Kinetics and Catalysis

Background

Kinetics is the study of rates of chemical reactions. Sometimes it is useful to speed up desired reactions or to inhibit unwanted reactions, so understanding the principles that influence reaction rates can be practical. Conversely, the rates of reactions can reveal information about the precise pathway, or **mechanism**, by which a reaction occurs.

In general, the rate of a simple chemical reaction is proportional to the concentrations of the reactants, because the more reactant molecules are present, the more likely it is that some of them will react. If the reaction involves more than one molecule, increasing the concentrations increases the probability of the reacting molecules meeting. Most reactions are faster at higher temperature, because the greater speed increases the frequency of meetings, and the greater kinetic energy more easily overcomes any activation barrier.

A catalyst is a substance thet speeds up a reaction without itself being consumed in the reaction. Catalysts typically lower the activation energy of a reaction, or facilitate a different reaction pathway with a lower activation energy.

Objective

Observe the effect on reaction rate of increasing the partial pressure of a reactant. Observe the effect of a catalyst on a chemical reaction, and observe the effect of temperature on reaction rate.

Safety

Wear chemical splash goggles and gloves. Wear closed-toed shoes and long pants.

Reaction 1. Collecting Oxygen

Introduction

This is a necessary preparation step for the other reaction. You will collect oxygen gas produced by the decomposition of household hydrogen peroxide. The balanced equation for this reaction is

$$2\ H_2O_2 \rightarrow 2\ H_2O + O_2$$

The reaction is favorable, but it happens only very slowly at normal temperatures. In this activity we will use a catalyst to accelerate the reaction. The catalyst is the enzyme catalase, which is found in many living organisms, including humans. We will use catalase from yeast.

The oxygen gas is conveniently collected by water displacement. This is accomplished by holding a water-filled collection flask inverted under water and filling it with gas expelled through plastic tubing from the stoppered reaction flask.

Materials

<u>Equipment:</u> Erlenmeyer flasks (2), one-hole rubber stopper, flexible tubing, glass rod

<u>Consumables:</u> yeast, water, 3% hydrogen peroxide solution

Procedure

Set up the collection flask by submerging it in a tub of water. Tip the flask so that all its air escapes and invert it so that the mouth is downward. Pour 3% hydrogen peroxide into the other flask, to make it about half full. Have the rubber stopper with flexible tubing ready for the transfer.

When you are ready to go, add about 1 mL of the yeast suspension to the hydrogen peroxide solution. Place the stopper with flexible tubing in the flask, and place the other end of the tubing in the water in the tub. Allow several mL of gas to bubble form the end of the tube to flush the air from the system, and then set up the tube and collection flask so that the oxygen gas bubbles into the collection flask.

When the collection flask is filled, stopper it and remove it from the tub of water.

Wastes

The only waste from this particular activity is the yeasty former hydrogen peroxide solution. This can be poured down the drain. Wash and drain the flask.

Questions

1. When yeast was combined with hydrogen peroxide, what happened?

2. Why is the oxygen gas collected under water instead of just letting the oxygen flow into an empty (air-filled) flask?

3. What did you need to do to maintain oxygen production?

4. What factors influenced the reaction rate of hydrogen peroxide decomposition? What effect did they have?

Reaction 2. Combustion

Introduction

This is a comparison of reaction rates when a gaseous starting material (oxygen) is present in different concentrations. The title reaction is the rapid oxidation of iron in air. Another reaction in this activity is the combustion (burning) of wood.

Materials

Equipment: tongs, glass rod

Consumables: steel wool of different coarseness, matches, 2 flasks of oxygen, candle (optional), wooden splint, sand

Procedure

Wood

First, try the wooden splint. Light it on fire and let it burn for a little while so that about a 2-cm length is burning. Then blow it out so that it is glowing rather than flaming. Then insert the glowing end (you weren't trying to hold it by the glowing end, were you?) into the flask of oxygen.

5. What happens?

Steel wool

Now do basically the same thing with steel wool.

First, briefly uncork your flask of oxygen gas and pour a layer of sand into it. (This is to shield the glass bottom of the flask from the extreme temperature of the reaction.)

Get a wad of *coarse* steel wool small enough to easily drop into your flask of oxygen. It's hard to get steel wool to "burn" in air; you never get a flame. But if you hold it over a flame, the burning part will glow orange. Hold the wad over a flame with tweezers or tongs. When a little begins to glow orange, set it down on the ceramic tile.

6. What happens?

First double-check that the flask of oxygen has a layer of sand on the bottom. Light the wad of streel wool again. This time, immediately move the glowing steel wool from the flame to the flask of oxygen.

7. What happens?

Repeat the same experiments with fine steel wool.

8. Compare the reactions of the fine steel wool to the reactions of the coarse steel wool.

Wastes

The waste from this activity is burned and unburned wood and steel wool. First, make sure that all materials are "cold out": no burning or glowing wood or steel wool, and all materials cold to the touch. Once they are cold out, the materials may be discarded in the trash.

Questions

9. What are the products of the combustion of steel wool?

10. How did pure oxygen affect the rates of the combustion reactions?

11. Write the rate expression for the forward reaction of combustion of steel wool. How does the rate expression explain the effect of carrying out the reaction in pure oxygen?

Scoring

Lab technique, safety, procedure, housekeeping	5 points
Answers to Questions	20 points