CHEMICAL ENGINEERING

SECTION - A

ONE MARKS QUESTIONS (1-20)

Use the following values: R (universal gas constant) = 8.314 J/mole k; g (acceleration due to gravity) = 9.81 m/s^2.

1. The inverse of a matrix $\begin{bmatrix} a & o \\ o & b \end{bmatrix}$ is

   a. $\begin{bmatrix} ab & o \\ o & 1 \end{bmatrix}$

   b. $\begin{bmatrix} b & o \\ a & b \end{bmatrix}$

   c. $\begin{bmatrix} 1/a & o \\ o & 1/b \end{bmatrix}$

   d.

2. The limit of f(x) = x/sin x as x $\to$ o is

   a. o

   b. 1

   c. 2

   d. ∞

3. Integrating factor for the differential equation

   $\frac{dy}{dx} + P(x)y = Q(x)$ is

   a. $\exp\left[\int Pdx\right]$

   b. $\exp\left[-\int Pdx\right]$

   c. $\int Pdx$

   d. dp/dx

4. If $\underline{i}, \underline{j}, \underline{k}$ are the unit vectors in rectangular coordinates, then the curl of the vector $i\underline{y} + jy + \underline{k}z$

   a. $\underline{k}$

   b. - $\underline{k}$

   c. $\underline{j} + \underline{k}$

   d. $\underline{i} + \underline{k}$

5. The solution for the differential equation

   $\frac{d^2y}{dx^2} + 5\frac{dy}{dx} + 6y = 0$ is

   a. $C_1e^{-2t} + C_2e^{3t}$

   b. $C_1 \sin 2t + C_2 \cos 2t$

   c. $C_1e^{2t} + C_2e^{-3t}$

   d. $C_1e^{-2t} + C_2e^{-3t}$

6. Solvay process is used for the manufacture of

   a. Caustic soda

   b. Soda ash

   c. Caustic potash

   d. Soda lime

7. Phthalic anhydride is- produ6ëd by the oxidation of

   a. Napthalene

   b. Benzene

   c. Toluene

   d. Aniline

8. Which of the following fuels has the highest calorific value per unit mass?

   a. Coal

   b. Kerosene

   c. Natural gas

   d. Furnace oil

9. The most widely used coagulant for removing suspended impurities from water is

   a. Bleaching powder

   b. Chlorine

   c. Calcium sulphate

   d. Alum

10. The shear stress-shear rate relationship for a liquid whose apparent viscosity decreases with increasing shear rate is given by

    a. $\tau_{yx} = -m\left|\frac{dv_x}{dy}\right|^{n-1}\frac{dv_x}{dy}$ for $n<1$

    b. $\tau_{yx} = -m\left(\frac{dv_x}{dy}\right)^n \quad n=1$

    c. $\tau_{yx} = -m\left|\frac{dv_x}{dy}\right|^{n-1}\frac{dv_x}{dy} \quad n>1$

d. $\tau_{yx} = -m\frac{dv_x}{dy} + \tau_o$

11. A Newtonian liquid (ρ density, μ = viscosity) is flowing with velocity v in a tube of diameter D. Let ΔP be the pressure drop across the length L. For a laminar flow, ΔP is proportional to

a. $L\rho v^2/D$

b. $D\rho v^2/L$

c. $L\mu v/L$

d. $\mu v/L$

12. Praudtl number is the ratio of

a. mass diffusivity to thermal diffusivity

b. momentum diffusivity to thermal diffusivity

c. Thermal diffusivity to mass diffusivity

d. Thermal diffusivity to momentum diffusivity

13. For a laminar flow of fluid in a circular tube, h_1 is the convective heat transfer coefficient at velocity V_1. If the velocity is reduced by half and assuming the fluid properties are constant the new convective heat transfer coefficient is

a. 1.26 h_1

b. 0.794 h_1

c. 0.574 h_1

d. 1.741 h_1

14. A metal wire of 0.01 m dia and thermal coductivity 200 w/m. °K is exposed to fluid stream with a convective heat transfer coefficient 1000 w/m^2 °K. The Biot Number is

