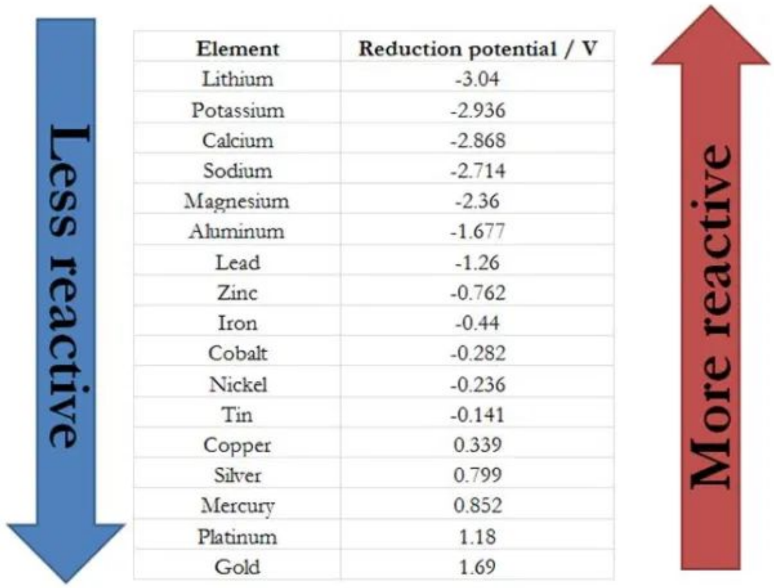
Activity Series Verification by the Reaction of Metals with a Strong Acid

I. Introduction

The topic of this investigation was to verify the activity series of tin, aluminum, zinc, copper, and magnesium by comparing their reactions in HCl. My research question is "Does the reaction of metals with Hcl align with their published activity series?" All metals were also submerged in water as a control trial.The activity series of metals is a tool used to predict the reactivity of metals with water and acids.[1] By comparing the reactions of the metals, I will be able to see if their reactions line up appropriately with their place in the activity series. Reduction potentials are another to measure activity series, but I will not be using them in my experiment.



Element	Reduction potential / V
Lithium	-3.04
Potassium	-2.936
Calcium	-2.868
Sodium	-2.714
Magnesium	-2.36
Aluminum	-1.677
Lead	-1.26
Zinc	-0.762
Iron	-0.44
Cobalt	-0.282
Nickel	-0.236
Tin	-0.141
Copper	0.339
Silver	0.799
Mercury	0.852
Platinum	1.18
Gold	1.69

[2]

I chose this topic because my experiment could be applied to choosing various types of metal containers to hold certain liquids in. Some containers would be safe to hold liquids in, as they do not react, but some containers may dissolve or react in contact with the liquids and therefore be unsafe to hold liquids in. My research could help to develop environmentally-friendly and cost-effective containers. Many containers require a plastic interior coating because they can react, but this plastic coating is harmful to the environment when disposed of. Some materials of cans can also be more expensive, such as tin. By using HCl, a very strong acid, my experiment could also determine which types of liquids the containers can hold. If a container could hold something as acidic as HCl, they could definitely hold a less acidic liquid, for example, orange juice. This could be applicable to our chemistry class when deciding which types of containers or liquids the school should buy to stock our classroom because the school will be looking for environmentally-friendly and cost-effective choices.

---

[1] Helmenstine, Todd. "Activity Series of Metals: Predicting Reactivity." *ThoughtCo*, ThoughtCo, 28 Feb. 2020, www.thoughtco.com/activity-series-of-metals-603960.

[2] Gendler, Isaac. "Chemical Activity Series." *Isaac's Science Blog*, 22 June 2017, www.isaacscienceblog.com/2017/06/13/chemical-activity-series/.

There were various safety precautions necessary in performing the experiment for my IA. Some of the solvent I worked with could emit toxic fumes, burn my hands or my clothing, and be unsafe to ingest. For example, HCl acid can cause redness, pain, and severe skin burns in contact with skin. Inhaling the fumes can cause coughing, choking, inflammation of the nose, throat, and upper respiratory tract, and in severe cases, pulmonary edema, circulatory system failure, and death. HCl can even cause severe burns to the eye and permanent eye damage[3].

To prevent myself from HCl, all experiments were performed in a fume hood. To prevent myself from harm, I wore safety goggles, wore gloves, performed experiments under the fume hood, and washed my hands before I left the classroom. Another possible safety hazard in my experiment was accidentally breaking the equipment. Dropping glass can be very dangerous as glass shards can cut when being picked up and are hard to spot. Cutting oneself on a glass shard could be even worse if the glass shard has traces of a toxic chemical on it. I tried to be careful when handling the equipment, as well as making sure to perform my experiment far away from my classmates, as all of the hazards stated above could apply to anyone else who gets close to my experiment.

II. Investigation

A. Background

Before working with the solvents water, HCl and the metals tin, aluminum, zinc, copper, and magnesium, it is important to have background knowledge on their appearances, properties, and uses. Below are summaries of the solvents and the solutes.

Water is one of the most widely known and versatile substances in the world. A water molecule contains one oxygen and two hydrogen atoms that are connected by covalent bonds. It is a liquid at standard ambient temperature and pressure, but it often co-exists with its solid state, ice; and gaseous state, steam. Water has countless uses, it is essential for life and the most widely used solvent. Water forms the world's streams, lakes, glaciers, oceans and rain, and makes up the fluids of most organisms.[4]

---

[3] “Hydrochloric Acid.” National Center for Biotechnology Information. PubChem Compound Database, U.S. National Library of Medicine, https://pubchem.ncbi.nlm.nih.gov/compound/Hydrochloric-acid.

