BIRLA INSTITUTE OF TECHNOLOGY, MESRA, RANCHI
(MID SEMESTER EXAMINATION SP2023)

CLASS: BTECH **SEMESTER : VI**
BRANCH: CHEMICAL AND CHEMICAL / (P&P) **SESSION : SP2023**

SUBJECT: CL320 CHEMICAL REACTION ENGINEERING - II

TIME: 02 Hours **FULL MARKS: 25**

INSTRUCTIONS:
1. The question paper contains 5 questions each of 5 marks and total 25 marks.
2. Attempt all questions.
3. The missing data, if any, may be assumed suitably.
***4*. Tables/Data handbook/Graph paper etc., if applicable, will be supplied to the candidates**

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Q.1(a)	Give two examples of industrially used heterogeneous catalysts. Also mention the processe(s) where these catalysts are used.	[2]	1	1
Q.1(b)	What are the basic material constituents of a heterogeneous catalyst and functions of each kind of material type?	[3]	1	2
Q.2(a)	In an experiment to determine the pore volume and catalyst-particle porosity, the following data were obtained on a sample of activated silica: Mass of catalyst sample placed in chamber = 101.5 g, volume of helium displaced by sample = 45.1 cm^3, volume of mercury displaced by sample = 82.7 cm^3. Calculate the pore volume (cm^3/g), density of solid material (g/cm^3) and particle porosity.	[2]	1	3
Q.2(b)	Briefly describe the method for the determination of BET surface area of a porous material.	[3]	1	2
Q.3(a)	List the steps involved in a heterogeneous catalytic reaction.	[2]	2	2
Q.3(b)	Consider the heterogeneous catalytic reaction,	[3]	2	3

$$A + B \rightleftharpoons C + D$$

The assumed reaction mechanism is:

Step 1: $A + S \rightleftharpoons A{\cdot}S$ (adsorption equilibrium constant = K_1)
Step 2: $B + S \rightleftharpoons B{\cdot}S$ (adsorption equilibrium constant = K_2)
Step 3: $A{\cdot}S + B{\cdot}S \rightleftharpoons C{\cdot}S + D{\cdot}S$ (surface reaction)
Step 4: $C{\cdot}S \rightleftharpoons C + S$ (adsorption equilibrium constant = K_4)
Step 5: $D{\cdot}S \rightleftharpoons D + S$ (adsorption equilibrium constant = K_5)

Considering surface-reaction as the rate limiting, derive the expression for the fraction of total sites occupied by species A.

Q.4 In 1980s, the government put forth the plan for automobile manufacturers to reduce emissions from automobiles over the next few years. To remove oxides of nitrogen (assumed to be NO) from automobile exhaust, a scheme has been proposed that uses unburned carbon monoxide (CO) in the exhaust to reduce the NO over a solid catalyst (copper), according to the reaction, [5] 2 3

$$CO + NO \rightarrow CO_2 + 0.5N_2$$

The following reaction mechanism has been proposed,

$$CO(g) + S \rightleftharpoons CO{\cdot}S \text{ (adsorption equilibrium constant = } K_1)$$

$$NO(g) + S \rightleftharpoons NO{\cdot}S \text{ (adsorption equilibrium constant = } K_2)$$

$$NO{\cdot}S + CO{\cdot}S \rightarrow CO_2 + 0.5N_2 + 2S \text{ (surface reaction)}$$

Considering surface reaction as the rate controlling, derive the following rate expression:

$$-r = \frac{kP_N P_C}{(1 + K_1P_C + K_2P_N)^2}$$

Where, P_N = gas-phase partial pressure of NO; P_C = gas-phase partial pressure of CO.

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Q.5(a)	Give two examples for each of the following non-catalytic fluid-solid reaction: (1) Fluid and Solid reactants → Fluid and Solid products (2) Fluid and Solid reactants → Solid products (3) Fluid and Solid reactants → Fluid products (4) Solid reactants → Fluid and Solid products	[2]	3	1
Q.5(b)	Shrinking-core model for spherical particles of unchanging size was first developed by Yagi and Kunii, who visualized five steps occurring in succession during the reaction. List the five steps of the model for the generalized non-catalytic fluid-solid reaction. Also draw the concentration profile of the reactant 'A(g)' which is reacting with another reactant 'B(s)'.	[3]	3	2

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