Parallels to GERD Medications - An Experimental Report

Aim

To investigate the changing the concentration of hydrochloric acid (0.5M, 1.0M,1.5M, 2.0M, 2.5M) and its effect on the amount of hydrogen gas produced, depicting the variation in the initial rate of reaction. This experiment aims to explore how changing the concentration of medication can help patients affected with Gastroesophageal Reflux Disease (GERD) disease

Objectives:

- Research the health issue of Gastroesophageal Reflux Disease (GERD)
- Interview close friend to understand an overview on how GERD disease can impact an individual's life
- Research the prominence of Acid Reflux amongst teenagers
- Understand the chemical processes of Gastroesophageal reflux disease (GERD) medication
- Design and complete an experiment which identifies the correlation between increasing GERD medication concentration and the increasing initial rate of reaction.
- Discuss how increasing the concentration of GERD medication impacts patients and how the designed experiment can be extended to investigate GERD medication in further detail.

Range of Approaches:

Type of Research	Overview of Procedure	Pros & Cons
Survey Research Paper	I could conduct a series of surveys for those who have GERD disease. The questions will consist of: **1.** The type of medication the patients use **2.** Medication concentration **3**. The speed it takes for the medications to work	By conducting a survey, a range of data could be obtained, from the type of medication patients prefer to use to the speed it takes to work. However, it will be difficult to get any conclusive results due to a lack of control variables. Patients could have varying degrees of severity of GERD or other health implications which could affect how fast the GERD medication takes to work.
Compare & Contrast Research Paper	I could compare and contrast 2-3 different GERD medications with different concentrations on the same patient. The patient's feedback and preference can be recorded and used as data for my experiment.	By comparing and contrasting 2-3 different concentrations of GERD medications on a patient, I could understand which medication can be optimal for a patient depending on the medication with the fastest rate of reaction. However, a medication which is optimal for one patient may not be optimal for another patient due to varying health conditions.
Experimental Research Paper	With access to a lab, I could mimic changing the concentration of GERD medication and its impact on the initial rate of reaction.	By using a lab, my results can be far more controlled and conclusive as I can carefully consider my independent, dependent and control variables. Additionally I can also use my creative thinking skills to design a lab experiment. However, the lab I will use will not provide varying concentrations of GERD medication due to safety issues. Thus, I will have to use varying concentrations of hydrochloric acid and magnesium to determine how concentration affects the initial rate of reaction.

Planned Outcome & Timeframe:

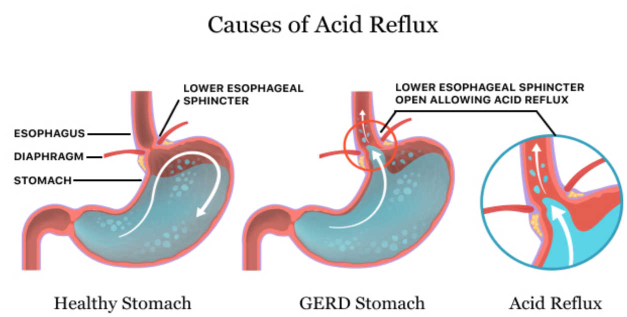
The experimental research paper option was chosen from the range of approaches above. This is due to how I had access to a lab environment which would allow me to have a more controlled environment for my research. This will result in the independent, dependent and control variables being more carefully monitored, helping my research results be more reliable and valid. Lastly, I will be able to use my creative thinking skills to design a lab procedure, work on my lab practical skills and execute my lab experiment.

	Steps	**Timeframe**
Background Research	Research the health issue of Gastroesophageal reflux disease (GERD)	February 1st - February 6th 2022
	Interview close friend to understand an overview on how GERD disease can impact an individual's life	February 8th 2022
	Research the prominence of Acid Reflux amongst teenagers	February 9th-13th 2022
	Understand the chemical processes of Gastroesophageal reflux disease (GERD) medication	February 14th -19th 2022
Experiment	Context & Research Question	February 20th-26th 2022
	Hypothesis	February 27th - 28th 2022
	Variables	March 1st - 4th 2022
	Materials & Procedure	March 5th - 6th 2022
	Raw Quantitative & Qualitative Observations	March 7th - 11th 2022
	Analysed Data - Graphs, Tables & Sample Calculations	March 12th - 19th 2022
	Conclusion	March 20th - 22nd 2022
	Evaluation	March 23rd - 26fh 2022
	Extension - Future Experiment	March 27th - 29th 2022
	Bibliography	March 30th-31st

Context - Wider Purpose for the Experiment

Gastroesophageal reflux disease, known as GERD is a prevailing issue amongst teenagers. According to the United States National Institute of Diabetes and Digestive and Kidney Diseases, **1 in 4 teenagers** are faced with the GERD health issue worldwide.

GERD disease refers to the flow of the acidic juices of the stomach into the oesophagus, resulting in symptoms such as heartburn, severe chest pain, regurgitation of food and a lump-like sensation in an individual's throat *(Denham)*. The sphincter, a band of muscles between the oesophagus and stomach, operates as a one-way valve, allowing food to go down into the stomach while preventing food and acid from backing up into the oesophagus. However, when the lower esophageal sphincter does not function as intended, it allows stomach acid and food contents to flow into the oesophagus causing GERD*(Gastroesophageal Reflux Disease)*.



(Gastroesophageal Reflux Disease)

As more and more teenagers are faced with obesity, their risk of developing GERD is heightened. Obesity places pressure on the sphincter valve, which in turn weakens it. Additionally, poor diets containing spicy foods, caffeine, peppermint, chocolate or excessive alcohol intake, has the potential to weaken the sphincter valve *(Klein)*. According to Ketah Shah, MD, who practises gastroenterology, internal medicine and paediatrics at Saddleback Medical Centre in Laguna Hills, California; "In Western countries – likely because of our poor dietary habits and inadequate physical activity, leads to increased rates of obesity", thus in turn, "fast foods, which have high fat content and may be deep-fried, are exactly the types of foods known to trigger GERD".

However, medication treatments such as antacids are known to dilute stomach acids which contain hydrochloric acid *(Antacid)*. Currently there are a variety of antacids which are composed of magnesium hydroxide and/or aluminium hydroxide, calcium carbonate or sodium bicarbonate. Patients depending on the severity of their gastric reflux are recommended a certain concentration of medication by doctors. Thus, increasing the concentration of GERD medication will increase the initial rate of reaction, thus treating the patient far more rapidly.

Hence, this experiment conducted in this lab report aims to identify the correlation between increasing the concentration of hydrochloric acid and its effect on the initial rate of reaction. The following equation will be used:

$$2HCl_{(aq)} + Mg_{(s)} \rightarrow MgCl_{2\ (aq)} + H_{2(g)}$$

Research Question

How does changing the concentration of hydrochloric acid (0.5M, 1.0M, 1.5M, 2.0M and 2.5M) affect the initial rate of reaction as measured by the volume of hydrogen gas produced using a gas syringe?

Hypothesis

If the concentration of hydrochloric acid increases **then** there will be a greater amount of hydrogen gas produced **due to** how there are more reactant particles moving together which cause more effective collisions leading to a greater reaction rate. The higher the concentration of reactants, the larger the volume of products and the frequency of the rate of reaction will be increased. *(Controlling the Rate) (How to Speed)*.

