

D-GT-M-DDB

CHEMICAL ENGINEERING

Paper—II

Time Allowed : Three Hours

Maximum Marks : 200

INSTRUCTIONS

Candidates should attempt Question Nos. 1 and 5 which are compulsory, and any THREE of the remaining questions, selecting at least ONE question from each Section.

All questions carry equal marks.

Marks allotted to each part of a question are indicated against each.

Answers must be written in ENGLISH only.

Assume suitable data, if considered necessary, and indicate the same clearly. Symbols and notations have their usual meanings.

Neat sketches may be drawn, wherever required.

Important Note

All parts/sub-parts of a question being attempted are to be answered contiguously on the answer-book. That is, where a question is being attempted, all its constituent parts/sub-parts must be answered before moving on to the next question.

Pages left blank, if any, in the answer-book(s) must be clearly struck out. Answers that follow pages left blank may not be given credit.

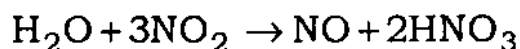
Section—A

1. Answer the following briefly and to the point :

5×8=40

- (a) What is the difference between molarity and molality? Which of these does not change with temperature? Why?

- (b) Give a brief account of standard Gibbs energy change and equilibrium constant for a reaction.
- (c) Explain the operation of heat pumps.
- (d) How much potassium chlorate must be taken to produce the same amount of oxygen as will be produced by 2.3 grams of mercuric oxide?
- (e) What is optimum temperature progression for exothermic reactions?
- (f) Explain Raoult's law and Henry's law, and their limitations.
- (g) Distinguish between space time, holding time and mean residence time.
- (h) Write down the relations among the partial molar properties for constant composition solutions.
2. (a) In the fixation of nitrogen by the arc process, air is passed through a magnetically flattened electric arc. Some of the nitrogen is oxidized to NO, which on cooling oxidizes to NO₂. Of the NO₂ formed, 66% will be associated to N₂O₄ at 26 °C. The gases are then passed into water-washed absorption towers where nitric acid is formed by the following reaction :



The NO liberated in this reaction will be reoxidized in part and form more nitric acid. In the operation of such a plant, it is found possible to produce gases

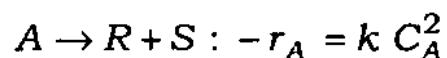
from the arc furnace in which the nitric oxide is 2% by volume, while hot. The gases are cooled to 26 °C at a pressure of 750 mm Hg before entering the absorption apparatus. Calculate the weight of HNO₃ formed per 100 m³ of gas entering the absorption system if the conversion to nitric acid of the combined nitrogen in the furnace gases is 85% complete. 20

(b) Compare the important aspects of different refrigeration cycles. 10

(c) Derive an equation for the coefficient of performance of the Carnot refrigeration cycle and calculate the coefficient of performance for a refrigeration cycle operating at a temperature level of 25 °C and ambient temperature of 30 °C. 10

3. (a) The azeotrope of the ethanol-benzene system has a composition of 44.8 mole percent ethanol with a boiling point of 68.24 °C at 760 mm Hg. At 68.24 °C, the vapour pressure of pure benzene is 517 mm Hg, and that of ethanol is 506 mm Hg. Calculate the van Laar constants for the system and evaluate the activity coefficients and vapour composition for a solution containing 10 mole percent ethanol. 15

(b) The solid catalyzed decomposition of gaseous A proceeds as follows :



A tubular pilot plant reactor packed with 100 litres of catalyst is fed with 200 litres/s of pure A at 300 °C and 20 atm. Conversion of reactant is 65%. In a larger plant, it is desired to treat 200 cu m/hr of feed gases at 40 atm absolute and 300 °C containing 60% A and 40% diluents to obtain 85% conversion of A. Compute the internal volume of the reactor required. 15

(c) A laundry can purchase soap containing 30% of water at a price of ₹ 2,000 per 100 kg of f.o.b. the factory. The same manufacturer offers a soap containing 5% of water. If the freight rate is ₹ 200 per 100 kg, what is the maximum price that the laundry should pay the manufacturer for the soap containing 5% water? 10

4. (a) Calculate the theoretical flame temperature of a gas containing 20% CO and 80% N₂ when burnt with 100% excess air, both gas and air initially being at 25 °C.

The standard heat of combustion of CO (g) at 25 °C and 1 atmosphere pressure is $\Delta H_c^\circ = 67636$ cal/gm mole. The mean molal heat capacities in cal/(gm mole) (K) within the temperature range involved are as under : 10

$$\text{CO}_2 = 11.82, \text{O}_2 = 7.903, \text{N}_2 = 7.471$$

- (b) A zero-order homogeneous gas reaction $A \rightarrow rR$ proceeds in a constant volume bomb with 20% inerts and the pressure rises from 1 to 1.3 atmospheres in 2 minutes. If the same reaction takes place in a constant pressure batch reactor, what is the fractional volume change in 4 minutes if the feed is at 3 atmospheres and consists of 40% inerts? 10
- (c) A steel casing ($C_p = 0.5 \text{ kJ/kg K}^{-1}$) weighing 40 kg and at a temperature of 450°C is quenched in 150 kg of oil ($C_p = 2.5 \text{ kJ/kg K}^{-1}$) at 25°C . If there are no heat losses, what is the change in enthalpy of (i) the casing and (ii) the oil? 8
- (d) Determine the equilibrium composition for the reaction $\text{CO} + 2\text{H}_2 = \text{CH}_3\text{OH}$ at 600 K and 300 atm pressure for a feed ratio of 1 mole of CO and 3 moles of H_2 . Fugacity coefficients for CO, H_2 and CH_3OH are 1.0, 1.2 and 0.47 respectively. The reaction equilibrium constant at 600 K and 300 atm is 0.91×10^{-4} . 12

Section—B

5. Answer the following briefly and to the point :

5×8=40

- (a) What is capitalized cost?
- (b) What do you mean by return on investment?
- (c) What is bulk polymerization?
- (d) Distinguish between soap and detergent.
- (e) What is acid rain?
- (f) What are the thermodynamic limitations of the ammonia synthesis reactions?
- (g) What is break-even point?
- (h) What are the various products of crude distillation?

6. (a) Explain the manufacture of polyvinyl chloride from ethylene with neat flow diagram.

15

(b) The original value of a piece of equipment is ₹ 11,000. Its salvage value is estimated to be ₹ 1,000 at the end of a service life estimated to be 10 years. Determine the asset (book value) of the equipment at the end of 5 years using straight line method and test book declining balance method, and compare.

10

(c) With a neat flow diagram, explain the removal of sulphur from fuel oil using hydrodesulphurization process.

15

7. (a) What are the factors that led to enactment of legislation on pollution? 10
- (b) Write about HAZOP and HAZAN with examples. 10
- (c) Discuss various air pollution control methods and describe the equipment used. 20
8. (a) Briefly describe the factors that influence the location of a chemical plant. 10
- (b) A company is considering which of two plants to build. Both plants cost ₹ 25 million. The gross profits of each plant are as follows :

Years	Plant—1	Plant—2
1	₹ 10,00,000	₹ 50,00,000
2	₹ 40,00,000	₹ 50,00,000
3	₹ 60,00,000	₹ 50,00,000
4	₹ 70,00,000	₹ 50,00,000
5	₹ 70,00,000	₹ 50,00,000

- The company is borrowing money from a bank at 7 percent interest compounded annually. Determine which plant should be built. 15
- (c) Explain the production of a detergent with a neat flow diagram. 15
