

BC2001x lab: week 4 Gravimetric experiments



Gravimetric = measuring masses

three choices:

- A: $\text{Cu} + \text{S}$
- B: $\text{BaCl}_2 \cdot n\text{H}_2\text{O}$
- C: $\text{Sn} + \text{O}$



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Review



relative uncertainty \equiv absolute uncertainty/value

Rules for Combining uncertainties:

MULTIPLICATION / DIVISION

The **relative** uncertainty of the result is the **sum** of the **relative** uncertainties of all the terms.

ADDITION / SUBTRACTION

The **absolute** uncertainty of the result is the **sum** of the **absolute** uncertainties of all the terms.

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ANALYSIS OF UNCERTAINTY in EXPERIMENTAL RESULTS



You will make a compound Cu_aS_b by reacting Cu with S.

What is the value of the **ratio** a/b?

Known sulfides of copper include
 CuS , Cu_2S , Cu_9S_5 .

Is one of these formed? Which one?

Is only one sulfide of copper formed, or a mixture?

Are the data sufficiently reliable to answer these questions?

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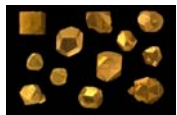
Procedure: making a sulfide of copper



1. **Weigh** a clean, dry, empty crucible.
2. Add a piece of copper wire. **Weigh** again.
3. Add an excess of sulfur (do not weigh).
4. Heat the mixture. [The reaction goes to completion: all the Cu reacts with S.]
5. Heat further. [The excess sulfur vaporizes and escapes or is combusted and escapes.]
6. Cool. **Weigh** the crucible and compound.

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SAMPLE CALCULATION: SULFIDE of IRON



The chemistry of Iron and Copper differ.

Iron (Fe) and Sulfur (S) form several known
compounds: Fe_aS_b :
 FeS , Fe_2S_3 , and FeS_2 .

What are corresponding ratios a/b ,
written as decimals?

Do these ratios have experimental uncertainty?

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SAMPLE DATA FOR A SULFIDE OF IRON



Experimental data:

mass of empty crucible	32.1045 g
mass of crucible with iron	32.8098 g
mass of crucible with compound	33.4140 g

Reference data (1997 Fisher table):

atomic weight of Fe	55.847(3) g/mole
atomic weight of S	32.066(6) g/mole

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Masses of Fe, S in compound



How many grams of Fe are in the compound?

mass of crucible + iron	32.8098 g
mass of crucible	<u>32.1045 g</u>
mass of iron	0.7053 g

How many grams of S are in the compound?

mass of crucible + compound	33.4140 g
mass of crucible + iron	<u>32.8098 g</u>
mass of sulfur	0.6042 g

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Moles of Fe and S in compound Fe_aS_b



First, ignoring uncertainties, calculate the result:

How many moles of Fe are in the compound?

$$\begin{aligned}\text{moles Fe} &= (\text{grams Fe}) / (\text{atomic weight Fe}) \\ &= (0.7053 \text{ g}) / (55.847 \text{ g/mole}) = a\end{aligned}$$

How many moles of S are in the compound?

$$\begin{aligned}\text{moles S} &= (\text{grams S}) / (\text{atomic weight S}) \\ &= (0.6042 \text{ g}) / (32.066 \text{ g/mole}) = b\end{aligned}$$

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Moles of Fe and S in compound Fe_aS_b



What is the ratio a/b?

$$\begin{aligned} a/b &= \text{moles Fe} / \text{moles S} \\ &= (\text{mass Fe}/\text{at wt Fe}) / (\text{mass S}/\text{at wt S}) \\ &= (\text{mass Fe})(\text{at wt S}) / (\text{at wt Fe})(\text{mass S}) \end{aligned}$$

$$\frac{a}{b} = \frac{(0.7053\text{g}) (32.066\text{ g/mol})}{(55.847\text{ g/mol}) (0.6042\text{g})} = 0.670252\dots$$

do not round yet, we will use uncertainties for that.

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Finding the uncertainty of the ratio a/b



Next, decide how to propagate the uncertainties:

Look at the equation:

$$a/b = (\text{mass Fe}) (\text{at wt S}) / (\text{at wt Fe}) (\text{mass S})$$

All arithmetic is multiplication and division,
so we must add the RELATIVE uncertainties
of the four terms!

But first we must find the absolute uncertainties.

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Finding the uncertainty of the masses



The mass of each element is found by **subtracting** the measured weights.

The estimated uncertainty associated with one weighing depends on the balance used, and is determined in lab.