In this experiment, the following concentrations of hydrochloric acid will be combined with 0.3 grams of magnesium respectively; 0.5M, 1.0M, 1.5% 2.0M and 2.5M. The highest concentration of hydrochloric acid (2.5M), will lead to the largest volume of hydrogen gas produced, thus, resulting in the greatest initial rate of reaction. This is due to how a greater concentration of hydrochloric acid, will have more acid particles (hydrogen ions) prevalent to collide with the 3cm of magnesium. Therefore, the frequency of effective collisions increases and causes a greater rate of reaction *(Khan) (Markgraf)*.

As hydrochloric acid and magnesium are combined, the amount of hydrogen gas produced will be recorded in 10 second intervals until 50 seconds. The relationship between the volume of hydrogen gas produced and the time taken will create an exponential slope with a plateau. The plateau of the slope will occur when the reaction has ceased and hydrogen gas is no longer being produced. The highest concentration of hydrochloric acid (2.5M), will have the steepest gradient at 10 seconds, thus showing the greatest initial rate of reaction. This is shown in Figure 1, as it depicts the amount of hydrogen gas produced in millilitres with respect to time taken in seconds using 2.5M of hydrochloric acid.

The final graph findings will depict a linear positive gradient as the initial rate of reaction will be directly proportional to the concentration of the hydrochloric acid. The highest concentration of hydrochloric acid (2.5M) will have the greatest initial rate of reaction whereas the lowest concentration (O.5M) will have the lowest initial rate of reaction. This is depicted in Figure 2.

Fig. 1 Volume of Hydrogen Gas (ml) with Respect to Time (s) Using 2.5M of Hydrochloric Acid

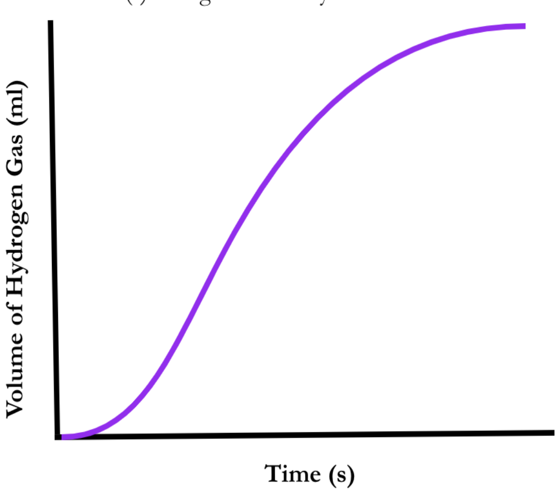
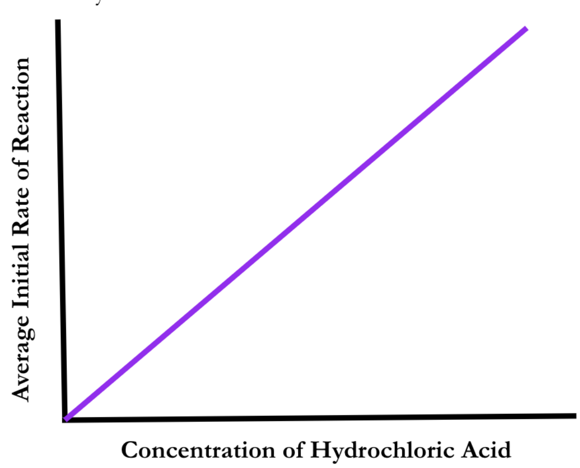


Fig. 2 Average Rate of Reaction as the Concentration of Hydrochloric Acid Increases



Variables

Independent Variable	How it is changed	Justifying Why it is Changed in this Manner
Changing the concentration of the hydrochloric acid (0.5M, 1M, 1.5M, 2.0M and 2.5M).	Hydrochloric acid concentrations of 0.5M, 1M, 1.5M, 2.0M and 2.5M will be combined with magnesium. Varying concentrations of hydrochloric acid will be purchased prior to conducting this experiment.	To achieve a valid practical with clear and observable trends, five variations of the independent variable is needed.

Dependent Variable	How is it measured	Justifying Why it is Measured in the Manner
The initial rate of reaction determined by the **volume of hydrogen gas** produced with respect to time taken.	Using a gas syringe, the volume of hydrogen gas produced will be measured in millilitres every 10 seconds up till 50 seconds. .	Using a gas syringe to measure the volume of hydrogen gas can make the experiment process far less complex as opposed to using the water displacement method.

Control Variables	How it remains consistent	Importance of Controlling These Factors
Length (cm) of Magnesium	The mass of the magnesium will remain consistent at 3cm. Amount of magnesium will be measured on a weighing scale.	Increasing the amount of magnesium will create an unfair experiment as inconsistent amounts of hydrogen gas will be produced between trials. Thus, the results would not purely reflect the increasing rate of reaction due to the increased concentration.
Surface Area of Magnesium	The magnesium used in this experiment is a general purpose agent magnesium ribbon. Thus 0.3 grams will be the mass of one piece of magnesium. The magnesium used in each trial will not be cut into multiple pieces.	If the surface area is greater by having multiple pieces of magnesium per trial then the rate of reaction will increase leading to an unfair experiment.
Millilitres (mL) of Hydrochloric Acid	This will be controlled by using a 10mL graduated cylinder.	By increasing the amount of hydrochloric acid randomly, the results will be affected as a greater amount of hydrogen gas will be produced. Thus, leading to an unfair experiment.

Total time and intervals	The volume of hydrogen gas produced will be measured every 10 seconds up until 50 seconds.	By measuring in consistent 10 second time intervals the graph produced for each trial will be consistent and allow for proper analysis between the varying concentrations of hydrochloric acid.
Temperature of Experimental conditions	The temperature of the lab will remain consistent at 22-23℃. Lab temperature will be monitored by a thermometer.	If the temperature fluctuates drastically within the lab the results would be affected as a higher temperature leads to a faster rate of reaction. This is due to the particles having a greater amount of energy, causing an increased amount of effective collisions.
Scientist Monitoring Time Intervals (s) & Scientist Recording Hydrogen Gas Production Rate (ml)	This experiment requires 2 scientists. One scientist will be recording 10 second time intervals and ensuring to call out the time intervals. The other scientist will be monitoring the gas syringe and recording the volume of gas produced after every 10 seconds.	Due to how each scientist has a different reaction time, having the same 2 scientists monitoring time intervals and gas production will minimise human error during the process of data collection.
Conical Flask Used to Combine Magnesium and the Hydrochloric Acid	The 100ml conical flask used to combine the hydrochloric acid and magnesium will remain consistent throughout the experiment.	Increasing the volume of the glass equipment that contains the reaction can affect the rate of reaction. The larger the glass equipment, the more area the particles have to spread out, slowing the rate of reaction. Whereas, a smaller glass equipment keeps the particles closer together for a faster rate of reaction.

