

Chem With Com

Solutions and Empirical Formula

- Chapter 1.2 (Phases and Classifications of Matter)
- Chapter 11.2 (Electrolytes) - how things mix - ion-dipoles
- Chapter 11.3 (Solubility) – miscibility
- Chapter 6.3 (Molarity)
- Chapter 6.4 (Other Units for Solution Concentrations)
- Chapter 6.2 (Determining Empirical and Molecular Formulas)

Adapted From: Paul Flowers, Edward J. Neth, William R. Robinson, PhD, Klaus Theopold, Richard Langley; Chemistry: Atoms First 2e; OpenStax; Feb 14, 2019; Houston Texas; https://openstax.org/books/chemistry-atoms-first-2e/pages/1-introduction

Mixtures

- Chapter 1.2 (Phases and Classifications of Matter)
- Chapter 11.2 (Electrolytes) - how things mix - ion-dipoles
- Chapter 11.3 (Solubility) – miscibility

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Mixtures

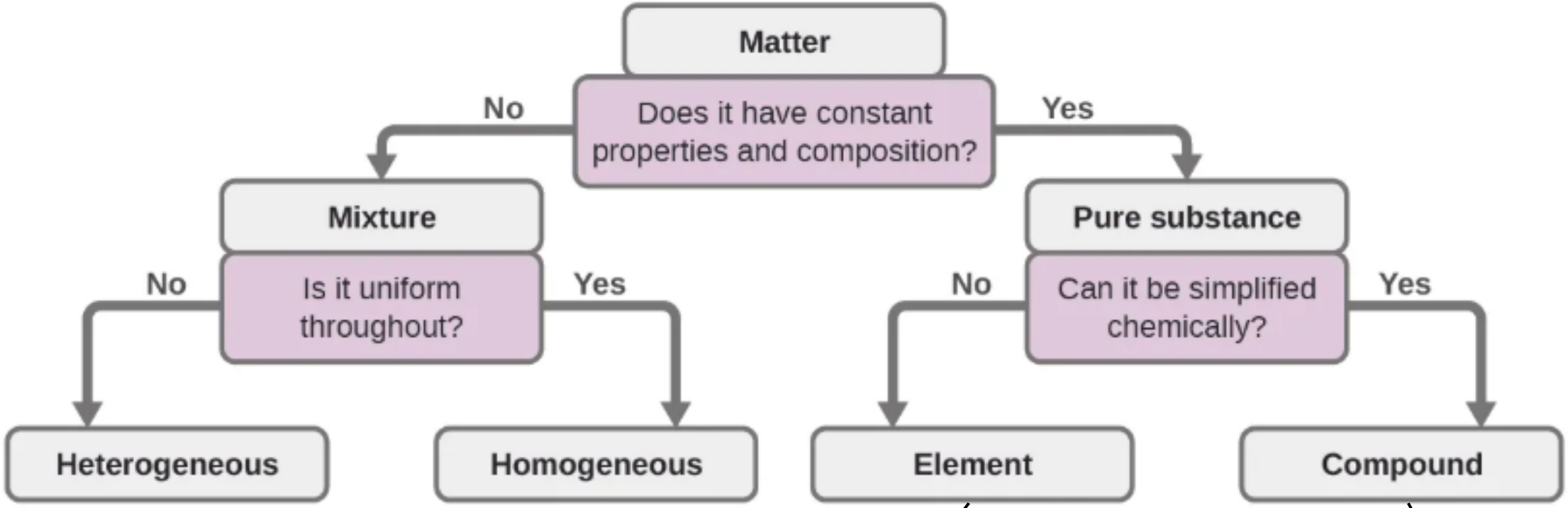
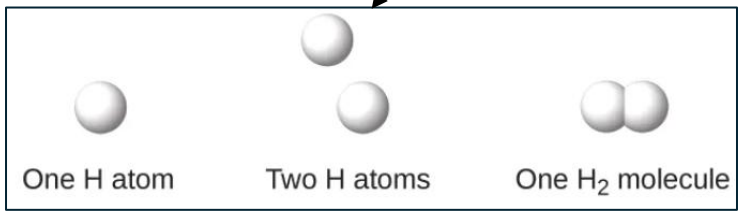
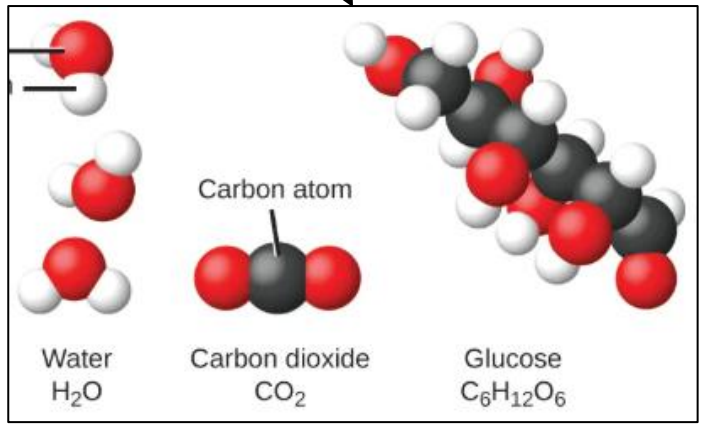


