CHEMICAL ENGINEERING

SECTION - A

(100 Marks)

Choose the correct answer and indicate the corresponding capital letter A. B, C or D in your answer book.

(23 × 1 = 23)

1. The tank of matrix $\begin{vmatrix} 1 & 0 & 0 \\ 0 & 2 & 0 \\ 3 & 0 & 0 \end{vmatrix}$ is
   a. 0
   b. 1
   c. 2
   d. 3
2. The angle between two vectors $2\bar{i} - \bar{j} + \bar{k}$ and $\bar{i} + \bar{j} + 2\bar{k}$ is
   a. 0°
   b. 30°
   c. 45°
   d. 60°
3. During coking of coal, the ash content (percentage)
   a. increases
   b. decreases
   c. remains constant
4. Jigging is a technique by which different particles can be
   a. separated by particle size
   b. separated by particle density
   c. separated by particle shape
   d. mixed
5. A particle attains its terminal settling velocity when
   a. gravity force + drag force = buoyancy force
   b. gravity force - drag force = buoyancy force
   c. buoyancy force + drag force = Gravity force
   d. drag force = buoyancy force
6. For an ideal fluid flow the-Reynolds number is
   a. 2100
   b. 100
   c. zero
   d. infinity
7. A fluid energy mill is used for
   a. cutting
   b. grinding
   c. ultra grinding
   d. crushing
8. For an ideal mixed flow reaction (CSTR) the exit age distribution E(t) is given by
   a. a dirac delta function
   b. a step function
   c. a ramp function
   d. none of the above
9. The conversion X_A and residence time data are collected for zero order liquid phase reaction in a stirred tank reactor, which of the following will be a straight line
   a. $X_A Vs\tau$
   b. $X_A V \ln \tau$
   c. $X_A / (1 - X_A) Vs\, \tau$
   d. $X_A (1 - X_A) Vs\, \tau$
10. The dimensions of rate constant for reaction 3A → B are (l/gmole)/min. Therefore the reaction order is
    a. 0
    b. 1
    c. 2
    d. 3
11. A first order-reaction A → B occurs in an isothermal porous catalyst pellet of spherical shape. If the concentration of A at the centre of the pellet is much less than that at the external surface, the process is limited by
    a. diffusion within the pellet
    b. reaction
    c. external mass transfer
    d. none of the above
12. A solid is transformed into vapour without going through the liquid phase at
    a. triple point

b. boiling point
c. below triple point
d. always

13. At the inversion point, the Joule-Thompson coefficient is
a. positive
b. negative
c. zero

14. The kinetic energy of gas molecules is zero at
a. 0°C
b. 273°C
c. 100°C
d. -273°C

15. The transfer function for a PD controller is
a. $K_c(1+\tau_D s)$
b. $K_c(1+1/\tau_D s)$
c. $K_c(\tau_D s)$
d. $K_c/\tau_D s$

16. The offset introduced by proportional controller with gain K_c in response of first order system can be reduced by
a. reducing value of K_c
b. introducing integral control
c. introducing derivative contra)
d. none of the above

17. Bode diagrams are generated from output response of the system subjected to which of the following input
a. impulse
b. step
c. ramp
d. sinusoidal

18. The root locus method, a pole of a transfer function G(s) is the value of s for which G(s) approaches
a. -1
b. 0
c. 1
d. ∞

19. Gas chromatography is used for measurement of
a. temperature
b. pressure
c. concentration
d. flow rate

20. According to Bode stability criterion, a system is unstable if the open loop frequency response exhibits -an amplitude ratio exceeding unity at frequency for which phase lag is
a. 0°
b. 45°
c. 90°
d. 180°

21. The response of two tanks of same-size and resistance in series is
a. under damped
b. critically damped
c. over damped
d. none of the above

22. The transfer function of a pure dead time system with dead time τ_d is
a. $\frac{1}{\tau_d s+1}$
b. $\tau_d s+1$
c. $e^{-\tau_d s}$
d. $e^{\tau_d s}$

