



UNIVERSITI KUALA LUMPUR
MALAYSIAN INSTITUTE OF CHEMICAL AND BIO-ENGINEERING TECHNOLOGY

FINAL EXAMINATION
OCTOBER 2025 SEMESTER

COURSE CODE : CKB20104
COURSE TITLE : REACTION ENGINEERING
PROGRAMME NAME : BACHELOR OF CHEMICAL ENGINEERING TECHNOLOGY
(PROCESS) WITH HONOURS
DATE : 24 JANUARY 2026
TIME : 9:00AM - 12:00PM
DURATION : 3 HOURS

INSTRUCTIONS TO CANDIDATES

1. Please read the instructions given in the question paper CAREFULLY.
2. This question paper is printed on both sides of the paper.
3. This question paper consist of ONE sections.
4. Section A consist of five questions. Answer FOUR (4) questions only.
5. Please write your answer on the answer booklet provided.
6. Please answer all questions in English only.
7. Refer to the attached Formula/ Appendies. ☐ *Tick if applicable*

THERE ARE 6 PAGES OF QUESTIONS INCLUDING THIS PAGE

SECTION A (Total: 100 marks)

Answer FOUR (4) questions.

Please use the answer booklet provided.

Question 1

The gas-phase reaction is given as follows



The irreversible reaction is carried out isothermally in a flow reactor. The feed mixture consists of 40 mol% inert and the balance of reactant A at a temperature of 320 K. The initial pressure for the reaction is 5 atm. The Levenspiel plot for the reaction is given as follows.

Refer Below - Figure 1 : The Levenspiel Plot.

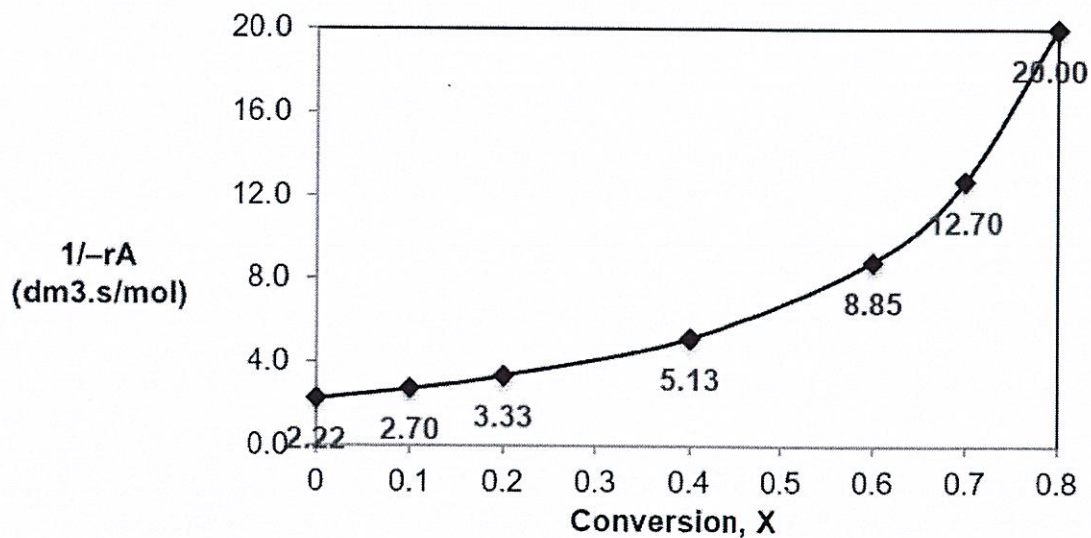


Figure 1: The Levenspiel Plot

- (a) The reaction was conducted in two Continuous Stirred Tank Reactors (CSTR) in series at an initial rate of $10.0 \text{ dm}^3/\text{s}$. Determine the volume of both reactors required to achieve 60% conversion at the first reactor and 80% overall conversion at the second reactor.

