UNIVERSITY OF JOHANNESBURG

PROGRAM	:	BACHELOR ENGINEERING TECHNOLOGIE: CHEMICAL
SUBJECT	:	**INTRODUCTION TO REACTOR DESIGN**
CODE	:	**IRDCHA3**
DATE	:	WINTER EXAMINATION 28 May 2019
DURATION	:	(X-PAPER) 08:30 - 11:30
WEIGHT	:	40: 60
TOTAL MARKS	:	100
EXAMINER	:	Prof. M BELAID
MODERATOR	:	Ms W Mohamed
NUMBER OF PAGES	:	3 PAGES
INSTRUCTIONS	:	ANSWER ALL QUESTIONS NON PROGRAMMABLE CALCULATORS PERMITED (ONE PER STUDENT)
REQUIREMENTS	:	2 SHEETS OF GRAPH PAPER

Question One [25 Marks]

We consider a gas reaction in which condensation occurs

$$C_2H_6\,(g) + 2Br_2\,(g) \rightarrow C_2H_4Br_2\,(g,l) + 2\,HBr$$

1.1. Set up a stoichiometric table for the reaction this reaction knowing that one of the products condenses during the course of the reaction. (15)
1.2. Sketch the concentration and flow rates of each species as a function of conversion. (10)

[25]

Question Two (Compulsory) [50 Marks]

The elementary liquid phase reaction A + B $\longrightarrow$ C is carried out in a 500 dm^3 reactor. The entering concentrations of streams A&B are both 2 molar and the specific reaction rate is 0.01 dm^3 / mol.min . Determine:

2.1. The time to achieve 90 % conversion in a batch reactor filled to the brim (8)

2.2. The reactor Volume of a CSTR to achieve 90 % conversion (feed of 10 mol A/min) (8)

2.3. The reactor Volume of a PFR to achieve 90 % conversion (feed of 10 mol A/min) (10)

2.4. Decide on the best sequence of reactors if you were to use an intermediate reactor at conversion of 60 % to achieve a final conversion of 90 % (12)

2.4. The equilibrium conversion and the volumes of CSTR and PFR to achieve 98 % of the equilibrium conversion assuming the reaction is reversible with Kc= 2 dm^3 /mol (12)

[50]

Question Three [25 Marks]

The irreversible isomerization

$$A \rightarrow B$$

was carried out in a *batch reactor* and the following concentration- time data were obtained:

T(min)	0	3	5	8	10	12	15	17.5
C_A (Mol/dm^3)	4.0	2.89	2.25	1.45	1.0	0.65	.25	0.07

3.1 Determine the reaction order, α , and the specific reaction rate, k_A. (20)

3.2 If you were to repeat this experiment to determine the kinetics, what would you do differently? Would you run at a higher, lower, or the same temperature? Take different data points? Explain. (5)

[25]

A.1 Useful Integrals in Reactor Design

$$\int_0^x \frac{dx}{1-x} = \ln\frac{1}{1-x} \tag{A-1}$$

$$\int_0^x \frac{dx}{(1-x)^2} = \frac{x}{1-x} \tag{A-2}$$

$$\int_0^x \frac{dx}{1+\varepsilon x} = \frac{1}{\varepsilon}\ln(1+\varepsilon x) \tag{A-3}$$

$$\int_0^x \frac{1+\varepsilon x}{1-x}\,dx = (1+\varepsilon)\ln\frac{1}{1-x} - \varepsilon x \tag{A-4}$$

$$\int_0^x \frac{1+\varepsilon x}{(1-x)^2}\,dx = \frac{(1-\varepsilon)x}{1-x} - \varepsilon\ln\frac{1}{1-x} \tag{A-5}$$

$$\int_0^x \frac{(1+\varepsilon x)^2}{(1-x)^2}\,dx = 2\varepsilon(1+\varepsilon)\ln(1-x) + \varepsilon^2 x + \frac{(1+\varepsilon)^2 x}{1-x} \tag{A-6}$$

$$\int_0^x \frac{dx}{(1-x)(\Theta_B - x)} = \frac{1}{\Theta_B - 1}\ln\frac{\Theta_B - x}{\Theta_B(1-x)} \qquad \Theta_B \neq 1 \tag{A-7}$$

$$\int_0^x \frac{dx}{ax^2+bx+c} = \frac{-2}{2ax+b} + \frac{2}{b} \qquad \text{for } b^2 = 4ac \tag{A-8}$$

$$\int_0^x \frac{dx}{ax^2+bx+c} = \frac{1}{a(p-q)}\ln\left(\frac{q}{p}\cdot\frac{x-p}{x-q}\right) \qquad \text{for } b^2 > 4ac \tag{A-9}$$

$$\int_0^W (1-\alpha W)^{1/2}\,dW = \frac{2}{3\alpha}\left[1-(1-\alpha W)^{3/2}\right] \tag{A-10}$$

TABLE A-1

x_i	y_i	Δx	Δy	$\frac{\Delta y}{\Delta x}$	$\frac{dy}{dx}$
x_1	y_1				$\left(\frac{dy}{dx}\right)_1$
		$x_2 - x_1$	$y_2 - y_1$	$\left(\frac{\Delta y}{\Delta x}\right)_2$	
x_2	y_2				$\left(\frac{dy}{dx}\right)_2$
		$x_3 - x_2$	$y_3 - y_2$	$\left(\frac{\Delta y}{\Delta x}\right)_3$	
x_3	y_3				$\left(\frac{dy}{dx}\right)_3$
		$x_4 - x_3$	$y_4 - y_3$	$\left(\frac{\Delta y}{\Delta x}\right)_4$	
x_4	y_4				$\left(\frac{dy}{dx}\right)_4$
		$x_5 - x_4$	$y_5 - y_4$	$\left(\frac{\Delta y}{\Delta x}\right)_5$	
x_5	y_5		etc.		

Ideal Gas Constant

$$R = \frac{8.314\ \text{kPa}\cdot\text{dm}^3}{\text{mol}\cdot\text{K}} \qquad R = \frac{1.987\ \text{Btu}}{\text{lb mol}\cdot{}^\circ\text{R}}$$

$$R = \frac{0.73\ \text{ft}^3\cdot\text{atm}}{\text{lb mol}\cdot{}^\circ\text{R}} \qquad R = \frac{8.3144\ \text{J}}{\text{mol}\cdot\text{K}}$$

$$R = 0.082\ \frac{\text{dm}^3\cdot\text{atm}}{\text{mol K}} = \frac{0.082\ \text{m}^3\cdot\text{atm}}{\text{mol K}} \qquad R = \frac{1.987\text{cal}}{\text{mol K}}$$