Ahmedabad University

Monsoon Term End Semester Examination 2025

Subject: CHE 316 Chemical Kinetics and Reaction Engineering

Attempt all questions. All questions carry equal marks.

Use of scientific calculator is permitted.

Date: 5th December 2025 **Timing: 11.00 to 02.00 PM** **Full Marks 40**

Qu 1a. 1.0 liter/ s of a 20% ozone – 80 % air mixture at 1.5 atm and 93^{0}C passes through a plug flow reactor. Under these conditions ozone decomposes by homogeneous reaction $2\ O_3 \rightarrow 3\ O_2$, $-r_{ozone} = k\ C^2_{ozone}$, k = 0.05 liter/ mol. S. What size reactor is needed for 50% decomposition of ozone?

Qu 1b. A plug flow reactor (2 m^3) processes an aqueous feed (100 liter/ min) containing reactant A (C_{Ao} = 100 m mol / liter). This reaction is reversible and represented by $A \leftrightarrow R$, $-r_A = (0.04\ min^{-1})\ C_A - (0.01\ min^{-1})\ C_R$ First find the equilibrium conversion and then find the actual conversion of A in the reactor.

OR

Qu 1a. What do you mean by an autocatalytic reaction? Derive an expressions for the maximum rate, $t_{max\ rate}$ and $X_{max\ rate}$. Explain the condition when will the autocatalytic character is masked by the zero-order behaviour?

Qu 1b. Gaseous reactant A decomposes as follows: $A \rightarrow 3\ R$, $-r_A = (0.6\ min^{-1})\ C_A$. Find the conversion of a 50% A - 50% inert feed (v_0 = 180 liter/ min), C_{A0} = 300 mmol/ liter) into a 1 m^3 mixed flow reactor.

Qu 2a. For first order reaction $A \rightarrow R$ in a series of two CSTRs, find out the optimum ratio of space times to minimize the total volume?

Qu 2b. At present, we have 90 % conversion of a liquid feed (n = 1, C_{A0} = 10 mol/ liter) to our plug flow reactor with recycle of product (R = 2). If we shut off the recycle stream, by how much will this change the processing rate of our feed to the same 90 % conversion.

OR

Qu 2a. At present 90% of reactant A is converted into product by a first order reaction in a single mixed flow reactor. We plan to place a second reactor like the one being used in series with it as specified below:

(i) For the same treatment rate as that used at present, how will this addition affect the conversion of reactant?

(ii) For the same conversion, by how much can the treatment rate be increased?

Qu 2b. Under ultraviolet radiation, reactant A of C_{A0} = 2 kmol/ m^3.min decomposes as follows: (i) $A \rightarrow R$ (r_R = 1.0 kmol/ m^3. Min) (ii) $A \rightarrow S$ ($r_S = 2C_A$ kmol/ m^3. Min) (iii) $A \rightarrow T$ ($r_T = C_A^2$ kmol/ m^3. Min).

Find the maximum expected Cs for isothermal operations in a (i) mixed flow reactor (ii) plug flow reactor (iii) reactor of your choice if unreacted A can be separated from the product stream and returned to the feed at $C_{A0} = 2$.

Qu 3a. Consider the following elementary reactions: $A + B \rightarrow R$ and $R + B \rightarrow S$ (Rate constants are respectively k_1 and k_2)

I. One mole of A and 3 moles of B are rapidly mixed together. The reaction is very slow, allowing analysis of compositions at various times. When 2.2 moles B remain unreacted, 0.2 mole S is present in the mixture. What should be the composition of the mixture (A, B, R and S) when the amount of S present is 0.6 moles?

II. One mole A is added bit by bit with constant stirring to 1 mole B. Left overnight and then analyzed, 0.5 mole S is found. What can we say about k_1/ k_2?

Qu 3b. Derive an equation of E curve for a CSTR.

OR

Qu 3a. Chemical X, a powdered solid, is slowly and continuously fed for half an hour into a well stirred vat of water. The solid quickly dissolves and hydrolyses to Y, which then slowly decomposes to Z as follows $Y \rightarrow Z$, $-r_Y = kC_Y$, $k = 1.5\ hr^{-1}$

The volume of liquid in the vat stays close to 3 m^3 throughout this operation, and if no reaction of Y to Z occurred, the concentration of Y in the vat would 100 moles/ m^3 at the end of the half hour addition of X.

i. What is the maximum concentration of Y in the vat and at what time is this maximum reached?

ii. What is the concentration of product Z in the vat after 1 hour?

