

Determination of the Composition of an Alloy

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Procedure

As described in the manual (EXPERIMENT 1).

Data and Observations

Table 1: Pure Metal



Data	Trial 1	Trial 2
Identity of Metal	Magnesium	Magnesium
Mass of metal (g)	0.0273 g	0.0290 g
Uncalibrated volume of eudiometer	Already calibrated	Already calibrated
Volume of hydrogen gas (mL)	28.7 mL	30.7 mL
Height of water column (cm)	21.4 cm	17 cm
Density of water (kg/m ³)	1000 kg/m ³	1000 kg/m ³
Acceleration due to gravity (m/s ²)	9.81 m/s ²	9.81 m/s ²
Pressure of water column (Pa)	2099.34 Pa	1667.7 Pa
Water Temperature (Celsius)	22.8°C	22.9°C
Water Vapour pressure (Pa)	2810 Pa	2810 Pa
Atmospheric Pressure (Torr)	753.812 Torr	753.812 Torr
Pressure of Hydrogen (Pa)	95590.66 Pa	96022.3 Pa
Room Temperature (Celsius)	22.7 °C	22.7 °C
Ideal Gas Constant, R	8.314 J K ⁻¹ mol ⁻¹	8.314 J K ⁻¹ mol ⁻¹
Actual Moles of Hydrogen (mol)	1.118x10 ⁻³	1.201x10 ⁻³
Theoretical moles of hydrogen (mol)	1.123x10 ⁻³	1.193x10 ⁻³
Percent Yield (%)	99.55%	100.67%

When performing this part of the experiment, it can be noted that both trials had similar data (Refer to Table 1). Even with extreme precautions, when pouring the HCL into the eudiometer, not only was the mist escaping from the beaker noticeable but as well as the foul, irritating smell of the acid. To add, the HCL acid was a transparent liquid, similar to water. When the eudiometer containing HCL and the distilled H₂O was inverted, the acid was seen descending down the tube. When the acid came into contact with the metal in the sample holder at the bottom, bubbles were created almost instantly and Hydrogen began to produce. Tapping the eudiometer was necessary due to the fact that the metal rose up too quickly and to ensure the metal remained in contact with the acid to complete the reaction. In addition, the piece of Magnesium had a lot of movement when it was rising to the top of the eudiometer. Once the reaction slowed down, there was less bubbles and the metal shrank and turned a white colour before dissolving.

Table 2: Alloy

Data	Trial 1	Trial 2
Unknown Number	5131	5131
Mass of metal (g)	0.032 g	0.0442 g
Uncalibrated volume of eudiometer	Already calibrated	Already calibrated
Volume of hydrogen gas (mL)	27.7 mL	36 mL
Height of water column (cm)	23 cm	14.6 cm
Density of water (kg/m ³)	1000 kg/m ³	1000 kg/m ³
Acceleration due to gravity (m/s ²)	9.81 m/s ²	9.81 m/s ²
Pressure of water column (Pa)	2256.3 Pa	1430.8 Pa
Water Temperature (Celsius)	22.7°C	22.5°C
Water Vapour pressure (Pa)	2810 Pa	2810 Pa
Atmospheric Pressure (Torr)	753.812 Torr	753.812 Torr
Pressure of Hydrogen (Pa)	95433.7 Pa	96259.2 Pa
Room Temperature (Celsius)	22.7 °C	22.7 °C
Ideal Gas Constant, R	8.314 J K ⁻¹ mol ⁻¹	8.314 J K ⁻¹ mol ⁻¹
Moles of Hydrogen (mol)	1.075x10 ⁻³	1.410x10 ⁻³
Mass of Zinc (g)	1.743x10 ⁻² g	2.594x10 ⁻²
Mass of Aluminum (g)	1.457x10 ⁻²	1.826x10 ⁻²
Percent Zinc (%)	54.47	58.69
Percent Aluminum (%)	45.53	41.31
Average Percent	43.42% Zn and 56.58% Al	43.42% Zn and 56.58% Al

