

Name : .....

Roll No. : .....

Invigilator's Signature : .....

**CS/B.Tech/BT(O)/SEM-5/BT-502/2012-13**

**2012**

**BIOREACTOR DESIGN AND ANALYSIS**

Time Allotted : 3 Hours

Full Marks : 70

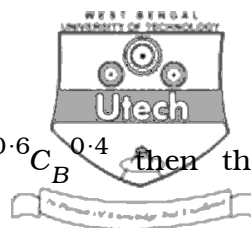
*The figures in the margin indicate full marks.*

*Candidates are required to give their answers in their own words  
as far as practicable.*

**GROUP – A**

**( Multiple Choice Type Questions )**

1. Choose the correct alternatives for any *ten* of the following :  $10 \times 1 = 10$
- i) Which of the following influences the rate of a chemical reaction performed in solution ?
- a) Temperature
  - b) Activation energy
  - c) Concentrations of reactants
  - d) All of the above influence the rate.
- ii) A student determined the value of the rate constant,  $k$ , for a chemical reaction at several different temperatures. Which of the following graphs of the student's data would give a straight line ?
- a)  $k$  versus  $T$
  - b)  $\ln k$  versus  $(1/T)$
  - c)  $\ln k$  versus  $T$
  - d)  $\ln k$  versus  $E_a$ .



iii) If the rate is given as  $-r_A = kC_A^{0.6}C_B^{0.4}$  then the molecularity and order of the reaction is

- a) 1 and 1
- b) 1 and 2
- c) 2 and 1
- d) 2 and 2.

iv) The rate law for certain reaction has a specific rate constant  $k$ , with unit of  $s^{-1}$ . What is the order of the reactions ?

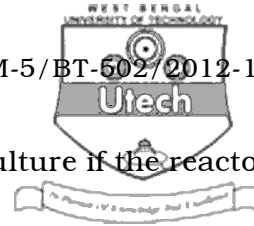
- a) 0
- b) 1
- c) 2
- d) cannot be determined.

v) The unit of 2nd order reaction constant when partial pressure will be used in place of concentration is

- a) atm-2
- b) time-1 atm-2
- c) time-1 atm-1
- d) atm-1.

vi) Batch reactor is a

- a) ideal reactor
- b) non-ideal reactor
- c) steady
- d) both (a) and (b).



vii) A CSTR can be used for animal cell culture if the reactor is modified as

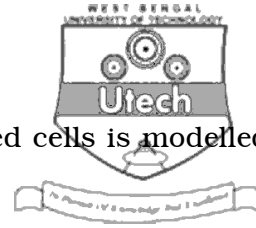
- a) without stirers
- b) removing baffles
- c) agitating with low rpm
- d) using micro-carriers.

viii) The  $k_L a$  value is related to

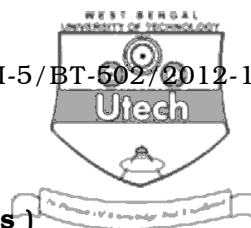
- a)  $O_2$  transfer rate
- b) Mass transfer unit
- c) Enzyme immobilization constant rate
- d) Rate of diffusion.

ix) Antibiotics formation is described by the kinetics of the type

- a) Growth associated
- b) Non-growth associated
- c) Growth and Non-growth associated
- d) Mass transfer controlling.



- x) A packed bed reactor with immobilized cells is modelled as a
- a) Plug flow reactor
  - b) Stirred tank reactor
  - c) Dispersion model
  - d) Plug flow with axial dispersion.
- xi) Perfusion reactor is used for
- a) Vaccine formation
  - b) Animal cell culture
  - c) Alcohol production
  - d) Biomass production.
- xii) Microbial fermentation is best carried out for high yield of cell mass by
- a) Plug flow reactor
  - b) Fed batch reactor
  - c) Back-mixed reactor
  - d) Fluidized bed reactor.

**GROUP – B****( Short Answer Type Questions )**

Answer any *three* of the following.  $3 \times 5 = 15$

2. Experimental studies of a specific decomposition of A in a batch reactor using pressure units show exactly the same rate at two different temperatures :

$$\text{at 400 K, } -r_A = 2 \cdot 3 P_A^2$$

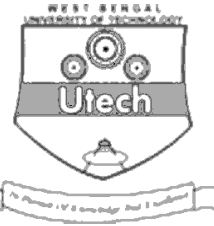
$$\text{Where } \begin{cases} -r_A = [\text{mol} / \text{m}^3 \cdot \text{sec}] \\ P_A = [\text{atm}] \end{cases}$$

$$\text{At 500 K, } -r_a = 2 \cdot 3 P_A^2$$

Transform the rate expressions into concentration units and then evaluate the activation energy.

