

Lab Report 4 - Rate of reaction

by George Butcher

Submission date: 09-May-2025 02:47PM (UTC+0100)

Submission ID: 258616125

File name: 60163_George_Butcher_Lab_Report_4_-_Rate_of_reaction_590580_1090166429.docx (2.06M)

Word count: 2981

Character count: 15255

ACDB 4011: RATE OF REACTION

Lab Report 4

George Butcher

UWTSD

Table of Contents

Introduction.	2
Hypothesis:	2
Variables:	2
Experiment 1 - Effect of HCl concentration on the speed of H ₂ gas evolution.	2
Experiment 2 - Effect of temperature on the speed of H ₂ gas evolution.	2
Experiment 3 - Effect of the surface area of Mg on speed of H ₂ gas evolution.	2
Equations:	3
Results.	4
Experiment 1 - Effect of HCl concentration on the speed of H ₂ gas evolution.	5
Experiment 2 - Effect of temperature on the speed of H ₂ gas evolution.	6
Experiment 3 - Effect of the surface area of Mg on speed of H ₂ gas evolution.	8
Discussion.	9
Conclusions.	10
References.	11
Appendix	12
Appendix 1 – Materials and equipment.	12
Appendix 2 – Procedures.	13

Introduction.

The rate of reaction is a fundamental concept in chemistry and it measures how quickly reactants are transformed into products in a chemical reaction [1]. The experiments mentioned in this lab report investigate how different variables affect the rate of reaction of magnesium reacting with hydrochloric acid. In the 3 experiments, the factors looked at are concentration of hydrochloric acid, temperature and surface area of magnesium used. According to the collision theory, collisions occur when particles collide with enough energy. From this it is expected that increasing concentration of the hydrochloric acid it will increase the rate of reaction, as it increases the number of particles per unit volume. It is also expected by increasing the temperature, the rate of reaction will increase as the particles will have more energy, making them move faster, increasing the frequency and energy of the collisions. Finally, in the last experiment, it is expected that increasing the surface area of the magnesium it will also increase the rate of reaction. This is because there will be more reactive surfaces for the hydrochloric acid to collide and react to.

Hypothesis:

1. Concentration - Increasing the concentration of hydrochloric acid will increase the rate of reaction with magnesium.
2. Temperature - Increasing the temperature will increase the rate of reaction between magnesium and hydrochloric acid.
3. Surface Area - Magnesium turnings will react faster than a magnesium ribbon due to greater surface area. *excellent hypothesis, well related to collision theory*

Variables:

Experiment 1 - Effect of HCl concentration on the speed of H₂ gas evolution.

- Independent Variable - Concentration of hydrochloric acid.
- Dependent Variable - Time for magnesium to fully dissolve.
- Controlled Variables - Temperature, volume of acid, mass and form of magnesium strip.

Experiment 2 - Effect of temperature on the speed of H₂ gas evolution.

- Independent variable - Temperature of the hydrochloric acid.
- Dependent Variable - Time for the magnesium to fully dissolve.
- Controlled Variables - Concentration and volume of hydrochloric acid, mass and form of magnesium strip.

Experiment 3 - Effect of the surface area of Mg on speed of H₂ gas evolution.

- Independent Variable - Surface area of magnesium.
- Dependent Variable - Time for magnesium to fully dissolve.
- Controlled Variables - Concentration and volume of hydrochloric acid, temperature.

Equations:

$$rate = \frac{\Delta V_{H_2}}{\Delta t} \text{ [cm}^3\text{/s]}$$

Equation 1

Results.

First, a balanced chemical equation for the reaction had to be figured out, this can be seen below in figure 1. Then the next step was to work out the mass and moles of magnesium as well as the moles of the hydrochloric acid, this can also be seen in figure 1 below.

