# Lab - Measurement & Calculations

## Purpose:

Practice making measurements and use dimensional analysis to calculate with appropriate significant figures.

## Inquiry:

What is the average thickness of aluminum foil, both heavy duty and regular?

Thickness of a thin sheet is ~~part~~ one dimension of both volume and density.

As Aluminum foil is quite thin, a ruler is not precise enough to determine thickness. I will need to use Density with mass and length & width to calculate the thickness.

## Safety:

All general lab safety precautions apply.
Aluminum and water are not corrosive or dangerous.
Take care when using glass graduated cylinders.

## Procedure:

(D) Density = $\frac{Mass(M)}{Volume(V)}$ (V) Volume = (L) Length x (W) Width x (T) Thickness

$$T = \frac{V}{L \times W}$$

$$D = M \times \frac{1}{L \times W \times T}$$

$$D = \frac{M}{L \times W \times T}$$

If I can determine the mass, the length the width and the density, I can calculate the thickness.

$$T = \frac{M}{L \times W \times D}$$

### Steps

1) Use granulated aluminum to determine density by taking a small sample & using a scale to determine mass.
2) Use water displacement of granulated aluminum sample to determine volume.
3) Obtain multiple trials worth of Data. Take an average from each set of measured values.

$$D = \frac{M}{V}$$

### Observations

1) scale was limited to ± .01 g
Aluminum granules appeared slightly oxidized
2) graduated cylinder measured to ± .01 mL
Some Aluminum dust floated on top.
3) third trial yielded a displacement of less than 1 mL. Limiting sig figs to 1 place.

Steps

4) obtain two samples each of regular & heavy duty Aluminum foil. Cut foil into a rectangle with 90° corners. Length of both sides should be consistent.

5) Measure the length, width, and mass of each sample

6) Use the average density, the length, width, and the mass to calculate thickness for both regular samples & both heavy duty samples

Observations

4) Regular & Heavy Duty foil was cut to 90° angles. A pen was used to measure and cut angles - some ink was present.

5) Ruler measured to ± .01 cm

6) Density calculation was limited to 2 sig figs. Length measurements were limited to 3 sig figs. Mass measurements limited to 2 sig figs.

Data:

Density Determination

| | Mass (g) | Volume (mL) |
|---|---|---|
| Trial 1 (granules) | 3.65 | 1.4 |
| Trial 2 | 2.77 | 1.0 |
| Trial 3 | 1.99 | .8 |

Density

Trial 1: $\frac{3.65g}{1.4cm^3} = \frac{2.6g}{cm^3}$  Trial 2: $\frac{2.77g}{1.0mL} = \frac{2.8g}{cm^3}$  Trial 3: $\frac{1.99}{.8} = \frac{2.5g}{cm^3}$

$\boxed{\text{Density Average} = \frac{2.6g}{cm^3}}$

Length, Width, & Mass

Regular

| L(cm) | W(cm) | M(g) |
|---|---|---|
| 7.57 | 3.45 | .12 |
| 7.62 | 4.15 | .15 |

Heavy Duty

| L(cm) | W(cm) | M(g) |
|---|---|---|
| 4.96 | 3.61 | .13 |
| 4.78 | 4.70 | .16 |

$$T = m \times \frac{1}{L} \times \frac{1}{W} \times \frac{1}{D}$$

Calculations

Regular Foil

Trial 1

$$T = .12\cancel{g} \times \frac{1}{7.57\cancel{cm}} \times \frac{1}{3.45\cancel{cm}} \times \frac{1cm^{\cancel{3}}}{2.6\cancel{g}} = .001767\,cm \approx \boxed{1.7 \times 10^{-3} cm}$$

Trial 2

$$T = .15\cancel{g}\left(\frac{1}{7.62\cancel{cm}}\right)\left(\frac{1}{4.15\cancel{cm}}\right)\left(\frac{1cm^{\cancel{3}}}{2.6\cancel{g}}\right) = .001824\,cm \approx \boxed{1.8 \times 10^{-3} cm}$$

Average

$\boxed{1.8 \times 10^{-3} cm}$

## Heavy Duty Foil

### Trial 1

$$T = .13\cancel{g}\left(\frac{1}{4.96\,\cancel{cm}}\right)\left(\frac{1}{3.61\,\cancel{cm}}\right)\left(\frac{1\,cm^{\cancel{3}}}{2.6\,\cancel{g}}\right) = .002792 \approx 2.8\times10^{-3}\,cm$$

### Trial 2

$$T = .16\,g\left(\frac{1}{4.78\,cm}\right)\left(\frac{1}{4.70\,cm}\right)\left(\frac{1\,cm^3}{2.6\,g}\right) = .002739 \approx 2.7\times10^{-3}\,cm$$

Average thickness

$$\boxed{2.8\times10^{-3}\,cm}$$

## Claim:

- The average thickness of regular foil is $1.8\times10^{-3}$ cm
- the average thickness of heavy duty foil is $2.8\times10^{-3}$ cm

## Evidence and Analysis:

Thickness could have been measured by taking a volume measurement and dividing by an area measurement. The extremely thin nature of the foil made volume measurements with availble equipment ineffective.

