**Catalysts**

*Introduction*

Catalysts are substances that change the rate of a chemical reaction but are not consumed in a chemical reaction. An excellent example of the effect on a catalyst in increasing reaction rates is the effect of either cupric ions or iodide ions on the decomposition of hydrogen peroxide. Hydrogen peroxide is a thermodynamically unstable material that can readily be oxidized to produce dioxygen or reduced to produce water. Hydrogen peroxide actually spontaneously decomposed, disproportionating to give dioxygen and water (Equation 1). Normally, this

2 H2O2(aq) 🡪 2 H2O(l) + O2(g) (Eqn. 1)

decomposition takes place slowly; thus, one can keep an aqueous solution of hydrogen peroxide in the dark in one’s bathroom for months. However, the addition of a catalyst can dramatically increase the rate of this decomposition. The demonstration will demonstrate the effects of cupric ions and iodide ions as catalysts. The catalyzed reactions are shown in Equations 2 and 3. Note

2 Cu2+(aq) + H2O2(aq) 🡪 2 Cu1+(aq) + O2 + 2 H+(aq) (Eqn. 2)

2Cu1+(aq) + H2O2(aq) + 2 H+(aq) 🡪 2 Cu2+(aq) + 2 H2O(l)

2 H2O2(aq) 🡪 2 H2O(l) + O2(g)

I-(aq) + H2O2(aq) 🡪 2 IO-(aq) + H2O(l) (Eqn. 3)

IO-(aq) + H2O2(aq) 🡪 I-(aq) + H2O(l) + O2(g)

2 H2O2(aq) 🡪 2 H2O(l) + O2(g)

in each case that the cupric ions or iodide ions consumed in the first step are produced in the second step so that they disappear in the overall equation, which is identical to that of the simple decomposition reaction (Eqn. 1). The catalyst work to change the rate of the reaction by changing the mechanism by which the reaction occurs.

*Demonstration*

Materials

1. Decomposition of peroxide

0.5 g CuCl2.2H2O

20 mL of 30 % H2O2

250-mL beaker

100-mL graduated cylinder

Waste bottle

1. “Elephant Toothpaste”

80 mL of 30 % H2O2

40 mL of dishwashing liquid

15 g KI dissolved in minimum volume of water in small beaker

500-mL graduated cylinder

100-mL graduated cylinder

Plastic container to place under 500-mL graduated cylinder

Waste bottle

Procedure

**Decomposition of Hydrogen Peroxide**

Add 20 mL of hydrogen peroxide to beaker. Add copper chloride. Solution will rapidly start to form bubbles and then boil. When the reaction is complete, a blue solution of hydrated cupric ions remains. Thus, the cupric ions are not consumed in the process.

**“Elephant Toothpaste”**

Add the 80 mL of 30 % hydrogen peroxide and 40 mL of detergent to the 500-mL graduated cylinder and place the cylinder in the large plastic container, which will collect of the foam about to be generated. Pour the KI solution in the graduated cylinder. The rapid evolution of O2 gas and potentially steam from the decomposition of the peroxide will generate a foam that resembles toothpaste coming from a tube of toothpaste.

**Safety Notes:** Safety goggles are required for all experiments.

Hydrogen peroxide is an extremely reactive chemical and should be handled with care. Wearing gloves is recommended when handling this chemical. Spills should be cleaned with large volumes of water. If contact is made with your skin, rinse thoroughly with water. The reactions also are quite exothermic and become very hot; contact with the reactions and containers during the course of the peroxide decomposition should be avoided.

The copper salts are toxic chemicals. Gloves should be worn when handling these chemicals. Additionally, the iodine-containing species can stain skin and other items; gloves should be worn handling the product of the elephant toothpaste reaction.

Unwanted chemicals are not to go down the drain but should be placed in appropriate waste containers.