Equipment

Quantity	**Equipment**
1	Retort clamp and stand
1	Phone with Camera (record data)
x3	10 mL Hydrochloric Acid (0.5M)
x3	10 mL Hydrochloric Acid (1.0M)

x3	10 mL Hydrochloric Acid (1.5M)
x3	10 mL Hydrochloric Acid (2.0M)
x3	10 mL Hydrochloric Acid (2.5M)
x15	3cm of General Purpose Agent Ribbon Magnesium
x6	Test Tubes
1	Test Tube Tray (with 3 test tube holders)
1	Weighing Scale
1	10mL graduated cylinder
1	100mL Conical Flask
1	Rubber Topper with Attached Rubber Tubing
1	Stopwatch
1	Gas Syringe
1	Funnel
3	Cups or Glass Beakers
2	Pairs of Latex Gloves

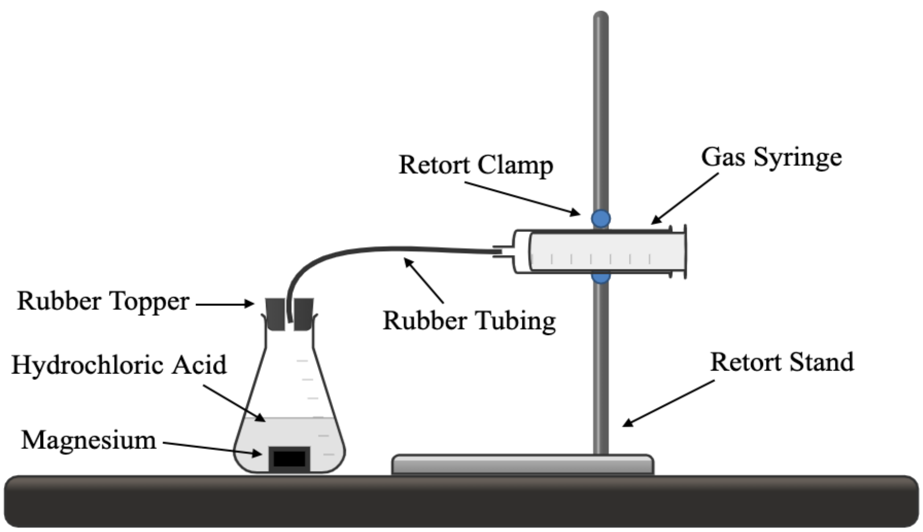
Safety Considerations

When conducting this experiment ensure to follow these safety precautions to avoid haphazard accidents.

Area of Concern	**Potential Hazard**	**Prevention and Management Methods**
Glassware	The use of glassware can result in breakage, posing a risk of injuries such as cuts.	Upon the unlikely event of glass breakage, fragments of glass should not come in direct contact with skin as it has the potential to cause cuts. Consequently, lab coats, safety goggles and closed-toe shoes must be worn at all times. During the procedure, caution must be taken to avoid any glass breakage.
Hydrochloric Acid	Hydrochloric acid is a corrosive solution. Therefore, direct contact or inhalation with the solution may result in minor to major burns, skin irritation or breathing difficulties.	Lab coats, safety goggles, closed-toe shoes should be worn all-times during the procedure. Gloves must be worn when handling the hydrochloric acid. Take extra caution to ensure the solution does not come into direct contact with skin or eyes.
Magnesium	Small magnesium particles can accidentally	Avoid rubbing eyes as magnesium particles

	be inhaled causing irritation when breathing. Irritation to the eyes is also a plausible safety hazard.	can cause irritation to the eyes. The procedure must be conducted in a lab with proper safety equipment such as a lab coat and safety goggles. Excess magnesium inhalation can lead to an illness known as "metal fume fever". It is recommended to wear a mask when conducting this procedure
Managing Waste	Hydrochloric acid, a corrosive substance, must be safely disposed of upon completing the procedure. Bench tops must be cleaned properly as spillages or splashes of hydrochloric acid can cause irritation or burns to other scientists using the lab.	Hydrochloric acid and magnesium can be poured down the drain as magnesium and hydrochloric acid is a neutralisation reaction. However, as hydrochloric acid is a corrosive acid, ensure to mix the solution with water prior to pouring down the drain. Additionally, it is required that scientists wipe the benchtop and equipment clean of any potential splashes of hydrochloric acid.

Diagram



Procedure

1.) Gather all equipment.
2.) Ensure lab space is not cluttered and glassware is clean.
3.) Set up a thermometer. Measure the temperature of the lab environment. Ensure to monitor temperature during the experiment.
4.) Using a retort clamp, secure the gas syringe horizontally.
5.) Attach rubber tubing securely to the gas syringe tip.
6.) Place 3 test tubes in the test tube rack.
7.) Ensure to wear gloves, lab coat and safety goggles before proceeding to the following steps.
8.) Using the 10mL graduated cylinder, measure 10mL of 0.5M acid.

9.) Using a funnel, pour 10mL of the 0.5M concentration of hydrochloric acid into one of the test tubes. Once completed, carefully place the test tube in the test tube rack. Repeat steps 6-8 with the two other test tubes. There must be 3 filled test tubes in total in the test tube rack.
10.) Measure 3 pieces of 3cm magnesium metal using a ruler. Place each piece in 3 separate glass cups.
11.) Take the first test-tube from the test tube rack, pour the 10mL of hydrochloric acid into the 100mL conical flask.
12.) Place the magnesium metal carefully into the conical flask.
13.) Immediately place the rubber topper and start the stopwatch.
14.) Record the gas volume at 10 second intervals using a stopwatch. Request your lab partner to call out the time every 10 seconds. Every 10 seconds, take a photo of the gas syringe using your phone. Stop photographing data once you reach 50 seconds.
15.) Dilute the magnesium chloride solution with water prior to pouring it down the drain and dispose of any leftover magnesium.
16.) Rinse the conical flask.
17.) Take the second test tube containing 10mL of hydrochloric acid from the test tube rack and pour into the conical flask. Repeat steps 11-14.
18.) Take the third test tube containing 10mL of hydrochloric acid from the test tube rack and pour into the conical flask. Repeat steps 11-14.
19.) Repeat steps 7-16 with 1.0M concentration of hydrochloric acid.
20.) Repeat steps 7-16 with 1.5M concentration of hydrochloric acid.
21.) Repeat steps 7-16 with 2.0M concentration of hydrochloric acid.
22.) Repeat steps 7-16 with 2.5M concentration of hydrochloric acid.
23.) Once completed, rinse all lab equipment and wipe the benchtop clean with water.

Results

Raw Qualitative Data Table:

Start of Procedure (0.5M of Hydrochloric Acid)	Middle of Procedure (1.5M of Hydrochloric Acid)	End of Procedure (2.5M of Hydrochloric Acid)
• Upon dropping the magnesium into the hydrochloric acid, bubbles are produced. • Volume of hydrogen gas slowly increases. • Colour remains as a clear, colourless solution. • Magnesium strip is not fully dissolved after each trial.	• Volume of hydrogen gas increases at a faster rate. • Colour remains as a clear, colourless solution. • The heat produced is more noticeable, heats up the conical glass flask - exothermic reaction. • Magnesium is almost fully dissolved after each trial. • More violent bubbles are produced when the magnesium piece is dropped into the hydrochloric acid solution.	• There is a large amount of heat produced after each trial as a result of the magnesium and hydrochloric reaction. Thus it is an exothermic reaction. • Magnesium strips are fully dissolved after each trial. • Colour remains as a clear, colourless solution. • The rate of hydrogen gas produced as measured by the gas syringe, increases very quickly.