Qu 3b. Derive an equation of E curve for a laminar flow reactor.

Qu 4a. The reversible first order gas reaction $A \leftrightarrow R$ is to be carried out in a mixed flow reactor. For operations at 300 K the volume of reactor required is 100 liters for 60% conversion of A. What should be the volume of the reactor for the same feed rate and conversion but with operations at 400 K?

Data: $k_1 = 10^3 \exp(-2{,}416/ T)$; $\Delta C_p = C_{pR} - C_{pA} = 0$; $\Delta H_r = -8{,}000$ cal/ mol at 300 K; $K = 100$ at 300 K; Feed consists of pure A. Total pressure stays constant.

Qu 4b. A reactor with several dividing baffles is to be used to run the reaction $A \rightarrow R$ with $r_A = 0.05 C_A$ mol/liter. Min. A pulse tracer test gives the following output curve:

Time, min	0	10	20	30	40	50	60	70
Concentration	35	38	40	40	39	37	36	35

i. Find the area under the C versus t curve.

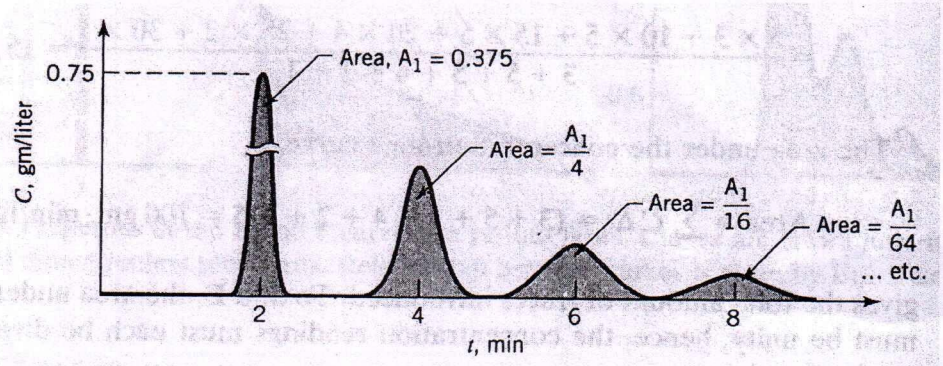
ii. Calculate the variance of the E curve.

iii. How many tanks in series is this vessel equivalent to?

iv. Calculate X_A assuming plug flow.
v. Calculate X_A assuming mixed flow.
vi. Calculate X_A assuming the tanks- in -series model.
vii. Calculate X_A directly from the data.

OR

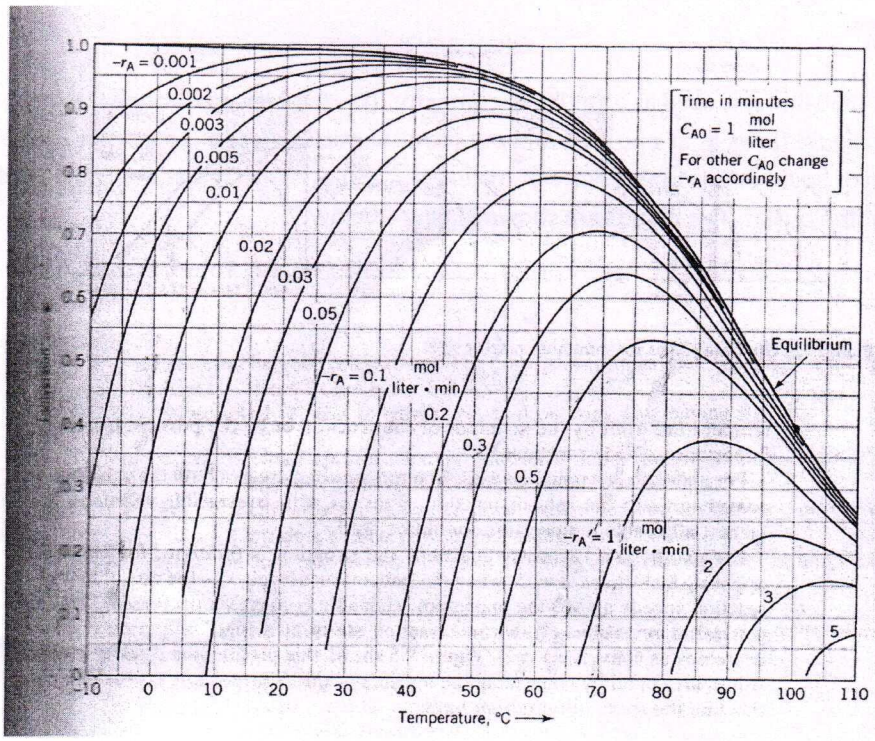
Qu 4a. A large tank (860 litres) is used as a gas liquid contactor. Gas bubbles up through the vessel and out the top, liquid flows in at one part and out the other at 5 litres/ s. To get. an idea of the flow pattern of liquid in this tank a pulse of tracer (M = 150 g) is injected at the liquid inlet and measured at the outlet. The results are shown in figure below:



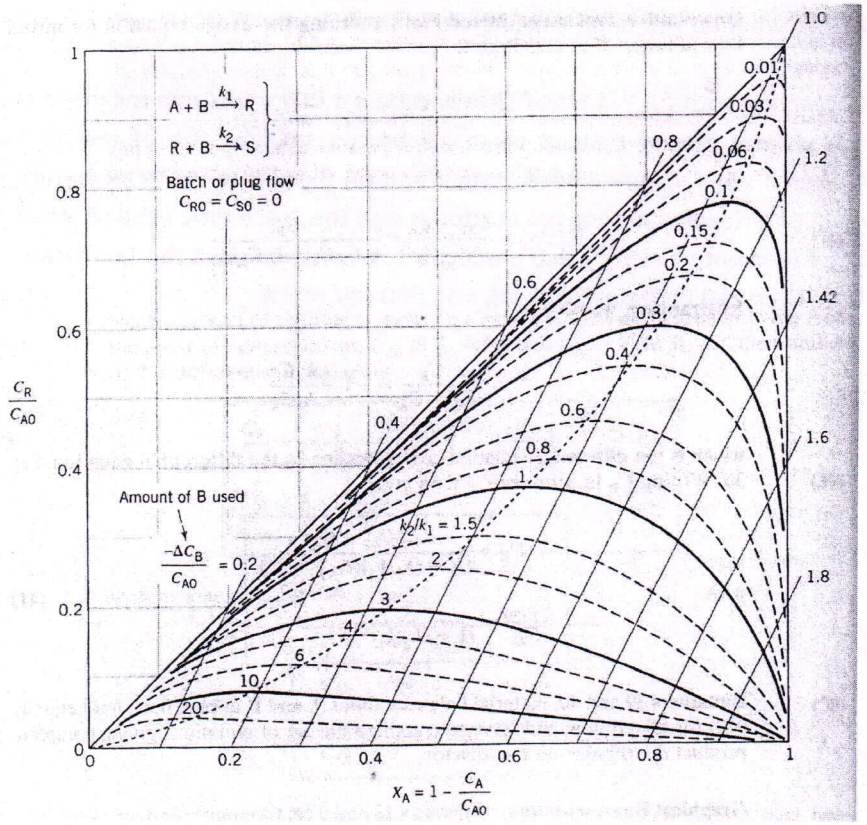
Figure

i. Is this a properly done experiment?
ii. If so find the liquid and gas fractions in the vessel
iii. Qualitatively what do you think is happening in the vessel.

Qu 4b. A first order reaction with C_{Ao} = 4 mols/ Litre and F_{A0} = 1,000 mols/ min is carried out in an adiabatic mixed flow reactor system, what will be the smallest size of reactor for 60% conversion. Sketch your recommended system and on it indicate the temperature of the flowing stream entering and leaving the reactor as well the space time needed. What will be the heat duty if feed enters at 20^0 C and product is to be withdrawn at this temperature?
Note that $C_{pA} = C_{PB}$ = 250 Cal/ mol A. K, - ΔH_r = 18,000 cal/ mol A



Temperature vs Conversion for a first order reversible exothermic reaction of Qu No 4b.



Distribution of Components in a Batch or Plug Flow Reactor for Qu No. 3a