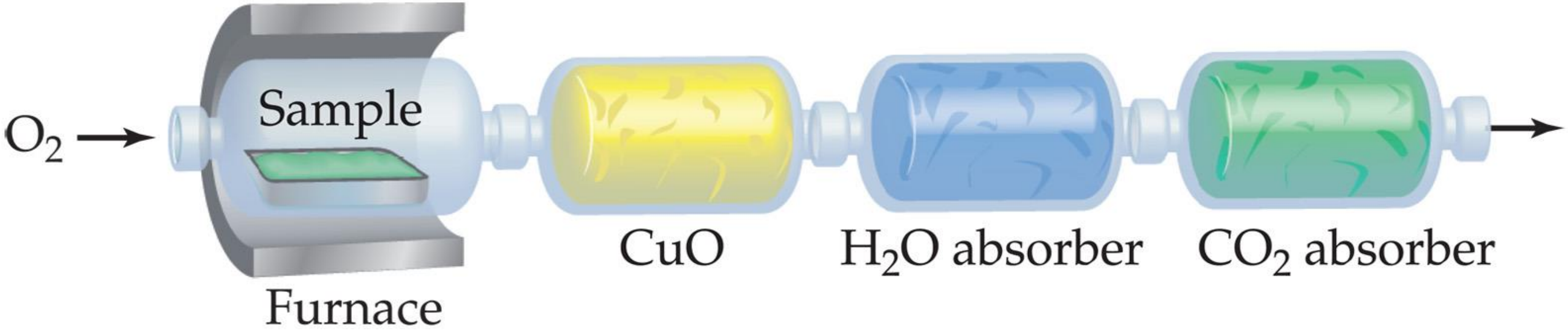
N30 – COMBUSTION ANALYSIS

It's just a more involved form of empirical formulas!

Target:

I can apply my knowledge of empirical formulas to data obtained from combustion analysis

Combustion Analysis



Compounds containing C, H and O are routinely analyzed through combustion in a chamber like this.

- C is determined from the mass of CO_2 produced.
- H is determined from the mass of H_2O produced.
- O is determined by difference after the C and H have been determined.

We have been working problems where we start with a % composition and doing this:

- % to mass
- Mass to mole
- Divide by small
- Multiply until whole

We don’t HAVE to start with a % composition though…

- As long as we can find the number of grams of each element, then we can find the empirical formula!

So…in combustion analysis problems…

- You will be figuring out the grams of each element in the sample using data and dimensional analysis, and do the normal empirical formula calculation!

So now it will be like this!

- ~~% to mass~~
- Mass to mole
- Divide by small
- Multiply til whole

Use Combustion Analysis Data and Dimensional Analysis to find grams

The amount of CO_2 gives the amount of C originally present in the sample compound

- All the carbon atoms in the unknown starting sample are rearranged into CO_2 product

- Why you ask? Because the law of conservation of mass is ALWAYS TRUE!

The amount of H_2O gives the amount of H originally present in the sample

- Why you ask? Why yes, that is correct. Because the law of conservation of mass is ALWAYS TRUE!

- Watch the subscript stoichiometry: 1 mol H_2O contains 2 mol H.

The amount of O originally present in the sample can be found by simple subtraction

- Mass of sample
  Mass of C
  – Mass of H
  = Mass of Oxygen!

- Why you ask? You know the answer!

Important Points to Know

- Must know the mass of the unknown substance before burning it
- The unknown will be burnt in pure oxygen, present in large excess
- The amount of oxygen will be determined by subtraction.
- The combustion products always have CO_2 and H_2O. Might have extra products if other elements are present!
- Nitrogen product can come in different forms. N_2, NH_3, etc. Will be given more info if needed. Often given as a separate experiment – will need to convert all to %'s if this is the case! Nitrogen is the problem child in combustion analysis.
- All the carbon winds up as CO_2 and all the hydrogen winds up as H_2O.

