CHEMICAL ENGINEERING

PAPER—II

Time Allowed : Three Hours

Maximum Marks : 200

QUESTION PAPER SPECIFIC INSTRUCTIONS

Please read each of the following instructions carefully before attempting questions

There are EIGHT questions in all, out of which FIVE are to be attempted.

Question Nos. **1** and **5** are compulsory. Out of the remaining SIX questions, THREE are to be attempted selecting at least ONE question from each of the two Sections A and B.

All questions carry equal marks. The number of marks carried by a question/part is indicated against it.

Unless otherwise mentioned, symbols and notations have their usual standard meanings.

Assume suitable data, if necessary and indicate the same clearly.

Neat sketches may be drawn, wherever required.

Attempts of questions shall be counted in sequential order. Unless struck off, attempt of a question shall be counted even if attempted partly. Any page or portion of the page left blank in the Question-cum-Answer Booklet must be clearly struck off.

Answers must be written in ENGLISH only.

SECTION—A

1. Answer all of the following questions : 8×5=40

(a) Define 'wet bulb' and 'dry bulb' temperatures. Dry mixture of HCl gas and air is passed over a heated catalyst, which promotes oxidation of acid. Air is used in 20% excess of that theoretically required. Calculate the weight of air supplied per kg of acid.

(b) A sample of limestone has $CaCO_3$ (84% w/w), $MgCO_3$ (12% w/w) and inert (4% w/w). Calculate the weight of CaO, obtained by 250 kg of sample limestone.

(c) Explain the need of equations of state for real gases, and discuss the limiting conditions that should be satisfied by an equation of state.

(d) For a reaction $A \rightarrow 4R$, occurring in a variable volume batch reactor, derive the following expression :

$$C_A = C_{A_0}\left(\frac{1 - X_A}{1 + \varepsilon_A X_A}\right)$$

where C_{A_0} and C_A are concentrations at $t = 0$ and time t; ε_A is fractional change in volume; X_A is the conversion.

(e) What is degree of dissociation? A vessel has one mole N_2O_4 at 27 °C and one atmospheric pressure. The dissociation reaction takes place as

$$N_2O_4 \rightleftharpoons \underset{(g)}{2NO_2}$$

Calculate the degree of dissociation, if K_p for the above reaction is 0·114.

2. *(a)* A 500 lit/s of gaseous mixture of the following composition (v/v) is at 27 °C and 2000 mm Hg gauge :

$$CH_4 = 20\%, \quad C_2H_6 = 30\%, \quad H_2 = 50\%$$

Calculate—

(i) the mole fraction of each component;

(ii) the molar density of the mixture. 15

(b) Discuss the term 'enthalpy of gaseous component'. C_8H_{18} is burnt with 20% excess air. Calculate the air/fuel ratio by weight. The average molecular weight of air is 28·84. 15

(c) Define the term 'adiabatic flame temperature'. A biogas sample has the following molar composition :

$$CH_4 = 64\%$$
$$CO_2 = 36\%$$

Calculate the average molecular weight of this sample. 10

3. (a) In a steam power plant, superheated steam at 673 K and 2 MPa enters the turbine and it is expanded to the condenser pressure of 7·5 kPa. Assuming an isentropic pump efficiency of 85% and an isentropic turbine efficiency of 90%, calculate the following :

(i) The ideal Rankine cycle efficiency for the given conditions

(ii) The thermal efficiency of the plant

Additional data :

The specific volume of saturated liquid at 7·5 kPa is $1 \cdot 008 \times 10^{-3}$ m^3/kg.

	Temperature (K)	*Pressure* (kPa)	*Enthalpy* (kJ/kg)	*Entropy* (kJ/kg-K)
Saturated liquid	313·44	7·5	168·79	0·5764
Saturated vapour	313·44	7·5	2574·80	8·2515
Superheated steam	673	2000	3247·60	7·1271

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(b) Conventionally a partial property $\overline{M}_i$ of species i in solution is defined as $\overline{M}_i \equiv \left[\frac{\partial(nM)}{\partial n_i}\right]_{P,T,n_j}$. Correspondingly, a constant-T, V partial property $\hat{M}_i$ may be defined as $\hat{M}_i \equiv \left[\frac{\partial(nM)}{\partial n_i}\right]_{T,V,n_j}$. Show that $\overline{M}_i$ and $\hat{M}_i$ are related by the equation $\hat{M}_i = \overline{M}_i + (V - \overline{V}_i)\left(\frac{\partial M}{\partial V}\right)_{T,x}$. 15