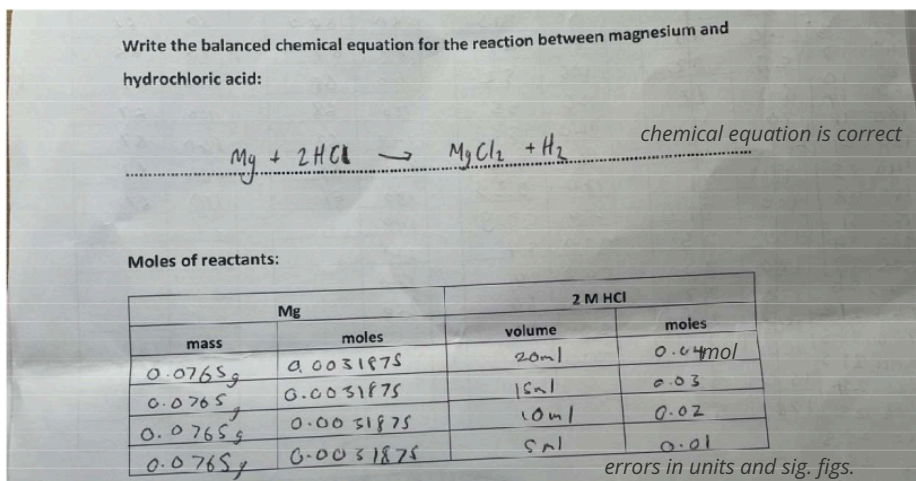


Figure 1 – Balanced chemical equation, including moles of Mg and HCl

avoid pictures like Figure 1 in your reports. they do not look good and reduce professionalism of the report; type it!

precision of pipette is 0.05 mL; volume should contain 2 decimals

Experiment 1 - Effect of HCl concentration on the speed of H₂ gas evolution.

The results of experiment 1 can be seen in figure 2 below.

I. Effect of concentration of HCl on speed of H₂ gas evolution:

0.5 M HCl		1.0 M HCl		1.5 M HCl		2.0 M HCl	
time, s	V H ₂ , ml	time, s	V H ₂ , ml	time, s	V H ₂ , ml	time, s	V H ₂ , ml
20	4	20	2.2	20	4.8	20	4.5
40	8	40	3.3	40	5.5	40	5.2
60	10	60	3.5	60	6.3	60	6.1
80	12	80	4.8	80	6.7	80	6.6
100	14	100	5.2	100	6.8	100	6.7
120	16	120	5.3	120	6.8	120	6.7
140	18	140	5.5	140	6.8	140	6.7
160	20	160	5.5	160	6.8	160	6.7
180	22	180	5.5	180	6.8	180	6.7
200	24	200	5.5	200	6.8	200	6.7
220	26	220	5.5	220	6.8	220	6.7
240	28	240	5.5	240	6.8	240	6.7
260	30	260	5.5	260	6.8	260	6.7
280	32	280	5.5	280	6.8	280	6.7
300	34	300	5.5	300	6.8	300	6.7
320	36	320	5.5	320	6.8	320	6.7
340	38	340	5.5	340	6.8	340	6.7
360	40	360	5.5	360	6.8	360	6.7
380	42	380	5.5	380	6.8	380	6.7
400	44	400	5.5	400	6.8	400	6.7
420	46	420	5.5	420	6.8	420	6.7
440	48	440	5.5	440	6.8	440	6.7
460	50	460	5.5	460	6.8	460	6.7
480	52	480	5.5	480	6.8	480	6.7
500	54	500	5.5	500	6.8	500	6.7
520	56	520	5.5	520	6.8	520	6.7
540	58	540	5.5	540	6.8	540	6.7
560	60	560	5.5	560	6.8	560	6.7
580	62	580	5.5	580	6.8	580	6.7
600	64	600	5.5	600	6.8	600	6.7
620	66	620	5.5	620	6.8	620	6.7
640	68	640	5.5	640	6.8	640	6.7
660	70	660	5.5	660	6.8	660	6.7
680	72	680	5.5	680	6.8	680	6.7
700	74	700	5.5	700	6.8	700	6.7
720	76	720	5.5	720	6.8	720	6.7
740	78	740	5.5	740	6.8	740	6.7
760	80	760	5.5	760	6.8	760	6.7
780	82	780	5.5	780	6.8	780	6.7
800	84	800	5.5	800	6.8	800	6.7
820	86	820	5.5	820	6.8	820	6.7
840	88	840	5.5	840	6.8	840	6.7
860	90	860	5.5	860	6.8	860	6.7
880	92	880	5.5	880	6.8	880	6.7
900	94	900	5.5	900	6.8	900	6.7
920	96	920	5.5	920	6.8	920	6.7
940	98	940	5.5	940	6.8	940	6.7
960	100	960	5.5	960	6.8	960	6.7
980	102	980	5.5	980	6.8	980	6.7
1000	104	1000	5.5	1000	6.8	1000	6.7

