UNIVERSITY OF JOHANNESBURG

PROGRAM	:	BACCALAUREUS TECHNOLOGIAE CHEMICAL ENGINEERING
SUBJECT	:	**REACTOR TECHNOLOGY IV**
CODE	:	**WER 411**
DATE	:	SUMMER EXAMINATION 2015 16 NOVEMBER 2015
DURATION	:	(SESSION 1) 08:30 - 11:30
TOTAL MARKS	:	100
EXAMINER	:	Mr. MBELAID
MODERATOR	:	Prof M ONYANGO 2221
NUMBER OF PAGES	:	3 PAGES (EXCLUDING COVER PAGE)
INSTRUCTIONS	:	ANSWER ALL QUESTIONS NON PROGRAMMABLE CALCULATORS PERMITED (ONE PER STUDENT)
REQUIREMENTS	:	2 SHEETS OF GRAPH PAPER

Question One

The gas phase reaction

$$\frac{1}{2} N_2 + 3/2\ H_2 \longrightarrow NH_3$$

Is to be carried isothermally. The molar feed is 50 % H_2 and 50 % N_2 at a pressure of 16.4 atm and 227 °C.

1.1. Construct a complete stoichiometric table (6)

1.2. What are C_{A0}, δ and ε calculate the concentrations of ammonia and hydrogen when the conversion of H_2 is 60 % (8)

1.3. Suppose by chance the reaction is elementary with K_{N2}= 40 dm3/mol.s, write the rate of reaction solely as a function of conversion for both flow system and batch reactor (5)

1.4 Draw a graphical representation of all concentrations and rate of reaction as function of conversion. (6)

[25]

Question Two

Using the following data

X	0	0.1	0.2	0.4	0.6	0.7	0.8
$F_{A0}/-r_A$ (mol/dm^3.min)	0.89	1.08	1.33	2.05	3.54	5.06	8.00

You have two CSTRs and two PFRs each with a volume of 1.6 m^3 use the data to calculate the conversion for each of the reactors in the following arrangements.

2.1 Two CSTRs in series. (3)
2.2 Two PFRs in series (3)
2.3 Two CSTRs in parallel with the feed F_{A0} divided equally between the two reactors. (4)
2.4 Two PFRs in parallel with the feed F_{A0} divided equally between the two reactors. (3)
2.5 A CSTR and PFR in parallel with the flow equally divided, also calculate the overall Conversion Xo (4)
2.6 A PFR followed by a CSTR (3)
2.7 A CSTR followed by a PFR (3)
2.8. A PFR followed by two CSTRs (3)
2.9 What is the best option from the arrangements above, if not what will be your suggestion? (4)

[30]

Question Three

The reaction of the production of 1.36 million ton per year of ethylene from the cracking of pure ethane

$$C_2H_6 \longrightarrow C_2H_4 + H_2$$

The reaction is irreversible and follows an elementary rate law. We want to achieve 80 % conversion of ethane. Operating the reactor isothermally at 1100 K at pressure of 6 atm. K= 0.072 s^{-1} at 1000 K

Determine the plug flow reactor volume necessary to produce 1.36 million ton per year.

[20]

Question four

In order to study the photochemical decay of aqueous bromine in bright sunlight a small quantity of liquid bromine was dissolved in water contained in a glass battery jar and placed in direct sunlight. The following data were obtained:

Time (min)	10	20	30	40	50	60
ppm Br_2	2.45	1.74	1.23	0.88	0.62	0.44

4.1 Determine the reaction order and calculate the reaction rate constant in the units of your choice. (14)

4.2 Assuming identical exposure conditions, calculate the required hourly rate of injection of bromine in kg into a sunlit body of water 0.095 m^3 in volume in order to maintain a sterilizing level of bromine of 1.00 ppm. (6)

4.3 What experimental conditions would suggest if you were to obtain more data? (5)

[25]

A.1 Useful Integrals in Reactor Design

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

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

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

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

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

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

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

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

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

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

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

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

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

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

R= 0.08206 lit.atm/mol.K.