[4] “Water.” National Center for Biotechnology Information. PubChem Compound Database, U.S. National Library of Medicine, https://pubchem.ncbi.nlm.nih.gov/compound/Water.


[5]

Water

Hydrochloric acid (HCl) is an acidic colorless watery liquid with a sharp, irritating odor. It consists of hydrogen chloride gas dissolved in water. HCl sinks and mixes with water, which is useful when diluting HCl with water. HCl can produce dense white corrosive vapors. Hydrogen chloride has a wide variety of uses, including cleaning, pickling, electroplating metals, tanning leather, and burning plastics.[6]

[7]

Hydrochloric Acid

As well as having a basic understanding of the solvents, it is important to have general knowledge on the metals used in the experiment, their common uses, and their reactions with HCl. All of the metals react with HCl in a single replacement reaction, in which the metal bonds

[5]Leung, Wendy. "Oxnard Hosts Water-Saving Workshops." Ventura County Star, Ventura County Star, 11 Mar. 2020, www.vcstar.com/story/news/local/2020/03/11/oxnard-hosts-water-saving-workshops-information-booths-throughout-march/5002065002/.

[6] "Hydrochloric Acid." National Center for Biotechnology Information. PubChem Compound Database, U.S. National Library of Medicine, https://pubchem.ncbi.nlm.nih.gov/compound/Hydrochloric-acid.

[7] Chillmaid, Martyn. "Bottle of Dilute Hydrochloric Acid." *Science Photo Library*, www.sciencephoto.com/media/576286/view/bottle-of-dilute-hydrochloric-acid.

with the chlorine, replacing the hydrogen. Since hydrogen and chlorine are both diatomic elements, they take the subscript 2. The reaction equations are shown with each metal.

Tin appears a soft, pliable metal at room temperature. Tin is often used to coat other metals to prevent corrosion, such as tin cans, which are made of tin-coated steel. Alloys of tin such as soft solder, pewter are also important. For example, a niobium-tin alloy is used for superconducting magnets. Tin is important in glass production too. Most window glass is made by floating molten glass on molten tin to and tin salts sprayed onto glass are used to produce electrically conductive coatings.[8]


[9]

$$Sn + 2HCl \rightarrow SnCl_2 + H_2$$ [10]

Tin Can and Balanced Equation

Aluminium is a silvery-white, lightweight and malleable metal. It has low density, is non-toxic, has a high thermal conductivity, has excellent corrosion resistance and can be easily cast and formed. It is the second most malleable metal and the sixth most ductile. These properties make aluminum useful in the production of a variety of products, such as cans, foils, kitchen utensils, window frames, beer kegs and airplane parts.[11]


[12]

$$2Al + 6HCl \rightarrow 2AlCl_3 + 3H_2$$ [13]

---

[8] "Tin - Element Information, Properties and Uses: Periodic Table." Tin - Element Information, Properties and Uses | Periodic Table, www.rsc.org/periodic-table/element/50/tin.
[9] Pappas, Stephanie. "Facts About Tin." LiveScience, Purch, 28 July 2015, www.livescience.com/37355-tin.html.
[10] S., Aadit. "Does Metallic Tin React with HCl?" *Numerade*, www.numerade.com/questions/does-metallic-tin-react-with-hcl/.
[11] "Aluminium - Element Information, Properties and Uses: Periodic Table." Aluminium - Element Information, Properties and Uses | Periodic Table, www.rsc.org/periodic-table/element/13/aluminium.
[12] "Learn What the Aluminum Recyclers Council Is Doing to Improve, Protect, and Promote the Industry of Recycling Aluminum Scrap." Learn What the Aluminum Recyclers Council Is Doing to Improve, Protect, and Promote the Industry of Recycling Aluminum Scrap., www.recyclealuminum.org/.
[13] The Organic Chemistry Tutor, director. *Aluminum + Hydrochloric Acid - Balanced Molecular and Net Ionic Equation*. *Youtube*, 2015, www.youtube.com/watch?v=qcGaAN4--aQ.

Aluminum Alloy and Balanced Equation

Zinc is a silvery-white metal with a blue tinge. Zinc is frequently used to galvanise other metals, such as iron, to prevent rusting. Zinc oxide is widely used in the manufacture of many products such as paints, rubber, cosmetics, pharmaceuticals, plastics, inks, soaps, batteries, textiles and electrical equipment. Zinc is essential for all living things, forming the active site in over 20 metallo-enzymes.[14]


[15]

$$Zn + 2HCl \rightarrow ZnCl_2 + H_2$$ [16]

Zinc Metal and Balanced Equation

Copper is a reddish-gold metal that is easily worked and drawn into wires. Historically, copper was the first metal to be worked by people. Traditionally, it has been one of the metals used to make coins, along with silver and gold. However, it is the most common and thus cheapest of the three, which is why all US coins are now copper alloys. Copper conducts both heat and electricity very well, and can be drawn into wires, therefore it is used in electrical equipment such as wiring and motors.[17]


[18]

$$Cu + 2HCl \rightarrow CuCl_2 + H_2$$ [19]

Copper Metal and Balanced Equation

---

[14] "Zinc - Element Information, Properties and Uses: Periodic Table." Zinc - Element Information, Properties and Uses | Periodic Table, www.rsc.org/periodic-table/element/30/zinc.

[15] Brightmore, Daniel. "Zinc Set for Global Gains from 2020." Investing | Mining Global, Daniel Brightmore, 29 Dec. 2019, www.miningglobal.com/investing/zinc-set-global-gains-2020.