[HCl]	time to dissolve Mg	average rate V / t	instantaneous rate at t = 0 s
0.5 M	600 s	$\frac{51.3}{600} = 0.0855 \text{ cm}^3/\text{s}$	$\frac{1.3}{2.0} = 0.65 \text{ cm}^3/\text{s}$
1.0 M	300 s	$\frac{24.6}{300} = 0.082 \text{ cm}^3/\text{s}$	$\frac{2.6}{2.0} = 1.3 \text{ cm}^3/\text{s}$
1.5 M	100 s	$\frac{6.8}{100} = 0.068 \text{ cm}^3/\text{s}$	$\frac{4.6}{2.0} = 2.3 \text{ cm}^3/\text{s}$
2.0 M	100 s	$\frac{6.7}{100} = 0.067 \text{ cm}^3/\text{s}$	$\frac{4.6}{2.0} = 2.3 \text{ cm}^3/\text{s}$

Figure 2 – Results from experiment 1.

all these numbers should be copied into the report and presented in tables

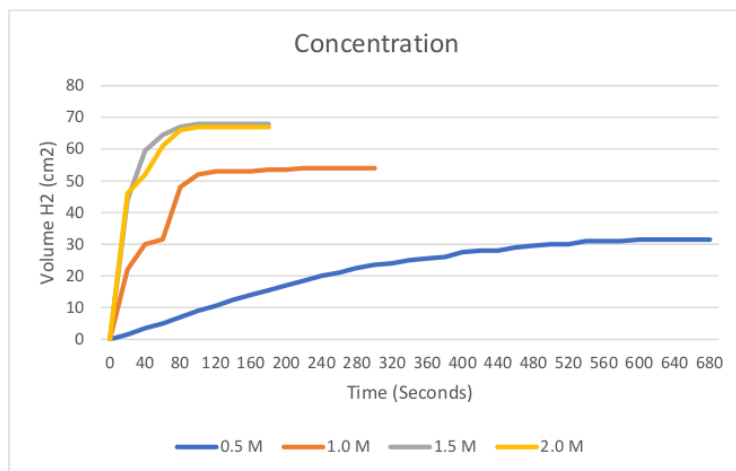


Figure 3 – Graph from experiment 1.

As can be seen in the results and graph above, as the concentration of HCl increases, the time required for magnesium to dissolve decreases, showing an increase in rate of reaction. For 0.5 mol concentration the average rate of reaction was $0.0325\text{cm}^3/\text{s}$, for 1.0 mol it was $0.245\text{cm}^3/\text{s}$, for 1.5 mol it was $0.68\text{cm}^3/\text{s}$ and finally 2.0 mol the average reaction rate was similar to 1.5 mol at $0.67\text{cm}^3/\text{s}$. This is due to the greater number of H^+ ions in more concentrated acid, resulting in more frequent collisions with magnesium atoms. The increase in both average and instantaneous rate confirms that concentration significantly influences the reaction rate. In this experiment it was expected to produce the same volume of H_2 , however the volume H_2 was increased over each experiment. This is probably due to the reaction being a lot slower for the first two concentrations so by the time that 5 of the same readings was taken the reaction wasn't fully completed. It is assumed that if the reaction was left, over time, the volume of H_2 would be the same. Regarding the last two concentrations, the results were very similar. The reaction time and the volume of H_2 were pretty much the same. This is probably due to another factor limiting the reaction rate like surface area of the magnesium or the temperature. After 1.5 mol of HCl the number of H^+ ions in the concentration had little effect of the rate of reaction. *it is H subscript 2*

Experiment 2 - Effect of temperature on the speed of H_2 gas evolution.

The results from experiment 2 can be seen in figure 3 below.

