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Sudsy Kinetics Chemical Demonstration Kit

Introduction

Teach kinetics concepts in a fun and sudsy way! This demonstration provides an interesting twist on the traditional "Old Foamey" or "Elephant Toothpaste" reaction. Not only will your students be amazed at the sudsy eruption—they will learn kinetics concepts along the way!

Chemical Concepts

- Kinetics/Catalysts
- Reaction intermediates
- Decomposition reactions
- Test for oxygen gas

Materials Needed (for each demonstration)

Chemicals

Hydrogen peroxide, H₂O₂, 30%, 20 mL*

Hydrogen peroxide, H₂O₂, 10%, 20 mL*

Hydrogen peroxide, H₂O₂, 3%, 20 mL*

Alconox[®] detergent, 3–4 g*

Sodium iodide solution, NaI, 2 M, 4–5 mL*

Tap water

Equipment

Graduated cylinders, 10-mL, 3

Graduated cylinders, 100-mL, 3

Graduated cylinders, 500-mL, 2
or Erlenmeyer flasks, 500-mL, 2

Large, plastic demonstration tray, several inches deep

Lighter or matches

Spoon or scoop

Wood splint

*Materials provided in kit

Safety Precautions

Hydrogen peroxide solution, 30%, is severely corrosive to the skin, eyes, and respiratory tract: very strong oxidant. Dangerous fire and explosion risk. **Do not** heat this substance. Sodium iodide is slightly toxic by ingestion. Although the Alconox detergent is considered nonhazardous, do not ingest the material. Do not stand over the reaction; steam and oxygen are produced quickly. Wear chemical splash goggles, chemical-resistant gloves, and a chemical-resistant apron. Please review current Material Safety Data Sheets for additional safety, handling, and disposal information.

Procedure

Part 1. Effect of Concentration on the Rate of the Reaction

1. Place three 100-mL graduated cylinders in a large, plastic demonstration tray. See Tips if one is not available.
2. Add 20 mL of 30% hydrogen peroxide to the first cylinder, 20 mL of 10% hydrogen peroxide to the second cylinder, and 20 mL of 3% hydrogen peroxide to the third cylinder.
3. Add 1 small scoop (3–4 g) of solid Alconox[®] detergent to each cylinder and swirl to dissolve the detergent.
4. Measure out 5 mL of 2 M sodium iodide solution in each of three 10-mL graduated cylinders. Ask your students to predict the order at which each of the peroxide solutions will react with the iodide.

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5. Ask for three student volunteers. Make sure the students are wearing chemical splash goggles; warn them to step back as soon as they pour. Have the students simultaneously pour the sodium iodide solution into the three cylinders containing the differing concentrations of hydrogen peroxide. Make observations. White foam erupts from the cylinder with the 30% peroxide the fastest, the 10% peroxide next, and only slowly rises up from the cylinder with 3% peroxide.

Part 2. Old Foamey—Observing a Reaction Intermediate and Products

1. Place a 500-mL graduated cylinder in a large, plastic demonstration tray.
2. Measure out 20 mL of 30% hydrogen peroxide and add it to the cylinder.
3. Add 1 small scoop (3–4 g) of solid Alconox[®] detergent to the cylinder and swirl the mixture to dissolve the detergent.
4. Measure out 5 mL of 2 M sodium iodide solution and, quickly but carefully, pour this into the cylinder. In a few seconds, copious amounts of white foam will be produced. Observe closely at the beginning of the reaction. A brown foam is produced at first but then turns white before it erupts out of the cylinder. This is due to the presence of the free iodine produced by the extreme oxidizing ability of the 30% hydrogen peroxide. (See Discussion.)
5. Notice the steam coming off from the foam—this indicates that the decomposition reaction is quite exothermic.
6. Light a wood splint and blow out the flame. Insert the glowing wood splint into the foam. The wood splint will re-ignite in the foam—this indicates that the gas in the foam is pure oxygen. Take the glowing splint out of the foam, re-insert it, and watch it re-ignite again. This can be repeated numerous times.

Part 3. Comparing the Rate of the Reaction with its Stoichiometry

Purpose: In this part, the total number of moles of peroxide is the same in each container, although one has been diluted with water. An equal volume of foam is produced by both but at different rates, with the more concentrated one reacting faster. The more dilute one will eventually produce an equal amount of product. This demonstrates that the *rate* at which the product is produced is not necessarily related to the *amount* of product.

