CONFIDENTIAL

UNIVERSITI TUN HUSSEIN ONN MALAYSIA

FINAL EXAMINATION
SEMESTER II
SESSION 2018/2019

COURSE NAME	:	CHEMICAL REACTION ENGINEERING
COURSE CODE	:	DAK 32203
PROGRAMME CODE	:	DAK
EXAMINATION DATE	:	JUNE / JULY 2019
DURATION	:	3 HOURS
INSTRUCTION	:	ANSWERS **TWO (2)** QUESTIONS IN SECTION A AND **TWO (2)** QUESTIONS IN SECTION B

THIS QUESTION PAPER CONSISTS OF **NINE (9)** PAGES

CONFIDENTIAL

SECTION A

Q1 (a) Chemical reaction engineering is virtually the heart of every chemical process.

(i) State **two (2)** importance of learning chemical reaction engineering.
(4 marks)

(ii) State **two (2)** parameters affecting the value of reaction rate, $-r_A$.
(2 marks)

(iii) List all the units involved in the reaction rate, r_i.
(3 marks)

(iv) Explain the differences between batch reactor and CSTR in terms of molar flow rate.
(4 marks)

(b) Methane gas can burn easily to produce hot flames, which can be used to boil water or cook. The combustion takes place in a 0.95 m diameter of cylindrical chamber. If this reaction consumes 1.8 kg/s of methane at a rate of 100 mol $CH_4/(m^3.sec)$, find the reactor length. The combustion equation for methane is $CH_4 + 2O_2 \rightarrow CO_2 + 2H_2O$. [Molecular weight for C = 12 g/mol, H = 1 g/mol]
(6 marks)

(c) State **one (1)** disadvantage for each reactor below.

(i) Batch reactor
(ii) CSTR
(iii) PFR

(6 marks)

Q2 (a) Iron react with oxygen gas to form iron (III) oxide, $4Fe + 3O_2 \rightarrow 2Fe_2O_3$

(i) Express an equation to show relationship between $-r_A$ and $+r_C$.

(2 marks)

(ii) Show the rate of iron being consumed, in $mol.L^{-1}s^{-1}$ if Fe_2O_3 was formed at a rate of $81.5\ g.L^{-1}s^{-1}$.

(2 marks)

(iii) State the value of N_{A0} (in mole) if initially there are 15.6 grams of O_2 used in the reaction. [Fe = 55.8 gram/mol, O = 16 gram/mol]

(3 marks)

(b) The combustion of hydrogen, $2H_2 + O_2 \rightarrow 2H_2O$ is carried out with the desired conversion of X = 70%.

(i) Compare CSTR and PFR volumes when the molar flow rate is 5 mole/sec. Use the reaction data in **Table 1**.

(6 marks)

(ii) State type of reactor to be used if the reaction requires good temperature control and must be carried out in the liquid phase.

(2 marks)

(c) Reactors can be run in series so that the total conversion process is split into few stages.

(i) Calculate total reactor volume for a series of reactors with the sequence of CSTR → PFR → CSTR, with conversions of 20% → 25% → 30%. F_{A0} is 30 mol/s. Use the same reaction data in **Table 1**.

(8 marks)

(ii) Explain why batch reactor cannot be used in the series reactor.

(2 marks)

SECTION B

Q3 (a) Reaction rate law is also known as "rate equation" or "rate law".

(i) Write the rate law for the reaction of $Cu + 2AgNO_3 \rightarrow 2Ag + Cu(NO_3)_2$.

(2 marks)

(ii) Write the non-elementary rate law equation and the reversible rate law equation for the reaction in **Q3 (a)(i)**.

(4 marks)

(iii) Explain *the order of reaction* and *the overall order of reaction* based on the reaction in **Q3 (a)(i)**.

(4 marks)

(b) Write a simplified chemical equation for each case below using the alphabetical symbol (eg: A, B, C, etc).

(i) Unimolecular reaction.
(ii) Bimolecular reaction.
(iii) Termolecular reaction.

(6 marks)

(c) The neutralization reaction below is carried out in a liquid phase, steady state CSTR.

$$3NH_4OH + H_3PO_4 \rightarrow (NH_4)_3PO_4 + 3H_2O$$

(i) Copy and complete **Table 2** in your answer script, assuming that the inert component in the reaction is Nitrogen.

(7 marks)

(ii) State **one (1)** use of the stoichiometric table.

(2 marks)

Q4 (a) The liquid phase reaction of sodium thiosulfate and hydrogen proxide is carried out in a **constant-volume** batch reactor as given below.

$$Na_2S_2O_3 + 2H_2O_2 \rightarrow \text{Product}$$

$k = 5.73 \times 10^{10} \exp(-E / RT)$	$T = 30°C$
$R = 8.314$ J / mol.K	$E = 76.48$ kJ/mol A
$C_{A0} = 100$ mol/m^3	$C_{B0} = 200$ mol/m^3

(i) Calculate the value of k.

(2 marks)

(ii) Write the rate law equation, when the actual reaction order is first order for component A and first order for component B.