[16] "Metals with Acid." *UW Dept. of Chemistry*, https://depts.washington.edu/chem/facilserv/lecturedemo/SpaceFillingModel-UWDept.ofChemistry.html.

[17] "Copper - Element Information, Properties and Uses: Periodic Table." Copper - Element Information, Properties and Uses | Periodic Table, www.rsc.org/periodic-table/element/29/copper.

[18] Pappas, Stephanie. "Facts About Copper." LiveScience, Purch, 12 Sept. 2018, www.livescience.com/29377-copper.html.

[19] "Metals with Acid." *UW Dept. of Chemistry*, https://depts.washington.edu/chem/facilserv/lecturedemo/SpaceFillingModel-UWDept.ofChemistry.html.

Magnesium is a lightweight silvery-white metal that ignites easily in air and burns with a bright light. Magnesium is used in products that benefit from being lightweight, such as car seats, luggage, laptops, cameras and power tools. As magnesium ignites easily in air and burns with a bright light, it's used in flares, fireworks and sparklers. Magnesium is also essential to life on Earth. Chlorophyll is the chemical that allows plants to capture sunlight, and photosynthesis to take place. Chlorophyll is a magnesium-centred porphyrin complex. Without magnesium, photosynthesis could not take place, and life as we know it would not exist.[20]


[21]

$$Mg + 2HCl \rightarrow H_2 + MgCl_2$$
[22]

Magnesium Metal and Balanced Equation

B. Experimental Procedure

1. Fill an Erlenmeyer flask with 10 mL of HCl using a 10 mL graduated cylinder
2. Place a funnel in the graduated cylinder and place a tissue inside the funnel so it covers the hole of the funnel
3. Place phone camera facing the flask and start filming
4. Set timer for 1 minute
5. Take a piece of copper
6. Drop the copper into the flask and start timer
7. Once the timer runs out, pour the contents of the flask into the funnel so the liquid falls into the graduated cylinder and the copper, if there is any left, is caught by the tissue in the funnel
8. Take the copper out of the funnel and wash it off with water (unless the piece was submerged in water already)
9. Dry the copper piece off
10. Take the mass of the copper piece

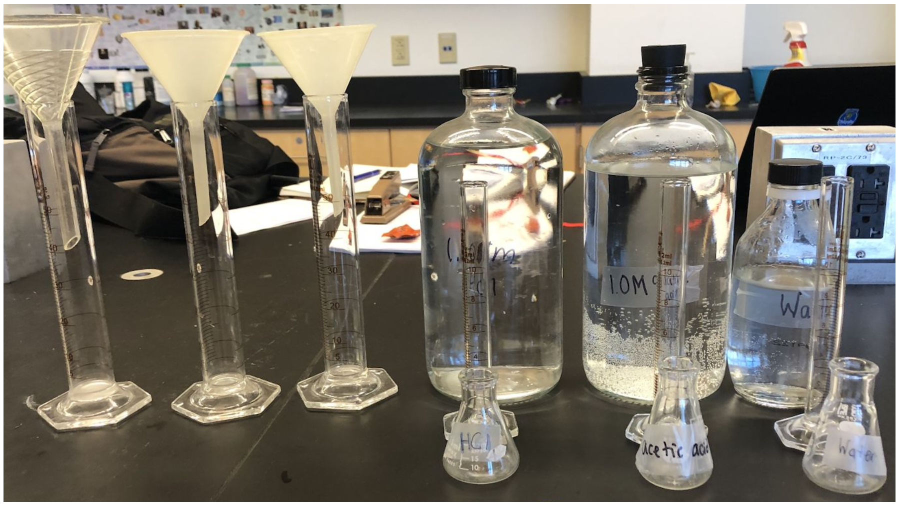
---

[20] "Magnesium - Element Information, Properties and Uses: Periodic Table." Magnesium - Element Information, Properties and Uses | Periodic Table, www.rsc.org/periodic-table/element/12/magnesium.

[21] "Magnesium Mg (Element 12) of Periodic Table: Elements FlashCards." Newton Desk, 22 Sept. 2019, www.newtondesk.com/magnesium-element/.

[22] "Metals with Acid." UW Dept. of Chemistry, https://depts.washington.edu/chem/facilserv/lecturedemo/SpaceFillingModel-UWDept.ofChemistry.html.

11. Repeat steps 1-10 with tin, aluminum, zinc, and and magnesium (keep in mind that steps 8-10 may not be necessary if the metal is completely dissolved and there is none left)
12. Repeat steps 1-11 with water instead of HCl



Experiment setup including funnels, 1M HCl, water, graduated cylinders, and labeled Erlenmeyer flasks (tissues not included and ignore equipment for acetic acid)

D. Results

Decrease in Moles (mol)

	Trial 1	Trial 2	Trial 3	Average
Tin	0.00023	0.00014	0	0.00012
Aluminum	0.00519	0.00334	0.00445	0.00433
Zinc	0.01	0.01	0.01	0.01
Magnesium	0.01	0.01	0.01	0.01
Copper	-0.0001	-0.0002	0.000401	0.0000337

*the negative sign means increase in moles

Percentage Change of Moles (%)

	Trial 1	Trial 2	Trial 3	Average
Tin	2.3	1.4	0	1.2
Aluminum	51.9	33.4	44.5	43.3
Zinc	100	100	100	100

Magnesium	100	100	100	100
Copper	-1	-2	4.01	0.337

Observations

The appearance of the tin and the copper changed very little during the experiment. Over the minute, there were a few bubbles, but otherwise, the tin stayed the same. The copper did not bubble at all. When both were drained and dried off, they looked the same as they did before they were submerged in HCl. In contrast, the magnesium and zinc reacted very strongly with the hydrochloric acid. Both metals would sit in the flask without any reaction for about 20 seconds, then start to fizz and emit gas very violently for the rest of the minute. After the minute was up, the metals had completely dissolved into the HCl and all that was left was a grey liquid paste. Aluminum's reaction fell somewhere between the tin and copper and the magnesium and zinc. It took about 30 seconds for aluminum to start fizzing and by the end of the minute, it was reacting strongly, dissolving into grey liquid and creating gas. However, aluminum started later than magnesium and zinc and didn't react as strongly as they did, so by the time it was drained and dried, there still was a smaller piece of aluminum left. This piece was a much darker grey and had a foul odor.

