KISII UNIVERSITY

UNIVERSITY EXAMINATIONS

SPECIAL EXAMINATION

FOURTH YEAR EXAMINATION FOR THE AWARD OF
THE DEGREE OF BACHELOR IN ANALYTICAL /INDUSTRIAL CHEMISTRY
SECOND SEMESTER 2021/2022
(JULY, 2022)

CHEM 421: REACTOR DESIGN

STREAM: Y4 S2 **TIME: 2 HOURS**

DAY: FRIDAY, 12.00 PM – 2.00 PM **DATE: 00/07/2022**

INSTRUCTIONS:

1. ***Do not write anything on this question paper.***
2. ***Answer Question(compulsory) ONE and any TWO Questions.***

QUESTION 1

A) Define the following (3 marks)

i) Chemical reactor

ii) Reactor Designer

iii) An ideal reactor

B) What factors are essential in choosing the right reactor for a process? (3 marks)

C) Outline the possible factors to consider for selection of a reactor design (4 marks)

D) Discuss characteristics of Tubular Reactor or Plug-Flow Reactor (PFR) (5 marks)

E) Explain why for an ideal tank reactor the reactions must be perfectly mixed (5 marks)

F) Express the fundamental performance equation and state its relevance in reactor design.

(4 marks)

G) Compare the disadvantages of Batch Reactors with those of Continuous-Stirred Tank Reactor (CSTR) (4 marks)

H) Outline the differences between Fluidized-Bed Reactor and Fixed Bed Reactor (4 marks)

I) Distinguish between the Arrhenius and Vant Hoff equations dealing with chemical reactions and state their relevance in chemical engineering. (4 marks)

J) With examples distinguish heterogeneous and homogeneous catalyst. (4 marks)

QUESTION 2

A) John studied chlorination of dichlorotetramethylbenzene in acetic acid at 30 ^{0}C.

$C_6Me_4Cl_2 + Cl_2 \longrightarrow HCl + C_6Me_3(CH_2Cl)Cl_2$

The data below are of those recorded in a well stirred batch reactor. Initial concentrations are as follows: Cl_2 = 19.2 moles/m^3, $C_6Me_4Cl_2$ = 34.7 moles/m^3

Time (Ksec)	0	48.4	85.1	135.3	171.3	222.9	257.4
Fraction of Cl_2 reacted	0	0.2133	0.3255	0.4226	0.5195	0.5955	0.6365

i) How would you confirm that the reaction is second order overall? (6 marks)

ii) Determine the plug flow reactor volume necessary to achieve 90% conversion of the chlorine using an input volumetric flow rate of 0.15 m^3/Ksec and the same initial conditions as used in the batch experiments. (5 marks)

B) For a bimolecular second order reaction of the form $A + B \longrightarrow C$.

Show the relationship between time (t), $R = C_{Bo}/C_{Ao}$, x = conversion fraction, and k = rate constant.

(4 marks)

QUESTION 3

A solution polymerization is to be carried out to 80% conversion in a series of stirred-tank reactors, all operating at the same temperature and rate of 0.5 hr^{-1}. Batch tests show that the reaction is first order to monomer, and 80% conversion is reached in 6 hours.

i) If five reactors of equal size are used, what total residence time is needed? (8 marks)

ii) What fraction of the total heat released is generated in each vessel? (7 marks)

QUESTION 4

A) The rate of a chemical reaction is given by $r = kC_A^n$. If 90% of the reactant **A** is converted to products in the reactor, and if one obtains a second reactor that is one half size of the first, determine the increase in capacity that results from the following types of operation

Two plug flow reactors in series and n = ½, 1, 3

Two plug flow reactors in parallel and n = 1, 2, 3

Assume that the exit composition from the last reactor remains unchanged in all cases and that none of **A** has been converted to products prior to entering the reactor and that it is a constant density system. "In series" assume that the small reactor precedes the larger one. (10 marks)

B) Repeat (A) for the case of CFSTRs. (5 marks)