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Universiti Tun Hussein Onn Malaysia

UNIVERSITI TUN HUSSEIN ONN MALAYSIA

FINAL EXAMINATION
SEMESTER II
SESSION 2014/2015

COURSE NAME	:	REACTOR TECHNOLOGY
COURSE CODE	:	DAK 30403
PROGRAMME	:	3 DAK
EXAMINATION DATE	:	JUNE 2015 / JULY 2015
DURATION	:	3 HOURS
INSTRUCTION	:	ANSWER **FOUR (4)** QUESTIONS ONLY

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

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Q1 (a) Decomposition of nitrogen dioxide which releasing oxygen and nitric oxide is an endothermic reaction. The reaction scheme can be written as follows.

$$2NO_2 \rightarrow 2NO + O_2$$

(i) Define $-r_{NO_2}$

(2 marks)

(ii) Given the reaction process as shown in **Q1 (a)** is an elementary reaction, write the rate expression for above reaction and state the reaction order.

(4 marks)

(iii) Determine the unit of reaction rate constant, k for the above reaction.

(6 marks)

(iv) Explain why reaction rate, $-r_A$ is important to show the "appearance" and the "disappearance" of a species in a reaction.

(3 marks)

(b) A reaction of one molecule A with two molecule B produce one molecule of component C. Write an equation to show molar relationship between rate of reaction for component A ($-r_A$) and component B ($-r_B$).

(4 marks)

(c) State any **THREE (3)** names of AutoCAD® commands used when designing a feed tank (a batch reactor).

(6 marks)

Q2 (a) (i) A batch reactor with a capacity of 500 L is used to achieve 40% conversion of reactant A. Calculate the necessary time (second) to achieve this conversion given the intitial amount of reactant A fed, N_{A0} is 2 mole.

Table Q2: Processed Data for component A

X	0.0	0.1	0.2	0.3	0.4
$-r_A$ (mol/m^3.s)	5.3	5.2	5.0	4.5	4.0
$1/-r_A$	0.189	0.192	0.200	0.222	0.250

X	0.5	0.6	0.7	0.8	0.85
$-r_A$ (mol/m^3.s)	3.3	2.5	1.8	1.25	1.0
$1/-r_A$	0.303	0.400	0.556	0.800	1.000

(6 marks)

(ii) A batch reactor is used to achieve 60% conversion of reactant A in a space of 2 second. Calculate the necessary volume (m^3) to achieve this conversion given the intitial amount of reactant A fed, N_{A0} is 1.5 mole. Use the data given in **Table Q2**.

(6 marks)

(iii) Calculate the necessary reactor height in **Q2 (a)(ii)** given that the reactor shape is cylindrical with 0.5 m radius.

(2 marks)

(b) Illustrate a continuous stirred tank reactor (CSTR) and all its associated symbol and components.

(5 marks)

(c) Name the appropriate or most suitable reactor used 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) A reaction involves multi-phases requires a specific reactor. The fluid is forced thorough the solid catalyst materials to suspend the reactor content vertically along the reactor. The contents of the reactor bed begin to expand and swirl around much like agitated tank.

(2 marks)

(iii) 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) State two types of rate law equations (elementary form and reversible form) for each of the chemical reactions below.

(i) $N_2O_4\,(g) \rightarrow 2NO_2\,(g)$

(ii) $2A \rightarrow B$

(iii) $0.5A + 1/3\,B \rightarrow C$

(12 marks)

(b) Show the units of reaction rate constant, k for all elementary rate law equations in **Q3 (a).**

(6 marks)

(c) Define *the overall order of reaction.*

(2 marks)

(d) Explain why based on actual equilibrium data, the rate law equations for reaction $CO + Cl_2 \rightarrow COCl_2$ is $-r_{CO} = kC_{CO}C_{Cl_2}^{3/2}$

(5 marks)

Q4 (a) You are employed as an assistant chemical engineer in a chemical manufacturing firm that produces chemical *A*. The firm wishes to expand its production capacity from 1 tonne/week of chemical *A* to 1 tonne/day. You are requested by your senior engineer to help the company in deciding to switch from batch process to continuous process. Discuss the differences between a continuous system (eg: CSTR) and a batch system.

(10 marks)

(b) (i) Prove that $k_2 = k_1 e^{-\frac{E}{R}\left(\frac{1}{T2}-\frac{1}{T1}\right)}$.

(5 marks)

(ii) Given that R = 8.314 J/mol.K, calculate the activation energy, E based on the data of the decomposition of benzene diazonium chloride as below.

Table Q4: Processed data for decomposition of benzene

k (second^{-1})	0.00043	0.00103	0.00180	0.00355	0.00717
ln (k)	– 7.75	–6.88	–6.32	–5.64	–4.94
1/ T (Kelvin^{-1})	0.00320	0.00314	0.00310	0.00305	0.00300

(4 marks)

(iii) Determine the range of frequency factor value, A for the decomposition process of benzene in **Table Q4.**

(6 marks)

Q5 (a) Nitric acid is made commercially from nitric oxide. Nitric oxide is produced by the gas phase oxidation of ammonia. The reaction for oxidation process is shown in the following reaction.

$$4NH_3 + 5O_2 \rightarrow 4NO + 6H_2O$$

The gas feed consists of 15 mol% ammonia in air at 7.5 atm and 227°C while the balance mol% is inert gas. The process is carried out in a CSTR reactor.

(i) Prove that $C_{A0} = y_{A0}\left(\frac{P_0}{RT_0}\right)$ where y_{A0} is the mole fraction (mol%).

(5 marks)

(ii) Calculate the entering concentrations of ammonia and oxygen in mol/L.

(4 marks)

(iii) State the compound used for the basis of calculation and give the reason.

(4 marks)

(iv) Write the equations to show concentration of ammonia and oxygen in terms of conversion, X after a period of time. Given ideal gas constant is 0.0821 (L.atm/mol.K).

(2 marks)

(b) Write the full form of stoichiometric table for the flow system in **Q5 (a) in** terms of conversion, X assuming there are no inert components involved in the oxidation process. Use symbol A, B, C and D for each components involved to simplify your answer.

(10 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.

$$\alpha_1 A \overset{k_C}{\rightarrow} C$$

$$\alpha_2 A \overset{k_U}{\rightarrow} U$$

(3 marks)

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

$$A \overset{k_A}{\rightarrow} B \overset{k_B}{\rightarrow} C$$

(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.

(8 marks)

- END OF QUESTION –

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Formula

$-r_A\ (mol/m^3.s) = k\ C_A$

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

Trapezoidal rule (two-point rule),

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

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

$$\int_{X0}^{X2} f(X)\,dX = \frac{(X_2 - X_0)/2}{3}[f(X_0) + 4f(X_1) + f(X_2)]$$

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

$$\int_{X0}^{X3} f(X)\,dX = \frac{3}{8} \times \frac{(X_3 - X_0)}{3}[f(X_0) + 3f(X_1) + 3f(X_2) + f(X_3)]$$

$V = \pi r^2 h$

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

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

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

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