23. The Lime constant of a first order process with resistance R and capacitance C is
a. R + C
b. R - C
c. RC
d. 1/RC

TWO MARKS QUESTIONS (24-47)

Choose the correct answer and indicate the corresponding capital letter A, B, C, D as the case may be in your answer book

(19 × 2 = 38)

24. A function $f(x) = 12x - x^3$ has maximum value at x =
a. -2
b. 0
c. 2
d. $\sqrt{12}$

25. $\lim_{x\to 0}\frac{\tan x}{x} =$
a. ∞
b. 1
c. 0
d. -1

26. The second order Thylor series expansion for a function $f(x) = x^2$ at $x = 1$ is
    a. x^2
    b. $1 + x^2$
    c. $1 + x + x^2$
    d. $1 – x + x^2$

27. The average value of function $f(x) = x^3$ in the interval $0 \le x \le 2$ is
    a. 1
    b. 2
    c. 4
    d. 8

28. An evaporator while concentrating an aqueous solution from 10 to 40% solids evaporates 30000 Kg of water. The amount of solids han4led by the system in Kg is
    a. 4000
    b. 9000
    c. 4600
    d. 3000

29. 1000 Kg of wet solids are to he dried from 60% to 20% moisture (by weight). The mass of moisture removed in Kg is
    a. 520
    b. 200
    c. 400
    d. 500

30. Assuming that CO_2 obeys perfect gas law, calculate the density of CO_2 (in Kg/m^3) at 263°C and 2 atm.
    a. 1
    b. 2
    c. 3
    d. 4

31. Pure O_2 is mixed with air to produce an enriched air containing 50 volume % O_2. The ratio of moles of air to O_2 used is
    a. 1.72
    b. 0.58
    c. 0.5
    d. 0.2

32. Hydraulic mean diameter for flow through packed bed of spherical particles of size D_p with porosity ε
    a. $D_p \frac{1}{6}\frac{\in}{1-\in}$
    b. $D_p \frac{1}{6}\frac{1-\in}{\in}$
    c. $D_p \frac{2}{3}\frac{1-\in}{\in}$
    d. $D_p \frac{2}{3}\frac{\in}{1-\in}$

33. Use of Raschig rings in place of crushed stones as packing in packed beds (other things being same)
    a. increases pressure drop, increases surface area
    b. increases pressure drop, decreases surface area
    c. decreases pressure drop, increases surface area
    d. decreases pressure drop, decreases surface area

34. A suspension of uniform particles in water at a concentration of 500 Kg of solids per cubic meter of slurry is settling in a tank. Density of the particles is 2500 Kg/m^3 and terminal velocity of a single particle is 20 cm/s. What will be the settling velocity of suspension? Richardson and laid index is 4.6.
    a. 20 cm/s
    b. 14.3 cm/s
    c. 7.16 cm/s
    d. 3.58 cm/s

35. Bed pressure drop in an air fluidized bed of catalyst-particles (p = 2000 Kg/m^3, D_P = 0.05 cm) of 60 cm bed depth and bed porosity of 0.5 expressed in cm of water (manometer) is
    a. 90
    b. 60
    c. 45
    d. 30

36. A pitot tube indicates 5 cm of water (manometer) when it is being used for measuring velocity of air. The velocity of air in m/s is
    a. 5
    b. 14.1
    c. 56.22
    d. 28.2

37. In distillation where q is defined as the moles of liquid flow in the stripping

section per mole of feed introduced, for saturated liquid feed

a. $q > 1$
b. $q < 1$
c. $q = 1$
d. $q = 0$

38. In gas liquid contact operation the number o ideal stages $N = (x_a - x_b)/(x_b - x_b^*)$. This is true when the stripping factor S is

a. $S > 1$
b. $S < 1$
c. $S = 1$
d. $S = \infty$

39. For absorbing a sparingly soluble gas in a liquid

a. gas side mass transfer coefficient should be increased
b. liquid side mass transfer coefficient should be increased
c. liquid side mass transfer coefficient should be decreased
d. mass transfer coefficients must be-kept constant