1. Carefully measure out 15 mL of 30% hydrogen peroxide and add it to a 500-mL graduated cylinder or Erlenmeyer flask.
2. Again, carefully measure out 15 mL of 30% hydrogen peroxide and add it to a different 500-mL graduated cylinder or Erlenmeyer flask. To this second cylinder or flask, also add 30 mL of tap water.
3. Add a scoop (3–4 g) of Alconox[®] detergent to each cylinder or flask. Swirl to dissolve the detergent.
4. Place both containers in the center of a large, plastic demonstration tray.
5. Ask for two student volunteers. Again make sure they are wearing goggles and are warned to step back. Have them add 4 mL of 2 M sodium iodide solution to each of the two cylinders. The reaction will turn brown immediately and white foam will rise up out of each cylinder, with the more concentrated mixture rising more rapidly. However, keep observing! Compare the final volume of foam produced by each reaction. The diluted peroxide will eventually produce the same amount of foam since an equal number of moles of hydrogen peroxide were used in each reaction.

Disposal

The foam and any solution left in the cylinder or on the plastic tray may be rinsed down the drain with excess water according to Flinn Suggested Disposal Method #26b. Please consult your *Flinn Chemical & Biological Catalog/Reference Manual* for proper disposal procedures.

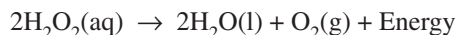
Tips

- In this kit, enough chemicals are provided to perform all 3 parts of the demonstration 7 times: 500 mL of 30% hydrogen peroxide, 140 mL each of 10% and 3% hydrogen peroxide, 200 mL of 2 M sodium iodide solution, and 200 g of Alconox detergent.
- Each part of the demonstration is designed to teach a different concept in chemistry. First perform Part 1 with the three concentrations of peroxide, discussing how rate is dependent on concentration. Ask students which one they would like to see again—they will surely choose the 30% one. Then perform Part 2 in a larger graduated cylinder, this time discussing the reactions that are occurring, the brown iodine intermediate, production of heat, and the formation of water and oxygen gas. Finally perform Part 3 in flasks. Discuss the stoichiometry of the decomposition reaction and use the ideal gas law ($PV = nRT$) to calculate the volume of gas that should be produced.

- The decomposition reaction is exothermic and the cylinder will become very hot. Be sure to let it cool before handling.
- This demonstration can be easily and safely scaled up for larger audiences. A 500-mL or 1-L Pyrex® graduated cylinder works well in this case.
- If no large plastic demonstration tray is available, consider using a plastic bag taped to the demonstration area or perform this demonstration in a laboratory sink.
- The safe products of this reaction, as well as the generous amount of detergent, makes cleanup very easy.

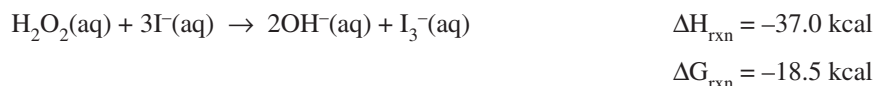
Discussion

Hydrogen peroxide decomposes to produce oxygen and water according to the decomposition reaction shown below

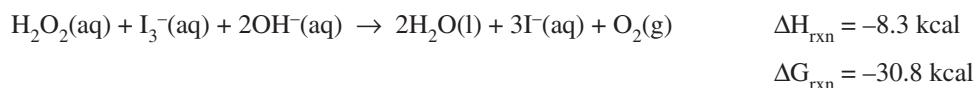


The reaction is quite slow unless catalyzed by a substance such as iodide ions, manganese metal, manganese dioxide, ferric ions, and many other substances such as yeast or even blood. A *catalyst* is a substance that, when added to a reaction mixture, participates in the reaction and speeds it up, but is not itself consumed in the reaction. The iodide ion is used as a catalyst in this demonstration. While the complete mechanism is not known, the observations of this reaction are consistent with the following reactions

Step 1: Hydrogen peroxide and iodide mix to cause spontaneous formation of the brown color from the I_3^- intermediate with very little foam. This reaction shows that the catalyst is indeed participating in the reaction.



Step 2: The intermediates then combine with additional hydrogen peroxide to cause the spontaneous disappearance of the brown color with the production of copious amounts of foam containing oxygen gas. The I^- is regenerated in the reaction, showing that the catalyst is not consumed in the reaction.



