Seat No.: ________  Enrolment No. 

# GUJARAT TECHNOLOGICAL UNIVERSITY

**BE - SEMESTER– VII (New) EXAMINATION – WINTER 2019**

**Subject Code: 2170501** **Date: 23/11/2019**

**Subject Name: Chemical Reaction Engineering - II**

**Time: 10:30 AM TO 01:00 PM** **Total Marks: 70**

**Instructions:**

1. **Attempt all questions.**
2. **Make suitable assumptions wherever necessary.**
3. **Figures to the right indicate full marks.**
4. **Extra graph may be provided.**

**Q.1** **(a)** From the first principle, prove that for a back mix reactor $E_\theta = e^{-\theta}$ **03**

**(b)** Explain complete segregation and complete micro-mixing. **04**

**(c)** A sample of the tracer hytane at 320 K was injected as a pulse to a reactor, and the effluent concentration was measured as a function of time. The measurements represent the exact concentrations at the times listed and not average values between the various sampling tests. **07**

| t, min | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 12 | 14 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Cpulse, gm/l | 0 | 1 | 5 | 8 | 10 | 8 | 6 | 4 | 3 | 2.2 | 1.5 | 0.6 | 0 |

i. Construct E(t) curve.

ii. Determine the fraction of material leaving the reactor that has spent 8 min or more in the reactor.

**Q.2** **(a)** Comment on the three moments of RTD. **03**

**(b)** Discuss Segregation model in brief. **04**

**(c)** A sample of the tracer hytane at 320 K was injected as a pulse to a reactor, and the effluent concentration was measured as a function of time resulting in the data shown in table below **07**

| t, min | 0 | 5 | 10 | 15 | 20 | 25 | 30 | 35 | 40 | 45 | 50 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Cpulse, gm/l | 0 | 1.2 | 3.1 | 4.2 | 5.8 | 3.5 | 2.2 | 1.6 | 1.0 | 0.4 | 0 |

The measurements represent the exact concentrations at the times listed and not average values between the various sampling tests. Calculate Peclet number, if dispersed plug flow model exists.



OR

**(c)** Air with gaseous A bubbles through a tank containing aqueous B. Reaction occurs as follows **07**

$$A(g) + 2B(l) \rightarrow R(l)$$

$-r_A = kC_AC_B^2$   $k = 10^6\ m^6/mol^2.hr$

For this system

$k_{Ag}\,a = 0.01\ mol/hr.m^3.Pa$   $f_l = 0.98$

$k_{Al}\,a = 20\ hr^{-1}$   $H_A = 10^4\ Pa.m^3/mol$

$D_{Al} = D_{Bl} = 10^{-6}\ m^2/hr$   $a = 20\ m^2/m^3$ reactor

For a point in the absorber-reactor where $P_A = 5000$ Pa and $C_B = 100$ mol/m$^3$

1) Locate the resistance to reaction
2) Calculate the rate of reaction (mol/m$^3$ hr)

| | | | |
|---|---|---|---|
| **Q.3** | **(a)** | Write in brief on how solubility data can help to predict the kinetic regime for fluid -fluid reactions | **03** |
| | **(b)** | How can Hatta number be used to decide the type of contacting device for fluid –fluid reactions | **04** |
| | **(c)** | Uniform-sized spherical particles $UO_3$, are reduced to $UO_2$, in a uniform environment with the following results: | **07** |

| t, h | 0.180 | 0.347 | 0.453 | 0.567 | 0.733 |
|---|---|---|---|---|---|
| $X_B$ | 0.45 | 0.68 | 0.80 | 0.95 | 0.98 |

If reaction follows the Shrinking Core Model, find the controlling mechanism and rate equation to represent this reduction.

**OR**

| | | | |
|---|---|---|---|
| **Q.3** | **(a)** | A closed vessel has flow for which dispersion number is 0.01, we wish to represent this vessel by tanks in series model. What value of number of tanks should be selected? | **03** |
| | **(b)** | Gaseous reactant A diffuses through a gas film and reacts on the surface of a solid B according to a reversible first order reaction: $-r = k_s(Cs - Ce)$, where Ce is the equilibrium concentration of A. Develop an expression for the rate of reaction accounting for both the mass transfer and reaction steps. | **04** |
| | **(c)** | Ram and Rima performed roasting of spherical solid particles containing B isothermally in an oven with gas of constant composition. Solids were converted to form non-flaking product according to the SCM as follows: | **07** |

$$A(g)+B(s)\rightarrow R(g)+S(s)$$

$C_A$=0.01 kmol/m$^3$ The density of solid B is 20 kmol/m$^3$. From the following conversion data (by chemical analysis) or core size data (by slicing and measuring), Ram proposed ash layer controlling while Rima proposed gas layer as the rate controlling mechanism for the transformation of solid from the kinetic data show below,

| dp (mm) | $X_B$ | t, sec |
|---|---|---|
| 1 | 0.3 | 2 |
| 1 | 0.75 | 5 |

Justify who is correct?

| | | | |
|---|---|---|---|
| **Q.4** | **(a)** | Draw a plot to show the progress of reaction of a single spherical particle of constant size with surrounding fluid measured in terms of time for complete conversion for all the different resistances. | **03** |
| | **(b)** | Derive the rate equation for fluid–fluid reaction in the case of instantaneous irreversible reaction with higher concentration of constituent B. | **04** |
| | **(c)** | A solid feed consisting of 30% of 1 mm particles and smaller, 30% of 2 mm particles and rest 4 mm particles all on weight basis, is to be passed through a tubular reactor like rotary kiln, where it reacts with gas of constant composition to give a hard solid product. Experiments show that the progress of conversion can reasonably be represented by reaction control in unreacted core model and that the time for complete conversion of 4 mm particle is 4 hours. Find the residence time needed in the tubular reactor for 85 % conversion of solids. | **07** |

**OR**

| | | | |
|---|---|---|---|
| **Q.4** | **(a)** | Draw neat diagram showing various contacting patterns for two phase reacting system. | **03** |
| | **(b)** | List the steps visualized by Shrinking core model for spherical particles of unchanging size. | **04** |
| | **(c)** | Explain Langmuir Hinshelwood Hougen Watson model for solid catalyzed gas phase reaction. | **07** |
| **Q.5** | **(a)** | What are the assumption for Langmuir Hinshelwood Hougen Watson model | **03** |
| | **(b)** | Write a brief note on Langmuir isotherm. | **04** |
| | **(c)** | Derive the effectiveness factor for first order catalyzed reaction | **07** |

**OR**

| | | | |
|---|---|---|---|
| **Q.5** | **(a)** | Classify catalyst used in chemical industries | **03** |
| | **(b)** | Write a brief note on working of fluidized bed reactor | **04** |
| | **(c)** | Spherical particles of zinc blende of size R=2 mm are roasted in an 8% oxygen stream at 800°C and 1 atm. The stoichiometry of the reaction is $2ZnS + 3O_2 \rightarrow 2ZnO + 2SO_2$ Assuming that reaction proceeds by the shrinking core model calculate the time needed for complete conversion of a particle and the relative resistance of ash layer diffusion during this operation. Film resistance can safely be neglected as long as a growing ash layer is present.<br>Data:<br>Density of solid $\rho_B$ = 4.13 gm/cm$^3$<br>Reaction rate constant $k_s$'' = 2 cm/sec<br>For gases in the ZnO layer $\check{D}_e$ = 0.08 cm$^2$/sec | **07** |



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