When testing the alloy, it was evident that the alloy reacted completely different than the metal. However, there were a few similarities between tests. For one, when the eudiometer was inverted, the acid was seen descending in the tube. Another similarity was how the alloy rose to the top of the eudiometer. The alloy had a lot of movement and there was a lot of fizzing and bubbles that occurred during the reaction due to the fact that there a lot of gas was produced. One major difference between tests was the length of the reaction. When testing the alloy, the reaction took much longer to react and terminate whereas with the metal, it was an instantaneous reaction. It was observed that only a few pieces rose to the top at once and the remaining pieces stayed at the bottom bubbling, but each piece ultimately rose to the top of the water. Once a piece alloy reached the top of the water, that piece began to dissolve into a misty black/grey colour and soon dissolved as a whole. However, trial 2 had different results. In trial 1, the liquid in the tube remained transparent whereas in trial 2, it turned more of a grey colour. In addition, trial 2 took much longer to react and finish in comparison to trial 1. To add, when the reaction was completed for trial 2, the eudiometer had bubbles along the sides of the glass even though the reaction was completed.

Sample Calculation: Pure Metal - Magnesium

1. Uncalibrated Volume of the Eudiometer:

Eudiometer was already calibrated.

2. Volume of Hydrogen gas:

$$V = 29.7\text{mL}$$

3. Pressure exerted by the water column:

$$\begin{aligned} p_{\text{Trial 1}} &= dgh \\ &= (1000 \text{ kg/m}^3)(9.81 \text{ m/s}^2)(0.214\text{m}) \\ &= 2099.34 \text{ Pa} \end{aligned}$$

$$\begin{aligned} p_{\text{Trial 2}} &= dgh \\ &= (1000 \text{ kg/m}^3)(9.81 \text{ m/s}^2)(0.17\text{m}) \\ &= 1667.7 \text{ Pa} \end{aligned}$$

4. Pressure of hydrogen gas:

Trial 1:

$$\begin{aligned} P_{\text{Hydrogen}} &= P_{\text{Atmosphere}} - P_{\text{Water Column}} - P_{\text{Water Vapour}} \\ &= 100500 \text{ Pa} - 2099.34 - 2810 \text{ Pa} \\ &= 95590.66 \text{ Pa} \end{aligned}$$

Trial 2:

$$\begin{aligned} P_{\text{Hydrogen}} &= P_{\text{Atmosphere}} - P_{\text{Water Column}} - P_{\text{Water Vapour}} \\ &= 100500 \text{ Pa} - 1667.7 - 2810 \text{ Pa} \\ &= 96022.3 \text{ Pa} \end{aligned}$$

5. Moles of hydrogen gas (experimental):

Trial 1:

$$\begin{aligned} PV &= nRT \\ (95590.66 \text{ Pa})(2.87 \times 10^{-5} \text{ m}^3) &= n(8.314 \text{ J K}^{-1} \text{ mol}^{-1})(295.15\text{K}) \\ 1.118 \times 10^{-3} \text{ mol} &= n \end{aligned}$$

Trial 2:

$$\begin{aligned} PV &= nRT \\ (96022.3 \text{ Pa})(3.07 \times 10^{-5} \text{ m}^3) &= n(8.314 \text{ J K}^{-1} \text{ mol}^{-1})(295.15\text{K}) \\ 1.201 \times 10^{-3} \text{ mol} &= n \end{aligned}$$

6. Moles of hydrogen gas (theoretical):

Trial 1:

$$n = \frac{m}{M}$$

$$= \frac{0.0273 \text{ g}}{24.305 \text{ g/mol}}$$

$$= 1.123 \times 10^{-3} \text{ mol}$$

Trial 2:

$$n = \frac{m}{M}$$

$$= \frac{0.0290 \text{ g}}{24.305 \text{ g/mol}}$$

$$= 1.193 \times 10^{-3} \text{ mol}$$

7. Percentage Purity of metal (percentage yield of hydrogen):

Trial 1:

$$\% \text{purity} = 1.118 \times 10^{-3} \text{ mol} / 1.123 \times 10^{-3} \text{ mol} \times 100 = 99.55\%$$

Trial 2:

$$\% \text{purity} = 1.201 \times 10^{-3} \text{ mol} / 1.193 \times 10^{-3} \text{ mol} \times 100 = 100.67\%$$