Figure 1.11 Depending on its properties, a given substance can be classified as a homogeneous mixture, a heterogeneous mixture, a compound, or an element.





Chapter 1.2, 2.4

Mixtures

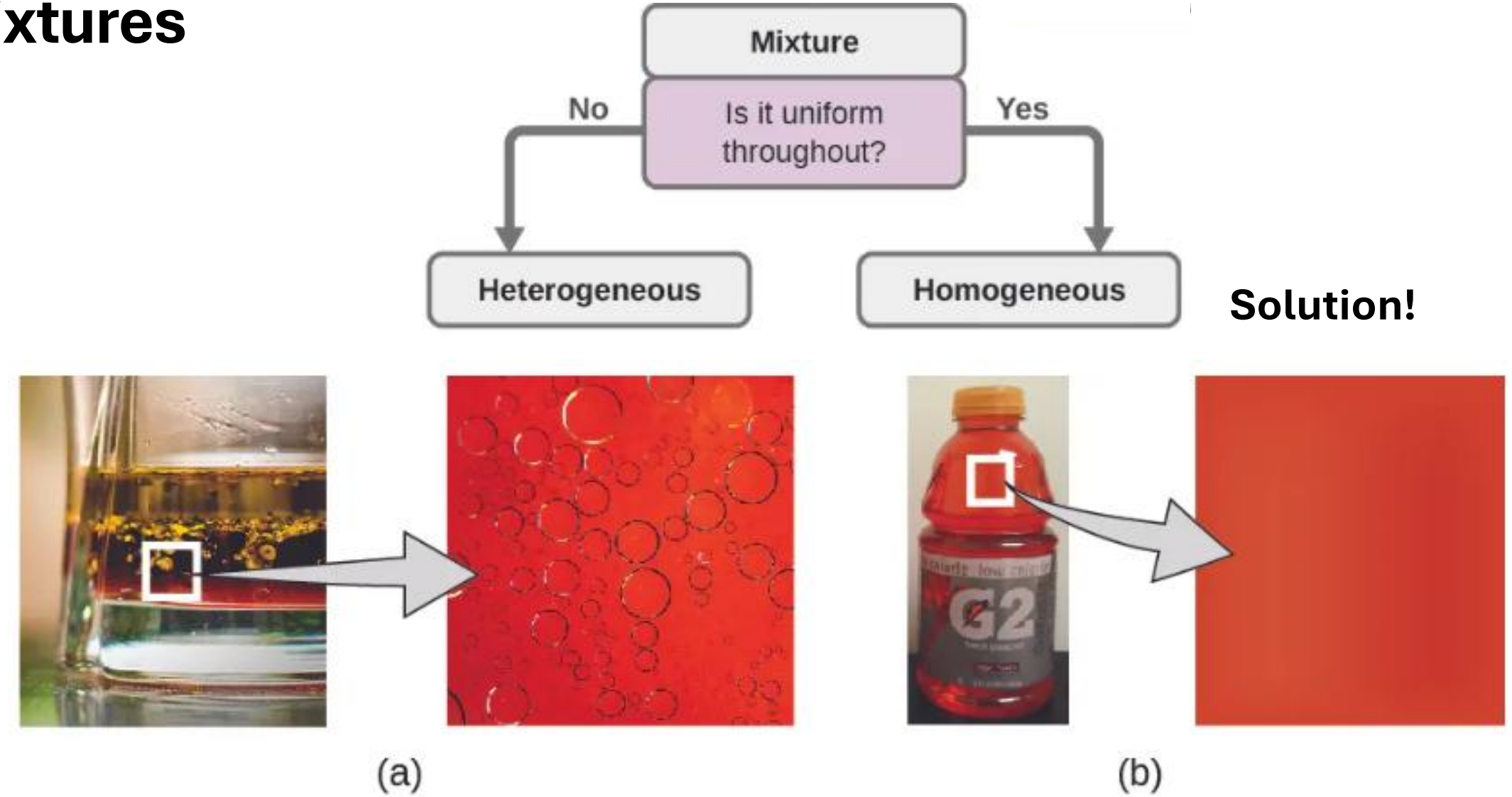


Figure 1.10 (a) Oil and vinegar salad dressing is a heterogeneous mixture because its composition is not uniform throughout. (b) A commercial sports drink is a homogeneous mixture because its composition is uniform throughout. (credit a "left": modification of work by John Mayer; credit a "right": modification of work by Umberto Salvagnin; credit b "left: modification of work by Jeff Bedford)

Dipole-Dipole Attractions (polar-polar)

