



UNIVERSITY OF GHANA
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BSC ENGINEERING SECOND SEMESTER EXAMINATIONS: 2016/2017

DEPARTMENT OF FOOD PROCESS ENGINEERING

FPEN 306: CHEMICAL REACTION ENGINEERING (2 CREDITS)

INSTRUCTIONS:

ANSWER FOUR (4) QUESTIONS – TWO (2) QUESTIONS FROM EACH SECTION

Use separate Answer Booklet for each Section

Graph sheets required

TIME ALLOWED: TWO (2) HOURS

SECTION A

1.

- Discuss the two methods of analysis of kinetic data obtain from a batch or flow reactor and compare and contrast the merits and demerits of each analytical technique.
- Reactant A decomposes in a batch reactor according to the equation



The composition of A in the reactor is measured at various times with results shown in the following columns 1 and 2.

Time, t (s)	Concentration, C_A (Mol/L)
0	10
20	8
40	6
60	5
120	3
180	2
300	1

Find a rate equation to represent the data using any appropriate kinetic analytical method.

For fractional life method assume $F = 80\%$ and $C = 10, 6$ and 2

- 2.
- The decomposition of A to produce B can be written as $A \rightarrow B$. When the initial concentration of A is 0.012 M, the rate is $0.0018 \text{ M min}^{-1}$ and when the initial concentration of A is 0.024 M, the rate is $0.0036 \text{ M min}^{-1}$.
 - Write the rate law for the reaction and find the rate constant.
 - If the activation energy for the reaction is 268 kJ mol^{-1} and the rate constant at 660 K is $8.1 \times 10^{-3} \text{ sec}^{-1}$ what will be the rate constant at 690 K?
 - The rate constant for the decomposition of N_2O_5 (g) at a certain temperature is $1.70 \times 10^{-5} \text{ sec}^{-1}$. If the initial concentration of N_2O_5 is 0.200 mol/l,
 - How long will it take for the concentration to fall to 0.175 mol/l
 - What will be the concentration of N_2O_5 be after 16 hours of reaction?
- 3.
- Distinguish between the following terms with the aid of equations as they are used in chemical reaction engineering studies
 - Molecularity and order of a reaction
 - Elementary and non-elementary reactions
 - Homogeneous and heterogeneous reactions
 - The decomposition of

$$\text{Z} \longrightarrow \text{X} + \text{Y}$$
 Follows first order kinetics, at a constant temperature the rate constant is $1.60 \times 10^{-5} \text{ sec}^{-1}$.
 - What is the half-life for the disappearance of Z?
 - After 15.0 hours, what fraction of the initial Z remains?

SECTION B

4. Laboratory measurements made prior to the design of a chemical reactor for a reaction at 149°C and 10 atmospheres (1013 kPa) provided the following data:

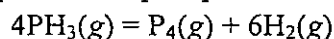
X_A	0.0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9
$-r_A$ (mol/dm ³ .s) $\times 10^{-3}$	5.3	5.2	5.0	4.5	4.0	3.3	2.5	1.8	1.25	1.0

A gas mixture consisting of 50% A and 50% inerts enters the reactor at a flow rate of $10 \text{ dm}^3/\text{s}$.

- Calculate the entering concentration C_{A0} and entering molar flow rate F_{A0}
- Calculate the sizes of two continuous stirred tank reactors (CSTRs) connected in series if the intermediate and final products have conversions of 40% and 80% respectively.

Assume the ideal gas constant $R = 0.082 \text{ dm}^3 \cdot \text{atm/mol.K}$

5. The gas phase decomposition of phosphine with stoichiometry



proceeds at 650°C according to a first-order rate equation.

$$-r_{\text{PH}_3} = (10/\text{hr})C_{\text{PH}_3}$$

The reaction is homogeneous and takes place in a plug flow reactor operating at 650°C and 0.460 MPa and can produce 80% conversion of a feed consisting of 108 mol/hr of pure phosphine. Determine the expansion factor of the reaction and size of the plug flow reactor used. Assume the universal gas constant $R = 8.314 \text{ Pa.m}^3/\text{mol.K}$

6. An elementary liquid-phase reversible reaction, $\text{A} + 2\text{B} = \text{R}$; with rate constants k_1 and k_2 for the forward and backward reactions respectively has the following rate equation:

$$-r_A = -\frac{1}{2}r_B = (25 \text{ liter}^2/\text{mol}^2 \cdot \text{min})C_A C_B^2 - (3 \text{ min}^{-1})C_R, \quad \left[\frac{\text{mol}}{\text{liter} \cdot \text{min}} \right]$$

The reaction take places in a 20-liter steady-state mixed flow reactor. Two feed streams, one containing 2.8 mol A/liter and the other containing 1.6 mol B/liter , are introduced at equal volumetric flow rates into the reactor, and 75% conversion of limiting component is desired. Draw a schematic diagram of the reactor.

- Determine the performance equation of the reactor.
- Determine the flow rate of each stream?