40. The rate constant of a chemical reaction increases by 100 times when the temperature is increased from 400 K to 500 K. Assuming transition state theory is valid, the value of E/R is

a. 8987 K
b. 9210 K
c. 8764 K
d. 8621 K

41. A closed system is cooled reversibly from 100°C to 50°C. If no work is done on the system

a. its internal energy (U) decreases and its entropy (S) increases
b. U and S both decrease
c. U decreases but S is constant
d. U is constant but S decreases

42. Identify an unbounded input from four inputs whose transfer functions are given below

a. 1
b. 1/5
c. $1/S^2$
d. $1/(S^2 + 1)$

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

(I) $y = x^2$
(II) $dy/dx = 2x$
(A) linear O.D.E.
(B) nonlinear O.D.E.
(C) linear algebraic equation
(D) nonlinear algebraic equation

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

(I) $dy/dx + 5y = 0, y(0) = y_o$
(II) $dy/dx + 5 = 0, y(0) = y_o$
(A) $y = y_o + 5x$
(B) $y = y_o - 5x$
(C) $y = y_o e^{-5x}$
(D) $y = y_o e^{5x}$

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

(I) catalytic reforming
(II) smoke point
(A) high speed diesel
(B) kerosene
(C) gasoline
(D) aromatics

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

(I) solutropic system
(II) equilibrium moisture content
(A) crystallization
(B) distillation
(C) extraction
(B) drying

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

(I) venturimeter
(II) wet gas meter
(A) static head
(B) kinetic energy
(C) volumetric displacement
(d) Fluid drag force

48. Fill in the blank.

(4 × 1 = 4)

a. In process heat exchangers _____ steam is preferred over _____ steam.
b. Hot gases at moderate pressure are usually in the _____ side of shell and tube exchangers. At higher

pressure, however, it is-customary to put gas in the

c. Arrhenius equation describing the effect of temperature on rate constant is _____.

d. In an agitated vessel, baffles are used to suppress

49. The rate of increase of number of bacteria under certain conditions is proportional to the number of bacteria. If the number doubles in 4 bows, how much increase in number of bacteria can be expected after 12 hours?

(5)

50. Methanol is produced by the reaction-of CO with H_2

$CO + H_2 \rightarrow CH_3OH$

Only 15% of carbon- monoxide-entering the reactor is converted to methanol. The methanol formed is condensed and recovered completely. The unreacted CO and H_2 are recycled back to the reactor. The feed will contain H_2 and CO in the ratio of 2:1. For 3200 Kg/hr of methanol produced, calculate.

(5)

(i) Kg mole/hr of fresh feed,

(ii) Kg mole/hr of recycle gas.

Mol. wt. of CH_3OH = 32

51. Calculate the surface volume mean diameter for the following particulate material. Show detailed calculations.

(5)

Size range, μm	Mass of particles in the range, gm
-704 + 352	25
-352 + 176	37.5
-176 + 88	62.5
-88 + 44	75
Pan	50

52. Estimate the heat transfer area for am exchanger to cool an organic liquid from 105°C to 50°C. The hot liquid will flow at a rate of 10,000 Kg/hr and will be cooled by using circulating foul water containing some salt. The cooling water will leave at 40°C. It is proposed to use one shell pass and two tube pass exchanger for the above duty.

(5)

Cooling water inlet temperature = 25°C

Heat capacity for water = 4.2 KJ/Kg. °C

Heat capacity for hot liquid = 2.84 KJ/Kg°C

F_t, the temperature correction for the design will be 0.85

The recommended overall heat transfer coefficient U will be 600 W/m^2 °C

53. For a first order reaction taking place in an isothermal batch reactor, 80% of liquid reactant is converted to product in 15 minutes. Calculate space velocity required to achieve same conversion in a plug flow reactor and in a backmix flow reactor.