E. Calculations

I had to do various calculations to make all the solvents and solutes proportional and to interpret my data. Standardizing the solvents and solutes would reduce the error in my experiment.

I started by making the HCl 1M, using this calculation. I found that 1M was not enough to create a reaction from most of the metals, so I switched to 12M HCl.

$$\frac{1\text{ mol HCl}}{\text{L solution}} \times \frac{36.46\text{g HCl}}{1\text{ mol HCl}} = \frac{36.46\text{g HCl}}{\text{L solution}}$$

Since I was dissolving the metals in one mole of solution, I had to use the molar mass of each metal to make sure the metal was proportional to each other. The molar masses of the metals and the molarity of the solvents need to be proportional because it is more important to measure the number of atoms which react, rather than the mass. For example, as shown below by the molar masses, each atom of tin is more than 4x as massive as an atom of aluminum.

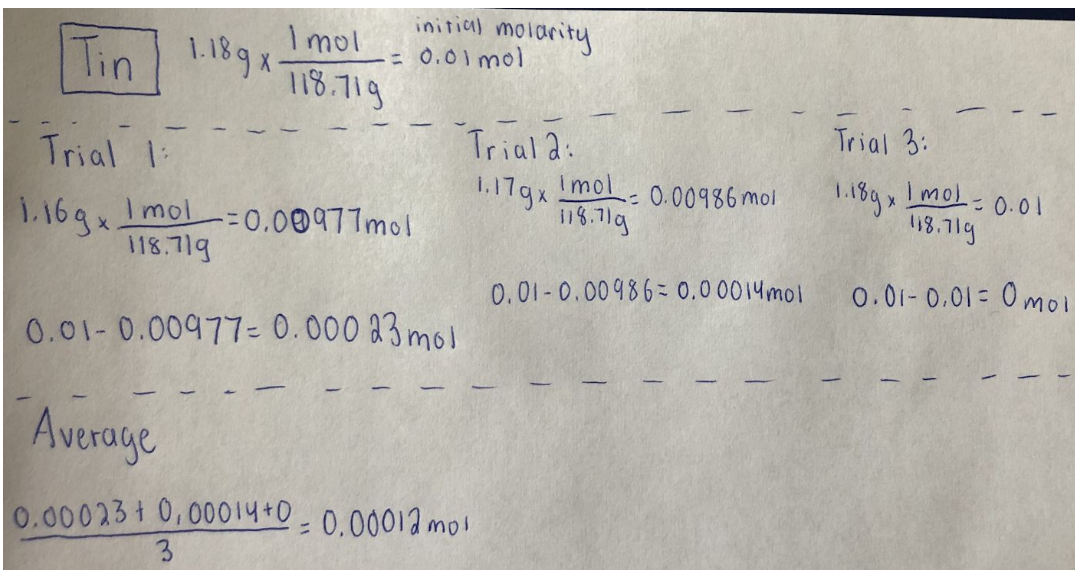
- Aluminum: 27g
- Tin: 118.18g
- Magnesium: 24.305g

- Zinc: 65.39g
- Copper: 63.546g

Since it would be challenging to obtain and dissolve such large amounts of metal, I scaled the numbers down by a factor of 100. Therefore, I divided each mass by 100 so the masses would be smaller, but still proportional. Below are the final amounts used in the experiment.

- Aluminum: 0.27g
- Tin: 1.18g
- Magnesium: 0.24305g
- Zinc: 0.6539g
- Copper 0.63546g

To calculate the change in moles, I started by calculating the initial molarity of each piece of metal. I already knew that the initial molarity would come out to be 0.01 moles for each piece, but I did the calculations out to make it clear how I got to this value. I then calculated the final molarity for each piece of metal using the same calculation I did for the initial molarity. To find the change in molarity, I subtracted the final molarity from the original molarity. For the average of each metal, I averaged change in molarity from the three trials.



Zinc

$0.6534g \times \frac{1mol}{65.38g} = 0.01mol$

Trial 1:

$0g \times \frac{1mol}{65.38g} = 0mol$

$0.01 - 0 = 0.01mol$

Trial 2:

$0g \times \frac{1mol}{65.38g} = 0mol$

$0.01 - 0 = 0.01mol$

Trial 3:

$0g \times \frac{1mol}{65.38g} = 0mol$

$0.01 - 0 = 0.01mol$

Average:

$\frac{0.01 + 0.01 + 0.01}{3} = 0.01mol$

Magnesium

$0.24305g \times \frac{1mol}{24.305g} = 0.01mol$

Trial 1:

$0g \times \frac{1mol}{24.305g} = 0mol$

$0.01mol - 0mol = 0.01mol$

Trial 2:

$0g \times \frac{1mol}{24.305g} = 0mol$

$0.01 - 0 = 0.01mol$

Trial 3:

$0g \times \frac{1mol}{24.305g} = 0mol$

$0.01 - 0 = 0.01mol$

Average:

$\frac{0.01 + 0.01 + 0.01}{3} = 0.01mol$

Aluminum

$0.27g \times \frac{1mol}{26.98g} = 0.01mol$

Trial 1:

$0.14g \times \frac{1mol}{26.98g} = 0.00519mol$

Trial 2:

$0.09g \times \frac{1mol}{26.98g} = 0.00334mol$

Trial 3:

$0.12g \times \frac{1mol}{26.98g} = 0.00445mol$

Average:

$\frac{0.00519 + 0.00334 + 0.00445}{3} = 0.00433mol$

Copper

$0.63546g \times \frac{1mol}{63.546g} = 0.01mol$

Trial 1:

$0.64g \times \frac{1mol}{63.546g} = 0.0101mol$

$0.01 - 0.0101 = -0.0001mol$

Trial 2:

$0.65g \times \frac{1mol}{63.546g} = 0.0102mol$

$0.01 - 0.0102 = -0.0002mol$

Trial 3:

$0.61g \times \frac{1mol}{63.546g} = 0.009599mol$

$0.01 - 0.009599 = 0.000401mol$

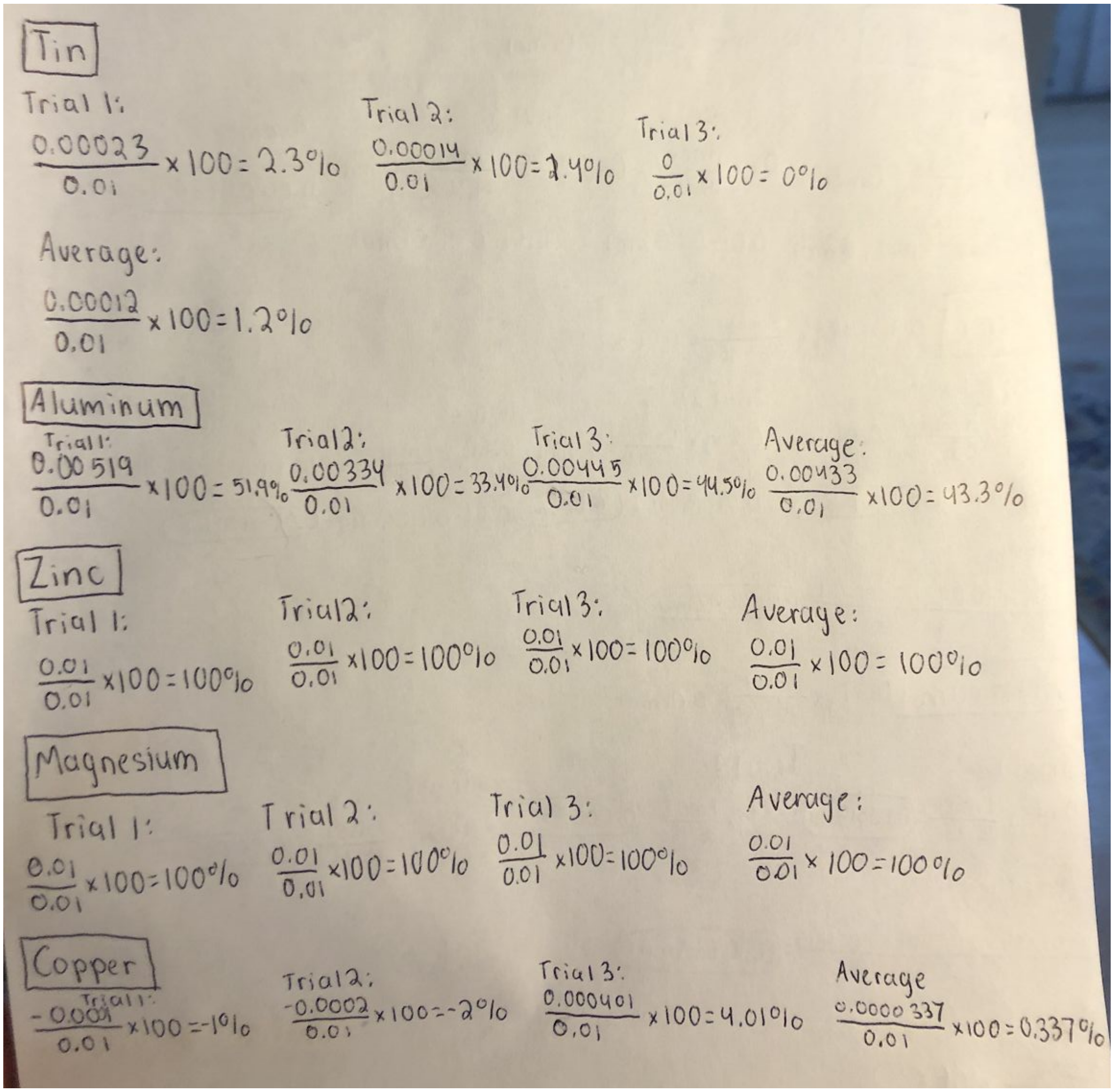
Average:

$\frac{-0.0001 + (-0.0002) + 0.000401}{3} = 0.0000337mol$

Percent Change

$$\text{Percent Change} = \frac{\text{New Value} - \text{Old Value}}{\text{Old Value}} \times 100\%$$

[23]



