Seat No.: _____ Enrolment No._____

GUJARAT TECHNOLOGICAL UNIVERSITY

BE - SEMESTER–VI (NEW) EXAMINATION – SUMMER 2021

Subject Code:2160503 Date:04/08/2021

Subject Name:Process Equipment Design -I

Time:02:30 PM TO 05:30 PM Total Marks: 70

Instructions:

1. **Attempt all questions.**
2. **Make suitable assumptions wherever necessary.**
3. **Figures to the right indicate full marks.**

Q.1 **(a)** To carry out separation of Benzene from mixture of BTX (Benzene-Toluene and Xylene, boiling point of Benzene < Toluene < Xylene), suggest light key component and heavy key component from mixture of BTX. **03**

If Toluene is to be collected in top than which components will be light key and heavy key?

(b) Suggest under which circumstances following situations takes place in distillation column, **04**

i) flooding, ii) weeping, iii) entrainment, iv) down comer backup

(c) Discuss with suitable diagram McCabe-Thiele method for design of binary distillation column. **07**

Q.2 **(a)** Suggest advantages of tray column over packed column. **03**

(b) What is the role of re-distributor, distributor, demister pads in packed bed absorption column and also suggest at which location in the column they will be placed? **04**

(c) Discuss design steps for a vertical decanter for extraction column. **07**

OR

(c) A chemical liquid is to be cooled from 90ºC to 45ºC by using brackish water in spilt ring floating heat type shell and tube heat exchanger where chemical liquid is circulated on shell side and water is on tube side. The design data are as follows. **07**

Chemical liquid data as follows:

Flow rate is 1,20,000 kg/h, density is 750 kg/m^3, Specific heat is 2.84 kJ/kgºC, thermal conductivity is 0.19 W/m ºC, Viscosity is 0.34 mNs/m^2.

Cooling water inlet temp. 25ºC, Cooling water outlet temp. 40ºC, Specific heat of water 4.2 kJ/kgºC, Viscosity of water 0.8 mNs/m^2, Thermal conductivity of water 0.59 W/mºC, Density of Water - 995 kg/m^3

Specification of fixed tube sheet heat exchanger: Shell inside diameter 800 mm , Tube O.D. 20 mm, Type of baffle 25% segmental, Tube I.D. 16 mm, Baffle spacing 178 mm, Tube length 4.83 m, Tube pitch 1.25*tube OD.

Type of tube arrangement – Triangular, Nos. of tube side passes 2, LMTD correction factor 0.85, Assume Overall heat transfer Coefficient 600 W/m^{2}ºC.

Calculate

(i) Number of tubes (ii) tube side heat transfer coefficient and (iii) shell side heat transfer coefficient. Use following correlation.

(ii) $\frac{hd}{k} = j_h RePr^{0.33}(\mu/\mu w)$

(iii) De = (1.1/do)*(Pt^2-0.917do^2)

Use j_h on shellside 0.0033 and j_h on tube side 0.0039

Q.3 **(a)** Discuss advantage and disadvantage of shell and tube heat exchanger. **03**

(b) Draw schematic diagram of various types of baffles and suggest under which circumstances they (any two) will be used in shell and tube heat exchanger. **04**

(c) Discuss stepwise design procedure for thermosyphon reboiler design. **07**

OR

Q.3 **(a)** Which are commonly used heating and cooling media for heat exchangers in chemical process industries. **03**

(b) Suggest suitable allocation of following fluids in shell and tube heat exchanger, i. most corrosive, ii. most hazardous, iii. hot, iv. condensing vapor **04**

(c) Discuss design procedure for kettle type reboiler design **07**

Q.4 **(a)** Using Fenske-Underwook-Gilliland method, determine minimum reflux ratio, minimum number of theoretical stages required, optimum reflux ratio and theoretical stages required for desired separation for following system. Feed flow rate is 100 kmol/hr and feed is saturated liquid. Composition of distillation column streams and average relative volatilities of all components of feed are as follows. **14**