Dipole-Dipole Attractions

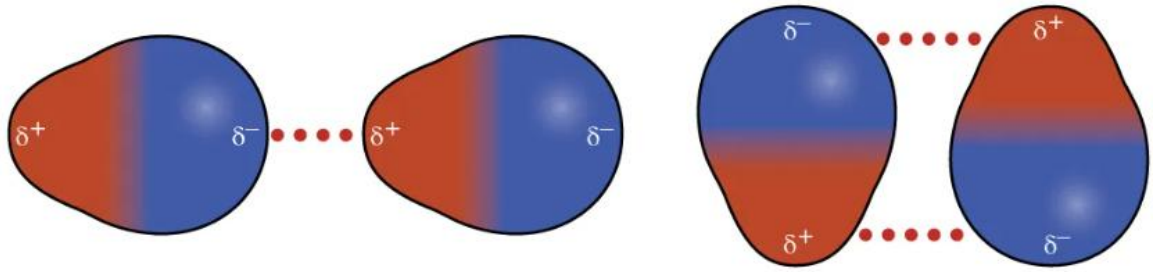


Figure 10.9 This image shows two arrangements of polar molecules, such as HCl, that allow an attraction between the partial negative end of one molecule and the partial positive end of another.

Review: Topic 7

Like dissolves like – polar dissolves polar and nonpolar dissolves nonpolar

Immiscible (doesn't mix)

oil
nonpolar
(no dipole)

water - H_2O
polar (dipole)

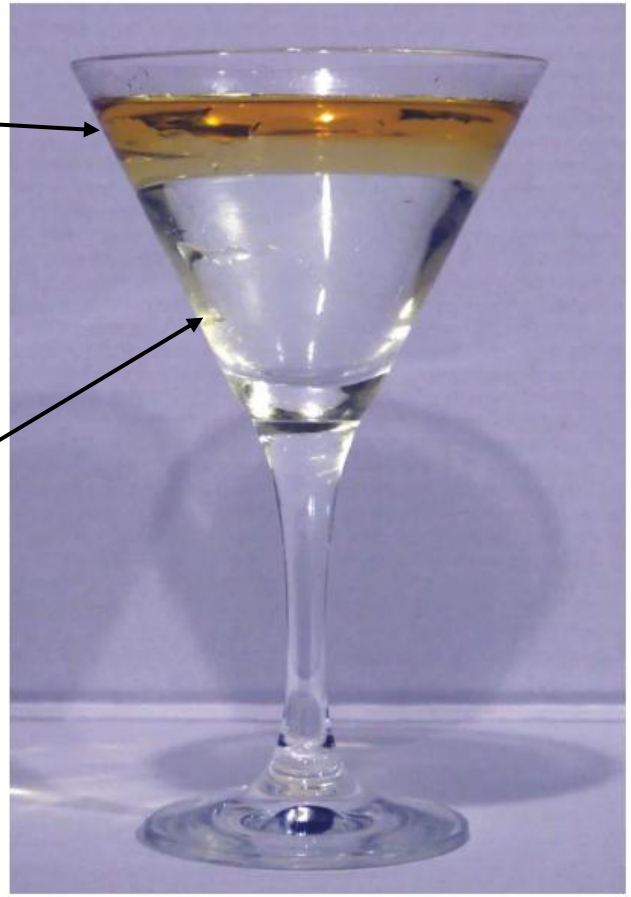


Figure 11.14 Water and oil are immiscible. Mixtures of these two substances will form two separate layers with the less dense oil floating on top of the water. (credit: "Yortw"/Flickr)