Steps to Solve

1) Determine the mass of each element present in the original compound using dimensional analysis
   - Carbon is always in CO_2 in the ratio of 1 mole CO2 = 1 mole C
   - Hydrogen is always in H_2O in the ratio of 1 mole H2O = 2 mole H
   - Nitrogen can be (NH_3, N_2, N, NO_2, etc…). If data from a separate experiment, make sure to convert masses to % values!
2) Subtract to solve for oxygen

   Sample mass – (C_{mass}+H_{mass}+$N_{\text{mass if necessary, or any other random element}}$)
3) Now continue with the Rhyme from before!
   - Mass to moles
   - Divide by small
   - Multiply until whole

Example #1

A sample of a compound that is known to contain only carbon, hydrogen, and oxygen is combusted, and the CO_2 and H_2O produced are trapped and weighed. The original sample weighed 8.38 g and yielded 16.0 g CO_2 and 9.5 g H_2O. What is the empirical formula?

Example #1

Original sample = 8.38 g and yielded 16.0 g CO_2 and 9.80 g H_2O

Moles of Carbon

$$\frac{16.0 \text{ g } CO_2}{} \left| \frac{1 \text{ mole } CO_2}{44.0 \text{ g } CO_2} \right| \frac{1 \text{ mole C}}{1 \text{ mole } CO_2} = 0.364 \text{ mole C}$$

Moles of Hydrogen

$$\frac{9.80 \text{ g } H_2O}{} \left| \frac{1 \text{ mole } H_2O}{18.0 \text{ g } H_2O} \right| \frac{2 \text{ mole H}}{1 \text{ mole } H_2O} = 1.09 \text{ mole H}$$

Example #1

Original sample = 8.38 g and yielded 16.0 g CO_2 and 9.80 g H_2O

Moles to Mass to Calculate Oxygen

$$\frac{0.364 \text{ mole C}}{} \left| \frac{12.0 \text{ g C}}{1 \text{ mole C}} \right. = 4.37 \text{ g C}$$

$$\frac{1.09 \text{ mole H}}{} \left| \frac{1.01 \text{ g H}}{1 \text{ mole H}} \right. = 1.10 \text{ g H}$$

Grams of Oxygen

8.38 g Sample – 4.37 g C – 1.10 g H = 2.91 g Oxygen

Example #1

Original sample = 8.38 g and yielded 16.0 g CO_2 and 9.80 g H_2O

Back to the Rhyme! *Mass to moles, divide by small, multiply till whole!*

$$\frac{2.91\ \text{g O}}{} \left| \frac{1\ \text{mole O}}{16.00\ \text{g O}} \right. = 0.182\ \text{mole O}$$

Therefore

0.364 mole C

1.09 mole H

0.182 mole O

Divide by small, multiply till whole (if needed)

$$\frac{0.364\ \text{C}}{0.182} = 2$$

$$\frac{1.09\ \text{H}}{0.182} = 5.989 \rightarrow 6$$

$$\frac{0.182\ \text{O}}{0.182} = 1$$

$$C_2H_6O$$

Example #2

Lysine is an amino acid which has the following elemental composition: C, H, O, N. In one experiment, 2.175 g of lysine was combusted to produce 3.94 g of CO_2 and 1.89 g H_2O. In a separate experiment, 1.873 g of lysine was burned to produce 0.436 g of NH_2. The molar mass of lysine is approximately 150 g/mol. Determine the empirical and molecular formula of lysine.

Example #2

Original sample = 2.175 g and yielded 3.94 g CO_2 and 1.89 g H_2O
Nitrogen Sample = 1.873g → 0.436 g NH2

Moles of Carbon

3.94 g CO2	1 mole CO2	1 mole C	= 0.0895 mole C
	44.01 g CO2	1 mole CO2	

Moles of Hydrogen

1.89 g H2O	1 mole H2O	2 mole H	= 0.2098 mole H
	18.015 g H2O	1 mole H2O	

Moles of Nitrogen – *data from other experiment!*

0.436 g NH2	1 mole NH2	1 mole N	= 0.02721 mole N
	16.023 g NH2	1 mole NH2	

Example #2

Original sample = 2.175 g and yielded 3.94 g CO_2 and 1.89 g H_2O

Nitrogen Sample = 1.873g → 0.436 g NH2

Moles to Mass

$$\frac{0.0895 \text{ mole C} \;\Big|\; 12.011 \text{ g C}}{\quad\;\Big|\; 1 \text{ mole C}} = 1.074 \text{ g C}$$