Suppose the uncertainty associated with each weighing step is ± 0.0002 .

mass of crucible + iron (g)	32.8098 \pm 0.0002
mass of crucible (g)	<u>32.1045 \pm 0.0002</u>
mass of iron (g)	0.7053 \pm 0.0004

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Estimation of maximum uncertainty or uncertainty analysis



We will use a systematic **tabular** method to propagate the estimated uncertainties of all quantities in the calculation to get the **estimated uncertainties of the final result.**

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The uncertainty table:
Estimation of maximum uncertainty



- 1) Convert absolute uncertainties of all quantities to relative uncertainties (written as %)
 (keep an extra digit to avoid roundoff error)

QUANTITY	VALUE	ABS UNC	REL UNC (%)
mass of Fe (g)	0.7053	± 0.0004	0.057
at wt. Fe (g/mole)	55.847	± 0.003	0.0054
mass S (g)	0.6042	± 0.0004	0.066
at wt. S (g/mole)	32.066	± 0.006	0.019

$(0.0004/0.7053) \times 100 = 0.057$ (no need to write this)

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The uncertainty table:
Estimation of maximum uncertainty



- 2) add all the relative uncertainties, giving the relative uncertainty of the result (a/b)

QUANTITY	VALUE	ABS. UNC.	REL. UNC. (%)
mass of Fe (g)	0.7053 ± 0.0004		0.057
at wt. Fe (g/mole)	55.847 ± 0.003		0.0054
mass S (g)	0.6042 ± 0.0004		0.066
at wt. S (g/mole)	32.066 ± 0.006		0.019
(a/b)	_____ ± _____		0.1474 %

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The uncertainty table:
Estimation of maximum uncertainty



- 3) multiply the relative uncertainty by the calculated value to get the absolute uncertainty:

QUANTITY	VALUE	ABS. UNC.	REL. UNC. (%)
mass of Fe (g)	0.7053 ± 0.0004		0.057
at wt. Fe (g/mole)	55.845 ± 0.002		0.0036
mass S (g)	0.6042 ± 0.0004		0.066
at wt. S (g/mole)	32.066 ± 0.006		0.019
(a/b)	_____ ± _____		← 0.1474...%

(a/b) is 0.6702759... with relative uncertainty 0.1474%

What is the absolute uncertainty?

$(0.670252)(0.1474)/100 = 0.00098795..$

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The uncertainty table:
Estimation of maximum uncertainty



- 4) Round the final value's absolute uncertainty to one digit

QUANTITY	VALUE	ABS. UNC.	REL. UNC. (%)
mass of Fe (g)	0.7053 ± 0.0004		0.057
at wt. Fe (g/mole)	55.847 ± 0.003		0.0054
mass S (g)	0.6042 ± 0.0004		0.066
at wt. S (g/mole)	32.066 ± 0.006		0.019
(a/b)	_____ ± _____		← 0.1474...%

The absolute uncertainty is 0.00098795 → _____

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The uncertainty table: Estimation of maximum uncertainty

5) Round the value to the same decimal place

QUANTITY	VALUE	ABS. UNC.	REL. UNC. (%)
mass of Fe (g)	0.7053 ± 0.0004		0.057
at wt. Fe (g/mole)	55.847 ± 0.003		0.0054
mass S (g)	0.6042 ± 0.0004		0.066
at wt. S (g/mole)	32.066 ± 0.006		0.019
(a/b)	_____ ± 0.001	←	0.1474 %

The rounded absolute uncertainty is 0.001

The value for (a/b) is 0.670252 → _____

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The completed uncertainty table

6) Enter these results into the last line of the table:

QUANTITY	VALUE	ABS. UNC.	REL. UNC. (%)
mass of Fe (g)	0.7053 ± 0.0004		0.057
at wt. Fe (g/mole)	55.847 ± 0.003		0.0054
mass S (g)	0.6042 ± 0.0004		0.066
at wt. S (g/mole)	32.066 ± 0.006		0.019
(a/b)	0.670 ± 0.001		0.1474...%

The uncertainty analysis tells us that 0.670 has **three** significant figures. Significant figure rules would have indicated **four**. This result is the better one.

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Final questions

Is the result $a/b = 0.670 \pm 0.001$ consistent with the formula Fe_2S_3 ?

We have included only **SOME** of the sources of uncertainty: what are some others?

Which are random, which are systematic?

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Uncertainty analysis: Summary of the steps in the procedure

When the calculation is all multiplication and division:

- 1) Convert absolute uncertainties of all quantities to relative uncertainties (written as %), (keep an extra digit to avoid roundoff error)
- 2) Add all the relative uncertainties, giving the relative uncertainty of the result,
- 3) multiply the relative uncertainty by the calculated value to get the absolute uncertainty,
- 4) Round the final absolute uncertainty to one digit,
- 5) Round the value to the same decimal place,
- 6) Enter results into the last line of the table.

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