NATIONAL UNIVERSITY OF SCIENCE AND TECHNOLOGY

FACULTY OF APPLIED SCIENCE

DEPARTMENT OF APPLIED CHEMISTRY

REACTOR TECHNOLOGY

SCH 4208

Second Semester Examination Paper

May 2015

This examination paper consists of 5 pages

Time Allowed: 3 hours
Total Marks: 100
Special Requirements: Graph paper
Examiner's Name: Mr. B. Nyoni

INSTRUCTIONS

1. Answer all questions in Section A and any other three questions from Section B.
2. Each question carries 20 marks.
3. Show steps clearly in any calculation.
4. Start the answers for each question on a fresh page.
5. Use of calculators is permissible.

MARK ALLOCATION

QUESTION	MARKS
1.	**20**
2.	**20**
3.	**20**
4.	**20**
5.	**20**
TOTAL	**100**

SECTION A

1 (a) (i) State the law of conservation of mass.

(ii) In what circumstances is the law of conservation of mass restricted. [4 marks]

(b) The catalytic reaction A $\longrightarrow$ 4R is run at 3.2 atm and 120^{o}C in a plug flow reactor which contains 0.01kg of catalyst and uses a feed consisting of the partially converted product of 20 liters/hour of pure un-reacted A. The results are as follows:

Run	1	2	3	4
C_{Ain}, mol/liter	0.100	0.080	0.060	0.040
C_{Aout}, mol/liter	0.084	0.070	0.055	0.038

Use a graphical method to find the rate equation to represent this reaction. [16 marks]

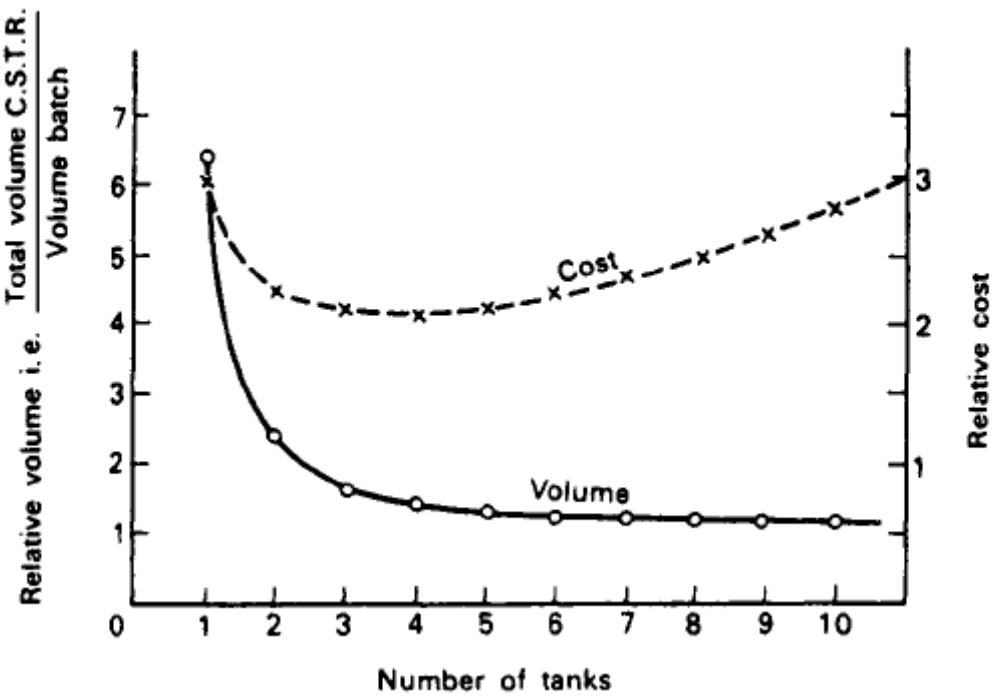
2 (a) (i) Define the following terms:

(1) reaction rate,
(2) order of reaction, and
(3) rate constant [6 marks]

(ii) With the aid of one example each, distinguish between:

(1) homogeneous and heterogeneous reactions
(2) first order and pseudo first order reactions [8 marks]

(iii) The figure below shows a comparison of size and cost of a CSTR with a batch reactor for a first order reaction with a conversion of 96%. Describe and explain the \ trend shown with respect to cost and volume of the reactors. [6 marks]



SECTION B

3 (a) With the aid of a flowchart diagram describe the main features of the Kompogas thermophilic dry digestion process. [5 marks]

(b) Ethyl formate is to be produced from ethanol and formic acid in a continuous flow tubular reactor operated at a constant temperature of 303 K (30◦C). The reactants will be fed to the reactor in the proportions 1 mole HCOOH: 5 moles C_2H_5OH at a combined flowrate of 0.0002 m^3/s (0.72 m^3/h). The reaction will be catalysed by a small amount of sulphuric acid. At the temperature, mole ratio, and catalyst concentration to be used, the rate equation determined from small-scale batch experiments has been found to be:

$$\mathscr{R} = \boldsymbol{k} C_F^2$$

where: $\mathscr{R}$ is formic acid reacting/(kmol/m^3s)

C_F is concentration of formic acid kmol/m^3, and

$\boldsymbol{k} = 2.8 \times 10^{-4}$ m^3/kmol s.

