EXPERIMENT 18A

Factors Affecting Reaction Rate

For a given set of conditions, every chemical reaction occurs at a characteristic rate. Chemical engineers are often interested in discovering ways to increase the rates of slow reactions, particularly when they are important to industrial processes. In industry, the general goal is to produce a top-quality material as quickly, efficiently, and cheaply as possible under the constraints of environmental and safety considerations.

The rate of a chemical reaction is determined by a large number of factors. Some reactions will take place very slowly under any conditions, while others are extremely rapid under any conditions. Most reactions can be affected by changing the conditions under which the reactions take place.

A chemical reaction occurs when the reacting particles have an effective collision that results in the formation of new particles. If the number of effective collisions can be controlled, then the rate of the reaction can be controlled. Some of the ways that can be used to change the number of collisions include changing the concentrations of the reactants, changing the surface area of the reactants, or changing the speed at which the particles are moving. The speed at which particles are moving is affected by temperature changes.

In order to observe the effect of each change, this experiment is divided into three parts. Each part varies only one condition: concentration of one reactant (Part I), surface area of one reactant (Part II), or temperature (Part III). Each of these factors will have an effect on the reaction rate, which you will measure.

Magnesium metal will be combined with hydrochloric acid in this experiment. The products of this reaction are hydrogen gas and magnesium chloride. The rate of the reaction is easily noted because the magnesium metal will be completely used up.

OBJECTIVES

1. to observe and record the effect of reactant concentration on the reaction rate
2. to observe and record the effect of reactant surface area on the reaction rate
3. to observe and record the effect of reactant temperature on the reaction rate

MATERIALS

Apparatus

3 beakers (250 mL)
4 test tubes (18 mm × 150 mm)
centigram balance
test tube rack
graduated cylinder (25 mL)
stirring rod
marking pen
stop watch or watch with second hand
thermometer
hot plate
sandpaper or emery cloth
scissors
metric ruler
safety goggles
lab apron
full face shield
plastic gloves

Reagents

0.5*M* hydrochloric acid
1.0*M* hydrochloric acid
3.0*M* hydrochloric acid
6.0*M* hydrochloric acid
magnesium ribbon
ice cubes

PROCEDURE

Part I Effect of Concentration on Reaction Rate

1. Put on your lab apron and safety goggles. In this experiment, you will be working with hydrochloric acid in several different concentrations.
2. Obtain a piece of magnesium ribbon from your teacher. Use the sandpaper to remove any coating from the outside of the metal. You will need a total of eleven pieces of magnesium that are each 1 cm long. Using the metric ruler and scissors, carefully cut an 11 cm strip of magnesium. Determine the mass of this strip using the balance. Record this value in your notebook. Now cut eleven pieces from the large strip of magnesium. It is important that each piece be exactly the same length so that the amount of magnesium does not change in each of the reactions. Divide the mass of the large strip by 11 to get the average mass of each 1 cm piece. Record this value in your notebook.
3. With a marking pen, label four test tubes with the appropriate concentration of acid to be added (6*M*, 3*M*, 1*M*, 0.5*M*).
4. Using a graduated cylinder, carefully measure 10 mL of each of the concentrations of acid and place in the appropriate test tube.
5. Starting with the lowest concentration first (0.5*M*), place the 1 cm piece of magnesium in the test tube containing the acid. Begin timing as soon as the magnesium comes into contact with the acid. Record the time it takes for all the magnesium to react in your copy of Table 1.
6. Repeat this procedure with each of the concentrations of acid. Calculate the average reaction rate by determining the grams of magnesium used per second. Record these values in Table 1.
7. Clean up according to the reagent disposal instructions.

CAUTION: Hydrochloric acid is corrosive to skin, eyes, and clothing. When handling the hydrochloric acid, wear safety goggles, lab apron, plastic gloves, and use a full face shield. Wash any spills or splashes immediately with plenty of water. Call your teacher.

Part II Effect of Surface Area on Reaction Rate

1. Relabel three test tubes as *A*, *B*, and *C*. Place 10 mL of 1.0*M* hydrochloric acid in each of the test tubes.
2. For this part of the experiment, you will need three 1 cm pieces of magnesium. Take one piece and use the scissors to cut the strip into as many slivers as possible. Be careful not to lose any of the slivers, as this will affect the results. Place the slivers in test tube *A*. In your copy of Table 2 in your notebook, record the time it takes for all of the magnesium to react. Take the second piece of magnesium. Fold and bend the piece so that it is rolled up as tightly as possible. Place the rolled magnesium into test tube *B*. Record the time it takes for the magnesium to react in Table 2.
3. The third piece will be left as is. Add this piece to test tube *C*. In Table 2, record the time that it takes for all the magnesium to react.
4. Rinse the test tubes and go on to Part III.

Part III Effect of Temperature on Reaction Rate

1. Label four 250 mL beakers *A*, *B*, *C*, and *D*. Add about 150 mL of water to beaker *A*. Place this beaker on a hot plate and begin heating to a temperature close to the boiling point of water. Add 150 mL of hot tap water to beaker *B*. You will want water that is approximately 50°C. If you need to raise the temperature slightly, put beaker *B* on the hot plate. In beaker *C*, you will have 150 mL of room temperature water. Record the exact temperature in your notebook. In beaker *D*, you will have 150 mL of ice and water that is approximately 0°C.
2. Place 10 mL of 1.0*M* hydrochloric acid into each of four test tubes. Place one of the test tubes into each of the beakers so that the acid will reach the temperature of the water in the beaker. Use the thermometer to check that the temperatures of the acids in the test tubes match those of the water baths. Do not proceed until they match.
3. Measure and record in your notebook the temperature of each test tube. Then, as in Part I, place a 1 cm magnesium strip in each of the test tubes, and record the amount of time necessary for the reaction to go to completion in your copy of Table 3.
4. Clean up all the materials. Before leaving the laboratory, wash your hands thoroughly with soap and water; use a fingernail brush to clean under your fingernails.

REAGENT DISPOSAL

Return any unused magnesium metal to the designated container. HCl solutions left in the test tubes after the reaction has finished should be returned to another designated container for neutralization before being discarded down the sink.

POST LAB DISCUSSION

In this experiment, you examined the effects of concentration, surface area, and temperature on the reaction between hydrochloric acid and magnesium. A reaction occurs only when an effective collision takes place between the particles involved. You will be asked to explain, in molecular terms, how each of these factors can change the number of effective collisions. The following review may help you.

Surface area is the actual area of a substance that is exposed in the reaction. If you can visualize a cube that is one metre on each side, you should be able to see that the surface area is equal to six times the area on one face of the cube. Thus the surface area of the cube is six square metres. If the cube is cut in half once, there is an increase in surface area because in addition to the faces that were previously exposed, two more faces are exposed. Thus the total surface area of the two shapes would be eight square metres.

The temperature of a sample is described as a measure of the average kinetic energy of its particles. The higher the temperature, the higher the average kinetic energy. Kinetic energy depends on two factors: the mass and the speed of the particles. Since the mass of the particles does not change when heated, the increase in kinetic energy is due to the increased speed of the particles involved.