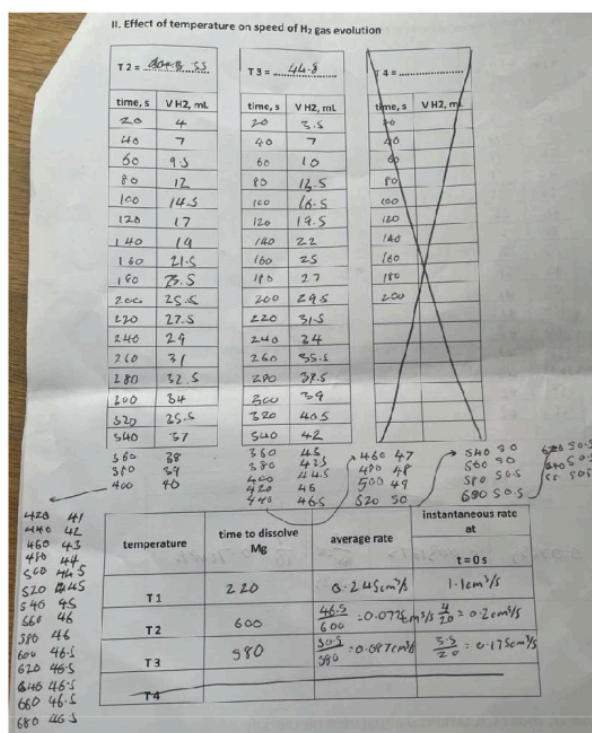


Figure 4 – Results from experiment 2.

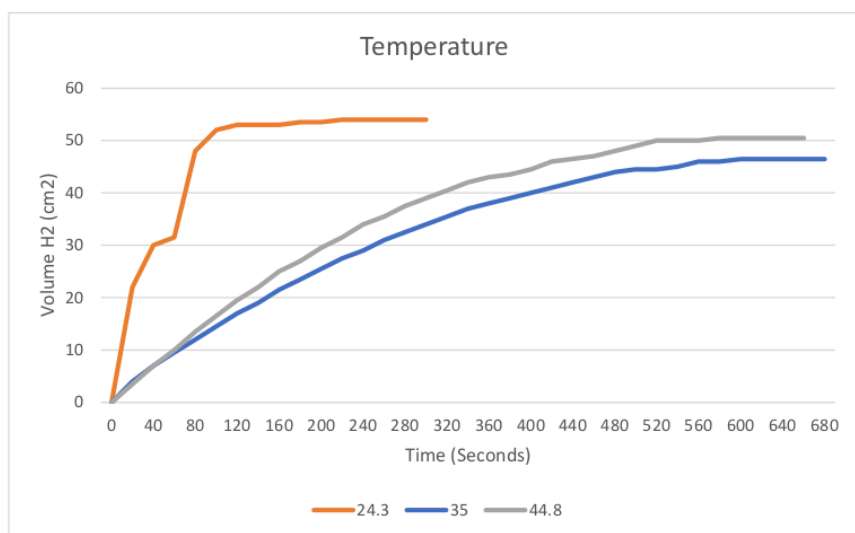


Figure 5 – Graph from experiment 2.

From the results and the graph above there was an unexpected outcome. It is expected that the increase of temperature will increase the rate of reaction. From the first experiment T1 was measure to be 24.3°C with a reaction time of 220 seconds, giving an average rate of 0.245cm³/s. In the first part of this experiment T2 was measured to be 35°C, however the reaction time increased to 600 seconds, giving it a slower reaction rate of 0.0775cm³/s. For the final part of this experiment T3 was measures to be 44.5°C, however the reaction time was only slightly quicker than T2 at 580 seconds giving it the average reaction rate of 0.087cm³/s. From these results it would suggest that increasing the temperature slows down the rate of reaction, this contradicts the expectations. Higher temperature should increase rate of reaction due to particles having more energy, increasing the frequency and energy of the collisions. The issues of the results are most likely due to human error. From these results it suggests that the experiment was done with lower concentration HCl, instead of the 1.0 M HCl intended. Other issue could be that there was inconsistent timing or measurements of temperature. There also could have been inconsistencies with the magnesium strip, oxidation layer of the magnesium might not have been fully removed from this experiment, slowing down the time of reaction. In the future for this experiment all measurements will have to be double checked to make sure that the results are consistent.

