Technical University of Mombasa

Faculty of Applied and Health Sciences

DEPARTMENT OF PURE AND APPLIED SCIENCES

UNIVERSITY EXAMINATION FOR THE DEGREE OF BACHELOR OF TECHNOLOGY IN APPLIED CHEMISTRY (ANALYTICAL OPTION)

BTAC 11M

ACH 4409: REACTOR DESIGN

SEMESTER EXAMINATION

DECEMBER 2013 SERIES 2 HOURS

Instructions to candidates:

This paper consists of **FIVE** questions

Answer question **ONE** (compulsory) and any other **TWO** questions

QUESTION ONE

a) Show that the half-life (t ½) of a reaction with respect to reactant A is given by the expression: $In\,t_{½} = (1-n)InC_{Ao} + In\left[\frac{2^{n-1}-1}{K(n-1)}\right]$

Where: n = order of reaction,

K = specific rate constant

C_{AO} = initial concentration of A

(8marks)

b) For a gas-phase reaction the rate of reaction is often described in teams of dp/dt instead of

dc/dt or dn/dt. Determine the relation among these three expression in an ideal gas where :

P = pressure

C = Concentration

n = Number of moles

t = Time

(5marks)

c) Table 1 below shows various half-life periods at different partial pressures of nitric oxide in a reaction of hydrogen with nitric oxide in which the partial pressure of hydrogen is kept constant by having it in excess.

$2NO + 2H_2 \longrightarrow N_2 + 2H_2O$

Table 1

Initial partial pressure of NO(bar)	4.13	5.22	6.72	8.16	8.95
Half-life(s)	490	388	301	248	226

(i) Determine graphically the order of reaction with respect to NO and the specific rate constant for the reaction. **(13marks)**

(ii) Write the rate law expression for the reaction. **(4marks)**

QUESTION TWO

a) Using general mole balance equation, show that the design equation for a continuous stirred tank reactor is;

$$V_{CSTR} = \frac{F_{AO} X_A}{-\lambda A},\ \varepsilon_A = O$$

b) Pure gaseous reactant A (C_{AO} = 100 millimol / litre) is fed at steady rate into a mixed reactor v = 0.1litre where it dimerizes (2A→R). For different gas feed rates the following data are obtained:

Table 2

Run number	1	2	3	4
Vo, Litre / he	30	9	3.6	1.5
C_A, millimol / litre	85.7	66.7	50	33.3

Find a rate equation for this reaction. **(14marks)**

QUESTION THREE

a) Using general mole balance equation, show that the design equation for a plug flow reactor is

$$V_{PFR} = FAO\int_{O}^{X_A} \frac{dx_A}{-\lambda A}, \quad \varepsilon_A = O$$

b) An experiment was carried out in an isothermal PFR on a neutralization reaction between an organic acid and a base: A(aq) + B(aq) → Products.

The data obtained was as shown in table 3 below.

Table 3

Conversion, X_A	0	0.2	0.4	0.6	0.8	0.95
-λA (mole/dm^3.min)	0.1	0.077	0.056	0.038	0.024	0.015

Given that ; FAO = 0.024 mole/min,

T = 300K,

Graphically determine the volume of the PFR that obtains 80% conversion. **(14marks)**

QUESTION FOUR

Dimethyl ether undergoes thermal decomposition at 504˚C according to the reaction

$(CH_3)_2O \longrightarrow CH_4 + H_2 + CO$

Variation of the total pressure 'P' is measured as a function of time and the results obtained are shown in table 4 below

Table 4

P(mmHg)	312	408	488	562	779
T(s)	0	390	777	1195	3155

a) Show that the reaction is first order.
b) Determine the rate constant for the reaction.
c) Write down the rate law equation

(20marks)

QUESTION FIVE

The homogeneous gas decomposition of phosphine

$4PH_3(g) \longrightarrow P_4(g) + 6H_2(g)$

Proceeds at 1200˚F with first order rate $-\lambda_{PH_3} = (10/hr)C_{PH_3}$

What size of plug flow reactor operating at 1200˚F and 4.6atm can produce 80% conversion of a feed consisting of 4lb-mol of phosphine per hour.

(20marks)