8. Average Percent Purity:

$$(100.67\% + 99.55\%) / 2$$

$$= 100.11\%$$

Sample Calculation: Alloy

1. Pressure of water column and hydrogen gas:

Trial 1:

$$P = dgh$$

$$= (1000 \text{ kg/m}^3)(9.81 \text{ m/s}^2)(0.23 \text{ m})$$

$$= 2256.3 \text{ Pa}$$

Trial 1:

$$P = dgh$$

$$= (1000 \text{ kg/m}^3)(9.81 \text{ m/s}^2)(0.146 \text{ m})$$

$$= 1430.8 \text{ Pa}$$

Trial 1:

$$P_{\text{Hydrogen}} = P_{\text{Atmosphere}} - P_{\text{Water Column}} - P_{\text{Water Vapour}}$$

$$= 100500 \text{ Pa} - 2256.3 \text{ Pa} - 2810 \text{ Pa}$$

$$= 95433.7 \text{ Pa}$$

Trial 2:

$$P_{\text{Hydrogen}} = P_{\text{Atmosphere}} - P_{\text{Water Column}} - P_{\text{Water Vapour}}$$

$$= 100500 \text{ Pa} - 1430.8 \text{ Pa} - 2810 \text{ Pa}$$

$$= 96259.2 \text{ Pa}$$

2. Moles of hydrogen gas:

Trial 1:

$$PV=nRT$$

$$(95433.7 \text{ Pa})(2.77 \times 10^{-5} \text{ m}^3) = n(8.314 \text{ J K}^{-1} \text{ mol}^{-1})(295.15 \text{ K})$$

$$1.075 \times 10^{-3} \text{ mol} = n$$

Trial 2:

$$PV=nRT$$

$$(96259.2 \text{ Pa})(3.60 \times 10^{-5} \text{ m}^3) = n(8.314 \text{ J K}^{-1} \text{ mol}^{-1})(295.15 \text{ K})$$

$$1.410 \times 10^{-3} \text{ mol} = n$$

3. Masses of Zinc and Aluminum in the alloy:

Mass of zinc = x

Mass of Aluminum = y

$$\text{Equation 1: } N_{\text{Hydrogen}} = \frac{x}{\text{Molar Mass Zn}} + \frac{3}{2} \cdot \frac{y}{\text{Molar Mass Al}}$$

$$\text{Equation 2: } x + y = M_{\text{Total of alloy}}$$

Trial 1

1) $x = 0.032 - y$

2) Sub equation into equation 1

$$3) 1.075 \times 10^{-3} = \frac{0.032 - y}{65.39} + \frac{3}{2} \cdot \frac{y}{26.982}$$

$$4) 1.075 \times 10^{-3} = \frac{0.032}{65.39} - \frac{y}{65.39} + \frac{3}{2} \cdot \frac{y}{26.982}$$

$$5) 5.856 \times 10^{-4} = -\frac{y}{65.39} + 0.0555y$$

$$6) 5.856 \times 10^{-4} = \frac{3}{2} \cdot \frac{y}{26.982} + 0.0555y$$

$$7) 5.856 \times 10^{-4} = 0.0555y - \frac{y}{65.39}$$

$$8) 5.856 \times 10^{-4} = \frac{3.629y}{65.39} - \frac{y}{65.39}$$

$$9) 5.856 \times 10^{-4} = y \left(\frac{3.629 - 1}{65.39} \right)$$

$$10) 5.856 \times 10^{-4} = \frac{2.629y}{65.39}$$

$$11) (5.856 \times 10^{-4})(65.39) = 2.629y$$

$$12) Y = \mathbf{1.457 \times 10^{-2} \text{ g}}$$

$$\text{Mass of zinc} = 0.032 \text{ g} - 0.01457 = 0.01743 \text{ g} = \mathbf{1.743 \times 10^{-2} \text{ g}}$$

Trial 2

$$1) x = 0.0442 - y$$

2) Sub equation into equation 1

$$3) 1.410 \times 10^{-3} = \frac{0.0442 - y}{65.39} + \frac{3}{2} \cdot \frac{y}{26.982}$$

$$4) 1.410 \times 10^{-3} = \frac{0.0442}{65.39} - \frac{y}{65.39} + \frac{3}{2} \cdot \frac{y}{26.982}$$

$$5) 7.341 \times 10^{-4} = -\frac{y}{65.39} + 0.0555y$$

$$6) 7.341 \times 10^{-4} = \frac{3}{2} \cdot \frac{y}{26.982} + 0.0555y$$

$$7) 7.341 \times 10^{-4} = 0.0555y - \frac{y}{65.39}$$

$$8) 7.341 \times 10^{-4} = \frac{3.629y}{65.39} - \frac{y}{65.39}$$

$$9) 7.341 \times 10^{-4} = y \left(\frac{3.629 - 1}{65.39} \right)$$

$$10) 7.341 \times 10^{-4} = \frac{2.629y}{65.39}$$

$$11) (7.341 \times 10^{-4})$$

$$12) (65.39) = 2.629y$$

$$13) Y = \mathbf{1.826 \times 10^{-2} \text{ g}}$$

$$\text{Mass of zinc} = 0.0442 \text{ g} - 0.01826 \text{ g} = 0.02594 \text{ g} = \mathbf{2.594 \times 10^{-2} \text{ g}}$$