Experiment 3 - Effect of the surface area of Mg on speed of H₂ gas evolution.

The results from experiment 3 can be seen in figure 4 below.

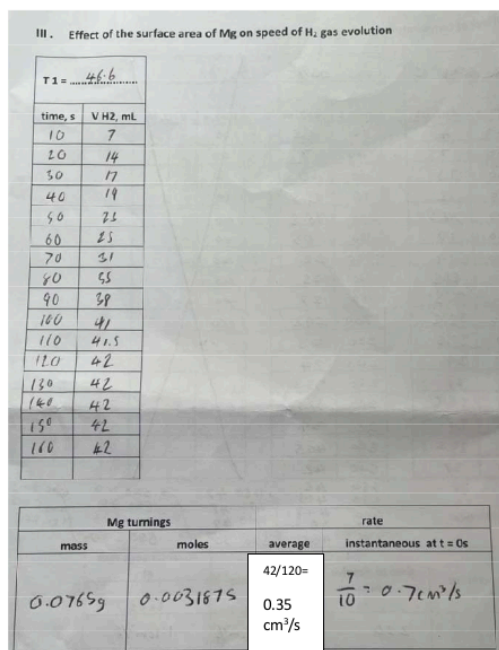


Figure 6 – Results from experiment 3.

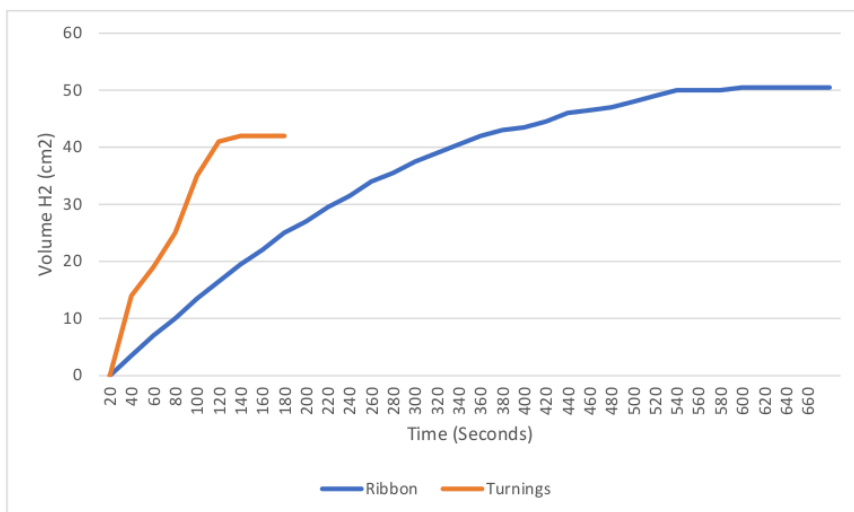


Figure 7 – Graph from experiment 3.

From the results and graph above it can be seen that the reaction time for the magnesium turnings was only 120 seconds giving the average reaction rate of $0.35\text{cm}^3/\text{s}$ and an instantaneous reaction rate of $0.7\text{cm}^3/\text{s}$. Comparing this to the last part of experiment 2 because the T values are the most similar. The reaction in experiment 2 took 580 seconds, with an average reaction rate of $0.087\text{cm}^3/\text{s}$ and an instantaneous reaction rate of $0.175\text{cm}^3/\text{s}$. It is clear to see that having a greater surface area of the magnesium results in a higher reaction rate. This is due to the greater surface area allowing more acid particles to collide with the magnesium. This supports the expected results that increasing surface area increases reaction rate. To increase the validity of these results it would help to have the T values exactly the same. It would also be beneficial to re-do experiment 2 as these results are not accurate.

Discussion.

The experiments above were done to demonstrate how three variables, acid concentration, temperature, and surface area, affect the rate of chemical reaction between hydrochloric acid (HCl) and magnesium (Mg). For concentration, in experiment 1, the results clearly showed that by increasing the concentration of hydrochloric acid it increased the rate of reaction. This aligns with the collision theory, which states that higher concentration increases the number of particles in a given volume, resulting in more frequent and effective collisions. Regarding temperature, the results collected showed that higher temperatures were associated with longer reaction time. This contradicts the expectations. This is likely due to human error rather than an actual inverse relationship. Theoretically, higher temperature increases the kinetic energy of particles, thereby increasing the frequency and energy of collisions and accelerating the reaction, however this was not seen in the results. This experiment should be completed again with measurements taken more accurately to ensure their validity. Finally, the results seen in the surface area experiment, showed a significant increase in rate of reaction with the increased surface area of the magnesium. Having an increased surface area, it allows more HCl particles to interact with the magnesium simultaneously, speeding up the reaction.