Raw Quantitative Data Tables:

Hydrogen Gas Production with Respect to Time with Varying Hydrochloric Acid Concentrations (0.5M, 1.0M, 1.5M, 2.0, 2.5)					
0.5M Hydrochloric Concentration *(10mL per each trial)*					
Trial 1		**Trial 2**		**Trial 3**	
Time (sec)	**Hydrogen Gas produced (mL)**	**Time (sec)**	**Hydrogen Gas produced (mL)**	**Time (sec)**	**Hydrogen Gas produced (mL)**
0	**0**	**0**	**0**	**0**	**0**
10	1	10	1	10	0.5
20	3	20	2	20	1.5
30	4	30	3	30	2.5
40	5	40	4	40	3.5
50	5.5	50	5	50	4.8
1.0M Hydrochloric Concentration *(10mL per each trial)*					
Trial 1		**Trial 2**		**Trial 3**	
Time (sec)	**Hydrogen Gas produced (mL)**	**Time (sec)**	**Hydrogen Gas produced (mL)**	**Time (sec)**	**Hydrogen Gas produced (mL)**
0	**0**	**0**	**0**	**0**	**0**
10	4	10	8.5	10	5
20	10.5	20	16.5	20	12.5
30	17.5	30	23	30	19.5
40	23	40	29	40	25
50	26.5	50	34	50	28.5
1.5M Hydrochloric Concentration *(10mL per each trial)*					
Trial 1		**Trial 2**		**Trial 3**	
Time (sec)	**Hydrogen Gas produced (mL)**	**Time (sec)**	**Hydrogen Gas produced (mL)**	**Time (sec)**	**Hydrogen Gas produced (mL)**
0	**0**	**0**	**0**	**0**	**0**

10	11.5	10	15	10	11
20	25	20	29	20	24.3
30	30.5	30	37.5	30	32.5
40	43.5	40	45	40	40
50	50	50	51	50	46
2.0M Hydrochloric Concentration ***(10mL per each trial)***					
Trial 1		**Trial 2**		**Trial 3**	
Time (sec)	**Hydrogen Gas produced (mL)**	**Time (sec)**	**Hydrogen Gas produced (mL)**	**Time (sec)**	**Hydrogen Gas produced (mL)**
0	**0**	**0**	**0**	**0**	**0**
10	16.5	10	19	10	11
20	31.5	20	30	20	28.5
30	46	30	44	30	44
40	56	40	54.5	40	53
50	61	50	60	50	57
2.5M Hydrochloric Concentration ***(10mL per each trial)***					
Trial 1		**Trial 2**		**Trial 3**	
Time (sec)	**Hydrogen Gas produced (mL)**	**Time (sec)**	**Hydrogen Gas produced (mL)**	**Time (sec)**	**Hydrogen Gas produced (mL)**
0	**0**	**0**	**0**	**0**	**0**
10	18	10	16	10	17
20	44	20	40	20	39
30	55	30	53.5	30	54
40	58.5	40	55	40	58.5
50	59	50	55	50	59

Temperature of Laboratory During Each Trial		
Concentration of Hydrochloric Acid (M)	**Trial**	**Laboratory Temperature (℃)**
0.5M	1	22
	2	22
	3	22
1.0M	1	22
	2	22.5
	3	22.5
1.5M	1	22
	2	22
	3	22
2.0M	1	22.5
	2	22.5
	3	22.5
2.5M	1	22.5
	2	22.5
	3	23

Other Raw Quantitative Data

Magnesium pieces for all the trials will remain consistent at 3cm.

Volume of Hydrochloric acid for all the trials will remain consistent at 10mL.

Analysis

Analysed Quantitative Data Table

Initial rate of reaction calculated during the first 10 seconds of a reaction. Values rounded to three significant figures

Concentration of Hydrochloric Acid (M)	Trial	Initial Rate of Reaction (mL of H_2 gas per second)
0.5M	1	0.140
	2	0.100

	3	0.0799
1M	1	0.553
	2	0.789
	3	0.633
1.5M	1	1.15
	2	1.33
	3	1.14
2.0M	1	1.53
	2	1.47
	3	1.42
2.5M	1	1.95
	2	1.82
	3	1.82

Sample Calculation Graphs of Analysed Quantitative Data

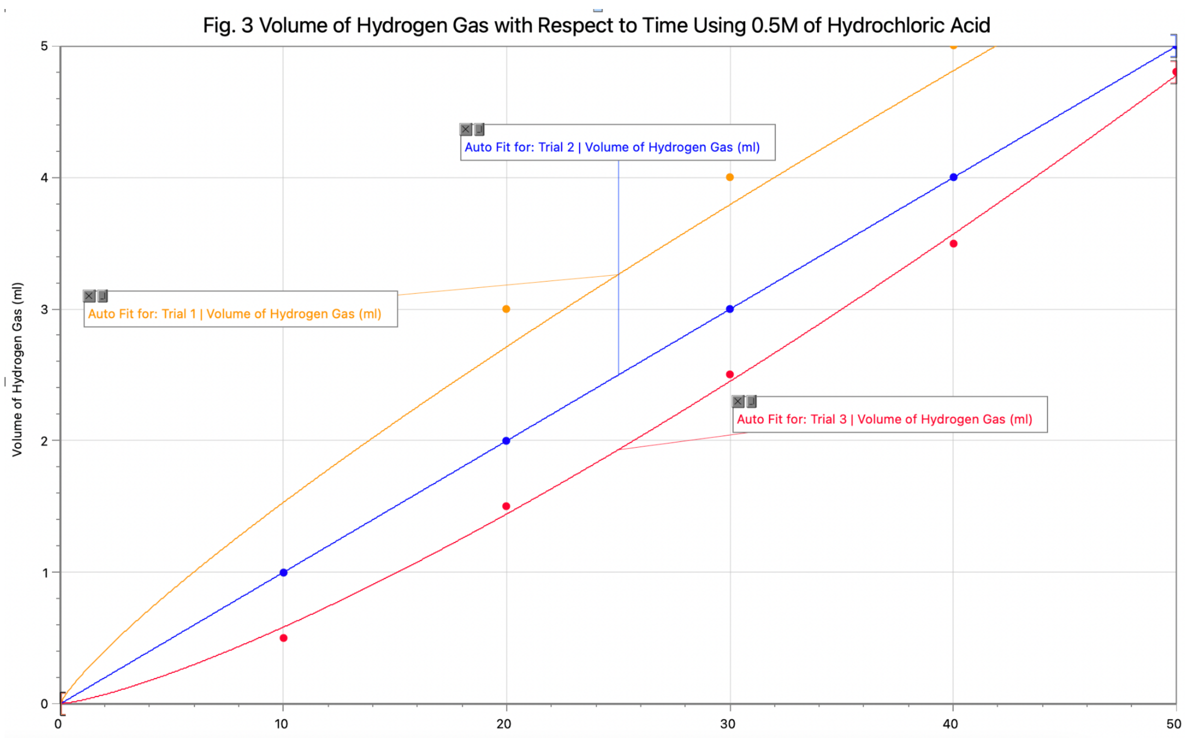


Fig. 4 Volume of Hydrogen Gas (ml) with Respect to Time Using 1.0M of Hydrochloric Acid