4. Percent composition of the alloy:

Trial 1

$$\text{Mass\% Zn} = \frac{m_{\text{Zn}}}{m_{\text{alloy}}} \times 100\%$$

$$= \frac{1.743 \times 10^{-2}}{3.20 \times 10^{-2}} \times 100\%$$

$$= 54.47\%$$

$$\begin{aligned}\text{Mass\% Al} &= \frac{m_{Al}}{m_{alloy}} \times 100\% \\ &= \frac{1.457 \times 10^{-2}}{3.20 \times 10^{-2}} \times 100\% \\ &= 45.53\%\end{aligned}$$

Trial 2

$$\begin{aligned}\text{Mass\% Zn} &= \frac{m_{Zn}}{m_{alloy}} \times 100\% \\ &= \frac{2.594 \times 10^{-2}}{4.42 \times 10^{-2}} \times 100\% \\ &= 58.69\%\end{aligned}$$

$$\begin{aligned}\text{Mass\% Al} &= \frac{m_{Al}}{m_{alloy}} \times 100\% \\ &= \frac{1.826 \times 10^{-2}}{4.42 \times 10^{-2}} \times 100\% \\ &= 41.31\%\end{aligned}$$

5. Average Percent composition of the alloy (average of zinc values and average of aluminum values):

Average % Composition of Zinc = 43.42%

Average % Composition of Aluminum = 56.58%

Discussion: (within space provided)

To put in simple words, an alloy is a metal in which it is composed of two or more metallic elements; in this case, the two metallic elements were zinc and aluminum. Secondly, it is important that the eudiometer is calibrated due to the fact that the final results will be inaccurate if not calibrated from the start. If it is not calibrated, the volume of the uncalibrated portion of the tube must be measured and taken into account when performing measurements throughout the lab. In another relation to the eudiometer, ensuring no air entered the apparatus when inverting it was crucial for accurate results. If air entered the tube, the volume of gas collected will be greater than the volume of gas produced. If some metal floats up and sticks to the eudiometer or does not completely react with the acid, it does affect the results. The metal would not react, therefore would result in the smaller amount of gas produced. To avoid this from occurring, tapping on the glass would make the metal fall back into the acid. It was

important to measure the mass of metal exactly but not the volume of the acid because in the reaction, the HCL acid is the excess and the metal is the limiting reactant. Before the experiment, I predicted that the test using the pure metal was going to have a completely different reaction in comparison to the test with the alloy. I believed this because the alloy was composed of two different elements (Zinc and Aluminum), whereas the metal was only Magnesium. Although, as results show, for the most part, both tests were different. For one, the alloy turned into a misty black/grey colour and more hydrogen gas was produced. In addition, the reaction for the alloy test was much longer than for the pure metal; this could be due to the strong bonds within the alloy (between Zn and Al) rather than one element reacting with the HCL acid. Prior to the tests with the alloy, I expected both trials to have the same result. However, as seen above (Refer to Observation section), trial 2 was much different than trial 1. The difference in trials could have been caused due to the imbalance of the elements in the alloy; in trial one, the alloy was composed of 54.47% Zinc and 45.53% Aluminum and in trial two, the alloy was composed of 58.69% Zinc and 41.31% Aluminum. Both percentages of purity of the metal were relatively high and this could have been the result of data or equipment error. One error could have been the measurement of the volume of hydrogen gas and even the height of the water column. When the volume of hydrogen gas was measured, the reaction may not have been fully completed, which could have resulted in a false reading on the eudiometer. To measure the height of the water column, a ruler was used to measure the height from the surface of the water in the eudiometer tube to the surface of the water in beaker. However, the smaller rulers did not give as accurate of results compared to the larger rulers because the ruler had to be moved every time the water column level surpassed the length of the ruler. If the percent yield was 100%, it can be said that it was a perfect and complete reaction. If on the other hand it was less than 100%, this means that the metal did not fully react to the HCL. One more possibility is if the percent yield is above 100%; this can be caused by errors as previously mentioned. Based on the recorded data above (Refer to Tables), it can be noted that the lower amount of mass of the pure metal or alloy, resulted in higher pressure of the water column. Therefore, it can be said that the mass and pressure of the water column are inversely proportional. This lab relates to the work in lecture courses because to perform this experiment, it was necessary to use stoichiometry and gas laws to find number of moles and the percentage composition of the alloy. An article written about an experiment similar to this one in particular is named "Effects of concentrations of NaCl and organic acid on generation of hydrogen from magnesium metal scrap." In other words, hydrogen gas was produced in an aqueous solution from magnesium scraps. This relates to this lab due to the fact that when the HCL acid was mixed with magnesium, hydrogen gas was produced.

