

BIRLA INSTITUTE OF TECHNOLOGY, MESRA, RANCHI  
(MID-SEMESTER EXAMINATION MO/2024)

CLASS: BTECH  
BRANCH: Chemical Engineering

SEMESTER: V/ADD  
SESSION: MO/2025

SUBJECT: CL325 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

- | Q.1 (a) | Mention the factors on which the size of real catalyst depends.  | [1]         | CO1        | BL<br>2 |
|---------|--|-------------|------------|---------|
| Q.1 (b) | A catalyst of 0.5 gm adsorbs 60 cm <sup>3</sup> of N <sub>2</sub> at STP to form a monolayer, and each N <sub>2</sub> molecule occupies 1.62 x 10 <sup>-15</sup> cm <sup>2</sup> . Calculate the specific surface area of the sample in cm <sup>2</sup> /gm.   | [2]         | CO1        | 3       |
| Q.1 (c) | Show the steps of a solid-supported catalyst preparation method with an example.   | [2]         | CO1        | 1       |
| Q.2     | Isomerization of <i>n</i> -pentene ( <i>N</i> ) to <i>i</i> -pentene ( <i>I</i> ) over alumina:<br>$N \xrightleftharpoons{Al_2O_3} I$ Mechanism is following (all steps are reversible):<br>Adsorption: $N + S \leftrightarrow N.S$<br>Surface reaction: $N.S + S \leftrightarrow I.S + S$<br>Desorption: $I.S \leftrightarrow I + S$                                    | [4+1<br>=5] | CO2<br>CO4 | 3       |
|         | I) Derive the rate law for mechanism if the surface reaction is the rate limiting step.<br>II) Derive the rate law if an inert <i>T</i> is present in the feed that is also reversibly adsorbed on the surface with following the scheme:<br>$T + S \leftrightarrow T.S$   |             |            |         |
| Q.3     | For the abatement of NO and CO as pollutants released from automobile exhaust, catalytic reduction of the exhaust stream is carried out in the tailpipe over a solid catalyst (typically Pt). The irreversible reaction can be represented as:<br>$CO + NO \rightarrow CO_2 + N_2$   | [1x2=<br>2] | CO2<br>CO4 | 3       |
| (a)     | Assuming associative(molecular) adsorption of CO and NO over the catalyst, show that the expressions for Langmuir adsorption isotherms for adsorbed CO.S and NO.S can be represented by<br>(i) $\frac{C_{CO.S}}{C_t} = \frac{K_{CO} p_{CO}}{1 + K_{CO} p_{CO} + K_{NO} p_{NO}}$<br>(ii) $\frac{C_{NO.S}}{C_t} = \frac{K_{NO} p_{NO}}{1 + K_{CO} p_{CO} + K_{NO} p_{NO}}$ |             |            |         |
|         | Here, $K_{CO}, K_{NO}$ are the adsorption equilibrium constant<br>$p_{CO}, p_{NO}$ are the partial pressures<br>$C_{CO.S}, C_{NO.S}$ are the concentrations of adsorbed CO and NO<br>$C_t$ is the molar concentration of the total active sites<br>(= $C_{CO.S} + C_{NO.S} + C_v$ )<br>$C_v$ the molar concentration of the vacant active sites                          |             |            |         |

(b) Experimental data showed that the reaction follows an irreversible surface reaction-limited scheme. Using suitable assumptions: [1+2=3]

- (i) Propose a mechanism obeying the rate equation given below, and  
(ii) Show that the rate of reaction ( $-r'_{NO}$ ) is given by:

$$-r'_{NO} = \frac{k_{NO} p_{NO} p_{CO}}{(1 + K_{NO} p_{NO} + K_{CO} p_{CO})^2}$$

- Q.4(a) Outline the factors on which effective diffusivity ( $D_e$ ) inside a porous catalyst depends. [2] CO4 2
- Q.4(b) Briefly explain the following (i) Global reaction rate and (ii) Mercury Intrusion Porosimetry. [1.5x2=3] CO1 2
- Q.5(a) Define the Thiele modulus for a porous catalyst. How does it influence the concentration of species inside a catalyst pore? [2] CO3 2
- Q.5(b) Show the plot of internal effectiveness factor ( $\eta$ ) vs Thiele Modulus ( $\phi$ ). With the help of the plot, explain the significance of  $\eta$  in the context of Internal pore diffusion and kinetic limited regimes. [3] CO3 3

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