# CHEMICAL ENGINEERING

## SECTION-A

## (80 Marks)

1. Match the following:

List I

A. Phenol formaldehyde
B. Nylon
C. High purity polyvinyl chloride
D. Styrene butadiene rubber

List II

1. Suspension polymerization
2. Emulsion polymerization
3. Solution polymerization
4. Bulk polymerizaton

(2)

2. Match the following:

List I

A. Methanol to gasoline
B. Edible oil hydrogenation
C. Methanation
D. Butyl acetate

List II

1. Raney nickel
2. Zeolite
3. Cation exchange resin
4. Nickel

(2)

3. Fill in the blanks

a. Pure terephthalic acid is manufactured by the oxidation of the oxidation of _____ and is used as a raw material for the manufacture of _____.

(2)

b. In the manufacture of Portland cement the major raw materials are _____, _____, _____ and _____.

(2)

4. Fill in the blanks

a. A wet paper pulp contains 75% water. After 100 kg of water is removed in a dryer, it is found that the pulp is now containing 30% water. The weight of the original pulp is _____.

(2)

b. The weather bureau reports a dry bulb temperature of ambient air as 29°C and relative humidity of 80%. The barometer reads 750 mm Hg. The percentage humidity of the ambient air is _____.

(Vapour pressure of water at 29°C = 30 mm Hg.)

(2)

c. $H_2S$ is produced from the reaction

$FeS + 2HCl \rightarrow FeCl_2 + H_2S$ .

120 kg of FeS react with 150 kg of HCl and 0.5k mol of $H_2S$ has been produced. The degree of completion of the reaction is and the limiting reactant is _____ and the limiting reactant is _____.

(2)

d. The heat absorbed For isothermal reaction

$C_4H_{10}(g) \rightarrow C_2H_4(g) + C_2H_6(g)$

at 298 K and 1 atm pressure is _____. Standard heat of combustion, kJ/mol

$C_2H_{10}(g) = -2873.5$

$C_2H_4(g) = -1411.9$

$C_2H_6(g) = -1561.0$.

(2)

5. Fill in the blanks

a. Spherical particles of limestone ($d_p$ = 0.16 mm, density = 2800 kg/m$^3$) take 5 minutes to settle under gravity through a 6 m column of a fluid of density 1200kg/m$^3$. The drag coefficient is equal to _____.

(2)

b. The equilibrium position of the float in a rotameter is determined by the balance of three forces. These are _____, _____ and _____.

(2)

6. Match the following:

(2)

List I

A. Edible oil.
B. Crude oil from oil wells
C. 98 % Sulphuric acid
D. Liquids containing suspensions of abrasive solid

List II

1. Diaphragm pump
2. Centrifugal pump
3. Gear pump
4. Air lift pump

7. For 500 < Re < 200000, the friction factor $f = 0.046\ (Re)^{-0.2}$ Find the colburn factor, $J_H$, at Re = 10000.

(2)

8. Fill in the blanks:

a. The sphericity of a non-spherical particle is defined as the ratio of to _____ to _____. The sphericity of a cylindrical particle of diameter 3 mm and length 3 mm is _____ mm.

(2)

b. The maximum diameter of a spherical sand particle (density 2650 kg/m$^3$) that will settle in the stokes law region in water (density 1000 kg/m$^3$, viscosity 0.001 kg/m.s) is _____ mm.

(2)

c. A vacuum leaf filter gives a total volume of 10m$^3$ of filtrate in 30 minutes. If the resistance of filter cloth is negligible, the time taken for the collection of 20 m$^3$ of filtrate is _____ minutes and for the collection of 30 m$^3$ of filtrate are _____ minutes.

(2)

d. For a two fold increase in pressure the specific resistance of a filter cake increases by _____, if the compressibility coefficient is 0.5 and increases by _____, if the compressibility coefficient is 0.8.

(2)

9. Fill in the blanks

a. An industrial wall is constructed of 20 cm thick fireclay (k = 1 W/m. °C). This is covered on the outer surface with a 3 cm layer of insulating material (k = 0.075 W/m.°C). The innermost surface is at 940°C and the outermost at 40°C. The steady rate of heat transfer through the wall is _____ W/m$^2$ and the temperature of the interface between the fireclay and the insulating material is _____ °C.

