-butanol	2	0.019
water	16	0.061

b) Write 12 steps design process for distillation column. **05**

Q.4. a) A manufacturing plant require an initial fixed capital investment (FCI) of Rs. 50000000 and working capital investment (WCI) of Rs. 7500000. It is estimated that the annual income will be Rs. 45000000 and annual expenses including depreciation will be Rs. 24000000 before income taxes. A minimum annual return of 16% before income taxes is required, before the investment is worthwhile. Income taxes amount to 25% of all pretax profits. Determine the following: **12**

i) Annual % returns on total initial investment before income taxes
ii) Annual % returns on total initial investment after income taxes
iii) Annual % returns on total initial investment before income taxes based on capital recovery with minimum profit.

b) Discuss the following: **08**

i) Payout period method of profitability analysis
ii) Replacement analysis

Q.5 a) Hexane at 37.80 ^{0}C is pumped through the system at a rate of 9.09 m^3 /h. The tank is at atmospheric pressure. Pressure at the end of discharge line is 345 kPa g. The discharge head is 3.05 m and the suction lift is 1.22 m above the level of liquid in the tank. The friction loss in suction line is 3.45 kPa and that in the discharge line is 37.9 kPa. The mechanical efficiency of the pump is 0.6. The density of hexane is 659 kg/m^3 and its vapour pressure at 37.8 ^{o}C is 33.71 kPa. Calculate $(NPSH)_A$ **10**

b) A 3 stage reciprocating compressor is used to compress 320 m^3/h of methane from 1 atm to 60 atm. Inlet temperature of methane gas is 28 ^{o}C. Specific heat ratio of methane is 1.31. Calculate: **10**

i) Power required for compression if mechanical efficiency of compressor is 80%
ii) Discharge temperature of gas after 1st stage.

Q.6. a) In order to make it worth-while to purchase a new piece of equipment, the annual depreciation costs for the equipment cannot exceed Rs. 3000 at any time. The original cost of the equipment is Rs. 30000, and it has zero salvage & scrap value. Determine the length of service life necessary if the equipment is depreciated by: **10**

i) Sum of the years digits method
ii) Straight line method

b) For the case of a nominal annual interest rate of 10% for capital of Rs. 5000, determine: **10**
i) Total amount accumulated after one year (365 days) with daily compounding.
ii) Total amount accumulated after 5 years with continuous compounding.
iii) The effective annual interest rate if compounding is continuous.

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