(c) Consider a reaction being carried out in gas phase :

$$aA + bB \rightarrow cC + dD$$

where a, b, c and d are the stoichiometric coefficients of the chemical species A, B, C and D, respectively. Given that the reactants and the products are at their standard state. Develop a series of speculative steps for carrying out this reaction, and show that the free energy changes calculated for these series of steps add up to conform the relationship $\Delta G^\circ = -RT \ln K$. 10

4. *(a)* What do you understand by 'plug flow'? Derive the design equation of a plug flow reactor (PFR) with the help of suitable assumptions. 10

(b) Define the term 'effectiveness factor' in heterogeneous catalysis. Also calculate the activation energy and frequency factor from the following data :

k, sec^{-1}	T, K
$4 \cdot 4 \times 10^{-4}$	312
$7 \cdot 2 \times 10^{-3}$	332

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(c) What do you understand by 'cascading of CSTRs'? $A + B \rightarrow C$ takes place in a two-stage CSTR, having volume of 100 m^3 and 25 m^3, respectively. The volumetric feed rate is 20 lit/min. $C_A = C_B = 1 \cdot 5$ g mol/lit and overall rate constant is 0·010 lit/g mol min. Calculate the overall conversion. 15

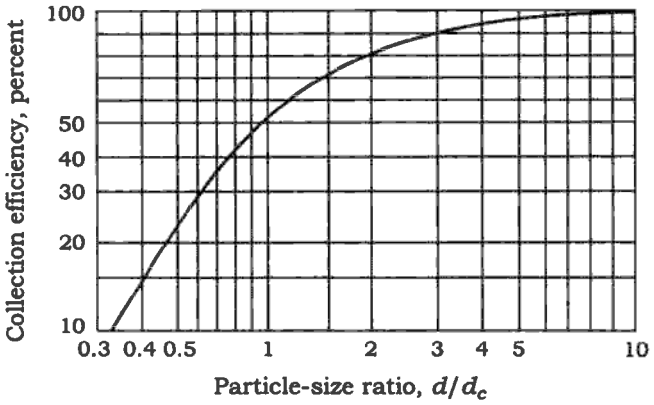
SECTION—B

5. Answer all of the following questions : 8×5=40

(a) Differentiate between soap and detergent. Discuss the reactions involved in the detergent manufacturing process from coconut oil.

(b) Describe coking of coal process. Also account for the major engineering problems associated with the process.

(c) A cyclone has an inlet width of 10 cm and four effective turns ($N = 4$). The gas temperature is 350 K and the inlet velocity is 10 m/s. The average particle diameter is 8 μm and the average density is 1·5 g/cm^3. What is the collection efficiency? The viscosity of air at 350 K is 0·0748 kg/m-h. We can assume that ρ_{air} is negligible compared to $\rho_{particles}$.



Cyclone efficiency

(d) A clean filter is found to weigh 10·00 g. After 24 hr in a high-volume sampler, the filter plus dust weighs 10·10 g. The air flow at start and end of test was 60 ft^3/min and 40 ft^3/min, respectively. What is the concentration of particulate matter?

(e) State and explain different types of depreciation.

6. (a) Discuss the importance of cracking process in petroleum refining. Describe in detail and compare hydrocracking and catalytic cracking processes with appropriate diagrams. 15

(b) Discuss and differentiate the structural, physical and mechanical properties of LDPE, HDPE and LLDPE. Also mention the general applications of various types of polyethylenes. 15

(c) What are antibiotics? Describe the production of antibiotics in industry by fermentation. 10

7. (a) Discuss the classification of air pollutants and water pollutants with proper examples. 15

(b) Discuss the Environment Protection Acts for air, water and forest conservation. 15

(c) Describe solid waste management. Also discuss the 'integrated solid waste management system' with suitable diagram and table. 10

8. (a) Write a note on 'estimation of purchase equipment cost'. Explain CPM and PERT with proper examples. 15

(b) Write a note on plant layout. During the design of a new project, make a decision regarding which type of pump should be used for a corrosive service. The options are as follows :

	Capital cost	*Operating cost* (per year)	*Equipment life* (years)
Carbon steel pump	$ 8,000	$ 1,800	4
Stainless steel pump	$ 16,000	$ 1,600	7

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(c) Explain non-discounted profitability criterion with the help of suitable example and diagrammatic illustration. 10

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