a. 5.6

b. 0.0125

c. 3.5

d. 0.0035

15. Diffusion coefficient in a binary gas mixture at low pressures varies with pressure as

a. P

b. P^2

c. 1:1

d. independent or P

16. Mass transfer coefficient, k according to penetration to theory varies with mass diffusivity as

a. $D^{0.5}$

b. D

c. 1/D

d. $D^{1.5}$

17. For the gaseous reaction 2A → B where the feed consists of 50 mol % inerts, the expansion factor is

a. 1

b. – 0.5

c. – 0.25

d. 0

18. To maximize the formation of R in the simultaneous reactions

A + B → R $\quad r_R = 2C_A^{0.5}C_B^2$

A + B → S $\quad r_S = 1.5\, C_A\, C_B$

we should have

a. low C_A, low C_B

b. low C_A, high C_B

c. high C_A, low C_B

d. high C_A, high C_B

19. Ideal gas low is applicable at

a. low T, low P

b. high T high P

c. low T, high P

d. high T, low P

20. The second low of thermodynamics states that

a. The energy change of a system undergoing any reversible process is zero

b. It is not possible to transfer heat from a lower temperature to a higher temperature

c. The total energy of the system and surrounding remains constant

d. None of the above

21. **Fill in the blanks. In the answer book write the question number and the answer only.**

(20 × 1 = 20)

a. The taylor's series expansion of f(x) around x = a is ___________.

b. For a differential function f(x) to have a maximum, $\frac{df}{dx}$ should be _________ and $\frac{d^2 f}{dx^2}$ should be _________.

c. M dx + N dy is an exact differential when ___________.

d. The integral of x sin x is ___________.

e. The Green's theorem relates _____ integrals to surface integrals.

f. If 'a' is a scalar and b is a vector, then $\nabla \times a\,\underline{b}$ = _____________.

g. The differential equation $\frac{d^2y}{dx^2} + y = 0$, with the conditions y(o) = o and y(1) = 1 is called a _________ value problem.

h. Double contact double absorption process is used for The manufacture of _________.

i. For an orifice meter, the pressure recovery is ________ than that for a venturimeter.

j. A gas bubble at a pressure of P_g is-passed through a solvent with a saturation vapor pressure of P_s. If the time of passage of the bubble is long and air is insoluble in the solvent, the mole fraction or solvent in the bubble will be equal to _________.

k. The heat of formation of a compound is defined as the heat of reaction leading to the formation of the compound from its ____________.

l. A supersaturated solution of a sparingly soluble solute, at a concentration of C, is being fed to a crystallizer at a volumetric flow rate of V. The solubility of the solute is C_s. The output rate of solids from an efficient crystallizer is ____________.

m. A body at 925 K emits an energy of 1.42×10^{11} σ w/m^2 (σ is Stefan Boltzmann-constant) in the wave-length Band between 3μm to 4μm. The fraction of this energy in the total energy emitted over the entire wavelength range is equal to ___________.

n. According to film theory for equimolar counter diffusion, the mass transfer coefficient is given by ____________.

o. The Reynolds analogy for mass transfer is give by ___________ and is applicable when Schmidt number is __________.

p. Sherwood number for flow in a pipe can be expressed as the ratio of the concentration gradient at ________ to the overall concentration difference.

q. The Arrhenius equation for the temperature dependency of the reaction rate constant is ____________

r. For a given conversion and a first-order reaction, the volume required for a mixed reactor is __________ than that for a plug flow reactor

s. The rate of reaction is defined as _______

t. The phase rule is given as ____________.

22. **State with reasons whether the statement is true or false.**

a. The series 1 + x + x^2 + x^3 + for x < 1 is divergent. ___________

b. As long as a pump is not used, a fluid will always flow from high pressure regious to low pressure resins.

c. If an insoluble gas is passed through a volatile liquid placed in a perfectly insulated container, the temperature of the liquid will increase.

d. When a vertical plate is heated in an infinite air environment under natural convection conditions, the velocity profile in air, normal to the plate, exhibits a maximum.

e. The maximum in the emissive power of a surface at a temperature of T_1 occurs at a wave length of λ_1. If the surface temperature is halved, the maximum in the emissive power would occur at a wave length of $0.5\lambda_1$.

