

**UNIVERSITY COLLEGE LONDON**

University of London

**EXAMINATION FOR INTERNAL STUDENTS**

For The Following Qualification:–

*M.Sc.*

**D8: Chemical Reaction Engineering**

**COURSE CODE : CENG00D8**

**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  $1 \text{ mol/dm}^3$ , whilst in its outlet is  $0.5 \text{ mol/dm}^3$ . 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

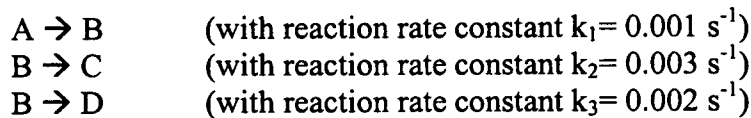
We wish to operate a reactor (or a combination of reactors) in such a way that we get 90% conversion of a feed stream in which the concentration of A is  $20 \text{ mol/dm}^3$ . If the flow rate is  $100 \text{ dm}^3/\text{min}$  find the reactor volume:

**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  $\delta$  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:  $y_{A,bulk} = 0.9$

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

**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**