NATIONAL UNIVERSITY OF SCIENCE AND TECHNOLOGY

FACULTY OF APPLIED SCIENCE

DEPARTMENT OF APPLIED CHEMISTRY

REACTOR TECHNOLOGY

SCH 4208

Supplementary Examination Paper

August 2015

This examination paper consists of 4 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. Show steps clearly in any calculation.
3. Start the answers for each question on a fresh page.
4. 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. [8 marks]

(b) In a process for the production of hydrogen required for the manufacture of ammonia, natural gas is to be reformed with steam according to the reactions:

$$CH_4 + H_2O \rightleftharpoons CO + 3H_2, \quad K_p(\text{at } 1173 \text{ K}) = 1.43 \times 10^{13} \text{ N}^2/\text{m}^4$$
$$CO + H_2O \rightleftharpoons CO_2 + H_2, \quad K_p(\text{at } 1173 \text{ K}) = 0.784$$

The natural gas is mixed with steam in the mole ratio $1CH_4 : 5H_2O$ and passed into a catalytic reactor which operates at a pressure of 3 MN/m^2 (30 bar). The gases leave the reactor virtually at equilibrium at 1173 K.

Show that for every 1 mole of CH_4 entering the reactor, 0.950 mole reacts, and 0.44 mole of CO_2 formed. [12 marks]

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

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

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

SECTION B

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

(b) The reaction described by the data in the following table is to be carried out in a PFR at 500 K and 830 kPa. The entering molar flow-rate of A is 0.4 mol/s. Use a graphical method to determine the volume of the reactor.

Conversion, X	0	0.1	0.2	0.4	0.6	0.7	0.8
$-r_A$ (mol/m^3.s)	0.45	0.37	0.30	0.195	0.113	0.079	0.05

[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. [8 marks]

(b) A bed in a fixed bed reactor consists of uniform spherical particles of diameter 3mm and density 4200kg/m^3. What will be the minimum fluidisation velocity in a liquid of viscosity 3 x 10^{-3} Ns/m^2 and density 1100 kg/m^3?

The Reynolds number N_{Re} at the fluidisation velocity is given by:

$$N_{Re} = 25.7[\sqrt{(1 + 5.53x10^{-5}N_{Ga})} - 1]$$

N_{Ga} is the Galileo number, given by;

$$N_{Ga} = D^3\rho(\rho_s - \rho)g/\mu^2$$

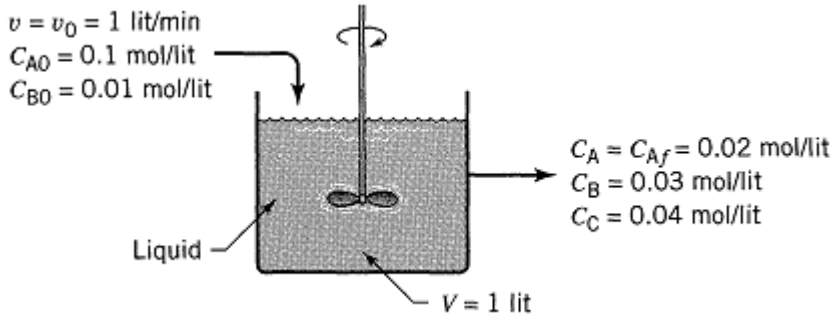
where:

D – diameter of particle
ρ_s – particle density
ρ – fluid density
g – acceleration due to gravity
μ – viscosity of fluid [12 marks]

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 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.



[15 marks]

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 hav studied. [5 marks]

(b) The catalytic reaction A $\longrightarrow$ 4R is run at 3.2 atm and 118^{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 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 marks]

End of Question Paper!!!