(2)

b. The Biot modulus for a 3 cm diameter sphere (k for the sphere = 5W/m °C) at 100°C subjected to a convective air flow resulting in an average convective heat transfer coefficient from the surface of 30W/m$^2$. °C is equal to _____.

(2)

10. Choose the correct answer:

The widely used Dittus - Boelter equation is valid provided

a. 2100 < Re < 10,000 and the properties of the fluid are evaluated at the average film temperature.
b. Re < 2100 and the properties of the fluid are evaluated at the bulk temperature.
c. 10,000 < Re < 120,000 and the fluid properties are evaluated at the bulk temperature.
d. None of the above.

(2)

11. Match the following

List I (Process)

A. Drop wise condensation of steam
B. Boiling water
C. Heating oils
D. Heating with Air

List I (Heat transfer Coefficient W/m$^2$.°C)

1. 1700 — 50,000
2. 50 — 1500
3. 1 — 5
4. 30,000 — 100,000

(2)

12. Fill in the blanks:

a. The diffusion rate of ammonia from an equation solution to the gas phase is $10^{-3}$ Kmol/m$^2$.s. The interface equilibrium pressure of $NH_3$ is 660 N/m$^2$ and the concentration of $NH_3$ in gas phase is 5%. If the total pressure is 101 N/m$^2$, temperature is 295 K and diffusivity of $NH_3$ is 0.24 cm$^2$/s, the gas film thickness is _____ mm.

(2)

b. The Fick's second law of diffusion in one dimension is _____.

(2)

13. Choose the correct answer:

1. For a gas obeying the van der Waals equation, at the critical temperature

a. both $\left(\frac{\partial p}{\partial V}\right)_T$ and $\left(\frac{\partial^2 p}{\partial V^2}\right)_T$ are zero

b. the first derivative is zero, while-the second -derivative is non-zero

c. the second derivative is zero, while the first derivative is non-zero

d. both the derivatives are non-zero.

(2)

2. For an ideal gas the slope of the pressure-volume curve at a given point will be

a. steeper or an isothermal than for an adiabatic process

b. steeper for an adiabatic than for an isothermal process.

c. identical for both the processes

d. of opposite signs

(2)

3. For a system in equilibrium, at a given temperature and. pressure:

a. the entropy must be a minimum

b. the enthalpy must be a minimum

c. the internal energy must be a minimum

d. the Gibbs-free energy must be a minimum.

(2)

4. To obtain the integrated form of Clausius-Clapeyron equation

$$\ln\frac{p_2}{p_1}=\frac{\Delta H_v}{R}\left[\frac{1}{T_1}-\frac{1}{T_2}\right]$$

from the exact Clapeyron equation, it is assumed that:

a. the volume of the liquid phase is negligible compared to that of the vapour phase

b. the vapour phase behaves as an idea! gas

c. the heat of vaporization is independent of temperature

d. all the above are applicable.

(2)

5. The shape of T-S diagram for Carnot cycle is

a. a rectangle

b. a rhombus

c. a trapezoid

d. a circle.

(2)

14. Choose the right answer:

1. The reaction of A and B produces the desired product R as well as the unwanted product S. What level of reactant concentrations (high, medium, low) should we use for the following reaction scheme in order to maximize the conversion of A to R.

Reaction Scheme:

$$A+B\rightarrow R \qquad r_1=k_1C_AC_B^2$$
$$A\rightarrow S \qquad r_2=k_2C_A.$$

a. Low $C_A$, Low $C_B$

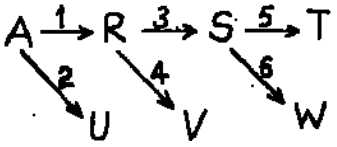
b. High $C_B$, Any $C_A$

c. High $C_A$, Low $C_B$

d. High $C_A$ Any $C_B$

(2)

2. Qualitatively, find the optimum temperature progression to maximize $C_T$ for the elementary reaction scheme given below:




$E_1$ = 25; $E_2$ = 10; $E_3$ = 25; $E_4$ = 35; $E_5$ = 40; $E_6$ = 25; (E = Activation energy)

a. Decreasing T

b. Increasing T

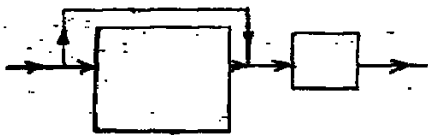
c. Decreasing T first and then increasing T

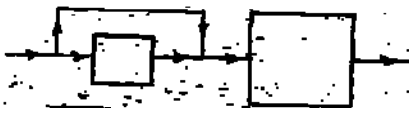
d. Constant T.

(2)

3. Your company has two mixed flow reactors of unequal size for producing a specified product formed by a homogeneous second order reaction. How should these reactors be connected to achieve a maximum production rate?

a.

b. 

c. 

d. 

(2)

15. Fill in the blank:

Far a-zero order solid catalyzed reaction a having a Thiele Modulus equal to one, the value of effectiveness factor is _____.

(2)

16. Choose the right-answer:

1. A certain thermocouple has a specific time constant, of 2s. If the process temperature changes abruptly from 800 to 900°C, the temperature reading in an indicator attached to the thermocouple after 6s will be approximately.

a. 860°C
b. 900°C
c. 890°C
d. 895°C

(2)

2. A plant has a water tank mounted on the top of a 27 m plat form. The tank is 10 m high. The height of water in the tank. if a pressure gauge on the second floor at a height of 5 m from the ground reads 2.7 bar is:

a. Full
b. 5.12 m
c. 3.12 m
d. 7.18 m.

(2)

3. A system has the transfer function $\frac{Y}{X} = \frac{10}{s^2 + 1.6s + 4}$.

A step change of 4 units magnitude is introduced in this system. The per cent overshoot is

a. 20
b. 30
c. 25
d. 35.

(2)

4. The type of process that most often can benefit from derivative control is

a. Flow
b. Level
c. Temperature
d. Pressure.

(2)

17. Fill in the blanks :

a. Narrow faced flange is the one where all the face contact area lies _____ the circle enclosed by the bolt holes.

(1)

b. In calculation of flange stress, the loads acting on the flange are to be calculated both for operating as well as for bolting up conditions and _____ of the two will be taken.

(1)

c. The rigidity of the cylindrical vessel subjected to external pressure may be increased by providing uniformly spaced, internal or external circumferential _____.

(1)

d. Expansion joints are provided in fixed tube heat exchangers to reduce _____ in the shell and tubes.

(1)

18. Choose the correct answer:

1. A standard type of heat exchanger with a negligible scrap value costs Rs. 40,000 and will have a useful life of 6 years. Assuming an effective compound interest of 10% per year. The capitalized cost of a heat exchanger will be

a. Rs. 60,880
b. Rs. 90.880
c. Rs. 91,880
d. Rs. 81,880.

(2)

2. A reactor having a salvage value of Rs. 10.000 is estimated to have a service life of 10 years. The annual interest rate is 10%. The original cost of the reactor was Rs. 80.000. The book value of the reactor after 5 years using sinking fund depreciation method will be:

a. Rs. 40,096
b. Rs. 43,196
c. Rs. 53,196
d. Rs. 60,196

(2)

3. The total capital investment for a chemical plant is Rs. 1,000,000 and the working capital is Rs. 100.000. If a turnover ratio is 1, the gross annual sales will be:

a. Rs. 800.000
b. Rs. 900,000
c. Rs. 1,000,000
d. Rs. 1,100,000

(2)

## SECTION-B

## (120 Marks)

19. Write down the main overall reaction equation for the manufacture of following chemicals

(6 × 2 = 12)

1. Soda ash
2. Superphosphate from phosphate rock
3. Urea
4. High octane petrol from naphtha
5. Vinyl acetate from ethylene
6. Acrylonitrile from propylene.

20.