(12 marks)

- (b) The reaction was conducted in two Plug Flow Reactors (PFR) in series. Determine the space time for both reactors required to achieve 40% intermediate conversion and an overall conversion of 80%.

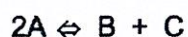
(9 marks)

- (c) Calculate the volume of a single Plug Flow Reactor (PFR) if given the overall conversion of 80%.

(4 marks)

Question 2

The production of B is carried out in an elementary reversible reaction in a flow reactor.



Pure reactant A at an initial concentration of 10.0 mol/L with the remainder inert in the liquid phase is fed to the system at an initial rate of 5.0 mol/s. The reaction rate constant is 2.5 L/mol.s, and the equilibrium constant is 0.5.

- (a) Develop a stoichiometric table for the above reaction. All values should be a function of conversion only by numerically evaluating all symbols (e.g., ϵ , Θ , and C_i).

(10 marks)

- (b) Determine the equilibrium conversion, X_e of the reaction.

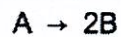
(6 marks)

- (c) Calculate the Continuous Stirred Tank Reactor (CSTR) volume if the reactor conversion is 80% of the equilibrium conversion.

(9 marks)

Question 3

The gas-phase decomposition of A to produce B is given below.



Initially, the mixture consists of 90 mol% reactant A and the remainder is compound I, an inert in the reaction. To scale-up the reactor, it is vital to determine the reaction rate data. The reaction is carried out in a constant-volume batch reactor at a pressure of 5.0 atm with an initial concentration of A at 5.0 mol/dm^3 . The concentration-time data is collected to plot a graph of $\ln(-dC_A/dt)$ against $\ln C_A$. This plot is shown in the figure below. The gradient of the plot is determined as 1.80 with a y-intercept of -2.35 . The concentration is measured in mol/dm^3 and time is measured in minutes.

Refer Below - Figure2 : $\ln(-dC_A/dt)$ vs $\ln C_A$.

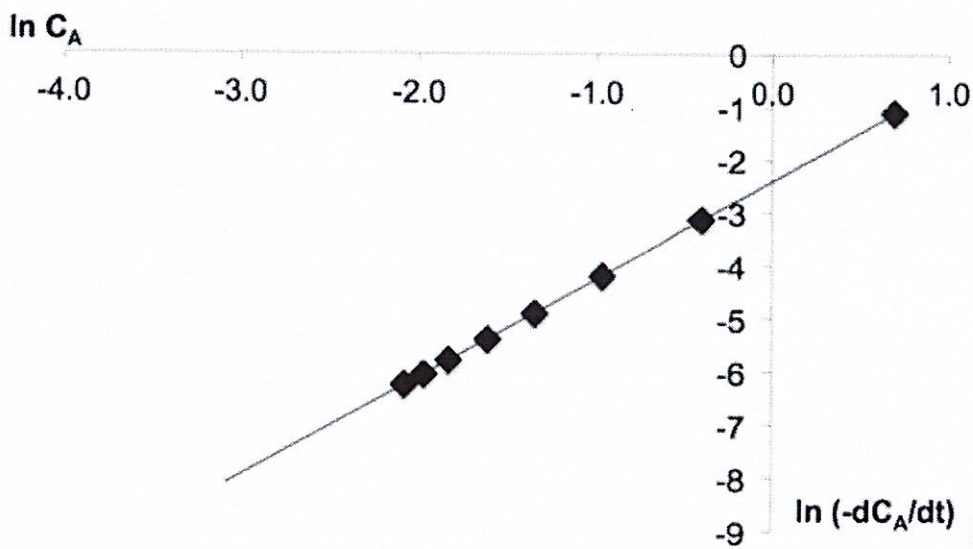


Figure 2: $\ln(-dC_A/dt)$ vs $\ln C_A$

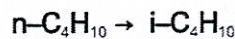
- (a) Determine the reaction order and the reaction rate constant. (4 marks)
- (b) Calculate the initial volumetric flow rate if the reaction is conducted in a 200.0 dm^3 Plug Flow Reactor (PFR) at 80% conversion of A. (10 marks)

- (c) If the reaction is conducted in two Continuous Stirred Tank Reactors (CSTR) connected in series, with 40% conversion in the first reactor and an overall 80% conversion, determine the space time for both reactors. Assume the initial rate is the same as in part (b).