Rate of reaction is highly relevant to a OME environment. Regarding concentration it is important to know the rate of reaction during chemical synthesis of energetic compounds. The ability to predict and control the rate of reaction ensures that the processes are safe and effective [2]. Temperatures effect on rate of reaction is crucial for explosive safety. Materials that react easily at elevated temperatures have serious risks during storage, handling, or accidental ignition. Temperature thresholds must be tightly regulated in OME environments to ensure the safe use of energetic materials [3]. Finally, surface area of explosives and propellants is normally increased to increase the rate of reaction. For example, gun powder is produced in a power form as it rapidly increases the rate of reaction allowing it to be more effective [4].

There are several limitations and potential sources of error for the 3 experiments in this lab report. The main issue from the experiments was the effect of temperature on speed of H^2 evolution (experiment 2). Higher temperatures should increase rate of reaction due to particles having more energy, increasing the frequency and energy of the collisions.

However, the results did not show this. The issues of the results are most likely due to human error. From the results it suggests that the experiment was done with lower concentration HCl, instead of the 1.0 M HCl intended. The other issue could be that there was inconsistent timing or measurements of temperature. There could have also been temperature loss when moving the HCl from the water bath to the syringe, this could have allowed cooling. In future for this experiment all measurements will have to be double checked to make sure that the results are consistent. Regarding all the experiments other sources of error could be the inaccurately measuring the time. Gas measurements, the syringe would sometimes get stuck, affecting the H^2 volume readings. Mass and form of the magnesium's strips, although the ribbon length was controlled, surface condition (oxidation layer) or slight variations in mass might not have been fully accurate. To address these issues in future experiments, better measurements of time, H^2 volume and temperature will improve the results. It is also important to make sure the controlled variables are actually controlled, for example the oxidation layer on the magnesium strip and the concentration of the HCl for the last 2 experiments.

Conclusion.

In conclusion, this lab report investigated how three variables: concentration, temperature, and surface area affected the rate of reaction between magnesium and hydrochloric acid. It was found that increasing the concentration of HCl significantly increased the reaction rate up until the 1.5 mol concentration, after this it is likely that another factor was limiting the rate of reaction. This supports the hypothesis that increasing the concentration of hydrochloric acid will increase the rate of reaction with magnesium. For the temperature variable the data for had unexpected results. The rate of reaction appeared to decrease as temperature increased. This contradicts the hypothesis and the collision theory. These results are likely due to experimental errors. Finally, the surface area variable, it was found that a greater surface area increases the rate of reaction by providing more contact points for collisions. Supporting the hypothesis that magnesium turnings will react faster than a magnesium ribbon due to greater surface area. Overall, two of the three hypotheses were clearly supported by the data, while the temperature hypothesis could not be properly validated.

For future experiments it would be recommended to repeat the temperature experiment with more accuracy, making sure all measurements and timing are correct. It will also help to have better thermal insulation and faster transfer of reactants to minimize heat loss and ensure accurate results. Another way to increase the results validity is to use more precise timing methods, such as sensors or automated data loggers, to reduce human error, this will help especially in quick reactions. For future research it would be useful to measure additional variables such as catalysts or pressure and their influence on rate of reaction.

References.

