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UNIVERSITI TUN HUSSEIN ONN MALAYSIA

**FINAL EXAMINATION
SEMESTER II
SESSION 2015/2016**

COURSE NAME : REACTOR TECHNOLOGY
COURSE CODE : DAK 30403
PROGRAMME : 3 DAK
EXAMINATION DATE : JUNE / JULY 2016
DURATION : 3 HOURS
INSTRUCTION : ANSWER **FOUR (4)**
QUESTIONS ONLY

THIS QUESTION PAPER CONSISTS OF **EIGHT (8)** PAGES

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- Q1 (a) In a decomposition process, heated limestone molecules broke down into quicklime and carbon dioxide gas as per equation below;



- (i) Define the symbol of $-r_{\text{CaCO}_3}$ (3 marks)
- (ii) Write the general mole balance equation on component CaCO_3 using the unit of mol/L. (4 marks)
- (iii) State **TWO (2)** factors affecting the rate of reaction for this process. (4 marks)
- (iv) Write the equations to show the molar relationship of reaction rate for component A ($-r_A$) with the reaction rate of component B and component C. (4 marks)
- (b) The decomposition process takes place in a cylindrical chamber of 100 cm long and 50 cm diameter. If the 66 kg/s of CO_2 gas was produced, calculate the rate of reaction of the limestone and quicklime. (8 marks)
- (c) State any **TWO (2)** names of AutoCAD® commands used when designing a feed tank (a batch reactor). (2 marks)

Q2 (a) (i) State the role of Simpson's Rule in a reactor design. (3 marks)

(ii) 1.5 mol/(m³.s) of reactant A, F_{A0} is fed continuously into a CSTR to achieve 60% conversion of reactant A. Based on the data given in **Table Q2**, compare the reactor size (m³) between 60% and 80% conversion. (4 marks)

Table Q2: Processed data for component A

X	0.0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8
$-r_A$ (mol/m ³ .s)	5.3	5.2	5.0	4.5	4.0	3.3	2.5	1.8	1.3

(iii) Compare the batch reactor size with the CSTR size in **Q2 (a)(ii)** using the same set of data, assuming the reactant A quantity is 1.5 mole and its reaction time is 1 second. (6 marks)

(iv) Calculate each of reactor volumes when a CSTR and a PFR is arranged in series. The individual conversion, X for the CSTR is 30% and followed by a PFR with 40%. The entering molar flow rate, F_{A0} is 2.5 mol/s. Use processed data as in **Table Q2**. (8 marks)

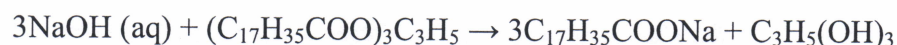
(b) Name the appropriate reactor type for the given process description.

(i) The reactor used widely for fermentation process such as brewing and crystallization process for drug manufacturing usually need higher conversion with respect to time. The longer the reactant left inside the reactor, the higher percentage of yield. Normally all the reactants are charged at once and after the fermentation process complete it will be discharged altogether. (2 marks)

(ii) Liquid, gaseous or slurries phase of reaction can be carried out in this type of reactor. It is suitable to model a reaction in continuous flowing phase as well as reactions involving changing temperatures, pressures and densities as it flows. Using this type of reactor resulting in higher volumetric conversion, but may result in uncontrolled temperature gradient. (2 marks)

- Q3** (a) (i) Define elementary rate law and non-elementary rate law, with suitable examples. (4 marks)
- (ii) Write the elementary rate law equation, non-elementary rate law equation and reversible rate law equation based on chemical equation below. (8 marks)
- $$0.2A + 3B \rightarrow 5C$$
- (b) (i) For a reaction rate law of $-r_A = k_A C_A$, show the unit of its reaction rate constant, k. (3 marks)
- (ii) Show the units of reaction rate constant, k for elementary and non-elementary rate law equations in **Q3 (a)(ii)**. (6 marks)
- (c) Explain the differences between *the order of reaction* and *the overall order of reaction* with the suitable examples. (4 marks)

- Q4** Saponification process for the formation of soap is commonly carried out in a batch reactor. The reactants used are aqueous caustic soda and glyceryl stearate, as in the equation below.