(5)

SECTION - B

FIVE MARKS QUESTIONS (54-73)

54. Find eigen values and eigenvectors of matrix

$$\begin{bmatrix} 4 & -5 \\ 1 & -2 \end{bmatrix}$$

55. The Orsat analysis of a flue gas is

CO_2	127%
O_2	7.1%
N_2	80.2%

Determine the percent excess air used in the combustion. The nitrogen present in the flue gas is contributed by air only.

56. Pure CO is mixed with 100% excess air and burnt. Only 0% of CO burns. The reactants are at 100°C and the products are at 300°C. Calculate the amount of heat added or removed per Kg mole of CO fed to the reactor.

Data: Mean molal specific heats between 25°C and T°C (given below) in KJ/Kg mole. °K are

Gas	**T=100°C**	**T=300°C**
CO	29.22	30.61
CO_2	-------	4377
O_2	29.64	30.99

N_2	29.17	29.66

Standard heat of formation at 25°C in KJ/Kg mole is

CO	-110524
CO_2	-393514

57. Bituminous coal with a calorific value of 20000 KJ/Kg is-used for generating steam in a boiler how much coal has to be burnt to generate 1 MW of energy. Efficiency of combustion is 0.75. How much air is needed if 50% excess air is to be used. Assume that coal contains 67% carbon and 33% ash.

58. A chemical reaction vessel made of plain carbon steel is to be designed for operation at a pressure of 15 bar absolute and a temperature of 290°C. The ellipsoidal bottom will have a ratio of major axis: minor axis of 2:1. As a safeguard it is proposed to provide a corrosion allowance of 10% of calculated thickness. Design pressure may be taken as 110% of the operating pressure. At the operating conditions the design stress permissible (I) will have a value of 85 N/mm^2. Calculate the thickness of the cylindrical portion of the reactor and the ellipsoidal bottom. Fig. I may be referred for dimensions

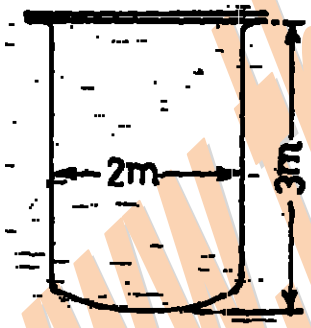

FIG - 1

59. A pressure filter is operated in the constant rate mode to yield 10 m^3 in the first ten minutes, as the operating pressure increases from zero. In the next 20 minutes the filtration was continued at constant pressure, after which it was stopped.
    (a) Estimate the total volume of filtrates obtained during filtration.
    (b) Estimate the washing rate at the end of filtration. Also determine washing Lime if the volume of wash liquid equals the volume of filtrate obtained.

60. A binary mixture of 100 μm size having densities of 2 gm/cm^3 and 4 gm/cm^3 is to be classified by ellutriation technique using water. Estimate the range of velocities that can do the job and recommend a suitable value.

61. A small model reactor is to be built for scale up-studies of the behaviour of a proposed large industrial stirred tank reactor having 1000 time capacity. The bigger unit of 2 m diameter will have a liquid depth of 2 m. This will be fitted with a four blatted Rushton turbine of 0.6 m diameter.
    (i) Estimate the dimensions of the smaller unit.
    (ii) For the optimum stirrer speed of 330 rpm observed is the smaller model, what will be the recommended speed in the industrial unit under the following conditions:
        (a) Power per unit volume is kept constant:
        (b) Reynolds number does not change.
    (iii) What design criteria would you recommend for this type of study?