Tin

Trial 1: $\frac{0.00023}{0.01} \times 100 = 2.3\%$

Trial 2: $\frac{0.00014}{0.01} \times 100 = 1.4\%$

Trial 3: $\frac{0}{0.01} \times 100 = 0\%$

Average: $\frac{0.00012}{0.01} \times 100 = 1.2\%$

Aluminum

Trial 1: $\frac{0.00519}{0.01} \times 100 = 51.9\%$

Trial 2: $\frac{0.00334}{0.01} \times 100 = 33.4\%$

Trial 3: $\frac{0.00445}{0.01} \times 100 = 44.5\%$

Average: $\frac{0.00433}{0.01} \times 100 = 43.3\%$

Zinc

Trial 1: $\frac{0.01}{0.01} \times 100 = 100\%$

Trial 2: $\frac{0.01}{0.01} \times 100 = 100\%$

Trial 3: $\frac{0.01}{0.01} \times 100 = 100\%$

Average: $\frac{0.01}{0.01} \times 100 = 100\%$

Magnesium

Trial 1: $\frac{0.01}{0.01} \times 100 = 100\%$

Trial 2: $\frac{0.01}{0.01} \times 100 = 100\%$

Trial 3: $\frac{0.01}{0.01} \times 100 = 100\%$

Average: $\frac{0.01}{0.01} \times 100 = 100\%$

Copper

Trial 1: $\frac{-0.0001}{0.01} \times 100 = -1\%$

Trial 2: $\frac{-0.0002}{0.01} \times 100 = -2\%$

Trial 3: $\frac{0.000401}{0.01} \times 100 = 4.01\%$

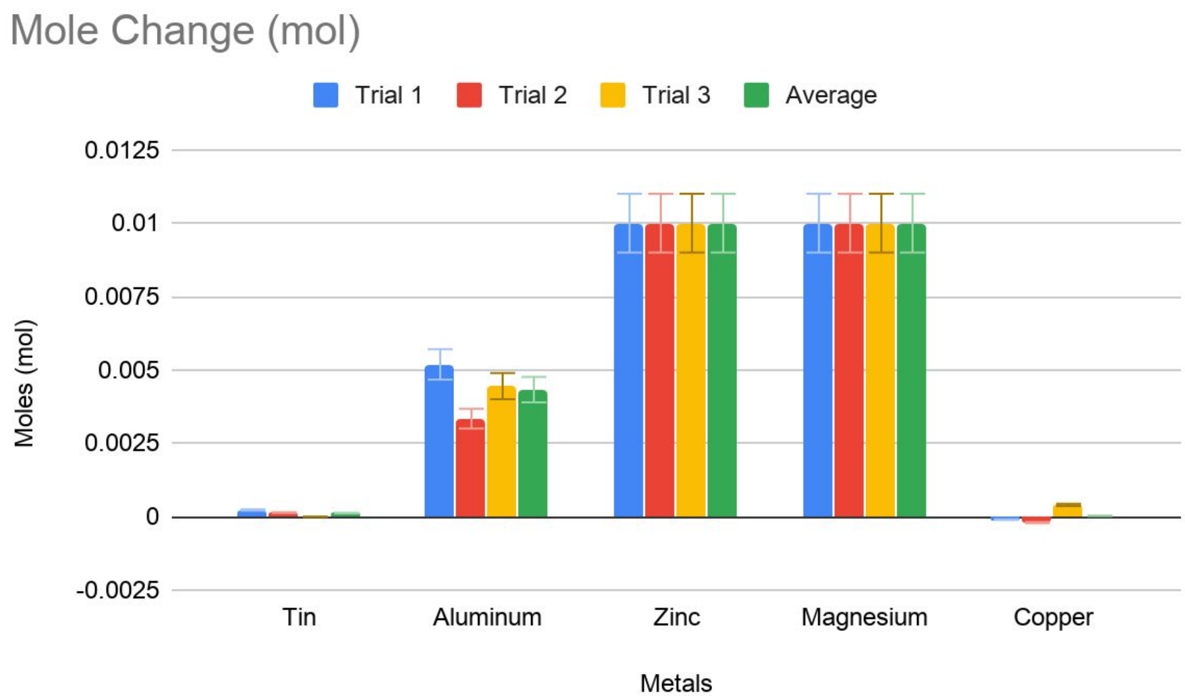
Average: $\frac{0.0000337}{0.01} \times 100 = 0.337\%$