The pressure is not excessive, so the ideal gas law can be used.

3. For the decomposition  $A \longrightarrow R$ ,  $C_{A0} = 1$  mol/litre, in a batch reactor conversion is 75% after 1 hour, and is just completed after 2 hours. Find a rate equation to represent these kinetics.
4. An aqueous feed of A and B ( 400 litre/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 is represented by  $A + B \longrightarrow R$ ,  $-r_A = 200 C_A C_B$  mol/lit.min. Find the volume of reactor needed for 99.9% conversion of A to product.
5. What are the different thump rules for scale up of reactors ? What are their limitations and failures ?
6. Write a short note on trickle bed and membrane reactor.

**GROUP – C****( Long Answer Type Questions )**

Answer any *three* of the following.  $3 \times 15 = 45$

7. a) In a number of separate runs different concentrations of substrate and enzyme are introduced into a batch reactor and allowed to react. After a certain time the reaction is quenched and the vessel contents analyzed. From the results found below find a rate equation to represent the action of enzyme on substrate :

| Run | $C_{E0}(\text{mol} / \text{m}^3)$ | $C_{A0}(\text{mol} / \text{m}^3)$ | $C_A(\text{mol} / \text{m}^3)$ | $t(\text{hr})$ |
|-----|-----------------------------------|-----------------------------------|--------------------------------|----------------|
| 1   | 3                                 | 400                               | 10                             | 1              |
| 2   | 2                                 | 200                               | 5                              | 1              |
| 3   | 1                                 | 20                                | 1                              | 1              |

- b) Liquid A decomposes by first-order kinetics, and in a batch reactor 50% of A is converted in a 5-minute run. How much longer would it take to reach 75% conversion ?  $10 + 5$
8. a) The specific growth rate for inhibited growth in a chemostat is given by the following equation :

$$\mu_g = \mu_m S / (K_s + S + IK_s / K_I)$$

Where

$$S_0 = 10 \text{ g/l} \quad K_s = 1 \text{ g/l} \quad I = 0.5 \text{ g/l}$$

$$Y_{X/S}^M = 0.1 \text{ g cells / g subs}$$

$$X_0 = 0 \quad K_I = 0.01 \text{ g/l} \quad \mu_m = 0.5 \text{ h}^{-1} \quad k_d = 0$$

- Determine  $X$  and  $S$  as a function of  $D$  when  $I = 0$
- With inhibitor added to a chemostat, determine the effluent substrate concentration and  $X$  as a function of  $D$ .
- Determine the cell productivity.  $DX$  as a function of dilution rate.



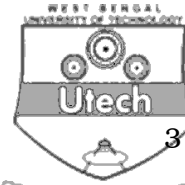
- b) One litre per minute of liquid containing A and B ( $C_{A0} = 0.1$  mol/litre,  $C_{B0} = 0.01$  mol/litre) flow into a mixed reactor of volume  $V = 1$  litre. The materials react in a complex manner for which the stoichiometry is unknown. The outlet stream from the reactor contains A, B and C ( $C_{Af} = 0.02$  mol/litre,  $C_{Bf} = 0.03$  mol/litre,  $C_{Cf} = 0.04$  mol/litre). Find the rate of reaction of A, B and C for the conditions within the reactor . 10 + 5

9. A reactor with a number of dividing baffles is to be used to run the reaction  $A \longrightarrow R$  with  $-r_A = 0.05 C_A$  mol/litre. min

A pulse tracer test gives the following output curve.

| Time (min)            | 0  | 10 | 20 | 30 | 40 | 50 | 60 | 70 |
|-----------------------|----|----|----|----|----|----|----|----|
| Concentration reading | 35 | 38 | 40 | 40 | 39 | 37 | 36 | 35 |

- a) Calculate  $X_A$  from the dispersion model assuming small deviation from plug flow
- b) Calculate  $X_A$  directly from the data. 8 + 7
10. a) What all points should be considered to design a bioreactor for animal cell culture. Describe the operation of hollow fiber reactor for the production of monoclonal antibody from hybridoma cells and indicate the design.
- b) What is the importance of plant cell culture ? What are the differences between plant cells and microbes and implication for bioreactor design ? 9 + 6



3 × 5

11. Attempt any *three* of the following :

- a) What is space time and holding time for flow reactor ?  
What is the relation between space time and holding time for constant density and changing density system ?  
Explain with example.
  - b) What are the advantages and disadvantages of bubble column reactor for aerobic microbial fermentation ?
  - c) Describe the method of determining  $k_L a$  by the steady state method where the oxygen uptake rate (OUR) is  $q_{o2} X$ .
  - d) Write a short note on bioreactor consideration in immobilized cell system.
-