Conclusion: (no more than two lines)

As calculated, there was 1.118×10^{-3} moles of hydrogen in trial 1 and 1.201×10^{-3} of hydrogen moles in trial 2. In addition, the average composition of the alloy was 43.42% Zinc and 56.58% Aluminum.

Works Cited

Yu, Uan, & Hsu. (2011). Effects of concentrations of NaCl and organic acid on generation of hydrogen from magnesium metal scrap. *International Journal of Hydrogen Energy*, International Journal of Hydrogen Energy.

water

Mg → magnesium

Data Tables

Table 1. Pure Metal

Data	Trial 1	Trial 2
Identity of Metal	Magnesium	Magnesium
Mass of metal (g)	0.0273g	0.0290g
Uncalibrated volume of eudiometer (mL)		
Volume of hydrogen gas (mL)	28.7 mL	30.7 mL
Height of water column (cm)	21.4 cm	17.4 cm
Density of water (kg/m ³)	1000	1000
Acceleration due to gravity (m/s ²)	9.8	9.8
Pressure of water column (Pa)		
Water Temperature (°C)	22.8	22.9
Water Vapour pressure (Pa)	2810	2810
Atmospheric Pressure (Torr)	753.812 Torr	753.812 Torr
Pressure of Hydrogen		
Room Temperature	22.8	22.9
Ideal Gas Constant, R	0.082	0.082
Actual Moles of Hydrogen (mol)	1.119 x 10 ⁻³	1.201 x 10 ⁻³
Theoretical moles of Hydrogen (mol)	1.12 x 10 ⁻³	1.143 x 10 ⁻³
Percent Yield (%)	99.55%	100.67%

10.5 kPa

Observations (Part 1):

paper holding Mg = 0.4104g

⇒ once eudiometer was flipped w/ HCl and H₂O, the acid splashed down the tube

⇒ once the acid reacted with Mg, bubbles were created and the metal rose up fast

⇒ once reaction was slowing down, much less bubbles

Mg 1	0.0273g
Mg 2	0.0290g

⇒ foul ⇒ irritating ⇒ steam

alloy liquid $\frac{3}{4}$ look longer
 more grey
 bubbles remained on the electrode

Table 2. Alloy

Data	Trial 1	Trial 2
Unknown Number	5131	5131
Mass of alloy (g)	0.032g	0.0442g
Uncalibrated volume of eudiometer (ml)		
Volume of hydrogen gas (ml)	37.7 ml	36 ml
Height of water column (cm)	2.3 cm	14.6 cm
Density of water (kg/m ³)	1000	1000
Acceleration due to gravity (m/s ²)	9.8	9.8
Pressure of water column (Pa)		
Water Temperature (°C)	22.7	22.5
Water Vapour pressure (kPa)	2.61	2.61
Atmospheric Pressure (Torr)	753.812	753.812
Pressure of Hydrogen		
Room Temperature	22.7	22.7
Ideal Gas Constant, R		
Moles of Hydrogen (mol)		
Mass of Zinc (g)		
Mass of Aluminum (g)		
Percent Zinc (%)		
Percent Aluminum (%)		
Average Percent		

Observations (Part 2):

- ⇒ acid spiraling down
- ⇒ takes longer to react/finish
- ⇒ fizzing, bouncing, a lot of movement
- ⇒ bottom is bubbling
- ⇒ The pieces at the top, turns misty black/grey
- ⇒ only a few pieces rise at a time
- ⇒ fizzing is longer w/ alloy
- ⇒ once at top, falls apart, dissolves