**NATIONAL UNIVERSITY OF SCIENCE AND TECHNOLOGY**
**DEPARTMENT OF APPLIED CHEMISTRY**
**BACHELOR OF SCIENCE HONOURS DEGREE**
**END OF FIRST SEMESTER EXAMINATIONS – MAY 2014**
**REACTOR TECHNOLOGY – SCH 4208**
**TIME: 3 HOURS**

**Instructions to candidates:**

1. Answer all questions in Section A and any three questions in Section B.
2. Show all your steps clearly in any calculation
3. Start the answers for each question on a new page.

**Additional material:**

Graph paper

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## SECTION A

**1 (a)** (i) State the law of conservation of mass
(ii) In what circumstances is the law of conservation of mass restricted. [8]

**(b)** A preliminary assessment of a process for the reduction of toluene is to be made. The reaction involved is:

$$C_6H_5.CH_3 + H_2 \rightleftharpoons C_6H_6 + CH_4$$

The feed to the reactor will consist of hydrogen and toluene in the ratio 3:1 respectively.

(i) Calculate the equilibrium conversion based on toluene, for an outlet temperature of 900K. The equilibrium constant $K_p$, is 227.

(ii) Calculate the temperature rise which would occur with this feed if the reactor was operated adiabatically and the products were withdrawn at equilibrium. For reaction at 900K, $\Delta H$ = 45000 kJ/kmol.

Specific heat capacities at 900K (kJ/kmol): $C_6H_6$ = 198, $C_6H_5CH_3$ = 240, $CH_4$ = 67, $H_2$ =30.

[12]

**2 (a)** (i) With the aid of examples, distinguish between elementary and non elementary reactions. [8]

(ii) For any two types of reactors, discuss the advantages and limitations of each type of reactor. [8]

(iii) What type of reactor is preferred if the rate of heat evolution is high. Explain your answer [4]

## SECTION B

**3 (a)** With the aid of a diagram describe the main features of a batch reactor. [5]

**(b)** The alkylation of toluene with acetylene in the presence of sulphuric acid is carried out in a batch reactor. 6000 kg of toluene is charged in each batch, together with the required amount of sulphuric acid and the acetylene is fed continuously to the reactor under pressure. Under circumstances of intense agitation, it may be assumed that the liquid is always saturated with acetylene, and that the toluene is consumed in a simple pseudo first-order reaction with a rate constant of 0.0011 $s^{-1}$. If the reactor is shut down for a period of 900 s (15 min) between batches, use a graphical method to determine the optimum reaction time for the maximum rate of production of alkylate, and calculate this maximum rate in terms of mass P toluene consumed per unit time.

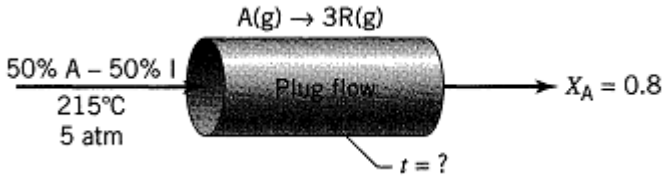
[15]

**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. [8]

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

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

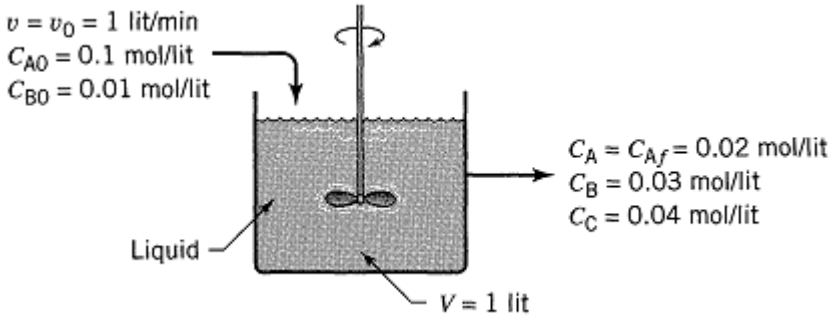
Find the space time needed for 80% conversion of a 50% A -50% inert feed to a plug flow reactor operating at 215°C and 5 atm ($C_{AO}$ = 0.0625 mol/liter)




[12]

**5 (a)** (i) Explain the term **mixed flow** as applied to mixed flow reactors.
(ii) Give another name that is commonly used for mixed flow reactor [5]

**(b)** One liter per minute of liquid containing A and B ($C_{AO}$ = 0.10 mol/liter, $C_{BO}$ = 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.




[15]

**6 (a)** Any type of reactor with known contacting pattern may be used experimentally to explore the kinetics of catalytic reactions. List the five experimental methods you have studied. [5]

**(b)** The catalytic reaction A ⟶ 4R is run at 3.2 atm and 118°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 unreacted 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.

[15]

*End of question Paper!!!*