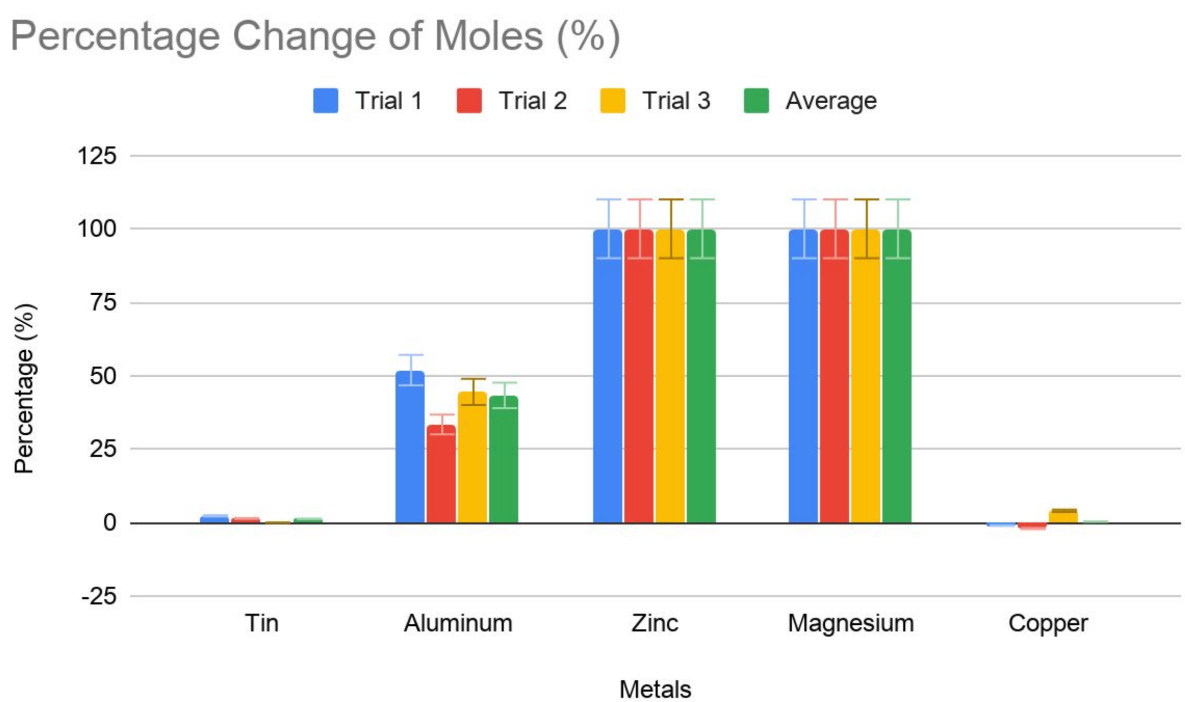
F. Discussion

To interpret my data, I created two tables depicting the change in moles and percentage change in moles. It is important to see the change in moles to understand how many molecules

[23] "Percent Change." *Online Math Learning*, www.onlinemathlearning.com/percent-change-algebra.html.

were lost but it is also important to see the percentage change in moles to understand that some of the metals lost all of their atoms, while some lost very few. These tables show the degree to which each metal reacted, with the taller bars representing greater reactions, as well as providing a clear means of comparing the metal





To answer the research question, I compiled the metals into a table based on their reactivity, with the most reactive metals at the top and the least reactive at the bottom. I based reactivity on the amount of moles, or essentially atoms, lost, with more reactive metals losing more moles. I put magnesium and zinc in the same row because I felt they were equally reactive as they both lost all of their mass. On the other side of the table, I added a section of the activity series, focusing on the five metals in my experiment to compare my results to the activity series.

<table>
<tr><td>Magnesium and Zinc</td><td rowspan="4">↑</td><td rowspan="4">Magnesium
Aluminum
Lead
Zinc
Iron
Cobalt
Nickel
Tin
Copper [24]</td></tr>
<tr><td>Aluminum</td></tr>
<tr><td>Tin</td></tr>
<tr><td>Copper</td></tr>
</table>

The places of magnesium, copper, and tin all match up on the activity series, as copper and tin were the least reactive of the metals and magnesium was the most reactive. However, aluminum is two places above zinc, which seems strange considering that aluminum lost about 40% of its moles while zinc lost 100% in the experiment. This could be due to the fact that the metals only reacted with the HCl for one minute. It was clear in the aluminum trials that the aluminum had a strong reaction with the HCl, it just took longer for it to begin fizzing than zinc, thus had less time to fizz and dissolve. This makes sense, as the activity series is not reliant on time, it simply measures which metal will displace more ions.[25]

G. Error Analysis

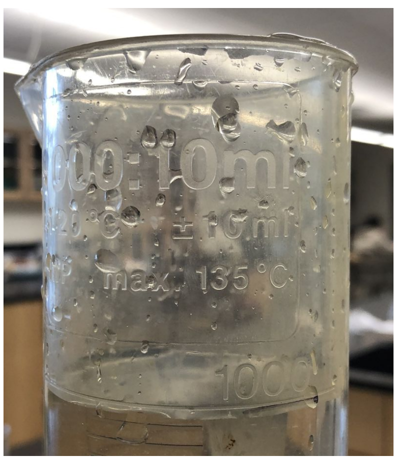
There are a few factors that may alter the results of the experiment, but I have attempted to reduce them.

A significant error is that the metals have different surface areas because they were only available in different forms. The magnesium was available in little strips, the copper was available in wire, the tin and zinc were available in sheets, and the aluminum was available in small aluminum foil tins. Each of these forms have different surface areas, which is a problem because the ones with more exposed surface area will react faster. This means that the tin, zinc, and aluminum are likely to react faster than the copper and magnesium. I attempted to reduce that error by folding the tin, zinc, and aluminum into thin sheets and rolling up the copper and

[24] Helmenstine, Todd. "Activity Series of Metals: Predicting Reactivity." *ThoughtCo*, ThoughtCo, 28 Feb. 2020, www.thoughtco.com/activity-series-of-metals-603960.
[25] Helmenstine, Todd. "Activity Series of Metals: Predicting Reactivity." *ThoughtCo*, ThoughtCo, 28 Feb. 2020, www.thoughtco.com/activity-series-of-metals-603960.

magnesium, to try and reduce the surface area of all the metals. However, even though I did even out the surface area a bit, I didn't completely eliminate the difference in surface area.

Another possible error is that the scales could be off by a hundredth of a gram or so. As shown in the pictures below, the scale can fluctuate between two different masses, such as 0.18 and 0.19 grams. As the difference is only a hundredth of the gram, this error should not have a significant impact on the results, but the smaller the mass, the greater difference one hundredth of a gram makes so this could possibly impact masses of magnesium or remaining pieces of aluminum.