Miscible (mixes well)

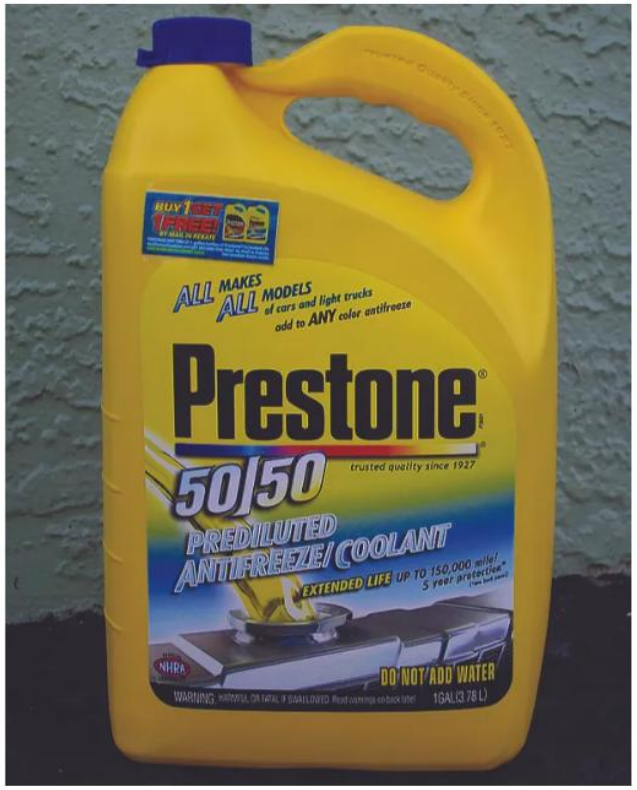
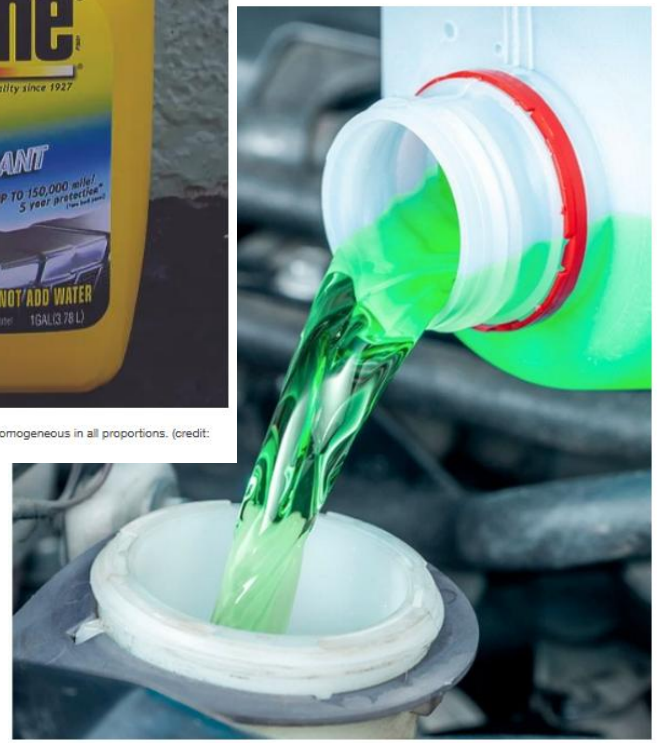


Figure 11.13 Water and antifreeze are miscible; mixtures of the two are homogeneous in all proportions. (credit: "dno1967"/Wikimedia commons)

water - H_2O
polar (dipole)

