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University Examinations 2022/2023

THIRD YEAR, SECOND SEMESTER EXAMINATION FOR THE DEGREE OF BACHELOR OF SCIENCE (CHEMISTRY), BACHELOR OF SCIENCE EDUCATION SCIENCE

SCH 3354: CHEMICAL KINETICS

DATE: APRIL 2023 **TIME:2 HOURS**

INSTRUCTIONS: *answer question one and any other two questions*

QUESTION ONE (30 MARKS)

a) Using the decomposition of dinitrogen pentoxide at 50^{o}C, define a reaction rate and state the formular that describes a reaction quantitively (4 marks)

b) Define molecularity of a reaction and explain unimolecular and biomecular reaction (4 marks)

c) Consider the following reactions. Assuming the species involved take part determining the rate of reactions. For each reaction state the law and write the relevant formular

(i) $O_3(g) \rightarrow O_2(g) + O(g)$ (3 marks)

(ii) $CH_3Br(aq) + OH^-(aq) \rightarrow Br^-(aq) + CH_3OH(aq)$ (3 marks)

(iii) $A + A + B \rightarrow$ Products (3 marks)

d) Describe the distinction among a homogenous, heterogenous catalyst and an enzyme (6 marks)

e) Define a reaction mechanism (2 marks)

f) Discuss the importance and application of chemical kinetics (5 marks)

QUESTION TWO (20 MARKS)

a) Describe the following terms

i) Collision theory in relation to why reaction rates depend on temperature (2 marks)

ii) Activation energy (2 marks)

iii) Transition state (2 marks)

b) For reaction of the type A + BC → AB + C (where the reaction occurs in a single step with the transition state configuration being A---B---C, sketch a potential energy profile for the reaction and label all parts (6 marks)

c) Write and define the terms in the Arrhenius equation (4 marks)

d) Explain what a catalyst is and how it affects a reaction rate (4 marks)

QUESTION THREE (20 MARKS)

a) The following two-step mechanism has been proposed for the gas-phase decomposition of nitrous oxide (N_2O):

Step 1. $N_2O(g) \longrightarrow N_2(g) + O(g)$

Step 2. $N_2O(g) + O(g) \longrightarrow N_2(g) + O_2(g)$

i) Write the chemical equation for the overall reaction (4 marks)

ii) Identify any reaction intermediates (2 marks)

iii) What is the molecularity of each of the elementary reactions? (2 marks)

iv) What is the molecularity of the overall reaction? (2 marks)

b) The experimental rate law for the decomposition of ozone is second order in ozone and inverse first order in molecular oxygen (10 marks)

$$2\,O_3(g) \longrightarrow 3\,O_2(g) \qquad \text{Rate} = -\frac{\Delta[O_3]}{\Delta t} = k\frac{[O_3]^2}{[O_2]}$$

Show that the following mechanism is constituent with the experimental rate law, and relate the observed rate constant to the rate constants for the elementary reactions:

$$O_3(g) \underset{k_{-1}}{\overset{k_1}{\rightleftharpoons}} O_2(g) + O(g) \quad \text{Fast, reversible}$$

$$O(g) + O_3(g) \xrightarrow{k_2} 2\,O_2(g) \quad \text{Slow, rate-determining}$$

$$2\,O_3(g) \longrightarrow 3\,O_2(g) \quad \text{Overall reaction}$$

QUESTION FOUR (20 MARKS)

Rate constants for the gas-phase decomposition of hydrogen iodide, $H_2(g) + I_2(g)$, are listed in the following table;

Temperature (°C)	k ($M^{-1}s^{-1}$)	Temperature (°C)	k ($M^{-1}s^{-1}$)
283	3.52×10^{-7}	427	1.16×10^{-3}
356	3.02×10^{-5}	508	3.95×10^{-2}
393	2.19×10^{-4}		

a) Find the activation energy (in Kj/mol) using all five data points. You must plot the appropriate graph on the graph paper provided (10 marks)

b) Calculate E_a from the rate constants at 283 °C and 508 °C. (5 marks)

c) Given the rate constant at 283 °C and the value E_a obtained in part (ii), what is the rate constant at 293 °C? (5 marks)