Elephant’s Toothpaste:  
Understanding Rate of Reaction and the Effects of Concentration

**Background:**

Hydrogen peroxide (H\textsubscript{2}O\textsubscript{2}) is a chemical compound found in most households in the United States. It is available in 3 forms, commercially; 3%, 10% and 30%, and usually sold in dark brown, opaque containers. Hydrogen peroxide is useful because it is a naturally unstable compound, and spontaneously undergoes a decomposition reaction, which is triggered by the presence of sunlight. The sunlight provides the activation energy necessary for the forward reaction.

3% hydrogen peroxide is a first aid staple in many households, routinely used to disinfect small wounds. Hydrogen peroxide also finds application as an antiseptic gargle, and an aid to ear wax removal. 10% Hydrogen peroxide is often used as a hair lightening oxidizing dye. It is important to note that hydrogen peroxide should never be taken internally- as side effects may include vomiting, severe internal burns and even death. 30% is not available for purchase by the general public. It is only used for laboratory purposes, and direct contact with skin is to be avoided.

The decomposition of hydrogen peroxide in aqueous solution proceeds very slowly- so slowly that a bottle can remain stable on a grocery store shelf for a very long time. This decomposition of aqueous hydrogen peroxide produces liquid water and gaseous oxygen.

The normal decomposition will be a little too slow for experimental purposes, so today we will be using a catalyst called potassium iodide to speed up this reaction. Invisible gas will be released, but we’ll trap it by adding liquid soap bubbles so we can “see” the gas. The soap bubbles will contain oxygen- a product of the reaction.

One theory used to predict the rates of chemical reactions, is called collision theory. Collision theory states that for a reaction to occur, atoms or molecules must come together or collide with one another. Not all collisions, however, bring about chemical change. According to the collision theory, the rate at which a chemical reaction proceeds is equal to the frequency of effective collisions. The presence of a catalyst, the concentration of the reactants, and the temperature of the reactants are all factors that may alter the rate of reaction.

**Objectives:**

1. Explain in terms of collision theory how concentration and the addition of a catalyst influence the rate of reaction.
2. Hypothesize the relationship that exists between concentration and rate of reaction
3. Predict the rate of reaction of various solutions to determine the effects of concentration
4. Follow a multi-step procedure

**Materials**

1. Hydrogen peroxide, H\textsubscript{2}O\textsubscript{2}, 30%, 80 mL
2. Hydrogen peroxide, H\textsubscript{2}O\textsubscript{2}, 3%, 80 mL
3. Two 1-L bottle
4. 25-mL graduated cylinder
5. KI Potassium iodide solution (20mL)
6. Dish soap

**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. Gloves, safety goggles, and aprons are **REQUIRED** for this lab. *Potassium iodide* is slightly toxic by ingestion. Potassium Iodide may stain your hands or clothing, so use appropriate caution.
Methods:
1. Place two graduated cylinders in a large, plastic demonstration tray.
2. Add 80 mL of 30% hydrogen peroxide to the first bottle and 80 mL of 3% hydrogen peroxide to the second bottle.
3. Add 5 squirts of dish soap to each cylinder and swirl to dissolve the detergent.
4. Measure out 20 mL of potassium iodide (KI) for each of 1-L bottles.
5. **Hypothesize** the relationship between the variables (concentration and reaction rate) and **predict** the order at which each of the peroxide solutions will react with the oxide.

<table>
<thead>
<tr>
<th>Hydrogen Peroxide Solutions</th>
<th>Predicted Order (fast/slow)</th>
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<tbody>
<tr>
<td>3% hydrogen peroxide</td>
<td></td>
</tr>
<tr>
<td>30% hydrogen peroxide</td>
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</table>

6. Pour the potassium iodide solution into the two bottles containing the differing concentrations of hydrogen peroxide.
7. Write down all your observations in the space provided below, and then clean up once the reaction has cooled.

**Disposal:**
1. The foam and solution left in the cylinder or on the plastic tray may be rinsed down the drain with excess water.
2. Clean up signature _________________________________

**Data:** Answer all questions in complete sentences on a separate sheet of paper.

1. Fill in the data table

<table>
<thead>
<tr>
<th></th>
<th><strong>Cylinder #1</strong></th>
<th><strong>Cylinder #2</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td>Concentration of H$_2$O$_2$</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total Volume of Chemicals added</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Observations (odors, colors, etc.)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
2. What happened when you mixed the solutions together?

3. Identify what the foam was made of.

4. What was the “smoke” you observed? (Remember, oxygen is colorless!)

**Conclusion:** Answer all questions in complete sentences on a separate sheet of paper.

1. The reaction that you performed was hydrogen peroxide \( \rightarrow \) water + gaseous oxygen. Balance the equation for the reaction.

2. Was the reaction endothermic or exothermic? Explain how were you able to tell?

3. What will happen to the number of particles in a given volume if the concentration increases?

4. Explain how increasing the number of particles would affect the rate of reaction?

5. What is the purpose of potassium iodide is in this chemical reaction?

6. Was the potassium iodide consumed in the reaction?
7. Compare the original volume of the reactants to the final volume of the products of the reaction. Is volume conserved in a chemical reaction? Explain your answer using specific values for the volumes of your products and reactants.

8. Hydrogen peroxide is useful because it is an unstable compound, and spontaneously undergoes a decomposition reaction. Use the potential energy diagram below, explain how the potassium iodide increased the rate of this reaction, and propose a reason why hydrogen peroxide is sold in dark brown plastic bottles.

Conclusion:
Summarize your understanding of kinetics, thermodynamics, and equilibrium using complete sentences. Your summary must include the words: concentration, catalyst, endothermic/exothermic, rate of reaction, and collision theory.