(2 marks)

(iii) Compare reaction times, t for 50% and 80% conversions.

(6 marks)

(b) You are now tasked to design the reactor volume based on the data given in **Q4 (a)**.

(i) Construct a table of conversion (X) versus rate law ($-r_A$) for 0%, 50% and 80% conversion based on rate law equation in **Q4 (a)(ii)**.

(4 marks)

(ii) Compare reactor volume, V for 50% and 80% conversions if $N_{A0} = 100$ mole.

(4 marks)

(c) The reaction **Q4 (a)** is then tested in a CSTR with the initial volumetric flow rate, v_0 of 0.5 Liter/s and 70% conversion. If the volumetric flow rate is increased two times from its original value, show the changes in the conversion value. Assume that first order for component A and zero order for component B.

(7 marks)

Q5 (a) Series and parallel reaction can be considered to be chosen for a complex reaction.

(i) Define parallel reaction and series reaction.

(4 marks)

(ii) Write **TWO (2)** set of reactions to differentiate between multiple and independent reaction.

(4 marks)

(b) The aim of selecting a parallel reaction is always to obtain high desired product.

(i) Write the reaction rate law for the parallel reaction below.

$$2A \xrightarrow{k_D} D$$

$$A \xrightarrow{k_U} U$$

(3 marks)

(ii) Explain **ONE (1)** method to maximize the desired product, D for the reaction in **Q5 (b)(i)**.

(2 marks)

(iii) State **ONE (1)** effect if the amount of undesired product, U is too high.

(3 marks)

(c) One of important variable for a series reaction is the reaction rate constant.

(i) State which one of the series reactions below is more preferred.

Reaction 1: $A \xrightarrow{k_1 = 10\ \text{sec}^{-1}} D \xrightarrow{k_2 = 2\ \text{sec}^{-1}} U$

Reaction 2: $A \xrightarrow{k_1 = 3\ \text{sec}^{-1}} D \xrightarrow{k_2 = 7\ \text{sec}^{-1}} U$

(3 marks)

(ii) Explain the effect on the reaction if the opposite answer in **Q5 (c)(i)** is chosen.

(2 marks)

(d) Write **TWO (2)** steps in the algorithm to solve complex, multiple reactions.

(4 marks)

Q6 (a) Catalyst have been used by the humankind for over 2000 years.

(i) Define the term catalyst.

(3 marks)

(ii) Name few examples of catalysts used in food industry.

(4 marks)

(b) Based on the statements below, state whether they are homogeneous or heterogeneous catalytic reaction.

(i) Dehydrogenation process of liquid cyclohexane using platinum-on-alumina as the catalyst.

(ii) "Fisher esterification" process occurs when a liquid alcohol and liquid acid react to form ester, using sulphuric acid solution as a catalyst.

(iii) "Haber process" occurs when hydrogen gas and nitrogen gas react to form ammonia, using metal iron as a catalyst.

(6 marks)

(c) A catalytic reaction occurs mainly at the fluid-solid interface.

(i) Explain porous catalyst, molecular sieves and monolithic.

(6 marks)

(ii) State **THREE (3)** ways to deactivate a catalyst.

(3 marks)

(d) State the **THREE (3)** main steps in the catalytic reaction based on the **Figure Q6 (d)**. Take note that the lined surface on each image sequence below is the catalyst surface.

(3 marks)

-END OF QUESTIONS –

FINAL EXAMINATION

SEMESTER/SESSION : SEMESTER II 2018/2019 PROGRAMME : DAK
COURSE NAME : CHEMICAL REACTION ENGINEERING COURSE CODE : DAK 32203

Table 1

X	$-r_A$ $(mol/m^3.s)$
0.00	3.9
0.20	3.5
0.45	2.6
0.70	1.1
0.75	1.23

Table 2

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

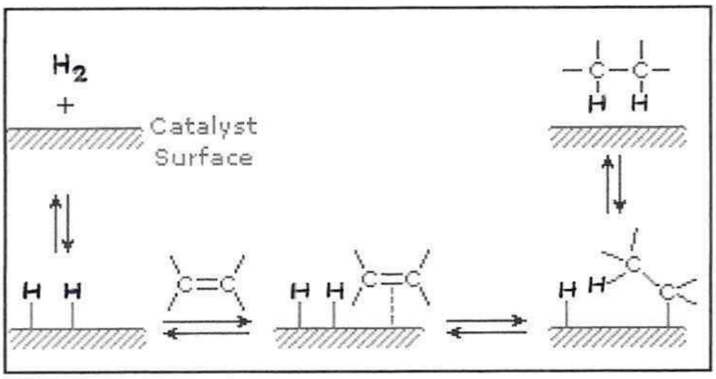

Figure Q6 (d)

FINAL EXAMINATION

SEMESTER/SESSION : SEMESTER II 2018/2019 PROGRAMME : DAK
COURSE NAME : CHEMICAL REACTION ENGINEERING COURSE CODE : DAK 32203

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.

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

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

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

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

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

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

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