1. Nitrogen from a cylinder is bubbled through acetone at 1.1 bar and 323 K at the rate of $2 \times 10^{-4}$ $m^3$/min. The nitrogen, saturated with acetone vapour, leaves at 1.013 bar, 308K at the rate of $3.83 \times 10^{-4}$ $m^3$/min. What is the vapour pressure of acetone at 308K?

(6)

2. Limestone mixed with coke is being burnt in a kiln. An average analysis of the limestone is $CaCO_3$:84.5%, $MgCO_3$:11.5% and the rest inerts. The coke contains 76% carbon, 21% ash and 3% moisture. The calcinations of $CaCO_3$ is only 95% complete and that of $MgCO_3$ 90%. The carbon in the coke is completely burnt to $CO_2$. The kiln is fed with 1 kg of coke per 5 kg limestone. Calculate weight per cent CaO in the product leaving the kiln.

(6)

21.

1. What size of orifice would give a pressure difference of 41 cm water column for the flow of liquid styrene of specific gravity 0.9 at 0.055 $m^3$/s in a 250 mm diameter pipe? Assume $C_D$ = 0.62.

(4)

2. A cylindrical tank 5 m diameter discharges through a pipe 50 m long and 250 mm diameter connected to the base of the tank. Show that the time taken for water level in the tank to drop from 4 m to 1 m above the bottom of the tank is given by

$$t = 90.3\sqrt{1+1600\left(\frac{R}{\rho u^2}\right)}\int_1^4 \frac{dh}{\sqrt{h}}$$

when it is assumed that $(R/\rho u^2)$ the resistance to flow per unit area of pipe surface, is constant.

(8)

22.

1. How is work index defined?

(1)

2. The power required to crush 100 tons/hr of a material is 179.8 kW, if 80% of the feed passes through a 51 mm screen and 80% of the product passes through a 3.2 mm screen. What is the work index of the material?

(3)

3. What will be the power required for the same teed at 100 tons/hr to be crushed to a product such that 80% is to pass through a 1.6mm screen?

(2)

4. In a mixture of quartz (sp. gr. = 2.65) and galena (sp. gr. = 75), the size of the particles range from 0.0002 cm to 0.001 cm. On separation in a hydraulic classifier using water under free settling conditions, what is the

maximum size of quartz and the minimum size of galena in the pure products?

(Viscosity of water = 0.001 kg/m.s., density = 1000 kg/m$^3$).

(6)

23.

1. In a cocurrent heat exchanger, an oil stream is cooled from 450K to 410K by water inlet and outlet temperatures of 300K and 350K respectively. The exchanger consists a number of tubes of 1 m length each. It is now desired to cool the oil to 390 K (instead of 410K) while maintaining the flow rate of oil, flow-rate of water, Inlet temperatures of oil and water, and the number of tubes at the same values as before. Calculate the length of each tube required for this purpose. Assume that the physical properties remain unchanged.

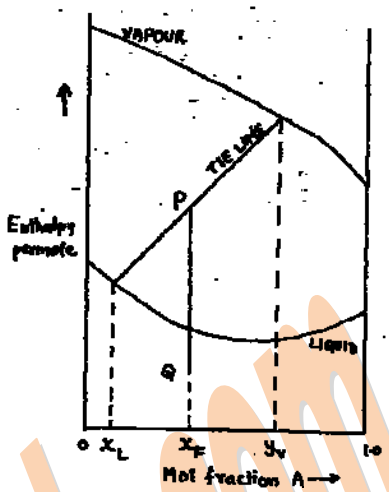
(6)

2. A horizontal steam pipe 20 m long, 50 mm internal diameter, 60 mm outside diameter loses 13.5 kW heat to the surroundings at 310K. The pipe caries steam at 500 K. Given, that the convective heat transfer coefficient $h_c = 1.65\ (\Delta T)^{0.25}$ W/m$^2$.K and the Stefan-Boltzmann constant = $5.67 \times 10^{-8}$ W/m$^2$.K. Find the emissivity of the bare surface of the pipe

(6)

24.

1. A continuous stream of a binary liquid mixture, containing $X_F$ mol fraction of A, is fed into a flash distillation unit. Feed is represented by point Q on the enthalpy-concentration diagram as shown in Figure. The products out of the unit are a vapour stream ($y_V$ m fraction of A) and liquid stream ($X_L$ mol fraction of A).




a. Obtain an expression for the ratio of vapour flow rate to feed flow rate in terms of compositions.

