UNIVERSITY OF JOHANNESBURG

PROGRAM	:	BACCALAUREUS TECHNOLOGIAE *CHEMICAL ENGINEERING*
SUBJECT	:	**REACTOR TECHNOLOGY IV**
CODE	:	**WER 411**
DATE	:	SUMMER EXAMINATION NOVEMBER 2019
DURATION	:	(Y-PAPER) 14:00 - 17:00
WEIGHT	:	40: 60
TOTAL MARKS	:	160

EXAMINER	:	Prof. M BELAID & Mr. O AYELERU	
MODERATOR	:	Prof. RK MBAYA	2221
NUMBER OF PAGES	:	3 PAGES	

INSTRUCTIONS	:	ANSWER ALL QUESTIONS NON PROGRAMMABLE CALCULATORS PERMITED (ONE PER STUDENT)
REQUIREMENTS	:	2 SHEETS OF GRAPH PAPER

Question One [24 Marks]

Benzyl amide is the product obtained from the liquid-phase reaction of ammonia and benzoyl chloride:

$$C_6H_5COCl + 2NH_3 \longrightarrow C_6H_5CONH_2 + NH_4Cl$$

2. Taking benzoyl chloride as your basis of calculation set up a stoichiometric table for a batch system. (12)

2.2 If the initial mixture consisted solely of ammonia at a concentration of 6 g mol/L and benzoyl chloride at a concentration of 2 g mol/L, calculate the concentrations of ammonia and benzyl amide when the conversion is 25 %.

(12)

[24]

Question Two [30 Marks]

The irreversible gas phase non-elementary reaction:

$$A + 2B \rightarrow C$$

is to be carried out isothermally in a constant pressure batch reactor. The feed temperature is 227 ^{0}C and the pressure is 1013 kPa. The feed composition is 33.3 % A and 66.7 % B. Laboratory data taken under identical conditions are as follows (note that at X =0, $-r_A$ = 0.00001):

$-r_A$ (mol/dm^3.s) X 10^3	0.01	0.005	0.002	0.001
Conversion	0.0	0.2	0.4	0.6

2.1. Estimate the volume of a plug flow reactor required to achieve 30 % conversion of A for an entering volumetric flow rate of 2 m^3/min (5)

2.2. Estimate the volume of a CSTR to take the effluent from the plug flow reactor above and achieve a 50 % total conversion (based on species A fed to the PFR). (5)

2.3. What is the total volume of the two reactors? (5)

2.4. What is the volume of a single PFR required to achieve 60 % conversion? (5)

2.5. What is the volume of a single CSTR required to achieve 50 % conversion? (5)

2.6. What is the volume of a second CSTR which may be used to raise the conversion from 50 % to 60 %? (5)

[30]

R = 0.082 dm^3. atm/mol. K

Question Three [22 Marks]

The following reaction takes place in a tubular reactor consisting of 60 parallel tubes (12.2 m long with a 1.9 cm inside diameter.

$$\mathbf{A} \longrightarrow \mathbf{B}$$

Bench scale experiments have given the reaction rate constant for this first order reaction as 0.00152 s^{-1} at 94 ºC and 0.0740 s^{-1} at 150 ºC.

3.1 Find an expression of k in function of T (12)

3.2 At what temperature should the reactor be operated to achieve a conversion of 80 %? (10)

Feed rate: 226.8 kg/h
Operating pressure: 790.6 kPa (abs)
Molecular weight of A= 73 kg / kmol
Reverse reaction is insignificant at these conditions

[22]

Question Four [24 Marks]

The irreversible isomerization

$$\mathbf{A} \rightarrow \mathbf{B}$$

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

4.1 Determine the reaction order, α , and the specific reaction rate, k_A. (16)

4.2 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. (8)

[24]

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

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

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

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