+

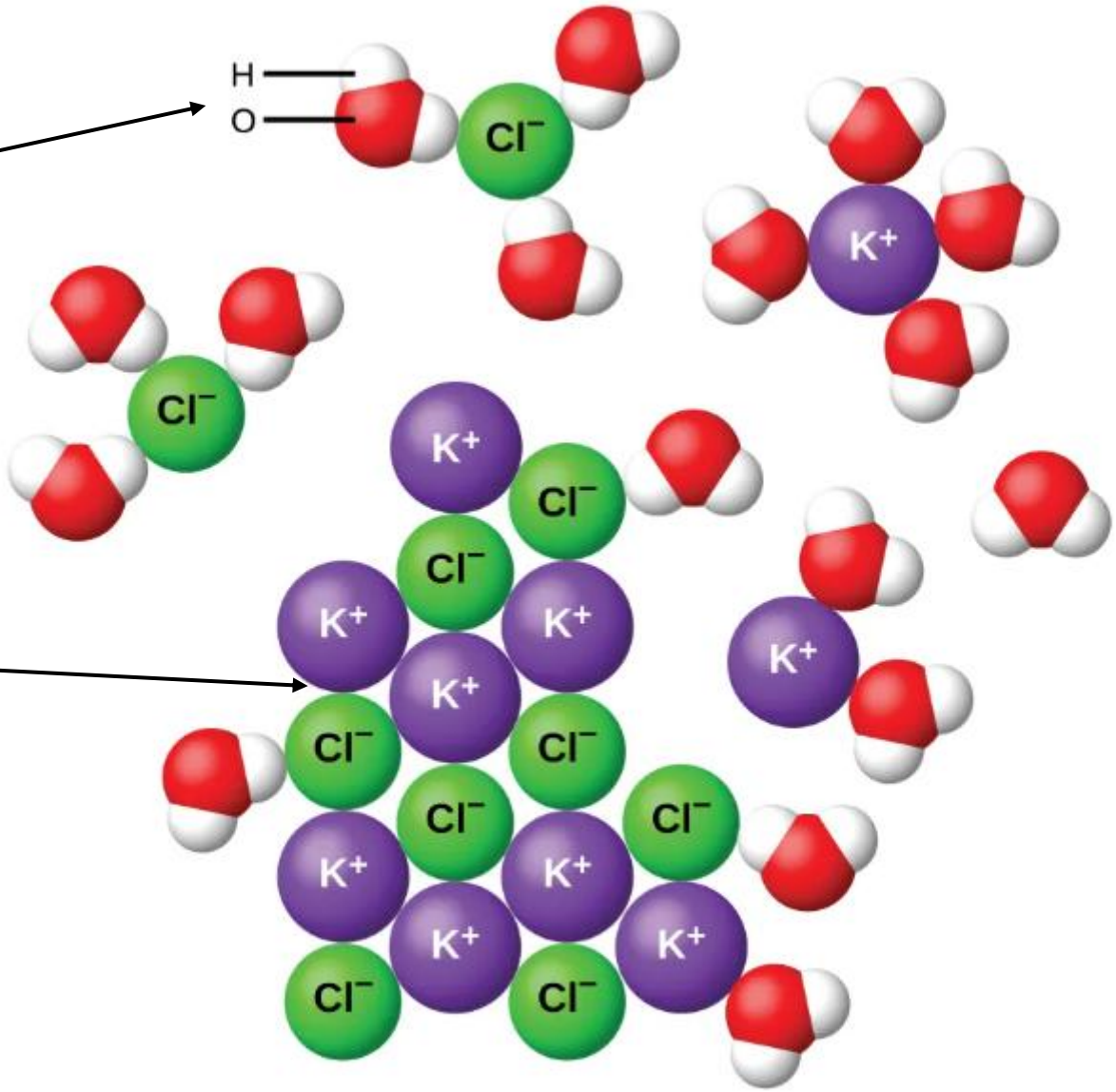
antifeeze – $C_2H_6O_2$
polar (dipole)



Like dissolves like - for liquids and solids as well (salt+water)

water - H_2O
polar (dipole)
Partially charged molecule

K^{1+} or Cl^{1-}
fully charged molecule



Miscible (mixes well)

Chapter 11.4

Figure 11.7 As potassium chloride (KCl) dissolves in water, the ions are hydrated. The polar water molecules are attracted by the charges on the K^+ and Cl^- ions. Water molecules in front of and behind the ions are not shown.