(2)

b. Show that the heat added per mole of teed is given by the distance PQ (See Fig.

(6)

2. An aqueous solution containing 1.5K mole X/m$^3$ is fed at 36 ml/s to the top of packed column of height 1.60 m and cross sectional area of 0.0045 m$^2$ and it leaves at the bottom with 1.4K mole/m$^3$. An organic solvent, B, containing 0.008 K mol X/m$^3$ flaws counter to the aqueous phase at 9 ml/s. The equilibrium relationship is

$$Cx^*_{organic} = 0.3Cx_{aqueous}$$

Determine:

a. The log means concentration difference for the transfer.

(2)

b. The overall volumetric transfer coefficient, based on the organic phase.

(4)

c. The height of transfer unit.

(2)

25.

1. Calculate the fraction of pure ethane that would dehydrogenate at 750 K and 5 atm., if the following reaction goes to equilibrium.

$$C_2H_6(g) \rightleftharpoons C_2H_4(g) + H_2(g)$$

$\Delta G°$ for the reaction at 750 K = 42.576 kJ. Assume ideal gas behaviour.

(6)

2. At 318 K at total pressure of 24.4 kPa, the composition of the. system ethanol (1) and toluene (2) at equilibrium is $x_1$ = 0.3 and $y_1$ = 0.634. The saturation pressure at the given temperature for pure components are

   $P_1$ = 23.06 kPA and $P_2$ = 10.05 kPa, respectively.

   Calculate:

a. The liquid phase activity coefficients
b. the value of $G^E/RT$ for the liquid phase.

26.

1. For a reversible exothermic elementary catalytic reaction of the type

   $$A \underset{k_2}{\overset{k_1}{\rightleftharpoons}} R$$

   find the Optimum operating reaction temperature a conversion level, $X_A$ = 0.8

   DATA: $k_1 = \exp(10 - 5000/T)$

   $k_2 = \exp(40 - 15000/T)$

   Maximum allowable temperature = 300 K.

   (6)

2. The rate of a liquid phase reaction of the type

   $A + B \rightarrow$ Products

   is found to be independent of concentration of A and B, and equal to 1 K mol/($m^3$) (mm) at 300 K. Find the conversion in a mixed flow reactor having volume equal to 2 $m^3$ with feed concentration of A and S equal to 5K mol/$m^3$, feed flow rate equal to 1 $m^3$/min., and reactor temperature equal to 300 K.

   If the activation energy of the reaction is given as 83.1 kJ/mol find the volume of an isothermal plug flow reactor for the same conversion and feed conditions as in the case of the above mentioned reactor but with reactor temperature kept at 320 K.

(6)

27.

1. Find the minimum value of 'K' such that a closed loop system having the following characteristic equation is stable:

   $$s^3 + Ks^2 + (K+1)s + 4 = 0$$

   (6)

2. An aqueous solution (density = 1000 kg/$m^3$, specific heat 4 kJ/kg°C) at 300 K is continuously fed at a flow rate of 1 $m^3$/min to a continuous flow stirred tank of volume 1 $m^3$ containing a heater having a heating capacity of 1000 kW. If the liquid in the tank is also at 300 K to start with, find the equation which predicts the exit temperature of the solution as a function of time after the heater is switched on.

   (6)

28.

1. A spherical storage tank is having an outer diameter of 2 m. and a thickness of 5 mm. The tank seams are welded and having joint efficiency of 0.85. The material of construction will be plain carbon steel. The chemical will be stored at the maximum temperature of 296 K. No corrosion problems are expected. What maximum internal pressure the tank will withstand safely?

   Allowable design stress value at working temperature = 118 MN/$m^2$.

   (4)

2. A heat exchanger with an initial investment of Rs. 300,000 has a 6 years life. How much can be spent on an improved design which has a life of 12 years and is expected to save Ps. 10.000 per year?

   Annual compound interest rate = 8%.

   (6)