(11 marks)

Question 4

Normal butane ($n\text{-C}_4\text{H}_{10}$) is isomerized to isobutene ($i\text{-C}_4\text{H}_{10}$). The reaction is carried out non-adiabatically in the liquid phase. The reaction can be represented as follows:



You are tasked with evaluating the suitability of a continuous stirred tank reactor with the inlet mixture of 90 mol% n -butane and 10 mol% i -pentane ($i\text{-C}_5\text{H}_{12}$), an inert in the reaction. Assume that the work done by the stirrer is negligible. The following additional information is provided:

Steam jacket area = 10 dm^2

Overall heat-transfer coefficient of jacket = $12.0 \text{ kJ/hr.dm}^2.\text{K}$

Heating fluid inlet temperature = 380.0 K

Initial flow rate of $n\text{-C}_4\text{H}_{10}$ = 25.0 mol/hr

Feed temperature = 300.0 K

Activation Energy = 2.0 kcal/mol

Frequency factor = 9.5 hr^{-1}

Refer Below - Table 1 : The properties of components A, B and inert. .

Table 1: The properties of components A, B and inert.

Data	Component		
	$n\text{-C}_4\text{H}_{10}$ (A)	$i\text{-C}_5\text{H}_{12}$ (I)	$i\text{-C}_4\text{H}_{10}$ (B)
Enthalpy of formation, $H_i^\circ(T_R = 273.0 \text{ K})$, kJ/mol	- 50.0	- 110.0	- 220.0
Constant heat capacity, $C_{p_i}(T_R = 273.0 \text{ K})$, kJ/mol. K	0.40	0.28	0.15

- (a) Calculate the reaction temperature if the desired conversion of n -butane in the reactor is 60%.

(17 marks)

- (b) Calculate the reactor volume given an initial concentration of $n\text{-C}_4\text{H}_{10}$ at 2.0 mol/dm^3 . The reaction follows the elementary rate law.

(8 marks)

Question 5

Multiple and heterogeneous reactions are widely encountered in the petrochemical industries as they can enhance the quality and yield of the produced fuel.

- (a) Explain THREE types of catalyst deactivation.

(9 marks)

- (b) Elaborate on the steps involved in a catalytic reaction with the aid of a diagram.

(8 marks)

- (c) The parallel reaction of ethyl bromide ($\text{CH}_3\text{CH}_2\text{Br}$) produces ethylene (C_2H_4) while avoiding the reaction that forms ethyl alcohol ($\text{CH}_3\text{CH}_2\text{OH}$). The chemical equations and their corresponding rate laws are provided below.

Refer Below - Figure3 : Chemical reaction pathway .

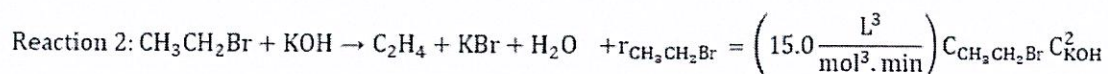
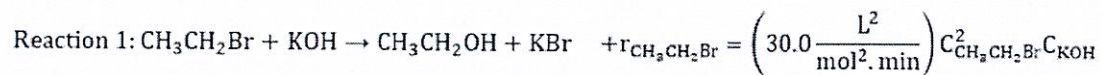


Figure 3: Chemical reaction pathway

- i. Calculate the instantaneous selectivity ($S_{D/U}$) of the desired product with respect to the undesired product in the reaction.

(3 marks)

- ii. Describe the reaction schemes and conditions (such as reactor type(s) and concentration) to maximise reaction selectivity.