f. For laminar flow over a flat plate of length L. the local mass transfer coefficient at a distance L from the leading edge is 1.5×10^{-2} m/s. Then the average mass transfer coefficient for the plate is 2×10^{-2} m/s

g. According to the penetration theory, the mass transfer coefficient decreases if the exposure time of an eddy to the solute decreases.

h. The concentration and hydrodynamic boundary layers over a flat plate are of equal thickness if Schmidt number is equal to unity

i. The Z-component of die total mass flux of a component A in a binary mixture of A and B is given by

$-D_{AB}\frac{dc_A}{dz}$

j. A medium is always required for heat to be transferred,

k. Forced convection is relatively more effective in increasing the rate of mass transfer if Schmidt number is larger.

l. If the rate of the irreversible reaction $A+B \rightarrow 2C$ is kC_AC_B, then the reaction is always elementary.

m. Two mixed reactors of unequal size are available for producing a specified product, formed by a homogeneous second order reaction. To achieve maximum production rate, the smaller reactor should be placed in series before the larger reactor.

n. For the same conversion, the holding time required in a batch reactor is always equal to space time required in a plug flow reactor.

o. The mechanism for the decomposition of CH_3 CHO into CH_4 and CO in the presence of I_2 is

$CH_3CHO + I_2 \rightarrow CH_3 + HI + CO;$ *slow*

$CH_3I + HI \rightarrow CH_4 + I_2;$ *fast*

Then, the rate of disappearance of CH_3 CHO is equal to $C_{CH_3I}C_{HI}$ and HI acts as a catalyst.

p. Pressure is an extensive property.

q. Work done by a gas during free expansion is zero.

r. A process is irreversible, as long as ΔS for the system is greater than zero.

s. The mechanical work done by a system is always equal to $\int Pdv$

23. Match the items in the left column with the appropriate items in the right column

a. (I) cosh (at)
(II) Sin (at)
(A) $a/(s^2 + a^2)$
(B) $a/(s^2 - a^2)$
(C) $s/(s^2 - a^2)$
(D) $s/(s^2 + a^2)$

b. (I) $\frac{dy}{dx} = x^2 + y^2$
(II) $\frac{dy}{dx} = x^2 + y$
(A) linear first order O.D.E. with constant coefficient.
(B) linear O.D.E. with variable coefficient.
(C) first order nonlinear O.D.E.
(D) linear second order O.D.E.

c. (I) catalytic cracking
(II) catalytic reforming
(A) kerosene
(B) Gasoline
(C) Aromatics
(D) Diesel

d. Match the appropriate materials for handling the following chemicals
(I) concentrated sulfuric acid
(II) Caustic Soda
(A) Brass
(B) Aluminium
(C) Nickel
(D) Lead

e. Match the appropriate catalyst with the-process
(I) hydtogena1ion of vegetable oils
(II) Ammonia Synthesis
(A) Iron
(B) Platinum
(C) Nickel
(D) Zeolites

f. match the reactions with names
(I) $CO + H_2O \rightleftharpoons CO_2 + H_2$
(II) $CH_4 + H_2O \rightleftharpoons CO + 3H_2$
(A) Boudard reaction
(B) Water gas shift reaction
(C) Water gas reaction
(D) Steam reforming

g. (I) Stanton Number
(II) Prandtl Number
(A) hD/k
(B) $h/(C_p\rho v)$
(C) C_pk/μ
(D) $C_p\mu/k$

h. For a sphere of density s and volume V placed in a fluid of density ρ

(I) Weight

(II) Buoyancy force

(A) $(\rho_s - \rho)Vg$

(B) ρVg

(C) $\rho_s Vg$

(D) $(\rho_s + \rho)Vg$

i. A Ural back body with a surface area A_1 having no concavities is surrounded by a large black surface of area A_2. Match the view factors

(I) F_{21}

(II) F_{22}

(A) 1

(B) 1 - (A_1/A_2)

