

UNIVERSITY COLLEGE LONDON

University of London

EXAMINATION FOR INTERNAL STUDENTS

For The Following Qualifications:–

B.Eng. M.Eng.

Chemical Eng E836: Chemical Reaction Engineering

COURSE CODE : CENGE836

UNIT VALUE : 0.50

DATE : 16-MAY-06

TIME : 10.00

TIME ALLOWED : 3 Hours

Answer FOUR questions. Only the first four answers will be marked.
ALL questions carry a total of 25 each, distributed as shown []

Graph paper provided.

Where numerical integration is required for any question use Simpson's rule as stated below.

For N+1 points where N is even,

$$\int_{x_0}^{x_N} f(X) dX = \frac{h}{3} (f_0 + 4f_1 + 2f_2 + 4f_3 + 2f_4 + \dots + 4f_{N-1} + f_N)$$

where $h = \frac{X_N - X_0}{N}$

1

- a) The elementary liquid phase reaction $A \rightarrow B$ takes place in two continuous stirred reactors connected in series. The concentration of reactant A in the inlet to the first reactor is 1 mol/dm^3 , whilst in its outlet is 0.5 mol/dm^3 . If the volume of the second reactor is four times that of the first, find the exit concentration from the second reactor. [15]
- b) If the order of the reactors is reversed, what is the final exit concentration? [10]

2

A reaction with the stoichiometry $A \rightarrow B$ displays the behaviour indicated below.

| $C_A \text{ (mol/dm}^3\text{)}$ | $-r_A \text{ (mol/dm}^3\text{ min)}$ |
|---------------------------------|--------------------------------------|
| 1 | 2 |
| 2 | 5 |
| 3 | 12 |
| 4 | 25 |
| 5 | 40 |
| 7 | 16 |
| 8 | 10 |
| 10 | 6 |
| 12 | 5 |
| 20 | 4 |

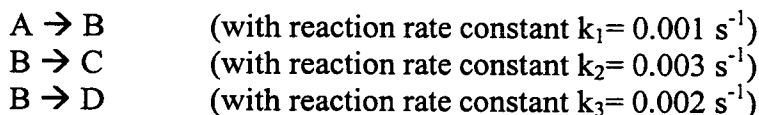
We wish to operate a reactor (or a combination of reactors) in such a way that we get 90% conversion of a feed stream in which the concentration of A is 20 mol/dm^3 . If the flow rate is $100 \text{ dm}^3/\text{min}$ find the reactor volume:

CONTINUED

- a) for a PFR [8]
- b) for a CSTR [7]
- c) for a combination of one PFR and one CSTR which minimises total reactor volume [10]

3

The elementary liquid phase reaction system



is carried out in a batch reactor in which initially there is pure A.

- a) Derive an equation for the concentration of A as a function of time. [4]
- b) What is the ratio C_A/C_{A0} after 1.5 min? [3]
- c) Derive an equation for the concentration of B as a function of time. [10]
- d) If $C_{A0} = 0.2 \text{ mol/dm}^3$, what is the concentration of B after 2 min? [5]
- e) At what time is the concentration of B at a maximum? [3]

4

- a) What is Knudsen diffusion? [5]
- b) Consider a porous catalyst pellet where a reaction occurs and mass/heat transfer resistances exist (both intraphase and interphase). Sketch the radial concentration and temperature profiles for an endothermic and exothermic reaction and explain why the profiles have these forms. [10]
- c) Reactant A, which is present in dilute concentrations, is diffusing at steady state from the bulk fluid through a stagnant film of B of thickness δ to the external surface of a spherical nonporous catalyst pellet with diameter d_p . Since $\delta \ll d_p$ we can neglect the curvature of the film. Determine the concentration profile (C_A as a function of film co-ordinate) and the molar flux of A (W_{Az}). [10]

Additional Information

Molecular Diffusivity: $D_{AB} = 10^{-6} \text{ m}^2/\text{s}$

Film thickness: $\delta = 10^{-6} \text{ m}$

Total concentration: $C_{T0} = 100 \text{ mol/m}^3$

Mole fraction of A at the bulk: $y_{A,\text{bulk}} = 0.9$

Mole fraction of A at the surface of the pellet: $y_{A,\text{surface}} = 0.2$

PLEASE TURN OVER

5

This question concerns the application of plug-flow reactors for biocatalytic reactions.

- (a) Derive an analytical expression (based on a mass balance) to describe the productivity of an enzyme catalysed reaction in a plug-flow reactor. Assume Michaelis-Menten kinetics apply and state any other assumptions used. [15]
- (b) Why is this type of reactor preferable for industrial operation rather than a continuous stirred tank reactor? [5]
- (c) For industrial operation why are such reactors frequently used with a recycle? [5]

END OF PAPER