Indian Forest Service
(Main) Exam, 2021

ZCVB-B-CHME

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.*

*Questions no. **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.*

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.

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.

*Answers must be written in **ENGLISH** only.*

SECTION A

Q1. Answer all the parts of the question : *8×5=40*

(a) A solution of sodium chloride in water contains 220 g NaCl per litre at 20°C. The density of the solution at this temperature is 1·145 g/cm^3. *8*

Calculate :

(i) Composition in weight percent

(ii) Volumetric percent of water

(iii) Composition in mole percent

(iv) Molality

(b) A steel casting of mass 10 kg at 1073·15 K is quenched in 100 kg of water at 303·15 K in an insulated container. The heat capacities of steel and water are 0·461 kJ/kg K and 4·23 kJ/kg K respectively. Calculate change in entropy of steel and water. *8*

(c) A gaseous feed of pure A (1 mol/L) enters in a mixed flow reactor having 2 L volume and reacts as follows :

$$2A \rightarrow R, \quad -r_A = 0{\cdot}05\ C_A^2 \text{ mol/L.s.}$$

Find what feed rate (L/min) will give an outlet concentration $C_A = 0{\cdot}5$ mol/L. *8*

(d) A refrigerator kept in a room receives electrical energy of 130 W to drive the system, and it rejects 350 W to the room air. Find the COP of the refrigerator. *8*

(e) An aqueous feed of A and B (400 L/min, 100 mmol A/litre, 200 mmol B/litre) is to be converted to product in a plug flow reactor. The kinetics of the reaction are represented by

$$A + B \rightarrow R, \quad -r_A = 200\ C_A.C_B \ \frac{\text{mol}}{\text{litre.min}}.$$

Find the volume of reactor needed for 99·9% conversion of A to product. *8*

Q2. (a) A furnace burning a hydrocarbon fuel oil has stack gas analysis on dry basis as follows :

$CO_2 = 10{\cdot}2\%$, $O_2 = 8{\cdot}3\%$, $N_2 = 81{\cdot}5\%$

Calculate :

(i) Composition of original fuel oil

(ii) Percentage of excess air used

(iii) Volume in litres of air supplied at standard conditions per kg of fuel oil *15*

(b) An isothermal gas phase reaction A → B takes place at 500 K and pressure 830 kPa. The data for chemical reaction rate as a function of conversion is as follows :

X	0·0	0·1	0·2	0·4	0·6	0·7	0·8
$-r_A$ mol/m^3.s	0·45	0·37	0·30	0·195	0·113	0·079	0·05

If this reaction is carried out in a CSTR and reactant A enters the reactor at 0·4 mol/s,

(i) calculate volume of reactor to achieve 80% conversion.

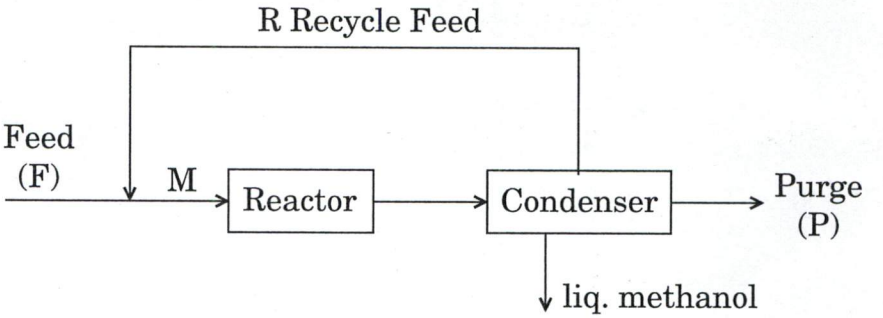
(ii) calculate the space time and space velocity for the reactor. *15*

(c) The equilibrium constant K_c for the below reaction at 373 K is 2·92. Determine the equilibrium concentration if 1 m^3 of aqueous solution containing 5 kmol of acetic acid, 10 kmol ethanol and 10 kmol water at 373 K is allowed to reach a state of equilibrium.

$CH_3COOH\ (l) + C_2H_5OH\ (l) \rightarrow CH_3COOC_2H_5\ (l) + H_2O\ (l)$ *10*

Q3. (a) For a reaction A → P, $-r''_A = \frac{-1}{s}\frac{dN_A}{dt} = K''\ C_A$ derive expression for concentration profile and effectiveness factor for first order reaction using single cylindrical pore model. *10*

(b) In synthesis of methanol, fresh feed containing 32% carbon monoxide, 64% hydrogen (H_2) and 4% of inerts (by volume) is mixed with recycle feed. Mixed feed entering reactor results in 20% per pass conversion of carbon monoxide. The product stream from reactor is fed to condenser, where all methanol formed gets condensed and the gases from condenser are recycled. In order to prevent build-up of inerts in recycle loop, a small portion of gases leaving the condenser is continuously purged. If mixed feed contains 15% inerts, calculate (i) Recycle ratio, and (ii) Purge ratio. *15*



(c) (i) What are chemical potential, fugacity and fugacity coefficient ?