(5 marks)

END OF EXAMINATION PAPER

Appendices

A. Ideal gas constant

$$R = 8.314 \frac{\text{dm}^3 \cdot \text{kPa}}{\text{mol} \cdot \text{K}} = 0.082 \frac{\text{L} \cdot \text{atm}}{\text{mol} \cdot \text{K}} = 0.73 \frac{\text{ft}^3 \cdot \text{atm}}{\text{lbmol} \cdot ^\circ\text{R}} = 1.987 \frac{\text{cal}}{\text{mol} \cdot \text{K}} = 8.3144 \frac{\text{J}}{\text{mol} \cdot \text{K}}$$

B. List of formulations

$$C_{A0} = \frac{y_{A0} P_0}{RT_0} = \frac{P_{A0}}{RT_0} \quad k_2 = k_1 \exp\left(\frac{E_a}{R}\right) \left[\frac{1}{T_1} - \frac{1}{T_2}\right] \quad k = A \exp\left(-\frac{E_a}{RT}\right)$$

$$\tau = \frac{V}{v_0} \quad SV = \frac{1}{\tau} \quad v = v_0(1 + \varepsilon X) \frac{P_0 T}{P T_0} \quad \varepsilon = y_{A0} \delta$$

$$t = N_{A0} \int_0^X \frac{dX}{-r_A V} \quad t = \frac{1}{k C_{A0}} \left[\frac{1}{\Theta_B - 1} \ln\left(\frac{\Theta_B - X}{\Theta_B(1 - X)}\right) \right]$$

$$V = F_{A0} \int_0^X \frac{dX}{-r_A} \quad V = F_{A0} \left(\frac{\Delta X}{3}\right) \left(\frac{1}{-r_{A(X_0)}} + \frac{4}{-r_{A(X_{\text{mid}})}} + \frac{1}{-r_{A(X)}} \right)$$

V

$$V = \frac{F_{A0}}{k C_{A0}^2} \left[\frac{1}{\Theta_B - 1} \ln\left(\frac{\Theta_B - X}{\Theta_B(1 - X)}\right) \right] \quad V = \frac{F_{A0}}{k C_{A0}} \left(\frac{P_0}{P}\right) \left[(1 + \varepsilon) \ln \frac{1}{1 - X} - \varepsilon X \right]$$

$$V = \frac{F_{A0}}{k C_{A0}^2} \left(\frac{P_0}{P}\right)^2 \left(2\varepsilon(1 + \varepsilon) \ln(1 - X) + \varepsilon^2 X + \frac{(1 + \varepsilon)^2 X}{1 - X} \right)$$

$$V = \frac{F_{A0} X}{-r_A} \quad V = \frac{F_{A0} X}{k C_{A0}^2 (1 - X) \left(\Theta_B - \frac{b}{a} X\right)} \quad V = \frac{F_{A0} X (1 + \varepsilon X)}{k C_{A0} (1 - X) \left(\frac{P_0}{P}\right)}$$

$$V = \frac{F_{A0} X (1 + \varepsilon X)^2}{k C_{A0}^2 (1 - X)^2} \left(\frac{P_0}{P}\right)^2 \quad V = \frac{F_{A0} X (1 + \varepsilon X)^2}{k C_{A0}^2 (1 - X) \left(\Theta_B - \frac{b}{a} X\right)} \left(\frac{P_0}{P}\right)^2$$

$$\ln t_{1/2} = (1 - \alpha) \ln C_{A0} + \ln \frac{2^{\alpha-1} - 1}{k(\alpha - 1)} \quad \ln\left(-\frac{dC_A}{dt}\right) = \alpha \ln C_A + \ln k$$

$$\ln(-r_{A0}) = \alpha \ln C_{A0} + \ln k$$

$$C_A = -kt + C_{A0} \quad \ln \frac{C_{A0}}{C_A} = kt \quad \frac{1}{C_A} = kt + \frac{1}{C_{A0}}$$

$$\dot{Q} - W_s - F_{A0} \sum_{i=1}^n \Theta_i C_{Pi} (T - T_0) - F_{A0} X [\Delta H_{Rx(T_R)}^\circ + \Delta C_P (T - T_R)] = 0$$