Some things are partially miscible

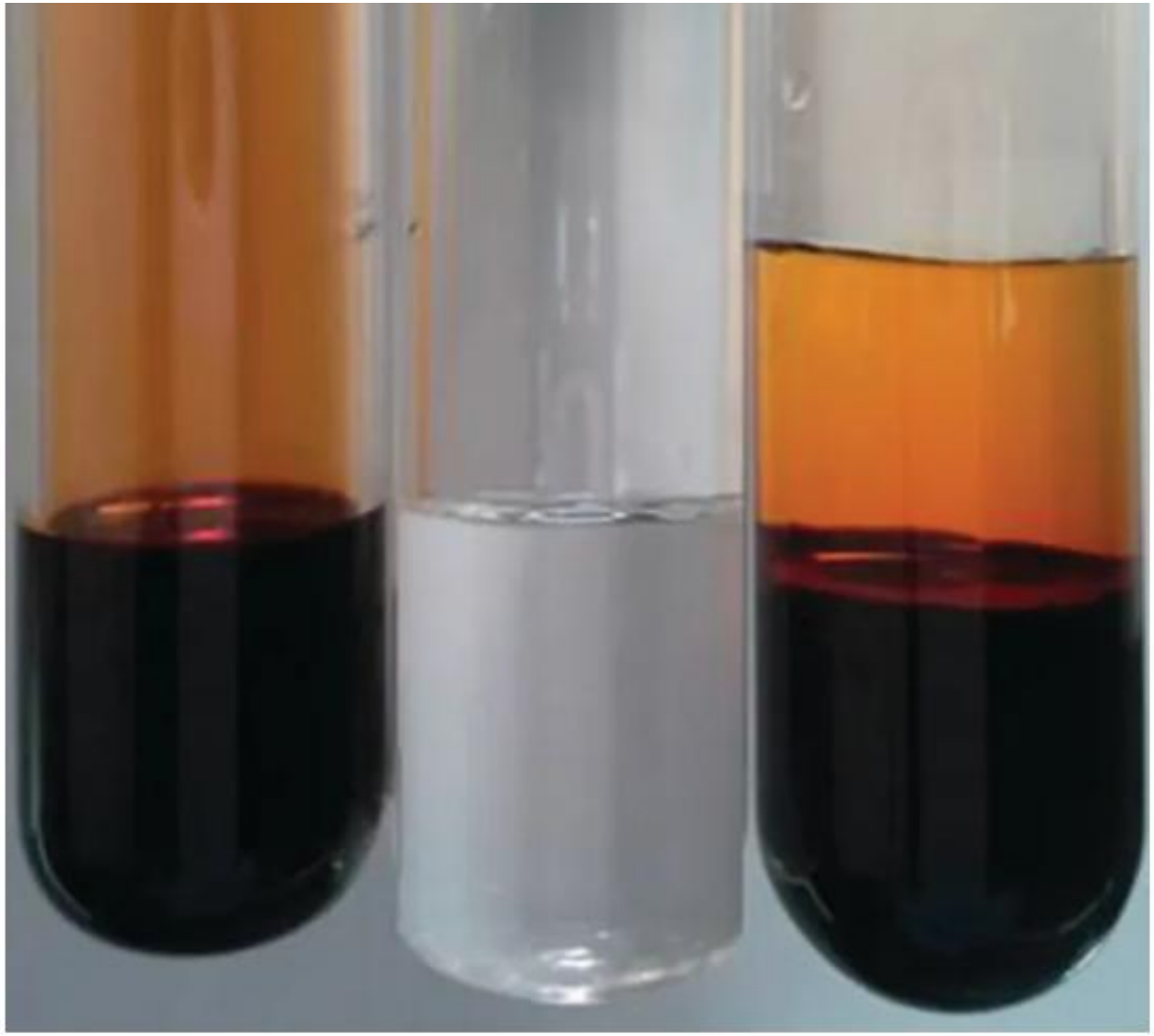


Figure 11.15 Bromine (the deep orange liquid on the left) and water (the clear liquid in the middle) are partially miscible. The top layer in the mixture on the right is a saturated solution of bromine in water; the bottom layer is a saturated solution of water in bromine. (credit: Paul Flowers)

Solutions

- Chapter 6.3 (Molarity)
- Chapter 6.4 (Other Units for Solution Concentrations)

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Solvent + Solute = Solution

Solvent = “more of”