$$\frac{0.2098 \text{ mole H} \;\Big|\; 1.008 \text{ g H}}{\quad\;\Big|\; 1 \text{ mole H}} = 0.2115 \text{ g H}$$

$$\frac{0.0272 \text{ mole N} \;\Big|\; 14.007 \text{ g N}}{\quad\;\Big|\; 1 \text{ mole N}} = 0.38114 \text{ g N}$$

Example #2

Original sample = 2.175 g and yielded 3.94 g CO_2 and 1.89 g H_2O

Nitrogen Sample = 1.873g → 0.436 g NH2

Convert to % values because N is from another experiment!

$$\frac{1.0753 \text{ g C}}{2.175 \text{ g Sample}} \times 100 = 49.44\% \text{ C}$$

$$\frac{0.2115 \text{ g H}}{2.175 \text{ g Sample}} \times 100 = 9.72\% \text{ H}$$

$$\frac{0.38114 \text{ g N}}{1.873 \text{ g Sample}} \times 100 = 19.17\% \text{ N}$$

Example #2

Original sample = 2.175 g and yielded 3.94 g CO_2 and 1.89 g H_2O
Nitrogen Sample = 1.873g → 0.436 g NH2

Subtract the % values from 100 to find how much Oxygen!

100 – 49.44C – 9.72H – 19.17N = 21.67% Oxygen

Back to the Rhyme!

% to mass, *mass to moles, divide by small, multiply till whole!*

49.44 % C → 49.44 g C
9.72 % H → 9.72 g H
19.17 % N → 19.17 g N
21.67 % O → 21.67 g O

Example #2

Original sample = 2.175 g and yielded 3.94 g CO_2 and 1.89 g H_2O
Nitrogen Sample = 1.873g → 0.436 g NH2

Back to the Rhyme!

*% to mass, **mass to moles**, divide by small, multiply till whole!*

49.44 % C → 49.44 g C
9.72 % H → 9.72 g H
19.17 % N → 19.17 g N
21.67 % O → 21.67 g O

$$\frac{49.44 \text{ g C}}{} \left| \frac{1 \text{ mole C}}{12.01 \text{ g C}} \right. = 4.116 \text{ mole C}$$

$$\frac{9.72 \text{ g H}}{} \left| \frac{1 \text{ mole H}}{1.008 \text{ g H}} \right. = 9.643 \text{ mole H}$$

$$\frac{19.17 \text{ g N}}{} \left| \frac{1 \text{ mole N}}{14.01 \text{ g N}} \right. = 1.3686 \text{ mole N}$$

$$\frac{21.67 \text{ g O}}{} \left| \frac{1 \text{ mole O}}{16.0 \text{ g N}} \right.$$

$$= 1.3544 \text{ mole O}$$

Example #2

Original sample = 2.175 g and yielded 3.94 g CO_2 and 1.89 g H_2O
Nitrogen Sample = 1.873g → 0.436 g NH2

Back to the Rhyme!

*% to mass, mass to moles, **divide by small,** multiply till whole!*

4.115 mole C
9.643 mole H
1.3686 mole N
1.3544 mole O

$$\frac{4.115 \text{ mole C}}{1.3544} = 3.04 \text{ C}$$

$$\frac{1.3686 \text{ mole N}}{1.3544} = 1.01 \text{ N}$$

$$\frac{9.643 \text{ mole H}}{1.3544} = 7.12 \text{ H}$$

$$\frac{1.3544 \text{ mole O}}{1.3544} = 1 \text{ O}$$

Example #2

Original sample = 2.175 g and yielded 3.94 g CO_2 and 1.89 g H_2O
Nitrogen Sample = 1.873g → 0.436 g NH2

Back to the Rhyme!

% to mass, mass to moles, divide by small, ***multiply till whole!***

3.04 C → 3
7.12 H → 7
1.01 N → 1
1 O → 1

$$C_3H_7NO$$