As aluminum is an element, and density is an intensive property of aluminum, Use of granulated aluminum for volume and mass measurements would ~~transfer to the~~ apply to the foil sample. Calculating the density of aluminum would allow the use of the foil mass in dimensionally determine thickness. (See Detailed Procedure & Calculations)

## Reading and Reflection.

According to elmhurst college, virtual chembook (Ophardt, 2003) the accepted value for the density of aluminum is 2.7 g/cm³. The calculations we used determined a density of 2.6 g/cm³.

According to U.S Packaging and Wrapping LLC (2019) ~~[illegible]~~ RA standard Duty Aluminum foil is measured ~~[illegible]~~ thick. The unit "mil" is 1/1000th of an inch. Standard RA foil is measured between .0004 in and .0007 in

$$\cancel{.0004\,mil\left(\frac{1\,in}{1000\,mil}\right)\left(\frac{2.54\,cm}{1\,in}\right)} =$$

$$.0004\,in\left(\frac{2.54\,cm}{1\,in}\right) = 1.0\times10^{-3}\,cm$$

~~.5 mil~~

$$.0007\,in\left(\frac{2.54\,cm}{1\,in}\right) = 1.8\times10^{-3}\,cm$$

the reported values from ~~this~~ the stated packaging company correspond with the values measured in the lab

Heavy Duty Foil is recorded as .001in and .0008in thick (U.S Packaging, 2013)

$$.0008\,\cancel{in}\left(\frac{2.54\,cm}{1\,\cancel{in}}\right) = .0020\,cm \approx 2.0\times10^{-3}\,cm$$

$$.001\,in\left(\frac{2.54\,cm}{1\,in}\right) = 2.5\times10^{-3}\,cm$$

The measured lab values for Heavy Duty Foil in the lab slightly exceed reported values.

The precision with which our measured values were reported (limited by the precision of the ruler, scale, and graduated cylinder) tend to correlate with the significant figures observed ~~from~~ both the academic source (Elmhurst, 2013) and the commercial source (U.S. Packaging, 2013)

We may be able to perform the analysis of thickness of aluminum foil with one additional significant figure by increasing the aluminum granule sample to insure water displacement of greater than one mL. However, the data reported as taken, truly limits precision to only 1 sig fig.

# Percent by Mass of $NaHCO_3$ and KCl Mixture.

## Purpose / Question:

Sodium bicarbonate and potassium chloride are both white powders. When mixed in an unknown proportion, chemical analysis can be used in determination of percent mass of each compound in the mixture.

Sodium bicarbonate will decompose when heated into water vapor and carbon dioxide.

$$2\,NaHCO_3 \rightarrow Na_2CO_3 + H_2O + CO_2$$

Potassium chloride will not decompose when heated. The difference in boiling points between $NaHCO_3$, $Na_2CO_3$ and KCl are sufficiently high to allow careful heating which will result in decomposition of $NaHCO_3$, without affecting melting of any other substance present.

After decomposition of $NaHCO_3$, the ratio of $CO_2$ & $H_2O$ lost to the original amount of $NaHCO_3$ will allow us to determine initial amount of $NaHCO_3$ present. Using Stoichiometric ratios it is possible to determine the amount of $CO_2$ & $H_2O$ that will be lost per gram of $NaHCO_3$

$$1.000\,g\ NaHCO_3 \left(\frac{1\ mol}{84.007\,g}\right)\left(\frac{1\ mol\ H_2O}{2\ mol\ NaHCO_3}\right)\left(\frac{18.013\,g}{1\ mol\ H_2O}\right) = \frac{.107\,g\ H_2O}{g\ NaHCO_3}$$

$$1.000\,g\ NaHCO_3 \left(\frac{1\ mol}{84.007\,g}\right)\left(\frac{1\ mol\ \cancel{H_2O}\ CO_2}{2\ mol\ NaHCO_3}\right)\left(\frac{44.009\,g}{1\ mol\ CO_2}\right) = .262\,g\ CO_2$$

Sodium bicarbonate will decompose at the constant ratio of .368 g $CO_2$ and $H_2O$, for every 1.000 g of $NaHCO_3$

By observing the mass lost in a $NaHCO_3$/KCl mixture when heated, the above ratio can be used to determine % $NaHCO_3$ in the mixture.

## Safety Considerations:

- Glassware will need to be prepared using HCl which is corrosive to skin and must be neutralized before

- Use of Hot glassware will require eye Protection and careful use of tongs to maneuver.

## Procedure/Observations:

### Procedure

1) Clean porcelain dish with 6M HCl, let soak, rinse thoroughly, and heat to constant mass let cool.
2) Mass dish and cover and record. Add appx 1g of $KCl/NaHCO_3$ mixture and record mass of mixture.
3) Heat sample gently for 5 min Ensure sample does not melt. Heat continuously for 15 min
4) Heat sample to constant mass.

