**How does the change in ethanol concentration affect the rate of hydrogen peroxide?**

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## Rationale

The rate of the chemical reaction is affected by the temperature increase, the concentration of the reacting chemicals, and the presence of enzymes. The human body digests food in the intestines and the stomach because of hydrochloric acid. The hydrochloric acid in the stomach performs the digestion process, but the presence of an enzyme affects the reaction rate. It is fascinating that enzymes control the reaction rate but do not get consumed in the reaction process. The enzymes bind the substrate they are acting on and remain in their original form at the end of a chemical reaction. During my investigation, I got fascinated by the knowledge that catalysts speed up a chemical reaction. I decided to explore how alcohol acts as catalase in a chemical reaction. Therefore, this investigation aims to find out how the change in ethanol concentration in a chemical reaction increases the decomposition rate of decomposition f hydrogen peroxide.

## Background theory

A catalyst is a substance that alters the reaction rate when it is present. It can be an element like nickel or sodium or a compound like potassium permanganate that dissolves in water. In chemistry, most of the catalysts used are acidic in nature and involved in a hydrolysis reaction. In a redox reaction, catalysts involve the transition of metals and substances where hydrogen gas is produced as a compound. In the human digestive system, various enzymes help digest food. They bind with the substrate and speed up the rate at which the food is broken down into small particles that the body can absorb. The enzymes are vital in chemical reactions since their absence could halt the chemical process or make the reaction process take a long time.

According to chemists, the catalyst in a chemical process provides the reaction with the least energy that starts the reaction process. The minimum energy provided by the catalyst is called the activation energy. A chemical process where the reactants have the least activation energy tends to form final products faster and easier. When the activation energy is very high, the reaction process cannot occur because the reactant particles tend to remain intact or do not vibrate. Particles that are not vibrating do not move, and the chemical reaction stops (Ranganathan & Sieber, 2018). The chemical reaction could continue if the activation energy is lowered to enable the particles to start moving by adding a catalyst. The catalyst provides active sites that act on the substrate and allow the reaction to start.

The active sites act like a special pocket that bounds the substrate molecules and allows them to start moving or vibrating. Therefore, ethanol will act like a catalyst in this exploration, and its concentration will change in the reaction. The significance of changing ethanol concentration is to test whether the reaction rate will remain the same. When ethanoic acid reacts with hydrogen peroxide, oxygen gas and water are produced, as shown in the equation below;

2 $H_2O_2$ and ethanol → $H_2O$ (l) + $H_2$ (g)

The equation above shows that ethanol acts as a catalyst, which helps the hydrogen peroxide decompose into water and oxygen gas. Therefore, the ethanol concentration will vary during the experiment, and the volume of the oxygen gas produced in 90 seconds. Therefore, the control variables of the experiment will be temperature, the volume of hydrogen peroxide, and the concentration of hydrogen peroxide $H_2O_2$.

## Research question

Does changing the concentration of ethanol affect the volume of oxygen gas produced due to the decomposition of $H_2O_2$?

## Aim

The experiment's main objective is to determine the effect of changing ethanol concentration on the decomposition of hydrogen peroxide.

## Variables

**Independent variable**: The concentration of ethanol in the decomposition of $H_2O_2$ will vary to determine if its changes affect the volume of the oxygen gas produced. The concentration will vary from 0%, 20%, 40%, 60%, 80%, and 100%.

**Dependent variable**:

The enzymatic reaction involving ethanol and hydrogen peroxide will be determined by measuring the volume of $O_2$ gas produced in 90 seconds. Therefore, the oxygen probe set up in the water bath will ensure that the volume of oxygen gas has been measured.

**Control variables**

| Variable | Method of control | Importance of control |
| --- | --- | --- |

| | | |
|---|---|---|
| - Temperature | During the experiment, a water bath will ensure that all the reactants and substrate react at 30 $^{0}C$. | In a chemical reaction, temperature affects the vibration of particles and regulates reactions. Inside the body, the enzymatic activity increases with an increase in temperature. It indicates that at high temperatures, reactant particles will vibrate faster, thus increasing the reaction rate and vice versa. Also, the enzymes are protein in nature, and the temperature change affects their enzymatic reaction. |
| Mass of the catalase | A weighing balance will be used to measure 5g of the powder in the chemical reaction. | A change in the volume or mass of the catalyst affects the number of particles binding with the substrate. Increasing the volume or mass of a catalyst increases the molecules binding with the substrates, thus increasing the reaction process. Therefore, to have a fair result in the decomposition of $H_2O_{2,\ an}$ equal amount of catalyst will be used in all the trials. |

| | | |
|---|---|---|
| Volume of $H_2O_2$ | A measuring beaker will measure 100 ml of $H_2O_2$ for experimenting. | A change in the experiment's hydrogen peroxide volume will increase the substrate concentration. As the number of substrate molecules increases, the catalyst volume will also be required to bind the increasing particles. Therefore, a constant volume of $H_2O_2$ will be used in all the trials to ensure fair results. |

