Universiti Tun Hussein Onn Malaysia

UNIVERSITI TUN HUSSEIN ONN MALAYSIA

FINAL EXAMINATION
SEMESTER II
SESSION 2022/2023

COURSE NAME	:	CHEMICAL REACTION ENGINEERING
COURSE CODE	:	DAK 22303
PROGRAMME CODE	:	DAK
EXAMINATION DATE	:	JULY / AUGUST 2023
DURATION	:	2 HOURS AND 30 MINUTES
INSTRUCTION	:	1. ANSWER **ALL** QUESTIONS
		2. THIS FINAL EXAMINATION IS CONDUCTED VIA **CLOSED BOOK**
		3. STUDENTS ARE **PROHIBITED** TO CONSULT THEIR OWN MATERIAL OR ANY EXTERNAL RESOURCES DURING THE EXAMINATION CONDUCTED VIA **CLOSED BOOK**

THIS QUESTION PAPER CONSISTS OF **SEVEN (7)** PAGES

Q1 (a) Industrial chemical process is designed to produce economically desired products.

(i) Explain the importance of physical treatment steps in chemical process.

(4 marks)

(ii) Explain how variables can affect the rate of reaction.

(4 marks)

(b) Combustion reactions of carbon coal, ethane and benzoic acid are given below.

Reaction 1: $C + O_2 \rightarrow CO_2$
Reaction 2: $2C_2H_6 + 7O_2 \rightarrow 4CO_2 + 6H_2O$
Reaction 3: $2C_6H_5CO_2H + 15O_2 \rightarrow 14CO_2 + 6H_2O$

(i) Calculate the rate of reaction for the component A for all reactions above. Note that every reaction produces 3 kg/s of CO_2.

(9 marks)

(ii) Name the component B for each reaction as in **Q1(b)(i)**.

(3 marks)

(c) The combustion of $C_3H_8 + 5O_2 \rightarrow 3CO_2 + 4H_2O$ is planned to be carried out in one of the cylindrical reactors below. This reaction will produce 2.7 kg/s of H_2O. The oxygen gas, O_2 can only be consumed 100 mol $O_2/(m^3.sec)$. If the reactor height must not exceed 1.5 meter, calculate the suitable reactor.
[MW for C = 12 g/mol, O = 16 g/mol, H = 1 g/mol, Br = 80 g/mol]

(5 marks)

Q2 (a) Formation of desired products is quantified using yield and conversion.

(i) A 100 moles of component A reacted to produce component B. Calculate the amount of N_A and N_{A0} for the conversion values of 50% and 80%.

(6 marks)

(ii) Explain the meaning of N_B and N_{B0} value in this reaction.

(4 marks)

(iii) Explain the relationship of conversion values and the N_{B0} value.

(2 marks)

(b) The combustion of hydrogen, $2H_2 + O_2 \rightarrow 2H_2O$ is carried out with the desired conversion of $X = 45\%$. Compare CSTR and PFR volumes when the molar flow rate of Hydrogen is 25 mole/s. Use the reaction data in **Table Q2(b)**.

(5 marks)

(c) A series of reactors has the sequence of PFR → PFR → CSTR, and each of their conversions are 20% → 25% → 25% respectively. The value of F_{A0} is 5 mol/s. Using the reaction data in **Table Q2(b)**, calculate the total reactor volume.

(8 marks)

Q3 (a) Based on the reaction of $Na_2S + 2HCl \rightarrow 2NaCl + H_2S$.

(i) Write the rate law equation for this reaction.

(4 marks)

(ii) Explain the reaction order for this reaction.

(4 marks)

(iii) Explain the overall order of reaction for this reaction.

(4 marks)

(b) State the molecularity for the reactions below.

(i) $A + A \rightarrow P$
(ii) $A + B \rightarrow P$
(iii) $A + A + A \rightarrow P$

(6 marks)

(c) Gas evolution reactions below are carried in steady state PFR.

$$Na_2SO_3 + 2HCl \rightarrow 2NaCl + H_2O + SO_2$$

$$Na_2S + 2HCl \rightarrow 2NaCl + H_2S$$

Select **one (1)** reaction from examples above and complete the stoichiometric table from the **Table Q3(c)** into your answer script. Assume that the inert component in the reaction is Nitrogen.

(7 marks)

Q4 (a) Catalyst can either accelerate or slow down a reaction.

(i) Explain porous catalyst using suitable diagram.

(4 marks)

(ii) Explain molecular sieves catalyst using suitable diagram.

(4 marks)

(b) Catalyst activity will decline over time due to catalyst deactivation phenomena. Explain the effect of aging and poisoning on the surface area of catalyst.

(6 marks)

(c) Sketch a diagram for each step in catalytic reaction below, to simulate the chronology of the reaction $C_2H_4 + H_2 \rightarrow C_2H_6$

(i) Diffusion.
(ii) Adsorption.
(iii) Reaction.
(iv) Desorption.
(v) Diffusion.

(15 marks)

– END OF QUESTIONS –

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Table Q2(b)

X	$-r_A$ $(mol/m^3.s)$
0.00	4.1
0.20	3.4
0.30	2.9
0.45	2.5
0.70	1.15
0.75	1.45
0.80	1.03

Table Q3(c)

Species Name	Symbol	Molar Flow Rate, F_i *(mol/s)*		
		Initial *(mol/s)*	Change *(mol/s)*	Remaining *(mol/s)*
				F_A =
				F_B =
				F_C =
				F_D =

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List of Formula

Batch reactor: $V = \frac{N_{A0}}{t} \int_{X(0)}^{X(t)} \frac{dX}{-r_A}$ Batch reactor time: $t = C_{A0} \int_{X(0)}^{X(t)} \frac{dX}{-r_A}$

CSTR: $V = \frac{(F_{A0}X)}{-r_A}$ CSTR in series: $V = F_{A0}(X_1 - X_0) \div -r_A$

PFR: $V = F_{A0} \int_{X(0)}^{X(t)} \frac{dX}{-r_A}$

Simpson's trapezoidal rule (two-point rule),

$$\int_{X0}^{X1} f(X)\, dX = \frac{h}{2}[f(X_0) + f(X_1)]$$

Simpson's one third rule (three point rule),

$$\int_{X0}^{X2} f(X)\, dX = \frac{h}{6}[f(X_0) + 4f(X_1) + f(X_2)]$$

Where, $f(X_0)$ is the value of $1 / (-r_A)$ at point X_0 and h is the distance between conversion points.

$C_{A0} = N_{A0} \div V$

$k = Ae^{\frac{-E}{RT}}$

$C_A = C_{A0}(1 - X)$

$F_A = F_{A0}(1 - X)$

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

$Da = \frac{-r_A V}{F_{A0}}$

$F_{A0} = v_0 C_{A0}$