Component	α_{avg}	Feed	Distillate	Residue
Benzene	8.96	2.2	22.8	0
Toluene	2.8407	7.4	72.2	0.5
Ethylbenzene	1	43.4	5.0	47.5
Styrene	0.6506	47	0	52

Toluene is light key and ethyl benzene is heavy key component. Gilliland co relation is given by:

$N - Nm / N+1 = 1 - \exp ((1 + 54.4\psi / 11 + 117.2\ \psi) * (\psi - 1 / \psi^{0.5}))$

Where $\psi = R - R_m / R + 1$

OR

Q.4 **(a)** Suggest suitable parameter change to reduce pressure drop in a pipe flow. **03**

(b) If for a particular pump location while design, calculated value of (NPSH)A is coming less than (NSPH)R. Give your suggestions for this situations and solutions if required. **04**

(c) Specific chemical is transferred using pump from a storage tank to a distillation column. The tank is blanketed with nitrogen and the pressure above the liquid surface is held constant at 2 bar g. Pressure inside distillation column is 1.1 bar. The minimum depth of liquid in the tank is 1 m. The feed point to the column is 40 m above the base of tank. The tank and column are connected by a 225 mm internal diameter commercial steel pipe, 1200 m long. The pipe running from the tank to the column contains the valves and fittings having total losses equivalent to 500 equivalent to pipe diameter. If the maximum flow rate required is 1,50,000 kg/hr, calculate the power required by pump. Pump efficiency is 70%. Density of the chemical fluid is 874 kg/m^3 and viscosity is 0.62 mNm^{-2}.s. Pressure drop for turbulent flow of fluid through commercial steel pipe in kPa/m $\frac{\Delta P}{L} = 4.07 * 10^{10} * G^{1.8} * Di^{-4.84} * \mu^{0.16} * \rho^{-1}$ **07**

Where G in kg/s, Di in mm, μ in kg/(m.s) and ρ in kg/m^3.

Q.5 **(a)** Why heat sensitive materials are separated under vacuum conditions in distillation column? **03**

(b) Suggest change in pressure drop with change in type of packing (rasching ring, birl saddles) and size of packing (1.5 inch, 1 inch). **04**

(c) Design a gas absorber to absorb one pollutant gas from the exits gas stream of boiler flue gas by using 1% lime Solution (by mass). The data for the scrubber is as follows. Volumetric flow rate of exist gas stream = 24000 Nm^3/h, **07**

Discharge pressure of gas from venturi = Atmospheric,

Temperature of gas mixture, entering the venturi scrubber = 90 °C,
SO_2 concentration in the boiler flue gas = 4000 ppm (or mg/kg),
Solvent to gas ratio = 1.4 L/m^3 ,
Throat velocity of gas phase = 100 m/s,
Average molar mass of flue gas = 29.48 kg/kmol,
Density of 1% lime Solution = 1012.5 kg/m^3 ,
Equilibrium mass of SO_2 per 100 mass of H2O = 0.035
Determine: (i) throat diameter of venturi scrubber, (ii) % removal SO_2 gases, (iii) pressure drop in venturi scrubber.

Use following correlation:

$$\text{Fractional solute removal} = \frac{y_1 - y_2}{y_1} = \eta \frac{(1 - mx_2 / y_2)}{\left(1 + \frac{mG_M}{L_M}\right)}$$

$$\text{Mass transfer efficiency } = \eta = 1 - e^{-N_G}$$

$$\text{Number of overall gas-phase mass transfer units } N_G = (K_G aRT / p_t)/\theta_c$$

$$\text{Venturi pressure drop } \Delta P = 2.584 \times 10^{-3} v_G{}^2 \rho_G A_{th}{}^{0.133} \left(L' / G'\right)^{0.78}$$

OR

Q.5 **(a)** Draw schematic diagram of 1-6 pass shell and tube heat exchanger. **03**

(b) Draw schematic diagram of U tube shell and tube condenser with all inlet and out let fluid directions. Why U-tube condenser is more common choice for shell and tube condenser design? **04**

(c) Explain Tinker's flow model with suitable schematic diagram. Also suggest solutions to reduce leakages and bypass considered in Tinker's flow model. **07**

****