Lab 22: Catalysts

Concepts to explore:

- Evaluate different catalysts to determine which one is the best choice
- Illustrate the differences between using heterogeneous and homogeneous catalysts
- Demonstrate how varying quantities of a catalyst affect the reaction

Introduction

Why do bubbles form when you put hydrogen peroxide on a wound?

Figure 1: Adding a catalyst can drastically speed up the rate of a chemical reaction. Catalysts play a direct role in the environment and in biology, and are often used in industrial applications for food processing and chemical refinement.

Ouch! You just scraped your knee. After you hobble to a sink to wash it off, you apply some hydrogen peroxide. Small bubbles start forming almost immediately. Why? The reason is because blood and tissue contain a certain enzyme that accelerates the decomposition reaction of hydrogen peroxide forming oxygen gas and water. The enzyme is a biological **catalyst**. When there is a need for speed in a reaction, using a catalyst is often the best method.

Many chemicals the human body needs are made within the cells. This means the human body has a need for super-fast chemical reactions. A high reaction temperature or a large concentration of the reactants will often sufficiently speed up a reaction in the laboratory. But our cells cannot rapidly increase their temperature or suddenly increase the availability of certain chemicals. Instead, the human body uses catalysts. A catalyst is a substance that speeds up a reaction, but is not consumed during the reaction. Biological catalysts are called enzymes. There are many different types of enzymes, and each type speeds up a certain reaction your body needs to have happen right then! Without catalysts your body could not do even the simplest task.

Reactions have a minimum amount of energy required to occur. This is called the **activation energy**. A catalyst will lower the activation energy by requiring less energy for the reaction to occur. Chemists cannot always speed up a reaction by changing the usual variables, and reactions that take a long time are seldom very useful. For this reason, chemists often add catalysts to speed up reactions.

After a chemist decides to use a catalyst, there are several things that have to be studied. One of the biggest challenges is finding the ideal catalyst for a particular reaction. Frequently several catalysts are found that will work, and they are compared to determine which is best. Some of the factors that a chemist will take into consideration include the desired speed of the reaction, the cost of the catalyst, how long the catalyst will work, and if it is toxic or harmful to the environment. Another characteristic to consider is a catalyst's phase. A **heterogeneous catalyst** is in a different state of matter (phase) than the reactants when it is applied, while a **homogeneous catalyst** is applied in the same phase. Generally, homogeneous catalysts will react faster, but heterogeneous catalysts are easier to separate from the products.

In addition to the enzymes in blood and tissue, there are several other catalysts that can be used to accelerate the reaction to decompose hydrogen peroxide into water and oxygen gas. Manganese dioxide, many fruits and vegetables, household bleach, and even soil can all be used to catalyze this reaction. A piece of a carrot put into a solution of hydrogen peroxide is an example of a heterogeneous catalyst, as the carrot is in a solid phase and the hydrogen peroxide is in a liquid phase. If

instead the carrot is made into a juice and added to the hydrogen peroxide solution, it is a homogeneous catalyst since it is then in the liquid phase.

Chemists also have to determine the optimal amount of a catalyst present in the reaction. If a catalyst is very expensive, toxic, or hard to remove from the product, they may use the least amount of catalyst that will work. If instead there is a need to have the reaction happen more rapidly, a chemist may choose to add more catalyst. There is a point however, where adding more catalyst will not increase the reaction rate. This is because there is as much or more catalyst than the limiting reactant.

Pre-lab Questions

1. What is a catalyst?

2. If you continue to add more catalyst will the speed of a reaction always continue to increase? Explain your answer.

3. In this lab you will produce oxygen and water from hydrogen peroxide (H_2O_2). Write a balanced reaction equation for this reaction.

4. What causes the bubbles to form in this reaction?

5. The exhaust gas from car engines pass through catalytic converters that contain very small amounts of solid platinum, palladium, and rhodium catalysts. Are these metals homogeneous or heterogeneous catalysts?

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Experiment: Reactions with Catalysts

In this laboratory exercise, you will evaluate carrots, tomatoes, yeast, and soil as catalysts to decompose hydrogen peroxide. You will also observe the differences between using a piece of carrot or carrot juice as a catalyst for this reaction. Finally, you will observe the effects of adding different amounts of carrot juice on the reaction rate.

Materials

Safety Equipment: Safety goggles, gloves

11 test tubes	250 mL beaker
10 mL graduated cylinder	Stir rod
Hydrogen peroxide (H_2O_2)	Soil
Yeast	Warm water (45°C)*
3 Droppers (pipettes)	Small piece of a carrot*
2 Test tube racks	Small piece of a tomato*
	*You must provide

Procedure

Part 1: Comparison of Different Catalysts

1. Place 11 test tubes in the test tube racks.
2. Use the permanent marker to label 5 of the test tubes **C**, **T**, **D**, and **Y**, symbolizing carrot, tomato, soil, and yeast. **HINT**: It's best to clearly label glassware to prevent cross contamination.
3. Mix 100 mL warm water (45°C) with one packet of yeast in a 250 mL beaker. Stir with the stir rod until dissolved.
4. Use a 10 mL graduated cylinder and a pipette to add 3 mL of hydrogen peroxide to EACH of the 5 **labeled** test tubes.
5. Carefully add a small piece (approximately 1 cm^2) of carrot to the test tube labeled **C**, and a small piece of tomato to the test tube labeled **T**. Add a similar small amount of soil to the test tube labeled **D**.
6. Measure 3 mL of yeast solution into a clean 10 mL graduated cylinder. Slowly add the yeast solution to the test tube labeled **Y**. Swirl until all bubbling and foaming stops. This will indicate the completion of the reaction.
7. Record observations for each of the reactions in the Initial Observations column in Table 1 in the Data section. Let the reactions continue until the end of the next part of the procedure.

Part 2: Catalyst Quantity Comparison

7. Use a permanent marker to label the 6 remaining test tubes, **1**, **5**, **10**, **1A**, **5A**, and **10A**.

8. Fill test tube **1A**, **5A**, and **10A** with 1 mL, 5 mL, and 10 mL of yeast solution respectively.
9. Use a 10 mL graduated cylinder and pipette to add 1 mL of hydrogen peroxide to the test tubes labeled **1**, **5**, and **10**.
10. **Simultaneously** (or as close to the same time as possible) pour the yeast solution from test tubes **1A**, **5A**, and **10A** into the corresponding test tubes **1**, **5**, and **10** containing the hydrogen peroxide.
11. Record your observations of the three reactions in Table 2 of the Data section. **HINT**: Be sure to note observations both of similarities and differences in the bubbling and foaming among the reactions.
12. Return to the test tubes in Part 1 and make final observations. Record your observations in the Final Observations Column in Table 1 of the Data section.

Data

Table 1: Catalyst comparison observations

Type of Catalyst	Initial Observations	Final Observations
Carrot		
Tomato		
Soil		
Yeast		

Table 2: **Catalyst quantity observations**

Amount of yeast	Observations
1 mL	
5 mL	
10 mL	

Post-lab Questions

1. Classify each catalyst you used as homogeneous or heterogeneous.

   Homogeneous catalysts:

   Heterogeneous catalysts:

2. Which catalyst made the reaction go the fastest? Is it a homogeneous or heterogeneous catalyst?

3. Which catalyst would be the easiest to remove from the water that was formed? Is it a homogeneous or heterogeneous catalyst?

4. Which amount of yeast solution you tested would be the best to use? Explain your answer.