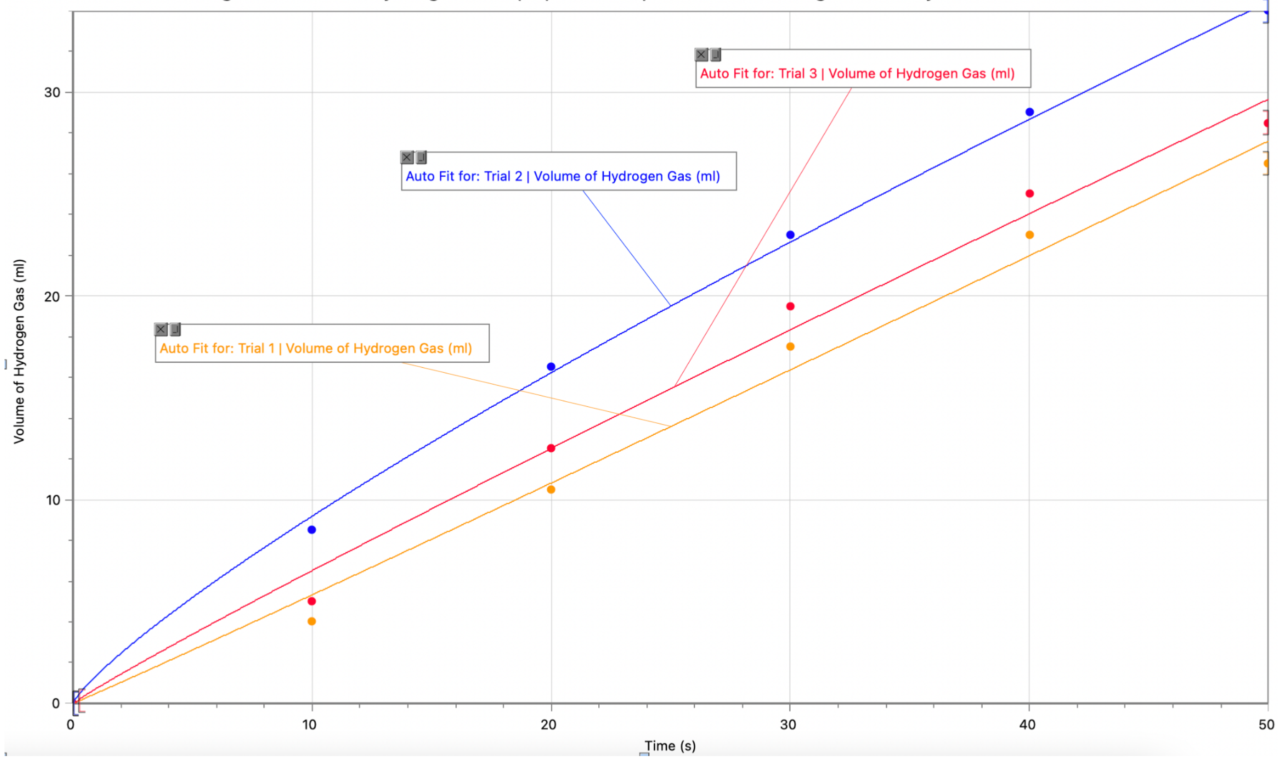


Fig. 5 Volume of Hydrogen Gas (ml) with Respect to Time Using 1.5M of Hydrochloric Acid

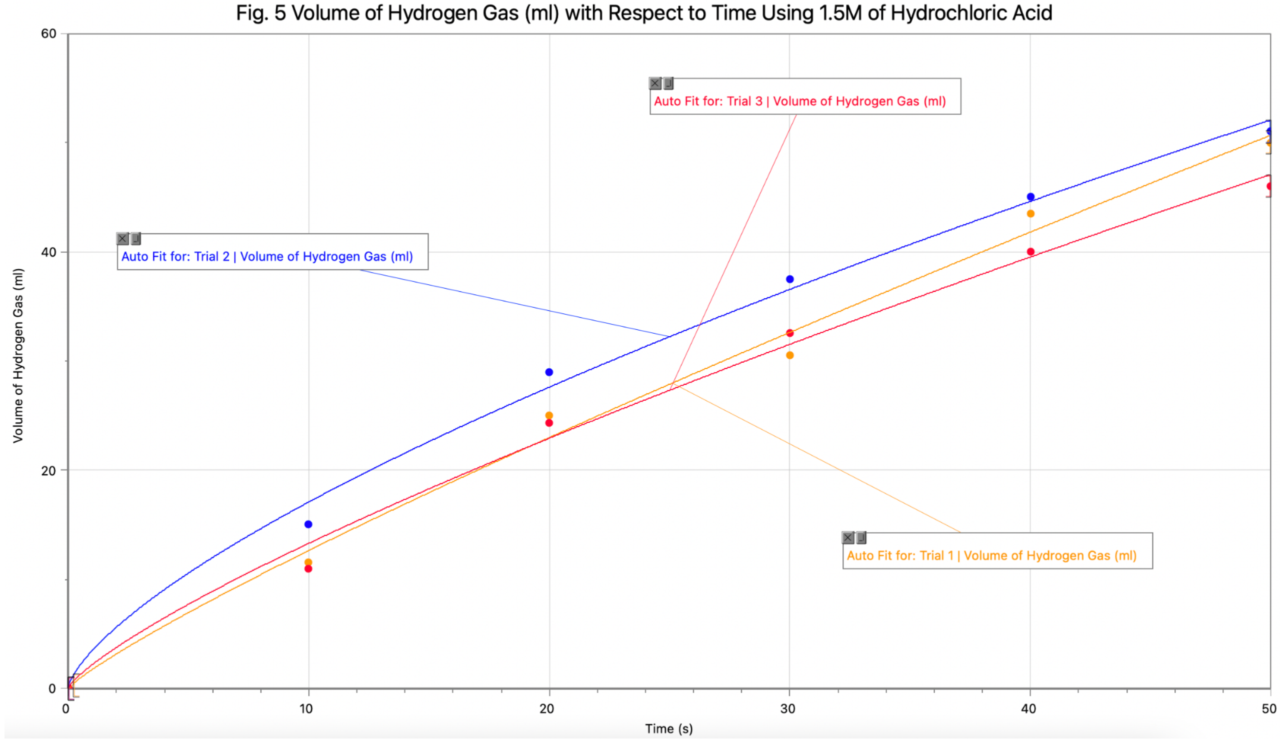


Fig. 6 Volume of Hydrogen Gas (ml) with Respect to Time Using 2.0M of Hydrochloric Acid