**Materials and equipment**

1. Ethanol solution
2. Conical flask
3. Catalase powder
4. Stopwatch
5. Oxygen probe and bottle
6. Water bath
7. Weighing balance
8. Measuring beaker
9. MacBook with Logger Pro
10. Pipette
11. 0.1 M of Hydrogen peroxide ($H_2O_2$) solution

**Procedure**

1. The equipment was arranged as needed to complete the experiment where the set-up probe was arranged.
2. A measuring cylinder measured 100 ml of hydrogen peroxide solution and poured it into the oxygen probe.
3. 5 g of catalase powder was measured with the weighing balance and transferred into the conical flask containing the $H_2O_2$. The stopwatch was immediately started, and the container was closed to tap the oxygen gas produced.
4. The reaction was allowed to continue for 90 seconds, and the volume of the gas produced was recorded.
5. The experiment was repeated six times.
6. The experiment was repeated, and 20 ml (20%) of ethanol was added into the conical flask containing 100 ml $H_2O_2$ and catalase. The volume of the gas produced in 90 seconds was determined and recorded in a table.
7. Six other trials were repeated, and the process was repeated with ethanol concentrations of 40, 60, 80, and 100%.

**Ethics, safety, and environmental issues**

The experiment involves two liquids that cause side effects when they come into contact with the body. Hydrogen peroxide causes mouth, eye, and skin irritation, and the person experimenting ensures that one wears protective clothes like gloves and lab coats. The surfaces affected should be cleaned if any spillage of hydrogen peroxide or ethanol happens on the working bench. After the experiment, the person who carried it should wash their hands with plenty of water and soap. The experiment conducted did not have ethical or environmental concerns.

## Data collection

The experiments to investigate how the change in concentration of ethanol affects the volume of oxygen produced when hydrogen peroxide decomposed with the presence of a catalyst were conducted for eight hours. The data collected consisted of seven trials to ensure that the most accurate data was collected for the analysis.

*Table 1: Raw data of volume of O2 gas produced and concentration of ethanol used*

| The concentration of ethanol in the experiment | The volume of oxygen (+- 0.05 $cm^3$) after 90 seconds. | | | | | | |
|---|---|---|---|---|---|---|---|
| | Trail 1 | Trail 2 | Trial 3 | Trail 4 | Trail 5 | Trial 6 | Trial 7 |
| **0** | 7.4 | 8.7 | 9.8 | 7.8 | 10.9 | 8.5 | 8.3 |
| **20** | 15.7 | 11.4 | 12.9 | 11.9 | 14.8 | 10.7 | 11.1 |
| **40** | 19.5 | 18.9 | 20.7 | 21.9 | 18.8 | 20.3 | 18.7 |
| **60** | 26.7 | 26.8 | 24.9 | 26.7 | 25.9 | 23.7 | 27.1 |
| **80** | 34.6 | 33.4 | 34.8 | 32.9 | 33.4 | 32.6 | 34.5 |
| **100** | 40.3 | 42.7 | 44.5 | 41.8 | 42.1 | 42.9 | 41.8 |

Table 1 above contains raw data on the volume of oxygen gas produced when the ethanol concentration was varied under a catalase. The data indicate that the volume of oxygen produced at a low ethanol concentration was low.

Processed data

| The concentration of ethanol in the experiment | The average volume of oxygen (+- 0.05 $cm^3$) after 90 seconds. | The standard deviation of the mean | Absolute error | Percentage error |
|---|---|---|---|---|
| 0 | 8.771429 | 1.11575 | 1.75 | 19.95 |
| 20 | 12.64286 | 1.785543 | 2.50 | 19.77 |
| 40 | 19.82857 | 1.106751 | 1.60 | 8.07 |
| 60 | 25.97143 | 1.154759 | 1.70 | 6.55 |
| 80 | 33.74286 | 0.817413 | 1.10 | 3.26 |
| 100 | 42.3 | 1.189237 | 2.10 | 4.96 |

The raw data collected during the experiment was processed, and the average of the trials was obtained. The standard deviation and percentage error of measurement were calculated as the following;

mean = (7.4 + 8.7 + 9.8 + 7.8 + 10.9 + 8.5 + 8.3) / 7 = 8.78 $cm^3$

next, in order to determine the percentage change, I decided to compute the absolute error of measurement;

absolute error = (maximum value - minimum value) / 2

Absolute error when the concentration of ethanol was 40% = (21.9 – 18.7) / 2 = 1.60

Nex, the percentage uncertainty of measurement was computed as shown by the formula below;

Percentage uncertainty = absolute uncertainty / measured quantity X 100

An example of a calculation was when the concentration of ethanol used was 40%;

% uncertainty = (1.60 / 19.83) * 100 = 8.07%

Next, the Standard deviation was computed as the following;

$$\text{Standard deviation, } \sigma = \sqrt{\frac{\sum (x_i - \mu)^2}{N}}$$

The standard deviation at a 40% concentration of ethanol was 1.11.

The processed data in table 2 indicate that increasing the concentration of ethanol in the presence of catalase increased the volume of oxygen produced. At 0% of ethanol (pure hydrogen peroxide without any ethanol), the volume of oxygen gas produced was 8.78 $cm^{3,}$ but increasing ethanol concentration increased the volume. When the ethanol concentration in the experiment was increased to 100%, the gas produced in 90 seconds increased to 42.30 $cm^3$.