(ii) Derive Gibbs-Duhem relation and rewrite it in terms of chemical potential. *15*

Q4. (a) A carbon particle having radius of 14 mm with bulk density of 2·8 g/cm^3 is burning in the oxygen stream containing 14% oxygen by volume at 800°C and 1 atm. Calculate the time required to complete burning of spherical carbon particle. The gas phase resistance is negligible. Chemical reaction controls for shrinking of carbon sphere. *15*

Atomic wt of carbon = 12,

Surface reaction rate constant

$K'' = 25$ cm/s

$R = 82{\cdot}06$ cm^3 . atm/mol . K.

(b) Define conversion, selectivity, yield, excess reagent, and limiting reagent. *10*

(c) We have a solid piece of stone having a mass of 15 kg and a tank containing 100 kg of liquid water. Initially the stone is 10·5 m above the water level, stone and water are at same temperature, state 1. The stone then falls with water.

Determine ΔU, ΔKE, ΔPE, Q and W for the following changes of state, assuming standard acceleration due to gravity as 9·01 m/s^2.

(i) The stone is about to enter the water, state 2.

(ii) The stone has just come to rest in the tank, state 3.

(iii) Heat has been transferred to the surroundings in such an amount that the stone and water are at the same temperature T_1, state 4. *15*

SECTION B

Q5. Answer all parts of the question : *8×5=40*

(a) Describe various types, causes and characteristics of ecological succession. *8*

(b) Define primary and secondary meteorological parameters for plume behaviour. *8*

(c) Differentiate amongst wet, dry and semi-dry process of cement manufacture. *8*

(d) What is Material Safety Data Sheet ? Discuss HAZOP and HAZAN. *8*

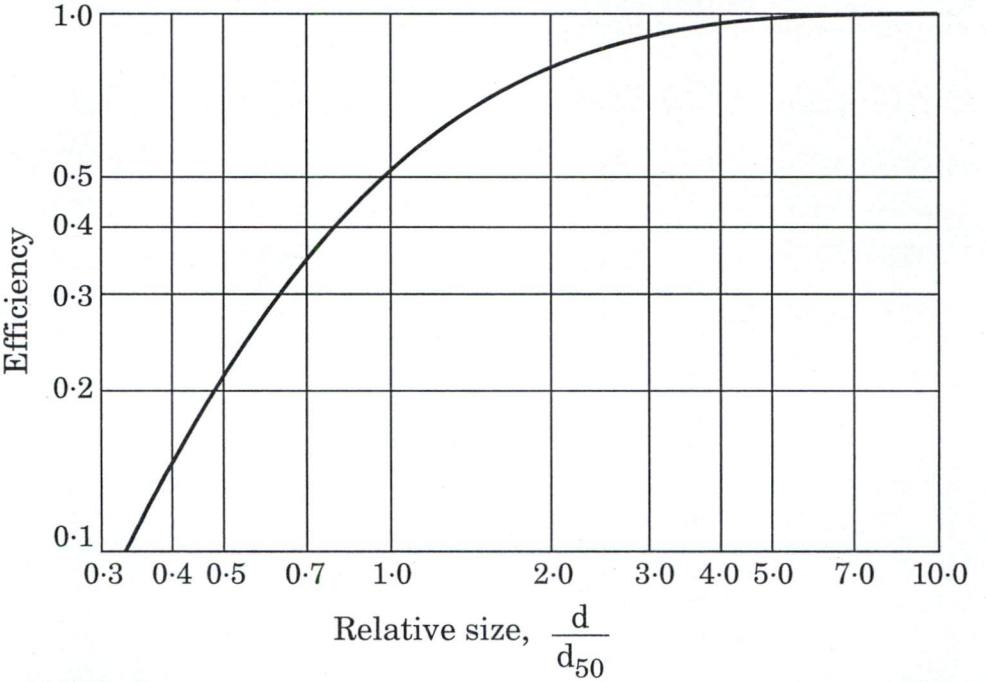
(e) Explain various types of capital cost estimation based on its accuracy and purpose. Draw a project cash-flow diagram to show break-even point. *8*

Q6. (a) A polluted air stream with a flow rate of 8·0 m^3/s is passed through an air cyclone of standard dimensions. The temperature of the air is 70°C. The diameter of the cyclone is 2·0 m. If the particle diameter is 10μ and density is 1·5 g/cm^3, determine

(i) removal efficiency of the particle with 05 number of effective turns.