Solute = “less of”

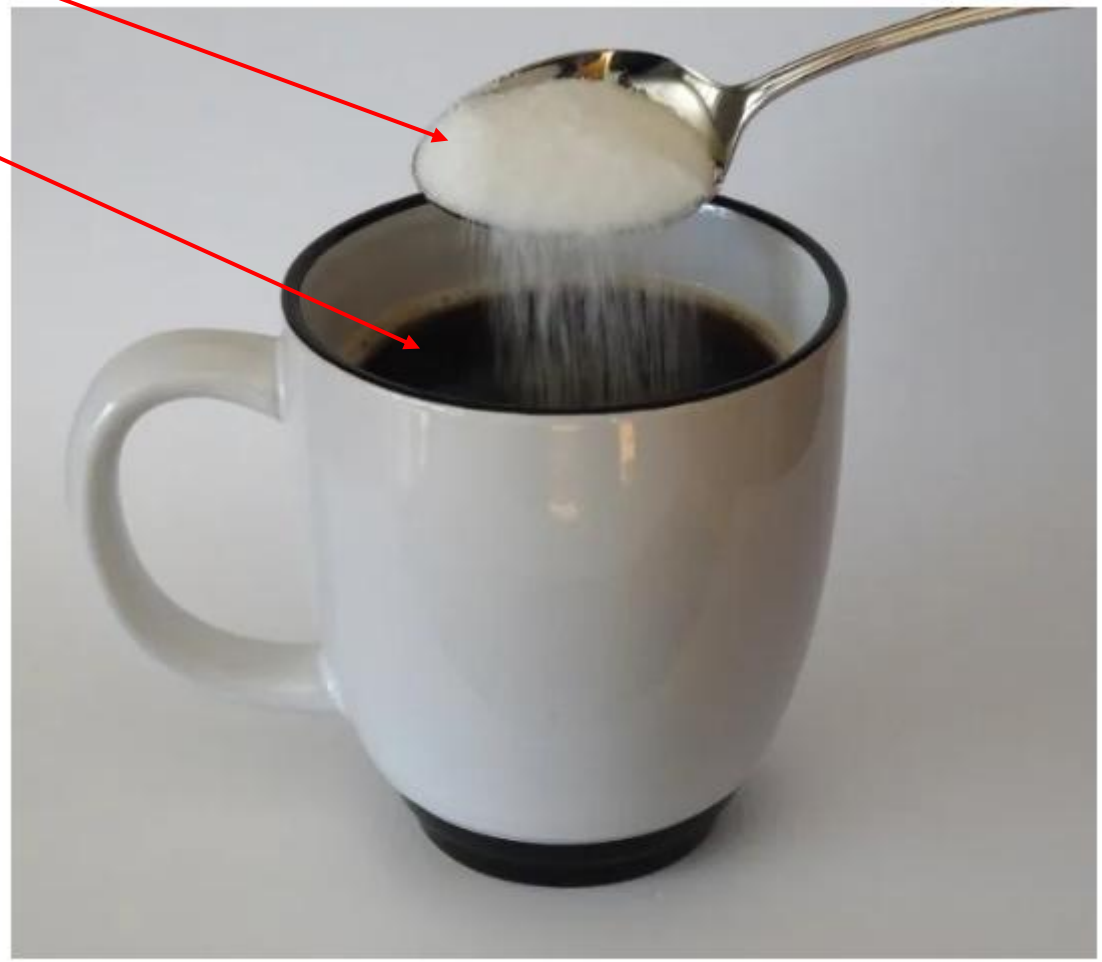


Figure 6.8 Sugar is one of many components in the complex mixture known as coffee. The amount of sugar in a given amount of coffee is an important determinant of the beverage's sweetness. (credit: Jane Whitney)

If water is the solvent, this is an aqueous solution. Aqueous solutions are annotated with an (aq) after a chemical formula

Concentration Equations

- Molarity Equation $$M = \frac{\text{mol solute}}{\text{L solution}}$$

- Dilution Equation $$M_1 L_1 = M_2 L_2 \quad \text{or} \quad C_1 V_1 = C_2 V_2$$

- Mass Percentage $$\text{mass percentage} = \frac{\text{mass of component}}{\text{mass of solution}} \times 100\%$$

