TECHNICAL UNIVERSITY OF MOMBASA

FACULTY OF APPLIED AND HEALTH SCIENCES

DEPARTMENT OF PURE & APPLIED SCIENCES

UNIVERSITY EXAMINATION FOR THE BACHELOR OF TECHNOLOGY IN APPLIED CHEMISTRY

(BTAC 14S & BTAC 15S2)

ACH 4201 : CHEMICAL KINETICS AND REACTION DYNAMICS

END OF SEMESTER EXAMINATION

SERIES: APRIL 2016

TIME: 2 HOURS

DATE: Pick Date Apr 2016

Instructions to Candidates

You should have the following for this examination

-Answer Booklet, examination pass and student ID

This paper consists of **FIVE** questions. Attempt question ONE (Compulsory) and any other TWO questions.

Do not write on the question paper.

QUESTION ONE

a) Differentiate between each of the following:
   i. Rate and rate law of a reaction (3 marks)
   ii. Average and instantaneous rate (3 marks)

b) Consider the reaction

$$4NO_{2(g)} + O_{2(g)} \longrightarrow 2N_2O_{5(g)}$$

Suppose that, at a particular moment during the reaction, molecular oxygen is reacting at the rate of 0.024M/s. At what rate is:

i. N_2O_5 being formed? (2 marks)
ii. NO_2 reacting? (2 marks)

c) The decomposition of a certain insecticide in water follows first-order kinetics with a rate constant of $1.45 yr^{-1}$ at 12^oC. A quantity of this insecticide is washed into a lake on 1st June, leading to a concentration of $5.0 \times 10^{-7} g/cm^3$. Assume that the average temperature of the lake is 12^oC.

i. What is the concentration of the insecticide on 1st June of the following year? (3 marks)
ii. How long will it take for the concentration of the insecticide to drop to $3.0 \times 10^{-7} g/cm^3$? (3 marks)

d) The following data were obtained for the decomposition of cyclopentene at 825K.

$$C_5H_{8(g)} \longrightarrow C_5H_{6(g)} + H_{2(g)}$$

Time(s)	**[C_5H_8] (mol/L)**
0	0.0200
20	0.0189
50	0.0173
100	0.0149
200	0.0112
300	0.0084
400	0.0063
500	0.0047
700	0.0027
1000	0.0011

Using the data above at this temperature, determine the

i. Order of reaction (9 marks)
ii. Rate constant (2 marks)
iii. Half-life of reaction (3 marks)

QUESTION TWO

a) The Michaelis-Menten enzyme kinetics equation is given as:

$$V_O = \frac{V_{\max}\,[S]}{K_m + [S]}$$

i. Define all the variables in the above equation (2 marks)
ii. State the main assumptions used to derive this equation (6 marks)

b) Briefly highlight the main features of the collision theory of chemical kinetics (8 marks)

c) Discuss how each of the following affects the rate of enzymatic reaction.
   i. Substrate concentration (2 marks)
   ii. Non-competitive inhibitors (2 marks)

QUESTION THREE

a) Briefly discuss how the collision theory explains the influence of temperature on the rate of reaction. (6 marks)

b) The reaction of nitric oxide with hydrogen at 1280°C is:

$$2NO_{(g)} + 2H_{2(g)} \longrightarrow N_{2(g)} + 2H_2O_{(g)}$$

The following data is collected at this temperature:

EXPERIMENT	**[NO] (M)**	**[H_2] (M)**	**Initial Rate (M/s)**
1	5.0×10^{-3}	2.0×10^{-3}	1.3×10^{-5}
2	10.0×10^{-3}	2.0×10^{-3}	5.0×10^{-5}
3	10.0×10^{-3}	4.0×10^{-3}	10.0×10^{-5}

Determine the:

   i. Rate law (4 marks)
   ii. Rate constant (1.5 marks)
   iii. Rate of reaction when [NO] = 12.0×10^{-3}M and [H_2] = 6.0×10^{-3}M (1.5 marks)

c) Consider the reaction mechanism

$$I_{2(aq)} \underset{}{\overset{\text{fast}}{\rightleftharpoons}} 2I^-_{(aq)}$$

$$H_{2(aq)} + 2I^-_{(aq)} \xrightarrow{\text{slow}} 2HI_{(aq)}$$

Derive the rate law if the reaction is dependent on the concentration of both H_2 and I_2 (4 marks)

d) From the rate law in (i) determine the:
   a) Order of reaction with respect to each reactant (1 marks)
   b) Overall reaction order (1 marks)
   c) Molecularity of reaction (1 marks)

QUESTION FOUR

a) The growth of *pseudomonas* bacteria is modeled as a first-order process with k = 0.023 min^{-1} at 37°C. The initial *pseudomonas* bacteria population density is 1.0×10^3 cells/L.

i. What is the population density after 3 hours 20 minutes? (4 marks)

ii. What is the time required for the population density to increase from 1.0×10^3 to 2.0×10^3 cells/L? (4 marks)

b) Differentiate between:
   i. Reaction mechanism and rate-determining step (3 marks)
   ii. Elementary and complex reaction (3 marks)

c) Sketch a potential energy profile for a three-step endothermic reaction in which the second-step is rate-determining. (6 marks)

QUESTION FIVE

a) Discuss the key features of the transition state theory applied to bimolecular reactions. (8 marks)

b) The rate of decomposition of azomethane ($C_2H_6N_2$) is studied by monitoring the partial pressure of the reactant as a function of time:

$$H_3C{-}N{=}N{-}CH_3 \longrightarrow C_2H_6 + N_2$$

The following data was obtained at 300°C.

Time (s)	Partial pressure of azomethane (mmHg)
0	284
100	220
150	193
200	170
250	150
300	132

From the above data at the given temperature determine:
   i. The rate constant (10 marks)
   ii. Half-life of the reaction (2 marks)