### Observations

1) After cleaning, small amounts of brown contaminant remained on dish
2) Contents for sample were taken from top of mixture, the mixture was hand mixed.
3) After 4 min, edges of sample started to melt. Heat was reduced. Sample formed crusty, cracked, appearance.
4) Sample measured within .01 g of previous measurement after 5 min of additional heating.

## Data Table:

| ~~Trial 1~~ | Trial 1 | Trial 2 |
|---|---|---|
| mass crucible | 100.09 g | 100.10 g |
| mass w/ mixture | 101.44 g | 101.64 g |
| mass mixture | 1.35 g | 1.44 g |
| mass after 15 min heat | 101.01 g | 101.31 g |
| mass after 5 min more | 101.00 g | 101.30 g |
| mass lost $CO_2/H_2O$ | .44 g | .54 g |

## Calculations mass % $NaHCO_3$:

Trial 1

$$.44\text{ g } CO_2/H_2O\left(\frac{1\text{ g } NaHCO_3}{.369\text{ g } CO_2/H_2O}\right) = 1.19\text{ g } NaHCO_3 \sim 1.2\text{ g } NaHCO_3$$

$$\frac{1.19\text{ g } NaHCO_3}{1.35\text{ g Total}} \times 100\% = 88.1\% \sim 88\%\ NaHCO_3$$

12% KCl

Trial 2

$$.54\text{ g } CO_2/H_2O\left(\frac{1\text{ g } NaHCO_3}{.369\text{ g } CO_2/H_2O}\right) = .921\text{ g } NaHCO_3$$

$$\frac{.921\text{ g } NaHCO_3}{1.44\text{ g Total}} \times 100\% = 63.96\%\ NaHCO_3 \sim 64\%\ NaHCO_3$$

36% KCl

## Claim:

The mixture of $KCl/NaHCO_3$, tested at various sample portions in the mixing container yielded the following:

Trial 1 showed 88% $NaHCO_3$ and 12% KCl

Trial 2 showed 64% $NaHCO_3$ and 36% KCl

## Evidence and Analysis:

From the two trials shown in the data, it is apparent that the mixture of $NaHCO_3$ and KCl was not mixed thoroughly. The process of heating to constant mass was followed in both experimental trials.

It is possible that results could involve error if the HCl used to clean the crucible was not entirely removed prior to testing. Any residual HCl will react with the $NaHCO_3$ to generate sodium chloride, water and $CO_2$.

The process used in both trials ensured thorough cleaning however. It is not likely that apreciable amounts of containment were present.

In the first trial at one point the $NaHCO_3$ started to melt. Molten $NaHCO_3$ can potentially react with silica present in the crucible releasing additional $CO_2$ and slightly affecting the outcome of the analysis. Heat was reduced immediately upon observation of molten $NaHCO_3$.

Limitations of precision in testing involved using a scale ~~the~~ with capacity limited to .01 grams. Measurements were then limited to two significant figures.

## Reading and Reflection:

Post-Lab questions-

If the laboratory technician accidentally mixed $NaHCO_3$ with $BaCl_2 \cdot 2H_2O$ instead of KCl, results would be affected. The hydrate $BaCl_2 \cdot 2H_2O$ will release 2 moles of water for every mole of $BaCl_2$ present. The additional release of $H_2O$ will result in additional mass loss when heating. As % $NaHCO_3$ is calculated from lost $CO_2$ + $H_2O$ this additional release of $H_2O$ will result in a % $NaHCO_3$ calculation that is too large.

Without knowledge of exactly how much $BaCl_2$ was added to the mixture, accurate measurement of the % $NaHCO_3$ will not be possible. It will be impossible to determine how much water mass was released from the $H_2O$ in the $BaCl_2$, and how much water mass was attributed to the $NaHCO_3$.

The law of conservation of mass states that total mass of materials present after a chemical reaction is the same as total mass present at the ~~end~~ beginning of the reaction (Brown-Lemay, p. 38, 2009). The law of constant composition states that the composition, elemental, of a pure compound is always the same, no matter ~~what~~ where the sample was generated or found (Brown-Lemay, p. 8, 2009).

According to the Natural Center for Biotechnology Information, sodium bicarbonate ($NaHCO_3$) will begin decomposition at 50°C, (Center for Biotech Info, 2014), ~~$Na_2CO_3$~~ ~~will~~ $NaHCO_3$ will melt at 270°C (chemicalbook.com, 2008). Sodium Carbonate will melt at 854°C (chemicalbook.com, 2008).

The application of the law of definite composition allows for the correct analysis of $NaHCO_3$ from lost $CO_2$ and $H_2O$. In the lab, maintaining a temperature between 50°C and 270°C will insure $NaHCO_3$ decomposition without melting. The process of heating to constant mass ensures that all $CO_2$ and $H_2O$ have been removed.