(C) A_1/A_2

(D) o

j. (I) Nusselt Number

(II) Biot Number

(A) $\frac{\text{Convectiv Resistance}}{\text{Fluid conduction resistance}}$

(B) $\frac{\text{Fluid conductance Resistance}}{\text{Convective resistance}}$

(C) $\frac{\text{Solid conduction resistance}}{\text{Convective resistance}}$

(D) $\frac{\text{Convective resistance}}{\text{solid convection resistance}}$

k. Critical thickness of insulation for

(I) sphere

(II) Cylinder

(A) h/k

(B) 2 k/h

(C) h/2h

(D) k/h

l. The diffusion coefficient varies as a function of temperature for

(I) gases

(II) liquids

(A) $T^{0.5}$

(B) $T^{1.5}$

(C) 1/T

(D) T

m. (I) Schmidt Number

(II) Lewis Number

(A) $\frac{\text{momentum diffusivity}}{\text{Thermal diffusivity}}$

(B) $\frac{\text{Thermal diffusivity}}{\text{mass diffusivity}}$

(C) $\frac{\text{momentum diffusivity}}{\text{mass diffusivity}}$

(D) $\frac{\text{mass diffusivity}}{\text{Thermal diffusivity}}$

n. (I) $A \rightarrow B \rightarrow C$

(II) $A + B \rightarrow 2B + C$

(A) rate of reaction of A shows a maximum with time

(B) C_B shows a maximum with time

(C) C_C shows a maximum with time

(D) C_B continuously decreases with time.

o. (I) dH

(II) dG (G - Gibbs free energy)

(A) TdS - PdV

(B) TdS + VdP

(C) –PdV – SdT

(D) VdP – SdT

p. (I) for any cyclic process

(II) for any adiabatic process

(A) ΔU = o

(B) Q = o

(C) W = o

(D) ΔU, Q and W all zero

24. Find the eigenvalues of the matrix

$$A=\begin{bmatrix} 0 & 2 \\ -1 & -1 \end{bmatrix}$$

(5)

25. In a batch reactor an irreversible first order reaction $A \rightarrow R$ takes place. The reaction rate constant (k) = 0.2 sec-1, and the initial concentration of A (CAo) = 0.1 mol/m3. Find the conversion of the reactant after 2 seconds.

(5)

26. Saturated steam at 130°C is flowing through a steel pipe of 0.021m inside diameter and 0.027m outside diameter. The pipe is insulated outside with 0.38m thick insulation. The ambient air outside the insulation is at 27°C. Calculate

   a. the rate of heat loss per meter length of tube.

   b. the overall heat transfer coefficient based on inside surface area of steel pipe,

   Additional data:

   Thermal conductivity of steel = 45 W/(m.k)

   Thermal conductivity of insulation = 0.064W/(m.k)

   Convective heat transfer coefficient inside the steel pipe = 5678 W/(m.^{2}k)

   Convective heat transfer coefficient outside the insulation = 11 W/(m.^{2}k)

(5)

27. The heat of reaction at 300 k and at one atmosphere pressure for the following gas phase reaction:

$$A + 3B \rightarrow C$$

is -50,000 calories per mole of A converted. Data on the molar heat capacity at constant pressure (cal/mol. K) of the various components are:

C_p for A = - 0.4 + 80 × 10^{-3} T, T in K

C_p for B = 7

C_p for C = 26

Calculate the heat of reaction at 500 K and at one atmosphere pressure.

(5)

28. Air at 30°C and 150 kPa in a closed container is compressed and cooled. It is found that the first droplet of water condenses at 200 kPa and 15°C. Calculate the percent relative humidity of the original air. The vapor pressures of water at 15°C and 30°C are 1.7051 kPa and 4.246 kPa respectively

SECTION - B

FIVE MARKS QUESTIONS

Answer any TEN questions in this section

29. Ethanol can be prepared by the following vapour phase reaction from ethylene:

$$C_2H_4(g) + H_2O(g) \rightleftharpoons C_2H_5OH(g)$$

The value of ΔG° for the above reaction at 1 atm and 125°C is 5040 J. Calculate the conversion obtained if an isothermal reactor operating at 125°C and 2 atm is fed with a mixture containing 50 mole % ethylene and 50 mole % 4 steam. Assume that equilibrium is reached at the exit of the reactor and gases behave ideally.