(i) Estimate the volume of the reactor required to convert 70 per cent of the formic acid to the ester.

(ii) If the reactor consists of a pipe of 50 mm i.d. what will be the total length required?

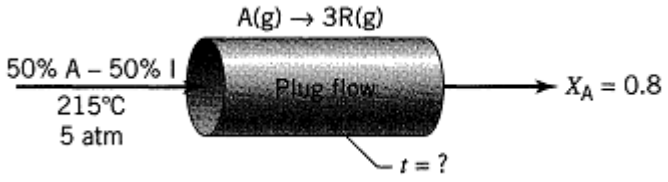
(iii) Determine also whether the flow will be laminar or turbulent and comment on the significance of this in relation to the estimate of reactor volume. The viscosity of the solution is 1.4×10^{-3}N s/m^2. [15 marks]

4 (a) Fixed-bed reactors and fluidized-bed reactors are some of the most important industrial reactors. With the aid of sketch diagrams explain their mode of operation and where they are applied. [6 marks]

(b) A homogeneous gas reaction A ⟶ 3R has a reported rate at 215°C

$$-r_A = 10^{-2} C_A^{1/2}, \qquad [\text{mol/liter} \cdot \text{sec}]$$

Find the space time needed for 80% conversion of a 50% A -50% inert feed to a plug flow reactor operating at 215°C and 5 atm (C_{AO} = 0.0625 mol/liter)

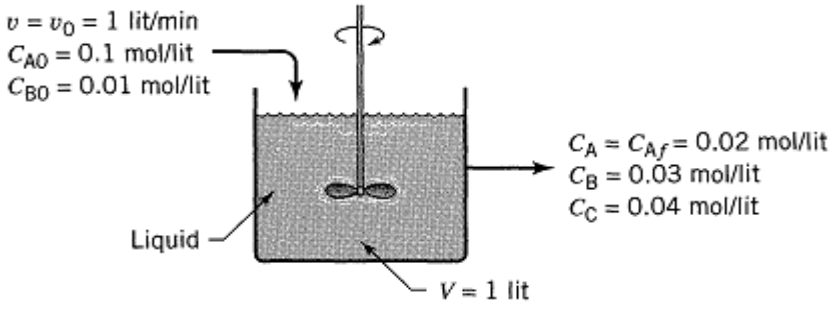


[12 mark]

(c) Explain why inerts are introduced into a reactor together with feed. [2 marks]

5 (a) Explain the term **mixed flow** as applied to mixed flow reactors. [4 marks]

(b) One liter per minute of liquid containing A and B (C_{AO} = 0.10 mol/liter, $C_{B}o$ = 0.01 mol/liter) flow into a mixed reactor of volume V = 1liter. 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/liter, C_{Bf} = 0.03 mol/liter, C_{Cf} = 0.04 mol/liter), as shown in the figure below. Find the rate of reaction of A, B, and C for the conditions within the reactor.



[12 marks]

(c) With the aid of examples, distinguish between elementary and non elementary reactions. [4 marks]

6. Ethyl acetate (M) is to be manufactured by the reversible esterification of acetic acid (A) with ethanol (B) to produce water (N) in an isorthermal batch reactor. A production rate of 10 tonne/day of ethyl acetate is required.

$$CH_3COOH + C_2H_5OH \longrightarrow CH_3COOC_2H_5 + H_2O$$

The reactor will be charged with a mixture containing 500 kg/m^3 ethanol and 250 kg/m^3 acetic acid, the remainder being water, and a small quantity of hydrochloric acid to act as a catalyst. The density of this mixture is 1045 kg/m^3 which will be assumed constant throughout the reaction. The reaction is reversible with a rate equation, over the concentration range of interest, can be written as:

$$R_A = k_f C_A C_B - k_r C_M C_N$$

At the operating temperature of 100^{o}C the rate constants are:

$k_f = 8.0 \times 10^{-6}$ m^3/kmol.s

$k_r = 2.7 \times 10^{-6}$ m^3/kmol.s

The reaction mixture will be discharged when the conversion of the acetic acid is 30%. A time of 30 minutes is required between batches for discharging, cleaning and recharging. Determine the volume of the reactor required. [20 marks]