**Graph**

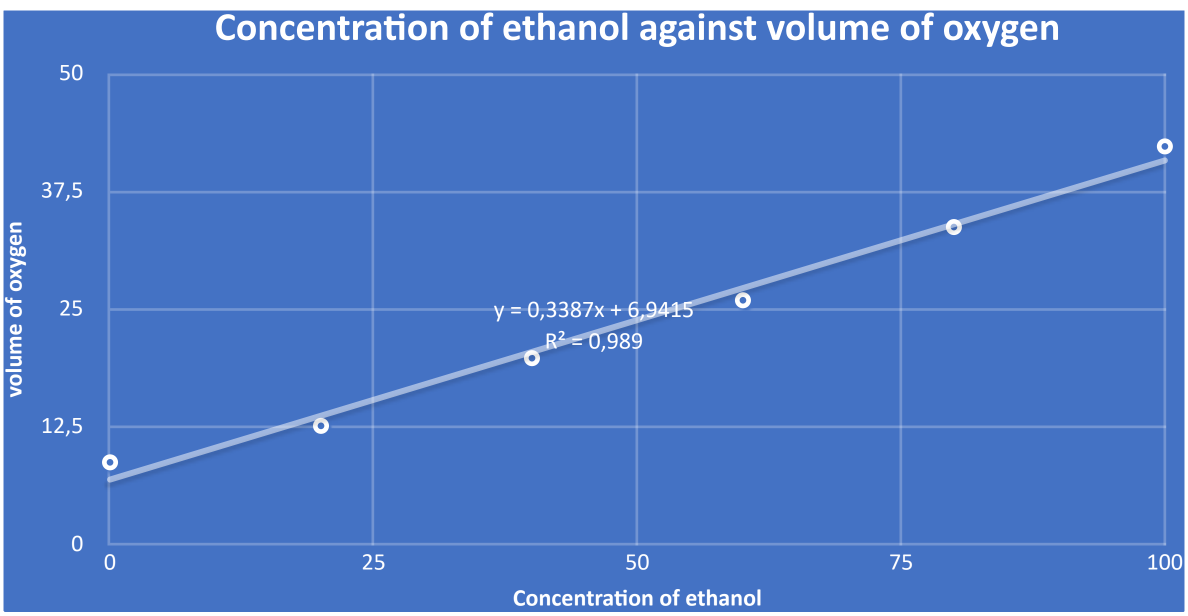


*Figure 1: Scatter plot of the volume of oxygen and concentration of ethanol*

From the scatter plot above, it is evident that the increase in ethanol concentration increased the volume of $O_2$ gas produced. The trend line and the gradient show a positive relationship. The gradient has a positive gradient that indicates a direct relationship between the volume of oxygen gas produced and ethanol concentration. This shows that increasing the concentration of ethanol in the presence of catalase increased the rate of decomposition of $H_2O_2$. Therefore, increasing the concentration of ethanol increased the rate of reaction.

**Evaluation, limitations, and further studies**

The investigation was successful because of the strength of the methodology and the research question. The methodology highlighted the independent and dependent variables of the experiment. The analysis also focused on answering the research question and proving the stated hypothesis. The experiment had some limitations since the measuring instruments, like the pipette, measuring beaker, weighing balance, and the gas cylinder, had measurement errors. The person conducting the experiment was most accurate and failed to start and stop the stopwatch at an exact time, leading to random errors. Also, the standard deviation calculated was high, indicating that variables in the seven trials collected varied from the mean.

The investigation to determine how the presence of catalase affected the decomposition of $H_2O_2$ when the concentration of ethanol was varied was interesting. I learned that increasing the concentration of ethanol increased the amount of oxygen gas produced. The essay was ideal because I learned how to arrange equipment in the laboratory and ensure that the experiment process was safe by wearing the necessary protective clothes, gloves, and safety goggles. I also learned how to plot a scatter plot and insert a trend line that shows the relationship between two variables. In the future, I would like to extend the experiment to find the activation energy required for hydrogen peroxide and hydrochloric acid.

## Conclusion

The investigation to determine the effect of changing the concentration of ethanol in the decomposition of hydrogen peroxide in the presence of catalase was successful. The research proved that ethanol affected the reaction rate since changing the concentration changed the volume of $O_2$ gas produced in 90 seconds. The graph of concentration against the volume of oxygen produced had a direct relationship with an upward trend line. The graph proved that increasing ethanol concentration increased the volume of oxygen gas produced. The volume of oxygen increased because the catalyst used was able to act on more particles or molecules when the concentration increased. Therefore, the exploration proved that changing the concentration of ethanol affected the chemical process. in conclusion, the decomposition of hydrogen peroxide is dependent on environmental factors and catalysts.

## References

Ranganathan, S., & Sieber, V. (2018). Recent advances in the direct synthesis of hydrogen peroxide using chemical catalysis—A review. *Catalysts*, *8*(9), 379.