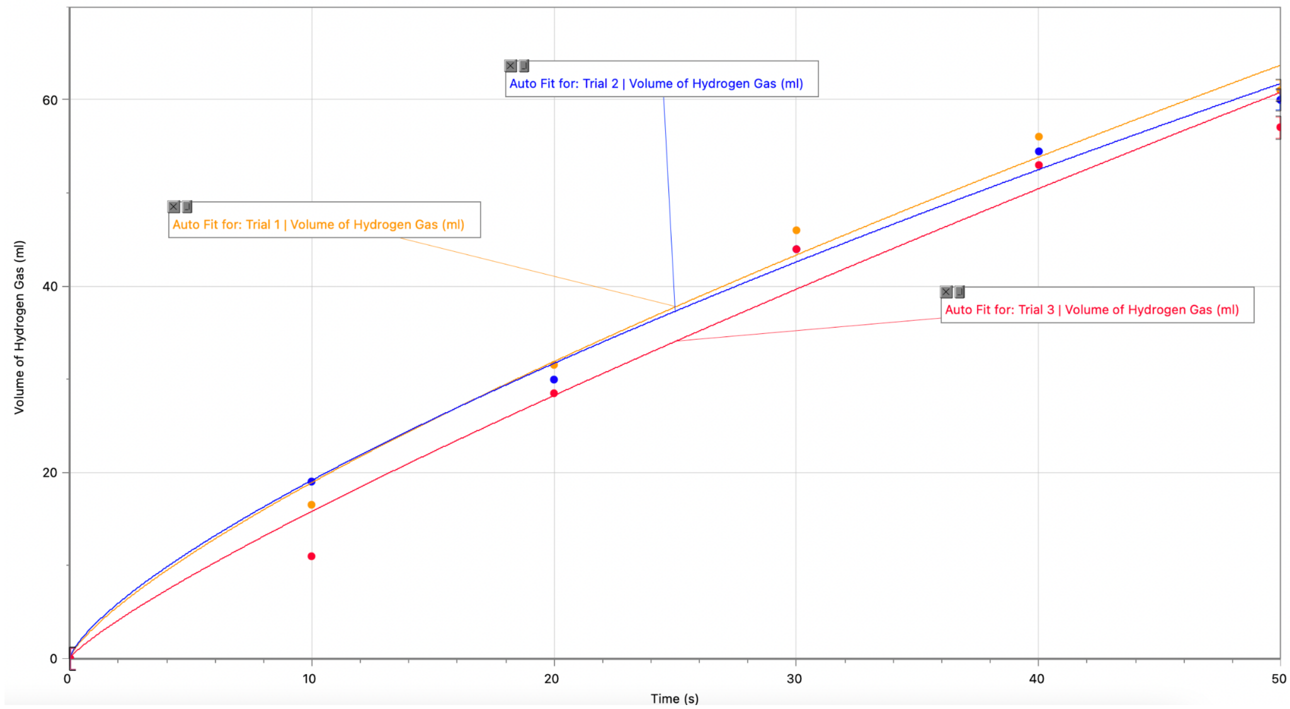
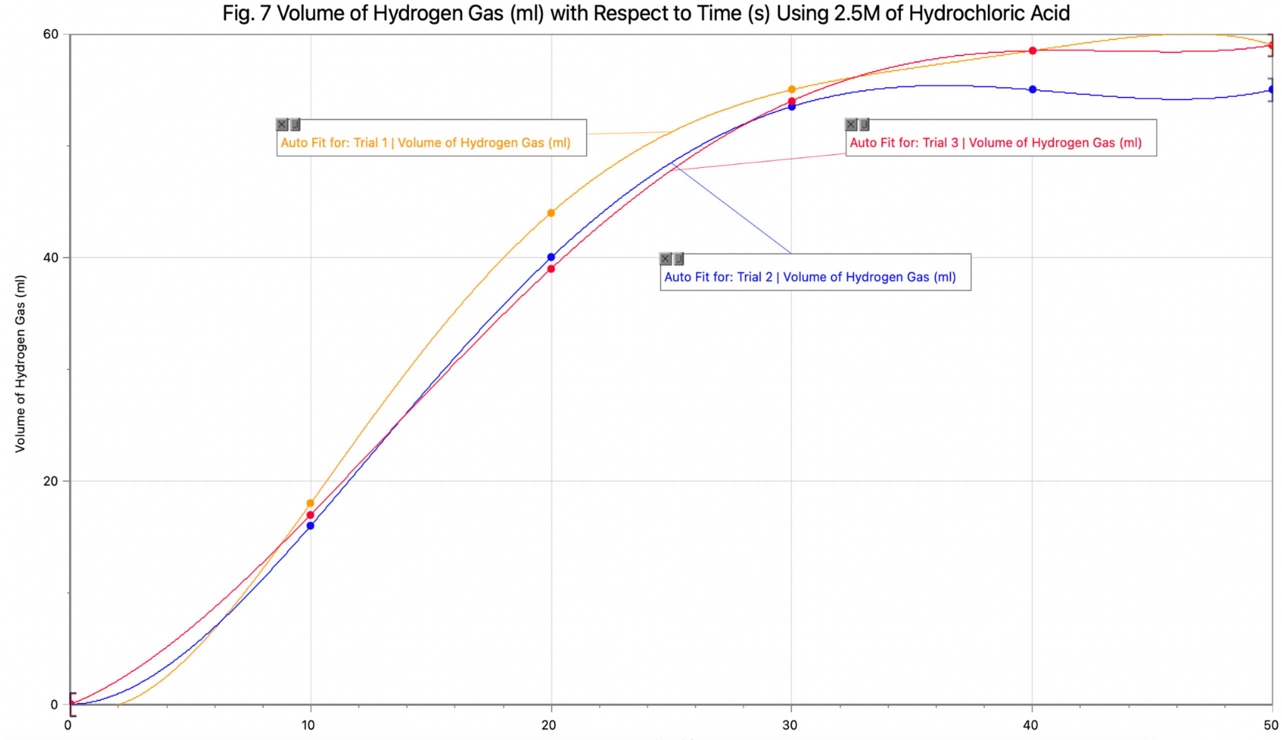


Fig. 7 Volume of Hydrogen Gas (ml) with Respect to Time (s) Using 2.5M of Hydrochloric Acid



Sample Calculation - Average Initial Rate of Reaction

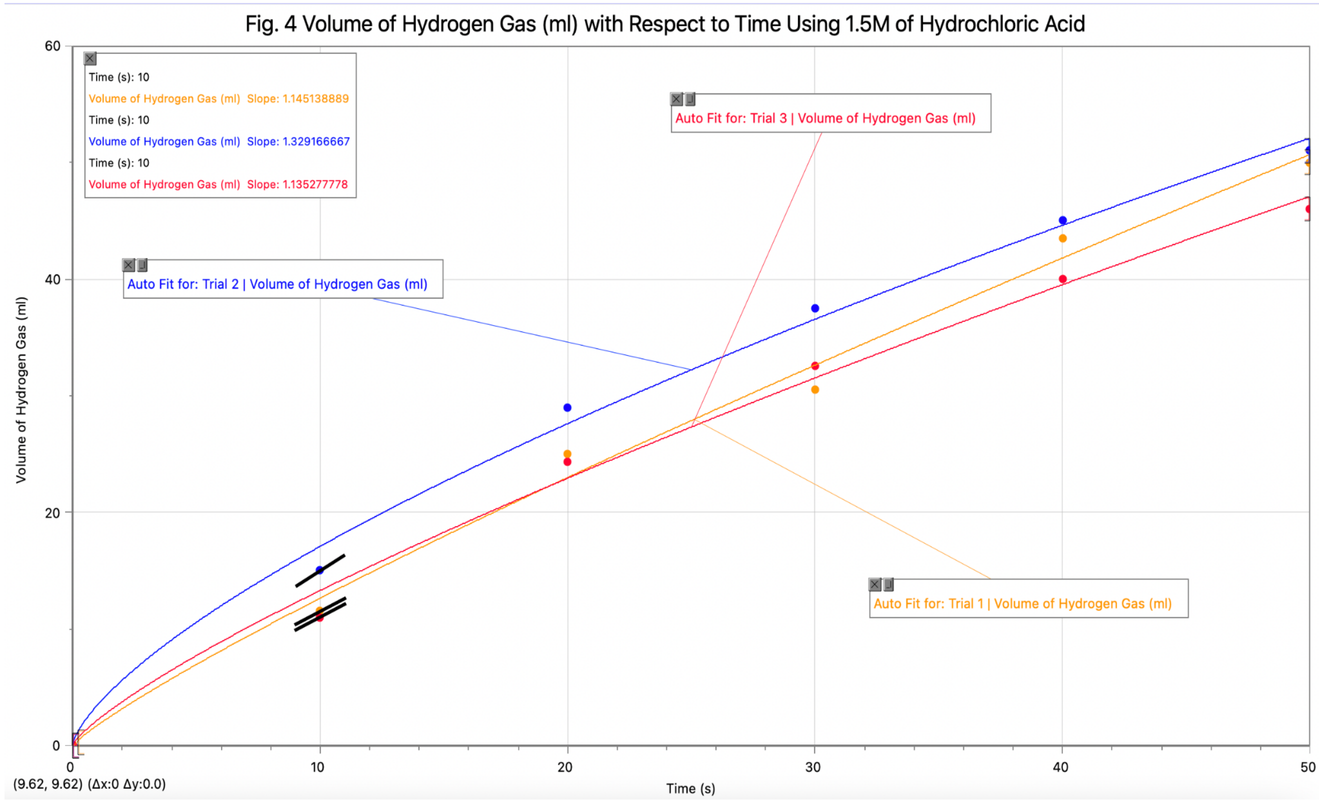
Calculating the average rate of reaction (mL of H_2 gas per second) with a concentration of **1.5M** of hydrochloric acid:

Initial Rate of Reaction (Trial 1): 1.15
Initial Rate of Reaction (Trial 2): 1.33
Initial Rate of Reaction (Trial 3): 1.14

Average Rate of Reaction:

$$\frac{1.15 + 1.33 + 1.14}{3} \approx 1.21$$

Sample Calculation - Initial Rate of Reaction



Screenshot depicting how LoggerPro, a graphing software, calculates the tangent of the slopes at 10 seconds. Thus, showing the initial rate of reaction for a **hydrochloric acid concentration of 1.5M**.

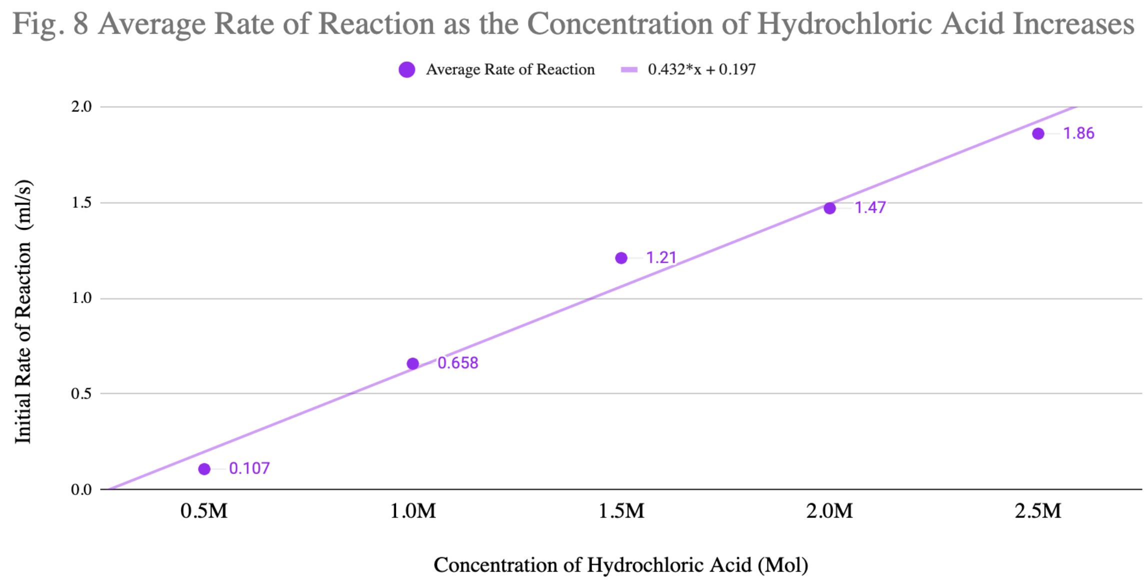
Processed Quantitative Data Table

Values rounded to three significant figures.

Rate of Reaction Each Time the Concentration of Hydrochloric Acid Increases by 0.5M	
Concentration of Hydrochloric Acid	**Average Rate of Reaction (mL of H_2 gas per second)**
0.5M	0.107

1.0M	0.658
1.5M	1.21
2.0M	1.47
2.5M	1.86

Processed Quantitative Data Graph



Conclusion

Figure 8 graph results show the rate of reaction does increase as concentration of hydrochloric acid increases. This can be deduced from the positive linear trendline. In the graph, the independent variable is the concentration of hydrochloric acid (0.5M, 1.0M, 1.5M, 2.0M and 2.5M) and my dependent variable is the initial rate of reaction as determined by the volume of hydrogen gas produced with respect to time taken. From my data, at a hydrochloric acid concentration of 0.5M, the rate of reaction was 0.107 mL of hydrogen gas per second. Whereas, the rate of reaction for 2.5M of hydrochloric acid was 1.86 mL of hydrogen gas per second. Hence this shows the general increase in rate of reaction as concentration increases. The positive linear slope supports my hypothesis that the rate of reaction increases as concentration of hydrochloric acid increases. With a greater hydrochloric acid concentration, there are more acid particles (hydrogen ions) prevalent to collide with the piece of magnesium. Therefore, the frequency of effective collisions increases, resulting in a faster chemical reaction and causing a greater rate of reaction.

As seen in the graphs above, there were anomalies in the data collected. In Figure 8, the equation of the trendline plotted was 0.432 + 0.197. The y intercept was 0.197, however it was supposed to be at 0, as the rate of hydrogen gas production per second (reaction) should be at zero when the concentration of hydrochloric acid is at zero. The average rate of reaction data points, as shown in Figure 8, do not follow a perfect linear trendline. Due to human error, some data points fall below or above the positive linear trend. For example, a concentration of 0.5M of hydrochloric acid results in 0.107 mL of hydrogen gas produced per second, falling below the expected trendline result. Whereas, a concentration of 1.5M of hydrochloric acid results in 1.21 mL of hydrogen gas produced per second, which is higher than projected trendline.

As shown in the sample calculation graphs of analysed quantitative data, certain graphs were shown to be accurate but not precise. For example, Figure 3 had a concentration of 0.5M of hydrochloric acid and amongst all the other concentrations of hydrochloric acid , the amount of hydrogen gas that was produced varied amongst all three trials. This resulted in 3 separate variations of initial rate of reactions for each of the trials. Trials 1, 2 and 3 had an initial rate of 0.140mL, 0.100mL and 0.0799 mL of hydrogen gas production per second (mL/s) respectively. Thus, the average between these numbers was not precise due to the varied initial rate of reaction amongst the trials. This shows that in order to be both precise and accurate, the procedure in the experiment can be improved.

Evaluation

During the process of the experiment, there were numerous instances to reflect on. This includes the challenges faced, the overall strengths and further improvements which can be made to the independent, dependent and control variables of the experiment. Overall, the procedure used was mostly valid. The nature of this experiment caused difficulty in data collection as data needed to be collected in a swiftly manner. Thus, to help minimise human error, a phone camera was used, which quite efficiently captured data. Strengths of this experiment included the relatively high validity and reliability of the results as determined by the scientific literature on the principles of chemistry. High validity and reliability were caused by numerous trials per concentration of hydrochloric acid. However, to improve, having smaller intervals for the concentration of hydrochloric acid, auto-timers for the data-collection photographs and more accurate measuring of the length of magnesium with machine technology can help improve the independent, dependent and control variables respectively. The overall validity of the experiment is further discussed in detail below.

Challenges Faced During the Experimental Process:

Prior to the experiment, I had to conduct multiple pilot trials to ensure that my data collection process was as accurate as possible.

