RATES OF CHEMICAL REACTIONS

OBJECTIVES

1. To experimentally determine how the nature of the reactants, the concentration of reactants, the temperature and the presence of a catalyst affect the rates of reactions
2. To understand the relationship (or the lack of) between the rate of a reaction and its equilibrium constant

INTRODUCTION

The rate of a chemical reaction is the change in the concentration of a reactant or a product per unit time. Reactions occur when reactant molecules collide with the proper orientation and with energy equal to or greater than the activation energy. Several factors affect the rates of reactions. These are:

A. Nature of the reactants

Reaction rates of ions in aqueous solution are usually extremely fast. Reactions between covalent molecules tend to be slow and have higher activation energies because covalent bonds must be broken. In the case of solids, the reaction rate will depend on the amount of surface area. For example, a flat smooth piece of iron will rust much more slowly than iron filings.

B. Concentration

The reaction rate will usually increase with an increase in reactant concentration.

C. Temperature

In almost every case, the reaction rate will increase with increasing temperature. Roughly speaking, for every $10^{o}C$ rise, the rate of a reaction will double.

D. Catalyst

A catalyst is any substance that will increase the reaction rate without being consumed in the reaction. Catalysts lower the activation energy required for a reactive molecular collision usually by providing a surface on which the reactants can meet.

The equilibrium expression for the reaction $aA + bB \text{ ------> } cC + dD$ is given by

$$K = \frac{[C]^c[D]^d}{[A]^a[B]^b} \qquad (1)$$

The equilibrium constant is the same regardless of the concentration of the reactants. A catalyst will not change the numerical value of the equilibrium constant but it will change how fast the equilibrium is reached. Changes in temperature will change the equilibrium constant.

To repeat, a reaction rate tells you how long it will take to get to equilibrium. An equilibrium constant tells you the ratio of products to reactants at equilibrium, at a given temperature). They are two physically independent quantities. Hence, the rate of a reaction and its equilibrium constant are not related.

PROCEDURE

A. Nature of reactants

Get two small pieces of chalk ($CaCO_3$) that are approximately the same size. Place one piece of chalk in a well of your 12-well plate. Crush the other piece of chalk into small pieces. Place all the pieces into a second well. Add equal amounts of dilute hydrochloric acid to each well. Observe and compare the rate of evolution of carbon dioxide. Repeat if necessary to confirm your results.

B. Concentration

Place equal amounts of zinc pieces into two small test tubes. Place 2 mL of 6 M HCl into one of the tubes and 2 mL of 3 M HCl in the other. Compare the reaction rates.

C. Effect of temperature

The effect of temperature will be determined by observing the reduction of potassium permanganate by oxalic acid, according to the equation:

$$3H_2C_2O_4 + 2KMnO_4 \text{ ------> } 6CO_2 + 2KOH + 2H_2O + 2MnO_2 \qquad (2)$$

The permanganate ion, MnO_4^-, is deep purple. The reaction is complete when this purple color disappears.

Fill 3 wells in your micro-well plate one-half full of warmed saturated oxalic acid. Add 3 drops of a 0.10 M $KMnO_4$ solution to the first well. Using a watch with a second hand, measure the time in seconds for the purple color to disappear. Repeat 2 more times.

Then, fill 3 other wells one-half full of room temperature saturated oxalic acid. Add 3 drops of 0.10 M $KMnO_4$ to the first well. Measure the time required for the purple color to disappear. Repeat 2 more times.

D. Effect of catalysts

Hydrogen peroxide, H_2O_2, slowly decomposes at room temperature. Fill a well in your microplate one-half full with hydrogen peroxide. Observe. Add a few grains of manganese dioxide. Observe.

RATES OF CHEMICAL REACTIONS
LABORATORY REPORT

Name _____

Date _____

A. Nature of reactants

REACTANTS	OBSERVATIONS
Large chalk piece + HCl	
Crushed chalk piece + HCl	

B. Concentration

REACTION	OBSERVATIONS
Zn + 6 M HCl	
Zn + 3 M HCl	

C. Temperature

Warmed oxalic acid reaction times:

1. _____
2. _____ average time _____
3. _____

Room temperature oxalic acid reaction times:

1. _____
2. _____ average time _____
3. _____

D. Catalysts

REACTANTS	OBSERVATIONS
H_2O_2	
H_2O_2 + MnO_2	

QUESTIONS

1. a. Write the balanced equation for the reaction of chalk ($CaCO_3$) with HCl.

b. What does the reaction of chalk with HCl show you about reaction rates?

2. a. Write the balanced equation for the reaction of zinc and HCl.

b. Write the equilibrium expression for the reaction of zinc and HCl.

Keq =

c. Should the equilibrium expression change if the size of the zinc pieces changes? Why or why not?

d. Should the reaction rate change if the size of the Zn pieces changes? Why or why not?

e. When the concentration of HCl is increased, what happens to the reaction rate?

Is this what you expected? Why or why not?

3. a. What effect does temperature have on the reaction rate of oxalic acid and permanganate?

b. Will temperature have an effect on the equilibrium constant of this reaction?

4. a. Write the balanced equation for H_2O_2 decomposition in the presence of MnO_2. The products are water and oxygen gas.

b. What effect does MnO_2 have on the reaction rate of the decomposition of hydrogen peroxide?

c. What effect does MnO_2 have on the equilibrium constant?

5. a. Does adding a catalyst to a given reaction shift the equilibrium so that more product is produced?

b. What is the main purpose of a catalyst?