- [1] M. UWTSd, "Log in to the site | Home," *Uwtsd.ac.uk*, 2025. *not an appropriate academic source for scientific theory*
<https://moodle.uwtsd.ac.uk/mod/resource/view.php?id=662297> (accessed May 09, 2025).
- [2] M. W. Beckstead, "Solid propellant combustion mechanisms and flame structure," *Solid propellant combustion mechanisms and flame structure*, vol. 65, no. 2, pp. 297–307, Jan. 1993, doi: <https://doi.org/10.1351/pac199365020297>. *title duplicated, no journal title Pure and Applied Chemistry; no access date*
- [3] S. Fordham, "High Explosives and Propellants," *Google Books*, 2025. *it's not a publisher*
<https://books.google.co.uk/books?hl=en&lr=&id=vfkkBQAAQBAJ&oi=fnd&pg=PP1&dq=S.+Fordham> (accessed May 09, 2025).
- [4] J. Prakash, "High Energy Materials: Propellants, Explosives and Pyrotechnics, 2nd ed." Available: https://ftp.idu.ac.id/wp-content/uploads/ebook/tdg/ADVANCED%20MATERIAL%20DESIGN/epdf.pub_high-energy-materials-propellants-explosives-and-p.pdf *publisher? year?*

Appendix.

Appendix 1 – Materials and equipment.

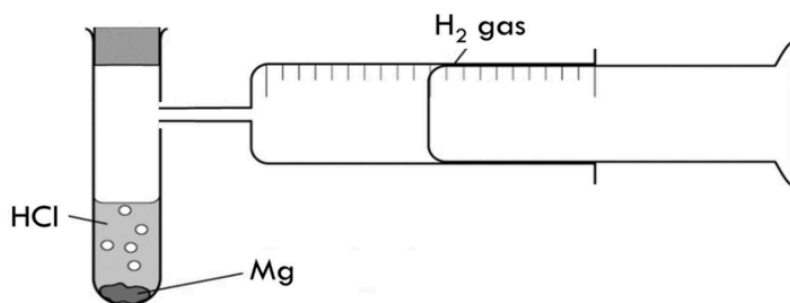
Lab tools and supplies:

- Long test tube with arm
- Gas syringe - syringe should not be allowed to become wet, or the plunger will stick inside the barrel
- Rubber bung and delivery tube to fit the test tube
- Two large beakers for the water bath and reaction mixture
- Pipette and pipette filler
- Two clamp stands
- Test tube holder
- Thermometer
- Ring stand, Bunsen burner, clay triangle
- Stopwatch
- Graph paper

Chemicals:

- Magnesium ribbon cut into 4 cm length and weighed
- Magnesium powder (same mass as ribbon)
- Hydrochloric acid (2.0 M and 1.0 M)
- DI water

Apparatus:



Keep the apparatus on the same level and the syringe perpendicular

Appendix 2 – Procedures.

Experiment 1 - Effect of HCl concentration on the speed of H₂ gas evolution.

1. Prepare FOUR 20.0 mL solutions of HCl with the following concentrations: 2.0 M (stock), 1.5 M, 1.0 M and 0.5 M. Use the pipette to measure appropriate volumes of the 2.0 M HCl solution and DI water.
2. Pour the HCl solution with the lowest concentration into the test tube with arm.
3. When ready, add a 4 cm strip of magnesium ribbon to the test tube, quickly put the bung back, and start the stopwatch.
4. For 1 M HCl use the Mg ribbon from the premeasured vial. This set of data will be needed for Part 3.
5. Record the volume of hydrogen gas given off at suitable intervals (e.g. 10 seconds). Continue timing until no more gas is given off.
6. After the reaction is completed, discard the reaction mixture in the waste beaker.
7. Measure the temperature of 1.0 M HCl. It will be needed for Part 2.
8. Repeat the same experiment for three other concentrations of HCl.

Plot the graph (V_{H_2} vs t) showing the change in volume of H₂ gas over time for each concentration of HCl.

For each concentration of HCl determine the:

1. Average rate of reaction (between $t = 0$ s and $t = t_1$; use the same t_1 for all concentrations)
2. Instantaneous rate of reaction at $t = 0$.

Experiment 2 - Effect of temperature on the speed of H₂ gas evolution.

1. Set up a water bath. Pour water into the large beaker and heat it over the Bunsen burner till the temperature of water increases by approximately 10 degC when compared to the initial temperature of 1 M HCl measured in the previous part.
2. Pipette 20 mL of 1.0 M stock solution into three test tubes.
3. Place the first test tube with 1.0 M HCl in the water bath and wait until the temperature of the acid reaches the temperature of the water in the water bath.
4. Quickly transfer the warm HCl into the tube with the arm, put 4 cm piece of magnesium ribbon, put the bung back, and start the stopwatch.
5. Continue timing until no more gas is given off.
6. After the reaction is completed, discard the reaction mixture in the waste beaker.
7. Repeat the same experiment for two more temperatures (ideally 10 degC apart).