Graduated cylinders are another measuring tool in which there is marginal room for error. As shown in the picture to the left, it is challenging to get the solution to exactly line up with the 1000 mL mark. Even if the water could exactly line up, there are drops on both the inside and the outside of the graduated cylinder that could add to the solution inside. These errors, while unavoidable, do not jeopardize the experiment. A few extra drops of water will not drastically change the water to HCl ratio, especially in a beaker already so big.

III. Conclusion

Based on the data it is clear that HCl quickly dissolves magnesium and zinc. It also dissolves aluminum, but not as quickly. It does not have an effect on copper and tin. The experiment confirmed the activity series for the most part, with the exception of aluminum and zinc. However, similar to the problem with the activity series verification, the real-life application was which types of metals can store HCl and the experiment was done for only one minute with small pieces of metal. The results have some significance, but they would not be able to fully predict whether a container made out of each metal would be able to hold HCl for a longer period of time. For example, based on the one minute trial, it is obvious that a magnesium or a zinc container would almost immediately fall apart as the HCl would dissolve it. It is likely that the HCl would eventually dissolve the aluminum too, as it began to during the trial, but there is no definitive evidence to prove this. The copper and tin remained unchanged during the trial but if they were holding HCl in containers for at least a day, the results could be much different. If I could do the experiment differently, next time I would make the time 5 minutes or longer, as the short amount of time caused the results of aluminum to be altered. I would also make sure that all the pieces of metal have the same amount of surface area, as greater surface area would result in a faster reaction, and could significantly impact the results.

Bibliography:

"Aluminium - Element Information, Properties and Uses: Periodic Table." Aluminium - Element Information, Properties and Uses | Periodic Table, www.rsc.org/periodic-table/element/13/aluminium.

Brightmore, Daniel. "Zinc Set for Global Gains from 2020." Investing | Mining Global, Daniel Brightmore, 29 Dec. 2019, www.miningglobal.com/investing/zinc-set-global-gains-2020.

Chillmaid, Martyn. "Bottle of Dilute Hydrochloric Acid." *Science Photo Library*, www.sciencephoto.com/media/576286/view/bottle-of-dilute-hydrochloric-acid.

"Copper - Element Information, Properties and Uses: Periodic Table." Copper - Element Information, Properties and Uses | Periodic Table, www.rsc.org/periodic-table/element/29/copper.

Gendler, Isaac. "Chemical Activity Series." *Isaac's Science Blog*, 22 June 2017, www.isaacscienceblog.com/2017/06/13/chemical-activity-series/.

Helmenstine, Todd. "Activity Series of Metals: Predicting Reactivity." *ThoughtCo*, ThoughtCo, 28 Feb. 2020, www.thoughtco.com/activity-series-of-metals-603960.

"Hydrochloric Acid." National Center for Biotechnology Information. PubChem Compound Database, U.S. National Library of Medicine, https://pubchem.ncbi.nlm.nih.gov/compound/Hydrochloric-acid.

"Learn What the Aluminum Recyclers Council Is Doing to Improve, Protect, and Promote the Industry of Recycling Aluminum Scrap." Learn What the Aluminum Recyclers Council Is Doing to Improve, Protect, and Promote the Industry of Recycling Aluminum Scrap., www.recyclealuminum.org/.

Leung, Wendy. "Oxnard Hosts Water-Saving Workshops." Ventura County Star, Ventura County Star, 11 Mar. 2020, www.vcstar.com/story/news/local/2020/03/11/oxnard-hosts-water-saving-workshops-information-booths-throughout-march/5002065002/.

"Magnesium - Element Information, Properties and Uses: Periodic Table." Magnesium - Element Information, Properties and Uses | Periodic Table, www.rsc.org/periodic-table/element/12/magnesium.

"Magnesium Mg (Element 12) of Periodic Table: Elements FlashCards." Newton Desk, 22 Sept. 2019, www.newtondesk.com/magnesium-element/.

"Metals with Acid." *UW Dept. of Chemistry*, depts.washington.edu/chem/facilserv/lecturedemo/SpaceFillingModel-UWDept.ofChemistry.html.

"Nitric Acid." National Center for Biotechnology Information. PubChem Compound Database, U.S. National Library of Medicine, https://pubchem.ncbi.nlm.nih.gov/compound/944.

Pappas, Stephanie. "Facts About Copper." LiveScience, Purch, 12 Sept. 2018, www.livescience.com/29377-copper.html.

Pappas, Stephanie. "Facts About Tin." LiveScience, Purch, 28 July 2015, www.livescience.com/37355-tin.html.

"Percent Change." *Online Math Learning*, www.onlinemathlearning.com/percent-change-algebra.html.

S., Aadit. "Does Metallic Tin React with HCl?" *Numerade*, www.numerade.com/questions/does-metallic-tin-react-with-hcl/.

"Sodium Hydroxide." National Center for Biotechnology Information. PubChem Compound Database, U.S. National Library of Medicine, https://pubchem.ncbi.nlm.nih.gov/compound/14798.

"Tin - Element Information, Properties and Uses: Periodic Table." Tin - Element Information, Properties and Uses | Periodic Table, www.rsc.org/periodic-table/element/50/tin.

The Organic Chemistry Tutor, director. *Aluminum + Hydrochloric Acid - Balanced Molecular and Net Ionic Equation*. *Youtube*, 2015, www.youtube.com/watch?v=qcGaAN4--aQ.

“Water.” National Center for Biotechnology Information. PubChem Compound Database, U.S. National Library of Medicine, https://pubchem.ncbi.nlm.nih.gov/compound/Water.

“Zinc - Element Information, Properties and Uses: Periodic Table.” Zinc - Element Information, Properties and Uses | Periodic Table, www.rsc.org/periodic-table/element/30/zinc.