(ii) effect on removal efficiency if instead of one single large unit, a bank of 100 cyclones with a diameter of 20 cm each are used.

Given the viscosity of air at 70°C is $2·1 \times 10^{-5}$ kg/m-s and the density of air is negligible as compared to the density of particle. *15*



(b) Describe using a neat flowchart, the manufacturing process of glass. Differentiate between Pyrex and Vycor glass. *15*

(c) Discuss the break-down of Direct and Indirect Capital investment items for a chemical process. *10*

Q7. (a) A capital investment gives a discrete compound interest at an effective annual rate of 5%. The maturity value after a period of 04 years becomes ₹ 2·0 lakhs.

(i) Determine the Present worth.

(ii) Determine the discrete rate of effective interest which will be received by the investor for a principal amount of ₹ 1·5 lakhs.

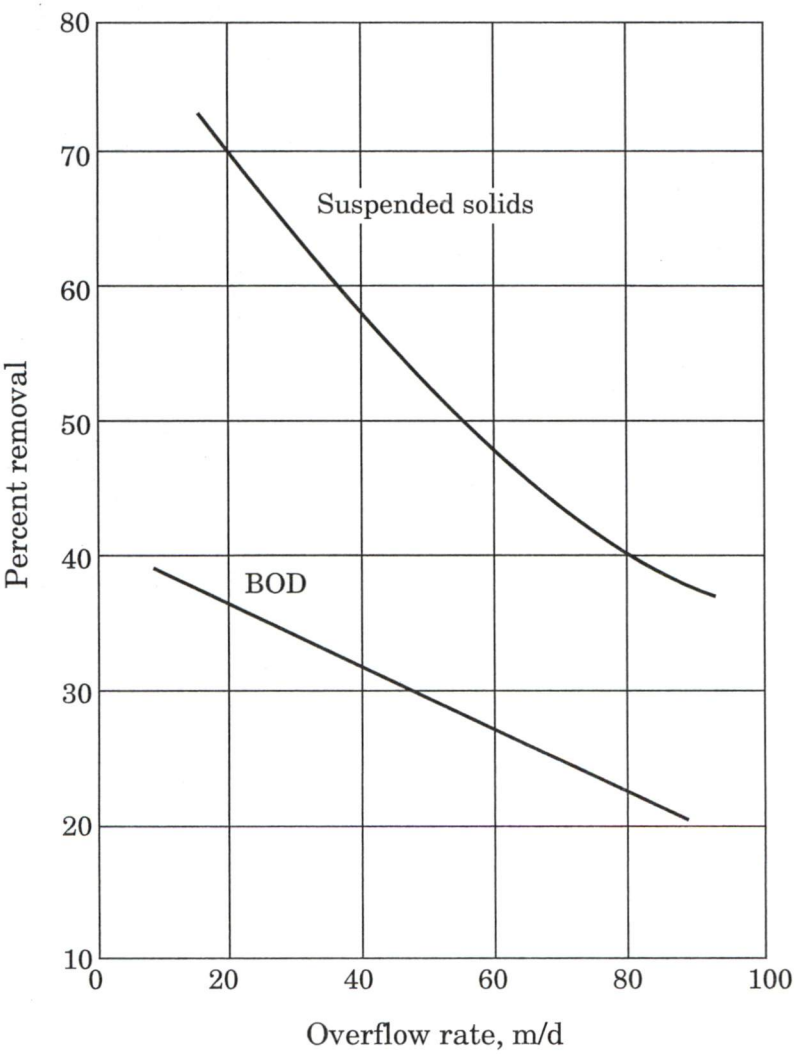
(iii) Determine the Present worth if interest rate is 5% compounded continuously in place of discrete. *15*

(b) Describe with a neat flowchart, the Solvay process of ammonia manufacture along with the reaction chemistry. *15*

(c) An industrial wastewater treatment plant processes an average flow of 6000 m^3/d with a primary sedimentation tank having a BOD removal efficiency of 30%.

(i) Determine the dimensions and detention time of the primary sedimentation tank.

(ii) What will be the effect on BOD removal efficiency at a peak flow of 12000 m^3/d ? *10*



Q8. (a) Define Balance Sheet and Financial Statement. Explain various parameters for plant location and site selection. *15*

(b) Write different types of paper products. Describe with a neat flowchart, the manufacturing process of paper. *15*

(c) (i) Describe various landfilling methods and design considerations.

(ii) What are Landfill Leachates ?

(iii) How is the movement of gases and leachates controlled during Landfilling process ? *10*