Overall Reaction: Combining Steps 1 and 2 gives the overall reaction shown below. Notice that the enthalpy or heat of reaction (ΔH_{rxn}) is a negative value, indicating that the reaction is exothermic and releases heat. The free energy of the reaction (ΔG_{rxn}), which takes into account not only the enthalpy but also the entropy of the reaction, is also a negative value, indicating that the reaction takes place spontaneously. If the reaction occurs spontaneously, then why is a catalyst needed? The iodide catalyst causes the reaction to occur at a reasonable rate—without it, the reaction would occur, but so slowly that it would not be observable.



Why all the foam? The volume of oxygen that is released from the reaction can be calculated using 15 mL (as in Part 3) of 30% hydrogen peroxide. Hydrogen peroxide solution (30%) has a specific gravity of 1.11 g/mL. Therefore, the mass of solution can be determined

$$1.11 \text{ g/mL} \times 15 \text{ mL} = 16.7 \text{ g of solution}$$

Since only 30% of the total volume of solution is H_2O_2 , then

$$30\% \text{ of } 16.7 \text{ g of solution} = 5.01 \text{ g of } \text{H}_2\text{O}_2$$

Since the molecular weight of H_2O_2 is 34.02 g/mol, the number of moles of H_2O_2 can be calculated

$$5.01 \text{ g} \times 1 \text{ mole}/34.02 \text{ g} = 0.147 \text{ mol of } \text{H}_2\text{O}_2 \text{ used}$$

From the balanced equation, there is a 2 to 1 ratio of hydrogen peroxide to oxygen gas. Thus, the number of moles of O_2 released can be determined

$$0.147 \text{ mol } \text{H}_2\text{O}_2 \times 1 \text{ mole } \text{O}_2/2 \text{ mol } \text{H}_2\text{O}_2 = 0.0736 \text{ mol } \text{O}_2$$

This shows that the reaction should produce 0.0736 moles of oxygen gas. To determine the volume of this amount of gas, use the ideal gas law, $PV = nRT$, assuming a reaction temperature of the steaming foam of approximately 100 °C (or 373 K) and standard pressure (1 atm). Solving for volume, $V = nRT/P$, where $n = 0.0736$ mol, $R =$ ideal gas constant $= 0.0821$ L·atm/mol·K, $T = 373$ K and $P = 1$ atm, the volume of oxygen gas can be calculated

$$V = (0.0736 \text{ mol}) (0.0821 \text{ L}\cdot\text{atm/mol}\cdot\text{K}) (373 \text{ K})/1 \text{ atm} = 2.25 \text{ L O}_2.$$

The volume of oxygen expected, then, is 2.25 liters. Discuss with your students how they could have predicted that the foam would overflow out of the 500-mL container using this calculation.

Student Exercise: Calculate the volume of foam that will be produced by 3% hydrogen peroxide, which has a specific gravity of 1.01 g/mL. Compare this to the 30% peroxide. Will the foam rise up and overflow out of a 500-mL container? Using the same procedure and steps as shown above, the volume of oxygen expected from 15 mL of 3% H₂O₂ is approximately 205 mL, using 100 °C (373 K). This is a high estimate since the reaction temperature is most likely less than 100 °C. Perhaps have students repeat the experiment, measuring the temperature of the reaction and then performing the calculations. The students can conclude that the foam will not overflow out of a 500-mL container. Finally, perform the demonstration for the students with 3% hydrogen peroxide. Allow students to determine if experimental results support their calculated results.

Connecting to the National Standards

This laboratory activity relates to the following National Science Education Standards (1996):

Unifying Concepts and Processes: Grades K–12

Evidence, models, and explanation

Content Standards: Grades 5–8

Content Standard B: Physical Science, properties and changes of properties in matter

Content Standards: Grades 9–12

Content Standard B: Physical Science, structure and properties of matter, chemical reactions, interactions of energy and matter

Answers to Worksheet Questions

Part 1. Data Table

	Cylinder #1	Cylinder #2	Cylinder #3
Concentration of H₂O₂	30%	10%	3%
Chemicals added	<i>Detergent and 5 mL of sodium iodide</i>	<i>Detergent and 5 mL of sodium iodide</i>	<i>Detergent and 5 mL of sodium iodide</i>
Observations	<i>Foam erupted quickly from the cylinder.</i>	<i>Foam rose from the cylinder at a slower rate than cylinder #1.</i>	<i>Foam rose very slowly inside the cylinder.</i>