Initially, to collect the amount of hydrogen gas, I would simply look at the gas syringe when my scientist partner would inform me at 10 second intervals up to 50 seconds. However, this was inaccurate at times because I would round the amount of hydrogen gas to the nearest fifth or tens. Additionally, I would take time to read and record the amount of gas which further causes timing inaccuracies.

Another method I used to collect the data in each trial was using my phone and recording a video. This method was far more accurate than the initial method. However, it was very time consuming to find the exact 10 second time intervals 5 times in each video, for all the 3 trials during the data collection process of the pilot trials. Thus, I wanted to figure out a more practical way to record my data which would help the analysing process of data be more efficient.

The final method was chosen to assist in data collection. It involved my scientist partner monitoring each 10 second interval whilst when informed, I would capture a photo on each 10 second interval. This method was the most successful as photos only took a couple of milliseconds to capture. Additionally, with the modern phone camera technology, the pictures taken were always clear. Thus, during the data analysing process I was able to be precise in observing the amount of hydrogen gas in the gas cylinder.

Strengths

The results obtained were reliable and mostly valid. To obtain reliability of the results, each concentration of hydrochloric acid (0.5M, 1.0M, 1.5M, 2.0M, 2.5M) had three trials where the initial rate of reaction was measured every 10 seconds up until 50 seconds. By having three trials for every concentration, each trial was graphed. The initial rate of reaction was calculated by obtaining the initial slope. Thus, the initial rate of reaction values were reliable as they were precise and did not differ greatly between the trials. However, the trendline predicted for the average rate of reaction amongst every concentration (Fig. 8) had a y- intercept value of 0.197 instead of 0, thus showing that the validity of the results can be improved.

As there are no theoretical values for this experiment, calculating the percentage error between the theoretical results and obtained results was not possible. However, this experiment's results will be evaluated by using the principles of chemistry, following trends given by scientific literature. The principles of chemistry state that higher the concentration of reactants, the larger volume of products and the faster the reaction, as a result of more effective collisions between the reactant chemicals *(Khan)*. Thus, the higher the concentration, the higher the initial rate of reaction. The relationship between the concentration and the rate of reaction should be a positive linear slope. The results obtained in Figure 8 show a positive proportional linear relationship between the hydrochloric acid concentration and the rate of reaction. However, each data point is not precisely on the trendline, highlighting how the validity of data collection outlined in the procedure can be improved.

Future Improvements to the Independent Variable

To obtain more accurate results, having smaller intervals for the concentration of hydrochloric acid would have led to a more accurate linear proportional relationship between the concentration of hydrochloric acid and the rate of reaction. For example, instead of having hydrochloric acid concentration values of 0.5M, 1.0M, 1.5M, 2.0M and 2.5M it could have been 0.25M, 0.5M, 0.75M, 1.0M and 1.25M.

Future Improvements to the Dependent Variable

When measuring the hydrogen gas production, variations in reaction time could have affected the credibility of the results. Every 10 seconds a scientist who was monitoring the time would alert the scientist monitoring the gas syringe who would immediately take a photo using their Iphone. However, there could have been an error on both ends. The scientist monitoring the time could have been a few milliseconds late and/or the scientists monitoring the gas syringe could have taken the photo 0.5 to 1 second too late. To improve, instead of photographing the gas syringe marker every 10 seconds, an auto timer can be programmed to make the phone take a photo every 10 seconds up until 50 seconds, which is the duration of each trial.

Future improvements for the Control Variables

Human error must be accounted for when measuring the length of magnesium (3cm) and the volume of hydrochloric acid (10mL). Measuring exactly 3 cm length of the magnesium strips consistently and precisely and 10mL of each concentration of hydrochloric acid would have further improved the accuracy of the obtained results. To improve, sophisticated technology could be used to determine both hydrochloric acid and length of magnesium measurements. Additionally, between each trial, the conical flask used to facilitate the chemical reaction between the magnesium strips and the hydrochloric acid could have been washed and dried thoroughly. This could have ensured that any water residue would not have diluted the acid.

Extension - Future Experiment to Further Investigate GERD medication

As demonstrated in the procedure, by increasing the concentration of hydrochloric acid, the initial rate of reaction increased. Thus, doctors can recommend patients with GERD disease a higher dosage of medication for a faster initial rate of reaction, helping the patient feel more comfortable in a shorter amount of time.

Currently, modern medication used to treat GERD disease (also known as acid reflux), involves the usage of a hydroxide to neutralise the hydrochloric stomach acid. To further understand the correlation between increasing concentration and the effect on the initial rate of reactions, scientists can vary the experiment done in the lab report to mimic the role of GERD medication *(Antacids)*.

The independent variable will be the concentration of the hydroxide. Whereas the dependent variable is the initial rate of reaction which can be determined by the volume of water produced in 10 second intervals up to 50 seconds. However, the volume and concentration of hydrochloric acid will remain as a control variable.

Due to a double displacement reaction between the hydroxide and the acid, water is created as opposed to a gas, thus the procedure used in the lab report will have to be altered in order to measure the volume of water produced. Depending on the scientists choice of hydroxide, the following chemical equations will be used during the experiment:

$$\mathbf{Al(OH)_{3\,(s)} + 3HCL_{(aq)} \rightarrow AlCl_{3\,(aq)} + 3H_20}$$
$$\mathbf{Ag(OH)_{2\,(s)} + 2HCL_{(aq)} \rightarrow MgCl_{2\,(aq)} + 2H_20}$$

Bibliography:

Antacids. 2004. *Encyclopedia of Gastroenterology, 2004*, www.sciencedirect.com/topics/neuroscience/antacid. Accessed 1 Mar. 2022.

"Controlling The Rate." *BBC Bitesize*, BBC, www.bbc.co.uk/bitesize/guides/z2gccdm/revision/3#:~:text=collide%20more%20often.-,Concentration,of%20a%20reaction%20will%20be. Accessed 1 Mar. 2022.

Denham, Jolanda. "Gastroesophageal Reflux Disease (GERD)." *Nemours Teenhealth*, kidshealth.org/en/teens/gerd.html. Accessed 1 Mar. 2022.

"Gastroesophageal Reflux Disease (GERD)." *National University Health System (NUHS)*, www.nuh.com.sg/Health-Information/Diseases-Conditions/Pages/Gastroesophageal-Reflux-Disease-(GERD).aspx. Accessed 1 Mar. 2022.

"How to speed up chemical reactions (and get a date)." *YouTube*, TedEd, 18 June 2012, youtu.be/OttRV5ykP7A. Accessed 1 Mar. 2022.

Khan, Sal. "Factors Affecting Reaction Rates." *Khan Academy*, www.khanacademy.org/science/ap-chemistry-beta/x2eef969c74e0d802:kinetics/x2eef969c74e0d802:reaction-rates/v/factors-affecting-reaction-rates. Accessed 1 Mar. 2022.

Klein, Karin. "An Adult Disease That More Teens Are Getting." *MemorialCare*, www.memorialcare.org/blog/adult-disease-more-teens-are-getting#:~:text=In%20fact%2C%201%20in%204,and%20can%20lead%20to%20cancer. Accessed 1 Mar. 2022.

Markgraf, Bert. "How Does Concentration Affect the Rate of Reaction?" *Sciencing*, 12 May 2018, sciencing.com/how-does-concentration-affect-the-rate-of-reaction-13712168.html. Accessed 1 Mar. 2022.