$$\dot{Q} = UA(T_a - T)$$

C. List of Integral Formulations

$$\int_0^X \frac{dX}{(1-X)} = \ln\left(\frac{1}{1-X}\right)$$

$$\int_0^X \frac{dX}{(1-X)^2} = \frac{X}{1-X}$$

$$\int_0^X \frac{dX}{(1-X)(\Theta_B - X)} = \frac{1}{\Theta_B - 1} \ln\left(\frac{\Theta_B - X}{\Theta_B(1-X)}\right)$$

$$\int_0^X \frac{1 + \varepsilon X}{(1-X)} dX = (1 + \varepsilon) \ln \frac{1}{1-X} - \varepsilon X$$

$$\int_0^X \frac{(1 + \varepsilon X)^2}{(1-X)^2} dX = 2\varepsilon(1 + \varepsilon) \ln(1-X) + \varepsilon^2 X + \frac{(1 + \varepsilon)^2 X}{1-X}$$

D. Factors for Unit Conversions

Quantity	Equivalent Values
Mass	$1 \text{ kg} = 1000 \text{ g} = 0.001 \text{ metric ton} = 2.20462 \text{ lb}_m = 35.27392 \text{ oz}$ $1 \text{ lb}_m = 16 \text{ oz} = 5 \times 10^{-4} \text{ ton} = 453.593 \text{ g} = 0.453593 \text{ kg}$
Length	$1 \text{ m} = 100 \text{ cm} = 1000 \text{ mm} = 10^6 \text{ microns } (\mu\text{m}) = 10^{10} \text{ angstroms } (\text{\AA})$ $= 39.37 \text{ in} = 3.2808 \text{ ft} = 1.0936 \text{ yd} = 0.0006214 \text{ mile}$ $1 \text{ ft} = 12 \text{ in} = 1/3 \text{ yd} = 0.3048 \text{ m} = 30.48 \text{ cm}$
Volume	$1 \text{ m}^3 = 1000 \text{ liters} = 10^6 \text{ cm}^3 = 10^6 \text{ ml} = 1000 \text{ dm}^3$ $= 35.3145 \text{ ft}^3 = 220.83 \text{ imperial gallons} = 264.17 \text{ gal}$ $= 1056.68 \text{ qt}$ $1 \text{ ft}^3 = 1728 \text{ in}^3 = 7.4805 \text{ gal} = 0.028317 \text{ m}^3 = 28.317 \text{ liters}$ $= 28\,317 \text{ cm}^3$
Pressure	$1 \text{ atm} = 1.01325 \times 10^5 \text{ N/m}^2 (\text{Pa}) = 101.325 \text{ kPa} = 1.01325 \text{ bars}$ $= 1.01325 \times 10^6 \text{ dynes/cm}^2$ $= 760 \text{ mm Hg at } 0^\circ\text{C (torr)} = 10.333 \text{ m H}_2\text{O at } 4^\circ\text{C}$ $= 14.696 \text{ lb}_f/\text{in}^2 (\text{psi}) = 33.9 \text{ ft H}_2\text{O at } 4^\circ\text{C}$ $= 29.921 \text{ in Hg at } 0^\circ\text{C}$
Energy	$1 \text{ J} = 1 \text{ N}\cdot\text{m} = 10^7 \text{ ergs} = 10^7 \text{ dyne}\cdot\text{cm}$ $= 2.778 \times 10^{-7} \text{ kW}\cdot\text{h} = 0.23901 \text{ cal}$ $= 0.7376 \text{ ft}\cdot\text{lb}_f = 9.486 \times 10^{-4} \text{ Btu}$
Temperature	$T (\text{K}) = T (^\circ\text{C}) + 273.15$ $T (^\circ\text{F}) = 1.8 T (^\circ\text{C}) + 32$ $T (^\circ\text{R}) = T (^\circ\text{F}) + 459.67$ $T (^\circ\text{R}) = 1.8 T (\text{K})$