30. An experimental determination of a vapour-liquid equilibrium state of ether (1) and acetone (2) binary system gave the following result

$x_1 = 0.3$ T = 40°C

$y_2 = 0.42$ P = 10^5 Pa

The saturation vapour pressures of the pure components at 40°C are

ether (1) = 1.21 × 10^5 Pa

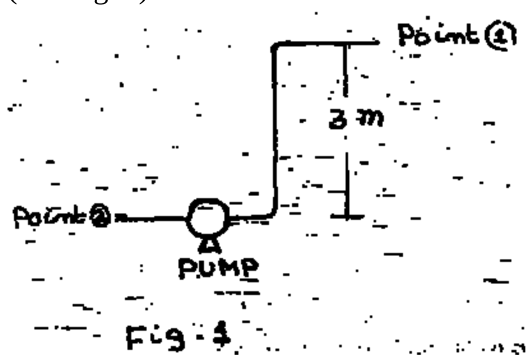
acetone (2) = 0.56 × 10^5 Pa

The vapour phase can be assumed to be ideal.

   a. Calculate the liquid phase activity coefficients

   b. What is the value of excess Gibbs free energy G^E/RT for the liquid phase?

31. The following data were obtained on a section of piping through which an incompressible viscous fluid is flowing. (See Fig. 1)



Point 1:

Pressure = 1.05 × 10^5 Pa

Cross-sectional area = 5 × 10^{-4} m^2

Elevation above point 2 = 3 m

32. The heat of

Pressure = 1.25 × 10^5 Pa

is Cross-sectional area = 15 × 10^{-4} m^2

Fluid velocity = 1 m/s

Other Data

Density of fluid = 1000 kg/m^3

Power delivered by the pump = 7.5 W

(assume efficiency = 1)

Predict whether flow is taking place from point 1 to 2 or from point 2 to 1.

33. A tube of 0.05 m^2 cross-sectional area is packed with spherical particles-up to a height of 0.25 m The porosity of the bed is 0.35: It is desired to fluidize the particles with water (ρ = 1000 kg/m^3, μ = 10^{-3} Calculate the minimum velocity of fluidization given the Ergun's equation:

$$-\frac{\Delta\rho}{L}\frac{D_p}{\rho_f V^2}\frac{\in^3}{1-\in}=\frac{150\mu(1-\in)}{D_p\rho_f V}+1.75$$

Data:

Diameter of particles = 0.01 m

Density of solid particles = 2600 kg/m^3

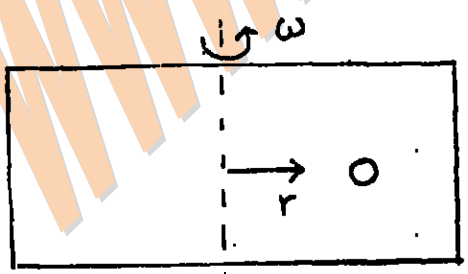
34. For geometrically similar baffled stirred tanks, the Power number is known to remain constant at Reynolds number.

   a. Let P be the power supplied per unit volume of the fluid, N the revolutions per second of the gaits ρ the density of the fluid, μ the viscosity of the fluid, and D the diameter of the impeller. The determine α, β, γ and δ in the following equation :

   $$P = N^{\alpha}\rho^{\beta}\mu^{\gamma}D^{\delta}$$

   b. What is the effect of Froude Number en P?

35. A particle of radius R and density ρ_s. is moving radially out in a centrifuge. The angular velocity of centrifuge is ω. The density and viscosity of the fluid are ρ and μ. It is expected that Stokes law for is valid. (See Fig. 2).



Assuming that the particle moves only radically, derive an expression for the radial velocity of the at any radial location r in the centrifuge.

36.

   a. The Thick modulus for a first order isothermal reaction for a flat plate geometry catalyst is found to be 2. Calculate the catalyst effectiveness factor.

   b. A gaseous reactant diffuses through a gas film and reacts on the surface of a non-porous spherical catalyst particle. The rate of surface reaction is k_1C_S, where C_S is the reactant concentration on the catalyst surface. The reaction rate constant (K_1) = 0.83 × 10^{-4} m/s and the gas film mass transfer coefficient (k_m) = 1.66 × 10^{-4} m/s. Derive the reaction rate expression in terms of bulk gas phase concentration (C_G).