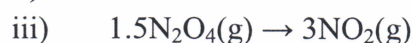
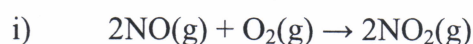
- (a) Set up a stoichiometric table to represent the concentration for each species in terms of its initial concentration, and the conversion, X . Your stoichiometric table should look like below.

Table Q4: Stoichiometric Table

Species	Symbol	$C_A \text{ (mol/m}^3\text{)}$		
		Initial (mol/m ³)	Change (mol/m ³)	Remaining (mol/m ³)
	A			$C_A =$
	B			
	C			
	D			
H ₂ O	I			$C_I =$

(6 marks)

- (b) State the equation for 'mole change' for all components in the reactions below. The equations must contain C_{A0} symbol.



(8 marks)

- (c) Based on the saponification process in **Q4 (a)**, the initial mixture consist of the sodium hydroxide (component A) at a concentration of 12 mol/L and glyceryl stearate at a concentration of 3 mol/L.

- i) Solve the final concentration of glycerine (component D) when the conversion of sodium hydroxide are 25% and 85%.

(4 marks)

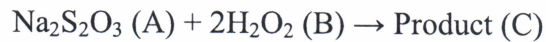
- ii) Calculate the initial concentration of component B and C.

(4 marks)

- iii) Select which is the limiting reactant in this reaction.

(3 marks)

- Q5** The liquid phase reaction of sodium thiosulfate (A) and hydrogen peroxide (B) is carried out in a **constant-volume** batch reactor. The reaction equation is as below.



$$k = 6.853 \times 10^{11} \exp(-E / RT)$$

$$R = 8.314 \text{ J / mol.K}$$

$$E = 76.480 \text{ kJ/mol A}$$

$$C_{A0} = 0.102 \text{ kmol/m}^3$$

$$T = 30^\circ\text{C}$$

- (a) Assuming second order kinetics with respect to A and zero order with respect to B, compare the reaction times needed for 40% and 80% conversion.

(10 marks)

- (b) Compare the reaction times needed for reaction temperatures of 60°C and 100°C, assuming second order kinetics with respect to A and zero order with respect to B, and constant conversion at 80%.

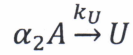
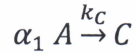
(10 marks)

- (c) Make **TWO (2)** conclusions from your findings in **Q5 (a)** and **Q5 (b)**.

(5 marks)

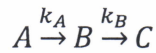
Q6 (a) Write the net rate law equations for the reactions below and state whether they are parallel or series reaction.

(i) Reaction of A to produce desired product C.



(3 marks)

(ii) Reaction of A to produce desired product C.



(3 marks)

(iii) Explain logically why a parallel reaction will use less space compared to a series reaction.

(3 marks)

(b) For reaction is **Q6 (a)(i)**, explain **TWO (2)** ways to maximize the desired product based on its instantaneous selectivity, $S_{D/U}$.

(8 marks)

(c) Discuss briefly on **FOUR (4)** classifications of catalyst with suitable examples.

(8 marks)

- END OF QUESTION -

FINAL EXAMINATION

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List of Formula

$-r_A$ (mol/m³.s)

$$\text{Batch, } V = \frac{N_{A0}}{t} \int_{X(0)}^{X(t)} \frac{dX}{-r_A} \quad \text{where} \quad t = \frac{N_{A0}}{V} \int_{X(0)}^{X(t)} \frac{dX}{-r_A}$$

$$\text{CSTR, } V = \frac{F_{A0}(X)}{-r_A} \quad \text{or} \quad V = \frac{F_{A0}(X_{out} - X_{in})}{-r_A}$$

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),

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

Simpson's three eights rule (four point rule),

$$\int_{X_0}^{X_3} f(X) dX = \frac{3}{8} \times \frac{h}{3} [f(X_0) + 3f(X_1) + 3f(X_2) + f(X_3)]$$

Where $f(X_0)$ is the value of $1 / (-r_A)$ at point X_0 and h is the distance between conversion points. Eg; for $(X_0 = 0.0)$, $(X_1 = 0.2)$, $(X_3 = 0.4)$ gives $h = 0.2$.

$$V = \pi r^2 h$$

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

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

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

$S_{D/U} = r_D / r_U$ (Desired product / Undesired product)

$$\int_{X_{A0}}^{X_A} \frac{1}{(1-X)^2} dX = \left[\frac{1}{(1-X)} \right]_{X_{A0}}^{X_A}$$