On the separate graph paper provided, plot the graph (V_{H_2} vs t) showing the change in volume of H₂ gas over time for each temperature.

For each concentration of HCl determine the:

1. 1 Average rate of reaction (between $t = 0$ s and $t = t_1$; use the same t_1 for all temperatures)

2. Instantaneous rate of reaction at $t = 0$.

Experiment 3 - Effect of the surface area of Mg on speed of H_2 gas evolution.

1. Use the pipette to transfer 20 mL of 1 M HCl at room temperature into the test tube with arm.
2. Quickly add the Mg turnings into the test tube, put the bung back, and start the stopwatch.
3. Continue timing until no more gas is given off.
4. After the reaction is completed, discard the reaction mixture in the waste beaker.

Plot the graph (V_{H_2} vs t) showing the change in volume of H_2 gas over time for each temperature. Determine the:

1. Average rate of reaction (between $t = 0$ s and $t = t_1$; use the same t_1 for both Mg samples).
2. Instantaneous rate of reaction at $t = 0$.

Lab Report 4 - Rate of reaction

GRADEMARK REPORT

FINAL GRADE

63 / 100

GENERAL COMMENTS

Engagement with Literature Skills 10/15

The report includes well-chosen OME-related references, effectively applied in the discussion. However, IEEE formatting is incorrect, and no literature supports core theory such as collision theory or rate laws.

Feedback: Strengthen theoretical support with chemical sources and use correct IEEE referencing throughout.

Knowledge and Understanding Skills 13/20

Theoretical concepts are introduced clearly, and hypotheses are well stated. The balanced equation is included. However, the dependent variable is misidentified, and theoretical depth (e.g. rate laws, activation energy) is missing.

Feedback: Correct the dependent variable and include deeper theoretical support for your hypotheses.

Cognitive and Intellectual Skills 16/25

Results are interpreted well, and possible errors are discussed. OME relevance is clear, but explanations of anomalies rely more on procedure than theory.

Feedback: Support unexpected results with kinetic reasoning and connect OME applications more directly to your findings.

Practical Application Skills 15/25

Data collection is structured and results are presented clearly. However, the method for calculating rates is not explained, and no reference is made to $\Delta V/\Delta t$ or tangent methods taught.

Feedback: Clearly explain how rates were calculated using defined methods and show your work.

Transferable/Professional Skills 10/15

The report is well structured, formal, and clearly written. Passive voice is used effectively. Some terms (e.g. "instantaneous rate") are not defined, and phrasing could be more precise. Tables should be generated within the main text. Avoid screenshots.

Feedback: Maintain the strong structure and tone. Define all key terms and refine language for scientific accuracy.

PAGE 1

PAGE 2

PAGE 3



Comment 1

good mention

Text Comment. excellent hypothesis, well related to collision theory

Strikethrough.

Strikethrough.

Strikethrough.

Text Comment. dependent variable in each case is the volume of hydrogen gas generated in the reactions

PAGE 4

PAGE 5

Text Comment. chemical equation is correct

Text Comment. mol

Text Comment. errors in units and sig. figs.

Text Comment. avoid pictures like Figure 1 in your reports. they do not look good and reduce professionalism of the report; type it!

Text Comment. precision of pipette is 0.05 mL; volume should contain 2 decimals

PAGE 6

Text Comment. all these numbers should be copied into the report and presented in tables

PAGE 7



Comment 5

excellent point

Text Comment. it is H subscript 2

PAGE 8

Text Comment. how did you determine the rates? kinetic information is derived experimentally using graphical method that must be very clearly described

PAGE 9

PAGE 10

PAGE 11

PAGE 12

Text Comment. not an appropriate academic source for scientific theory

Strikethrough.

Text Comment. title duplicated, no journal title Pure and Applied Chemistry; no access date

Text Comment. it's not a publisher

Strikethrough.

Text Comment. publisher? year?

PAGE 13

PAGE 14