37. 50% conversion is obtained in a CSTR for a homogeneous, isothermal, liquid phase, irreversible second order reaction. What is the conversion if the reactor volume is five times the original-all else remaining unchanged?

38. A homogeneous gas phase decomposition reaction 4A → B + 7S takes place in an isothermal plug flow reactor. Tire reaction rate is, $-r_A = k_1C_A$ with k_1 = 0.17 s^{-1}; feed concentration of A (C_{Ao}) = 0.1 mol/m^3 Feed Flow rate (F_{Ao}) = 0.17 mol/s. Determine the size of the reactor in order to achieve 50% conversion.

39. Derive art analytical expression for a unit impulse response of a system whose transfer function is given by

$$\frac{Y(S)}{X(S)}=\frac{1.5}{s^2+3s+2}$$

40. The transfer function of a process, a measuring element and a control valve is given respectively by

$$G_p = 2/(2s+1), G_m = 1/(5s+1), G_v = 1.5/(3s+1)$$

A proportional controller with a gain of K_c = 1 is used.

   a. Write the closed loop transfer function relating the output (Y) to tile set point (Y_r)

   b. What is the steady state error in the output for a unit step change in the set point?

41. The characteristic equation of a closed-loop system is given by

$$s^4+4s^3+6s^2+2s+3=0$$

Check whether the system is stable or not.

a. The cost of a blower in 1980 is Rs. 2,000

(i) What is the cost of the blower in 1998 with the same capacity? The cost index for the blower in 1980 and 1988 is respectively 250 and 300

(ii) What is the cost of a blower in l980 with double the capacity?

b. If the delivered costs of equipments of a fluid processing plant is Rs. 4×10^6 what is the capital cost of the plant?

42.

a. simplify the Fick's law of mass diffusion for equimolar counter diffusion for a binary system.

b. In a gas mixture of hydrogen and oxygen, steady state equimolar counter diffusion is occurring at a total pressure of 100 kPa and temperature of 20°C. If the partial pressures of oxygen at two planes 0.01m apart and perpendicular to the direction of diffusion are 15 kPa and 5 kPa, respectively and the mass diffusion flux of oxygen in the mixture is 1.6×10^{-5} k mole/m^2.s, Calculate the molecular diffusivity for the system

43. A stream of air at 100 kPa pressure and 300 K flowing on the tip surface of a thin flat sheet of solution naphthalene of length 0.2 m with a velocity of 20 m/s. The other data are:

Mass diffusivity of naphthalene vapour in air 6×10^{-6} m^2/s

Kinematic viscosity of air = 1.5×10^{-5} $\frac{m^2}{s}$

Concentration of naphthalene at the air-solid naphthalene interface = $1 \times 10^{-5} \frac{k\ mol}{m^3}$

Calculate:

(a) the average mass transk coefficient over the flat plate;

(b) the rate of-loss- of naphthalene from the surface per unit width.

$$Nu = 0.664 \, \mathrm{Re}_L^{1/2} \, P_e^{1/3}$$

You may use analogy between mass and heat transfer.

44. Carbon disulphide is to be absorbed from a dilute gas mixture of CS_2 - N_2 into a pure nonvolatile atmospheric pressure in a counter current absorber. The mole fraction of CS_2 in inlet gas stream is and the flow rate of gas stream, G is 1500 kmol/hr. The equilibrium relation is given by

y = 0.5 x

where x is the mole fraction of GS_2 in liquid stream. It is desired to reduce the mole fraction of CS_2 in exit gas stream to 0.005.

a. Calculate the minimum value of L/G where L is the liquid flow rate in kmol/hr.

b. Derive the equation for the operating line if 1.40 is equal to 1.5 times the minimum value.

45. A binary distillation column is operating under conditions specified below:

Feed rate = 350 k mol/hr

Overhead product rate = 150 k mol/hr

Mole fraction of more volatile component in overhead product = 0.97

Bottom product = 0.02

Bottom product rate = 200 k mole/hr

Reflux ratio = 3.5

In the stripping- section it was found that the mole fraction of the volatile component in the Leaving a plate is 0.33 while its mole fraction in the liquid coming to the same plate is 0.25. As constant molal counter flow, determine whether the feed is vapour of liquid or partially vaporized.