Part 2. Data Table

Chemicals used	<i>20 mL of 30% hydrogen peroxide, detergent, and 5 mL of sodium iodide solution</i>
Color of foam	<i>The foam is initially brown, but quickly turns white. Steam also rises from the foam.</i>
Glowing splint test	<i>When a glowing wood splint is placed in the foam, it ignites.</i>

Part 3. Data Table

	Cylinder #1	Cylinder #2
Concentration of H ₂ O ₂	30%	30%
Volume of water added	0 mL	30 mL
Observations	Foam erupted quickly from the cylinder.	Foam rose from the cylinder at a slower rate than cylinder #1, but the same amount of foam was produced.

Answers to Questions

1. Based on what you observed in Part 1, what conclusions can you make about the relationship between concentration and rate of reaction?

Concentration is directly proportional to rate of reaction. The lower the concentration is, the lower the reaction rate is, and therefore the longer the reaction takes. Also, reactants with lower concentrations seem to yield less product.

2. Consider the reactants in Part 2.

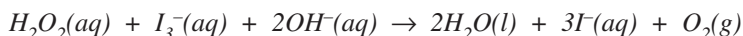
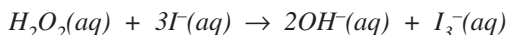
- a. What is responsible for the initial brown color of the foam?

The free iodine produced by the oxidation of sodium iodide by the hydrogen peroxide results in an initial brown color in the foam.

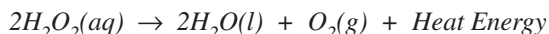
- b. What is responsible for the wood splint re-igniting?

Oxygen, a flammable gas released by the decomposition of hydrogen peroxide, caused the wood splint to re-ignite.

3. Write a chemical equation for each of the two steps in this reaction. In the first, hydrogen peroxide reacts with iodide ion from the sodium iodide. In the second, hydrogen peroxide reacts with the products of the first reaction.



4. Write the chemical equation for the overall decomposition of hydrogen peroxide. Include heat energy in the equation. Is this reaction endothermic or exothermic? What evidence do you have to support this?



This reaction is exothermic, as evidenced by the steam that rose off of the foam that was produced.

5. Explain why the reactions in Part 3 produced the same amount of foam but had different reaction times. *Hint:* Keep in mind the concentration of hydrogen peroxide before water was added to the second cylinder.

The moles of peroxide were the same in each cylinder, even though the concentrations were different due to one being diluted with water. Higher concentration results in a higher reaction rate, but a higher rate does not result in more product, which depends on its stoichiometry.

Acknowledgment

Special thanks to Walter Rohr of Eastchester High School in Eastchester, NY for bringing this demonstration to our attention.

Materials for Sudsy Kinetics—Chemical Demonstration Kit are available from Flinn Scientific, Inc.

Catalog No.	Description
AP4866	Sudsy Kinetics—Chemical Demonstration Kit
AP8599	Hydrometer Cylinder
AP5429	Demonstration Tray

Consult your *Flinn Scientific Catalog/Reference Manual* for current prices.

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Name: _____

Sudsy Kinetics Demonstration Worksheet

Part 1. Data Table

	Cylinder #1	Cylinder #2	Cylinder #3
Concentration of H ₂ O ₂			
Chemicals added			
Observations			

Part 2. Data Table

Chemicals used	
Color of foam	
Glowing splint test	

Part 3. Data Table

	Cylinder #1	Cylinder #2	Cylinder #3
Concentration of H ₂ O ₂			
Volume of water added			
Observations			

Discussion Questions

1. Based on what you observed in Part 1, what conclusions can you make about the relationship between concentration and rate of reaction?
2. Consider the reactants in Part 2.
 - a. What is responsible for the initial brown color of the foam?
 - b. What is responsible for the wood splint re-igniting?
3. Write a chemical equation for each of the two steps in this reaction. In the first, hydrogen peroxide reacts with iodide ion from the sodium iodide. In the second, hydrogen peroxide reacts with the products of the first reaction.
4. Write the chemical equation for the overall decomposition of hydrogen peroxide. Include heat energy in the equation. Is this reaction endothermic or exothermic? What evidence do you have to support this?
5. Explain why the reactions in Part 3 produced the same amount of foam but had different reaction times. *Hint:* Keep in mind the concentration of hydrogen peroxide before water was added to the second cylinder.