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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

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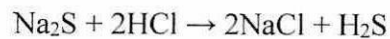
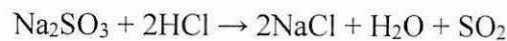
- Q1** (a) Industrial chemical process is designed to produce economically desired products.
- (i) Explain the importance of physical treatment steps in chemical process. (4 marks)
- (ii) Explain how variables can affect the rate of reaction. (4 marks)
- (b) Combustion reactions of carbon coal, ethane 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 $O_2/(m^3 \cdot sec)$. If the reactor height must not exceed 1.5 meter, calculate the suitable reactor. (5 marks)
[MW for C = 12 g/mol, O = 16 g/mol, H = 1 g/mol, Br = 80 g/mol]

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- 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, $2\text{H}_2 + \text{O}_2 \rightarrow 2\text{H}_2\text{O}$ 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 \rightarrow PFR \rightarrow CSTR, and each of their conversions are 20% \rightarrow 25% \rightarrow 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)

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- Q3** (a) Based on the reaction of $\text{Na}_2\text{S} + 2\text{HCl} \rightarrow 2\text{NaCl} + \text{H}_2\text{S}$.
- (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) $\text{A} + \text{A} \rightarrow \text{P}$
- (ii) $\text{A} + \text{B} \rightarrow \text{P}$
- (iii) $\text{A} + \text{A} + \text{A} \rightarrow \text{P}$ (6 marks)
- (c) Gas evolution reactions below are carried in steady state PFR.



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)

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- 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:
$$V = F_{A0}(X_I - X_0) \div -r_A$$

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

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

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

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

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

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

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

$$k = A e^{\frac{-E}{RT}}$$

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

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

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

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

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

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