



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

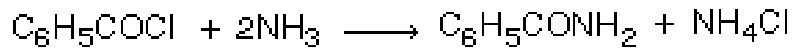
NUMBER OF PAGES : 3 PAGES

INSTRUCTIONS : ANSWER ALL QUESTIONS
NON PROGRAMMABLE CALCULATORS PERMITTED
(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:



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:



is to be carried out isothermally in a constant pressure batch reactor. The feed temperature is 227 °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, $-r_A = 0.00001$):

$-r_A \text{ (mol/dm}^3\text{.s) X } 10^3$	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 m³/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)

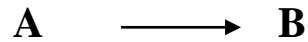
2.6. What is the volume of a second CSTR which may be used to raise the conversion from 50 % to 60 %? (5)

[30]

$$R = 0.082 \text{ dm}^3 \cdot \text{atm/mol} \cdot \text{K}$$

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).



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

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)

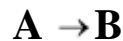
Molecular weight of A= 73 kg / kmol

Reverse reaction is insignificant at these conditions

[22]

Question Four [24 Marks]

The irreversible isomerization



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

$$\int_0^x \frac{dx}{1-x} = \ln \frac{1}{1-x} \quad (\text{A-1})$$

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

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

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

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

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

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

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

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

$$\int_0^W (1 - \alpha W)^{1/2} dW = \frac{2}{3\alpha} [1 - (1 - \alpha W)^{3/2}] \quad (\text{A-10})$$

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

$$R = \frac{8.314 \text{ kPa} \cdot \text{dm}^3}{\text{mol} \cdot \text{K}}$$

$$R = \frac{1.987 \text{ Btu}}{\text{lb mol} \cdot ^\circ \text{R}}$$

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

$$R = \frac{8.3144 \text{ J}}{\text{mol} \cdot \text{K}}$$

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

$$R = \frac{1.987 \text{ cal}}{\text{mol K}}$$