



NATIONAL UNIVERSITY OF SCIENCE AND TECHNOLOGY

FACULTY OF APPLIED SCIENCE

DEPARTMENT OF APPLIED CHEMISTRY

REACTOR TECHNOLOGY

SCH 4208

Examination Paper

March 2025

This examination paper consists of 4 pages

Time Allowed: 3 hours

Total Marks: 100

Special Requirements: Graph papers

Examiner's Name: Dr 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

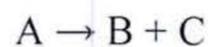
MARK ALLOCATION

| QUESTION | MARKS |
|--------------|------------|
| 1. | 20 |
| 2. | 20 |
| 3. | 20 |
| 4. | 20 |
| 5. | 20 |
| TOTAL | 100 |

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SECTION A

1. (a) (i) State the law of conservation of mass [2]
(ii) State the 1st law of thermodynamics. [3]
(iii) In what circumstances are the laws restricted. [3]
- (b) For each of the reactors, batch, plug flow (tubular) and mixed flow (CSTR), describe the following
(i) mode of operation
(ii) concentration profile [12]
2. (a) There are two procedures for batch reactor kinetics data, the integral and the differential methods. Describe the integral method procedure. [6]
- (b) Guess nth order kinetics for the following batch reactor data for the reaction,



where the composition of A in the reactor was measured at various times. Use fractional life method with $F = 0.8$.

| Column 1 | Column 2 |
|----------------|--|
| Time t, s | Concentration $C_A, \text{mol/liter}$ |
| 0 | $C_{A0} = 10$ |
| 20 | 8 |
| 40 | 6 |
| 60 | 5 |
| 120 | 3 |
| 180 | 2 |
| 300 | 1 |

Reported data

[14]

SECTION B

3. (a) Give the name of a commercial process used to produce ammonia from hydrogen and nitrogen. [1]

(b) List the sources of hydrogen and nitrogen. [4]

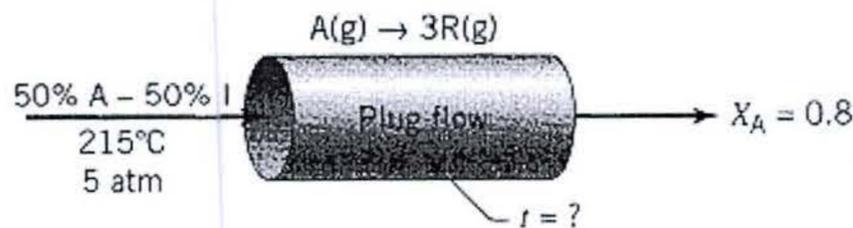
(c) In order to obtain a reasonable level of conversion at a commercially acceptable rate, ammonia synthesis reactors operate at pressures of 150 to 300 atm and temperatures of 700 to 750 K. Calculate the equilibrium mole fraction of nitrogen at 300 atm and 723 K starting from an initial composition of $N_2 = 25$ mol and $H_2 = 75$ mol. At 300 atm and 723 K, the equilibrium constant (K_p) is 2.64. [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. [6]

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

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

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 ($C_{A0} = 0.0625$ mol/liter) [12]



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

5. (a) (i) Define the following terms

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

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

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

(c) (i) Define activation energy. [2]

(ii) Milk is pasteurized if it is heated to 63°C for 30 min, but if it is heated to 74°C it only needs 15 s for the same result. Find the activation energy of this sterilization process. [4]

6. The following equilibrium data was obtained for the adsorption of copper ions using a certain commercial adsorbent.

| | | | | | | | |
|---------------------------------------|-------|-------|-------|-------|--------|--------|--------|
| t (min) | 0 | 20 | 40 | 60 | 80 | 100 | 120 |
| t/q _t | - | 451.4 | 735.1 | 992.9 | 1187.6 | 1384.8 | 1550.4 |
| log(q _e - q _t) | -1.11 | -1.48 | -1.63 | -1.77 | -1.99 | -2.28 | - |

Test the data for pseudo first and second-order kinetics and evaluate k₁ and k₂ if the models are as follows:

$$\log(q_e - q_t) = \log q_e - \frac{k_1 t}{2.303} \quad (\text{pseudo first-order model})$$

$$\frac{t}{q_t} = \frac{1}{k_2 q_e^2} + \frac{1}{q_e} t \quad (\text{pseudo second-order model})$$

where: q_e is the amount of copper ion adsorbed per gram of adsorbent at equilibrium (mg/g), q_t is the amount of copper ion adsorbed per gram of adsorbent (mg/g) at time t, k₁ is the pseudo first-order rate constant (min⁻¹) and k₂ is the pseudo second-order rate constant (g/mg.min). [20]

END OF QUESTION PAPER