

Birla Institute of Technology and Science, Pilani – Pilani Campus
Semester-II, 2021-22
Comprehensive Examination (Regular)
CHE G641: Reaction Engineering

Date: 6/5/2022

Day: Friday

Marks: 100 (Weightage: 40%)

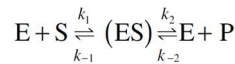
Duration: 3 Hrs

Instructions: Take suitable assumptions wherever necessary and state them clearly.

PART-A: CLOSED BOOK (Max. Marks: 40)

- Q.1 A.** Discuss the following:
- i.) Significance of Ranz-Marshall Correlation 4
 - ii.) Limitations of the Shrinking Core Model 4
 - iii.) Factors that influence the heterogeneous reactor design 4
- B.** Convert the following Shrinking Core Model equation into its dimensionless form and identify the important dimensionless numbers formed and write their significance: 8
- $$\left(\frac{C_{A0}b}{\rho_B}\right)t = \frac{R}{3k_g}X_B + \frac{R^2}{6D_e}\left[1 - 3(1 - X_B)^{2/3} + 2(1 - X_B)\right] + \frac{R}{k_s}\left[1 - (1 - X_B)^{1/3}\right]$$

- Q.2** Consider the reversible product-formation reaction in an enzyme-catalyzed bio-reaction: 10



Develop a rate expression (in the form as given below) for product-formation using the quasi-steady-state approximation, and determine the unknowns A, B, C and D:

$$v = \frac{d[P]}{dt} = \frac{A[S] + B[P]}{1 + C[S] + D[P]}$$

- Q.3** Derive an expression to show that the total amount of cell in the culture increases linearly with time in a fed-batch culture 10

PART-B: OPEN BOOK (Max. Marks: 60)

- Q.4** Enzyme E catalyzes the decomposition of substrate A. To see whether substance B acts as inhibitor we make two kinetic runs in a batch reactor, one with B present, the other without B. From the data recorded below: 12
- a) Find a rate equation to represent the decomposition of A.
 - b) What is the role of B in this decomposition?
 - c) Suggest a mechanism for the reaction.

Run1: $C_{A0}=600 \text{ mol/m}^3$, $C_{E0}= 8 \text{ gm/m}^3$, no B present

C_A	350	160	40	10
$t, \text{ hr}$	1	2	3	4

Run 2: $C_{A0}=800 \text{ mol/m}^3$, $C_{E0} = 8 \text{ gm/m}^3$, $C_B=C_{B0}=100 \text{ mol/m}^3$

C_A	560	340	180	80	30
$t, \text{ hr}$	1	2	3	4	5

- Q.5** The enzyme, urease, is immobilized in Ca-alginate beads 2 mm in diameter. When the urea concentration in the bulk liquid is 0.5 mM the rate of urea hydrolysis is $v=10$ mmoles-l-h. Diffusivity of urea in Ca-alginate beads is $D_e=1.5 \times 10^{-5}$ cm²/sec, and the Michaelis constant for the enzyme is $K_m=0.2$ mM. By neglecting the liquid film resistance on the beads (i.e., $[S_o]=[S_s]$) determine the following: **12**
- Maximum rate of hydrolysis V_m , Thiele modulus (ϕ), and effectiveness factor (η).
 - What would be the V_m , ϕ , and η values for a particle size of $D_p=4$ mm?
- Hint: Assume $\eta=3/\phi$ for large values of ϕ ($\phi > 2$).

- Q.6** Escherichia coli were cultured in a 10 L CSTR at 30°C. Its kinetics equation follows the Monod equation, where $\mu_{max}=1.0$ h⁻¹ and $K_s=0.2$ g/L. Glucose's feed concentration is 10 g/L, the feed volumetric flow rate is 5 L/h, and $Y_{x/s}=0.5$. Determine the following: **12**
- Cell concentration in the reactor
 - Cell productivity
 - Substrate concentration when the dilution rate is one-half of the maximum
 - Optimal feed rate
 - Optimal cell concentration in the reactor

- Q.7** A continuous stirred tank fermenter is operated at a series of dilution rates though at constant, sterile, feed concentration, pH, aeration rate and temperature. The following data were obtained when the limiting substrate concentration was 1.2 g/l and the working volume of the fermenter was 10 liters: **12**

Feed flowrate (l/h)	0.79	1.03	1.31	1.78	2.39	2.68
Exit substrate conc. (mg/l)	36.9	49.1	64.4	93.4	138.8	164.2
Dry weight cell density (mg/l)	487	490	489	482	466	465

Determine the following:

- i) The kinetic constants K_s , μ_m and k_d as used in the modified Monod equation:

$$\mu = \frac{\mu_m S}{K_s + S} - k_d$$

- ii) The growth yield coefficient, $Y_{X/S}$

- Q.8** Consider a small industrial fermenter running in a continuous mode with a fresh feed flowrate of 62 l/h, the effluent from the fermenter contains 10 mg/l of the original substrate. The same fermenter is then connected to a settler-thickener which has the ability to concentrate the biomass in the effluent from the tank by a factor of 3, and from this, a recycle stream of concentrated biomass is set up. The flowrate of this stream is 38 l/h and the fresh feed flowrate is at the same time increased to 100 l/h. Assume that the microbial system follows Monod kinetics. Data: $\mu_m=0.15$ h⁻¹ and $K_s = 95$ mg/l. **12**

Determine the following:

- Dilution rate when there is no recycle
- Volume of the fermenter when there is no recycle
- Net specific growth rate with recycle of biomass
- Substrate concentration in the recycle stream

*****Best Wishes*****