62. Air flows through a packed bed of a powdery material of 1 cm depth at a superficial gas velocity of 1 cm/sec. A manometer connected to the unit registers a pressure drop of 1 cm of water. The bed has a porosity of 0.4. Assuming that Kozeny-Carman equation is valid for the range of study, estimate the particle size of the powder.

$$\rho_{air} = 1.23 Kg/m^3$$

$$\mu_{air} = 1.8 \times 10^{-5} Kg/m.s$$

63. It is necessary to dry a batch of 160 Kg of a wet solid material from 30% to 5% moisture content, under constant rate and falling rate period. The falling rate is assumed to be linear. Calculate the total drying time considering an available drying surface of 1 m^2/40 Kg of dry solid. A constant drying flux of 3 × 10^{-4} Kg/m^{2}s is given.

    X_c she critical moisture content = 0.2 Kg moisture/Kg solid

X* the equilibrium moisture content = 0.05 Kg moisture/Kg solid

64. The equilibrium data for the distribution of a solute C between feed solvent A and the extracting solvent B is given below:

x conc. of C in raffinate Kg C/Kg A	0	0.1	0.2	0.3	0.4	0.45
y conc. of C in extract Kg C/Kg B	0	0.096	0.17	0.232	0.275	0.28

In a countercurrent contact operation 10 Kg/s of the feed containing 20% C in A (w/w) is treated with pure solvent so as to reduce the solute concentration to 5% (w/w). Calculate the solvent rate for operation with 2.5 times the minimum solvent rate.

65. A countercurrent plate absorber is to be installed for scrubbing of an air mixture containing 5 percent ammonia by volume. The scrubber is fed with water containing 0.002 mole NH_3 per mole of water. The scrubbing water flows at a rate of 1.0 mole water per mole air. It is necessary to absorb 85 percent of the ammonia present in the gas by operating the absorber at 20°C.

$$K = 0.80\frac{mol\ NH_3 / mol\ air}{mol\ NH_3 / mol\ H_2O}$$

Calculate the concentration of NH_3 in the outgoing liquid and estimate number of stages necessary for this operation.

66. The rate of a homogeneous liquid phase reaction is given as $-\gamma_A = KC_A^2$. This reaction takes place with 50% conversion in a back mix reactor. What will be the conversion if this reactor is replaced by a bigger one which is six times larger. All other conditions remain unchanged.

67. Liquid A decomposes in a batch reactor by a second order kinetics. If 50% of A is converted in a five minute run, how long it would take to reach 75% conversion.

68. Calculate the change in entropy when one gram of ice at 0°C is converted into steam at 100°C. Latent heat of fusion of ice = 80 cal/g. Latent heat of vaporization = 540 cal/g and mean specific heat of water between 0°C and 100°C = 1.

69. When a thermometer at 30°C is placed in a water bath at 90°C, the initial rate of rise in thermometer temperature is found to be 2°C/sec. What is the time constant of the thermometer, assuming it is a first order device with unity steady state gain? What will thermometer read after one minute?

70. A first order system with transfer function $G_p = Y(S)/X(S) = 1/(S+1)$ is subjected to input $X(t) = t$. Derive the expression for change in output Y(t) as a function of time. What is the maximum and minimum difference between input and output? At what time does this difference occur?

71. A first order reaction $A \rightarrow B$ is being carried out in a stirred tank reactor. The feed stream containing reactant A at concentration CAO is being fed at constant rate F_1 to the reactor. The volume and temperature of the reactor are constant. Derive a transfer function relating concentration of A in the product stream to concentration of A in the feed stream.

72. Amplitude ratio corresponding to crossover frequency of 10 rad/sec for a process is found to be 0.1.
    a. What is the ultimate gain?
    b. What is the period of sustained oscillations corresponding to ultimate gain?
    c. If a proportional controller is to be used, what is the value of proportional gain you would recommend?

73. The transfer function of a process, measuring device, controller and control valve, respectively is given by

$$G_P = \frac{K_p}{(s+2)(s+4)}, G_m = 1, G_c = K_c, G_v = 1$$

The root locus diagram of the system is given in figure 2.

    a. Identify locations of points A and B.
    b. At $K_c = 1$, the roots of the system are located at point C. Identify the location of point C.
    c. Determine the value of K_p