Molarity = moles solute / liters of solution

- Common unit of concentration in chemistry and biology

$$M = \frac{\text{mol solute}}{\text{L solution}}$$

- We also know we can readily convert moles to grams and grams to moles

Check Your Learning

A teaspoon of table sugar contains about 0.01 mol sucrose. What is the molarity of sucrose if a teaspoon of sugar has been dissolved in a cup of tea with a volume of 200 mL?

$$M = \frac{\text{mol solute}}{\text{L solution}}$$

Check Your Learning

Calculate the molarity of 6.52 g of $CoCl_2$ (128.9 g/mol) dissolved in an aqueous solution with a total volume of 75.0 mL.

$$M = \frac{\text{mol solute}}{\text{L solution}}$$

Check Your Learning

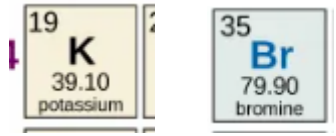
How many grams of $CaCl_2$ (110.98 g/mol) are contained in 250.0 mL of a 0.200-*M* solution of calcium chloride?

$$M = \frac{\text{mol solute}}{\text{L solution}}$$

Check Your Learning

What volume of a 1.50-*M* KBr solution contains 66.0 g KBr?

$$M = \frac{\text{mol solute}}{\text{L solution}}$$



Dilution Equation

$$M_1L_1 = M_2L_2$$ or $$C_1V_1 = C_2V_2$$

- M = molarity
- L = liters
- 1 = initial or starting
- 2 = final or ending

- C = concentration
- V = volume
- 1 = initial or starting
- 2 = final or ending

Check Your Learning

What is the concentration of the solution that results from diluting 25.0 mL of a 2.04-*M* solution of CH_3OH to 500.0 mL?

$$M_1L_1 = M_2L_2$$

Check Your Learning

A laboratory experiment calls for 0.125 *M* HNO_3. What volume of 0.125 *M* HNO_3 can be prepared from 0.250 L of 1.88 *M* HNO_3?

$$M_1L_1 = M_2L_2$$

Check Your Learning

What volume of a 0.575-*M* solution of glucose, $C_6H_{12}O_6$, can be prepared from 50.00 mL of a 3.00-*M* glucose solution?

$$M_1L_1 = M_2L_2$$

Mass Percent

$$\text{mass percentage} = \frac{\text{mass of component}}{\text{mass of solution}} \times 100\%$$

$$percent = \frac{part}{whole}\ x\ 100\%$$

*percent equation used in chapter 2

Check Your Learning

A bottle of a tile cleanser contains 135 g of HCl and 775 g of water. What is the percent by mass of HCl in this cleanser?

$$\text{mass percentage} = \frac{\text{mass of component}}{\text{mass of solution}} \times 100\%$$

Check Your Learning

What volume of concentrated HCl solution contains 125 g of HCl?

$$\text{mass percentage} = \frac{\text{mass of component}}{\text{mass of solution}} \times 100\%$$

"Concentrated" hydrochloric acid is an aqueous solution of 37.2% HCl

The density of this solution is 1.19 g/mL.

Percent Composition and Empirical Formula

- Chapter 6.2 (Determining Empirical and Molecular Formulas)

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Percent Composition

$$\frac{part}{whole}\ x\ 100\% = percent$$

A sample contains 1.2 g zinc and 0.75 g oxygen, what is the percent of each component?

zinc + oxygen

1.2 g zinc
+ 0.75 g oxygen
1.95 g total

To find the percent zinc:

$$\frac{part}{whole}\ x\ 100\% = percent$$

$$\frac{1.2\ g}{1.95 g}\ x\ 100\% = percent$$

grams cancel out

$$\frac{1.2\ \cancel{g}}{1.95\cancel{g}}\ x\ 100\% = percent$$

2 sigfigs

$$62\% = percent\ zinc$$

To find the percent oxygen, repeat with 0.75 g oxygen instead of 1.2 g zinc.

Alternatively you could take 100% (both zinc and oxygen) and subtract 62% (zinc).

Do not use the percent button on your calculator. Treat the % sign like a variable.

Check Your Learning

A 24.81-g sample of a gaseous compound containing only carbon, oxygen, and chlorine is determined to contain 3.01 g C, 4.00 g O, and 17.81 g Cl. What is this compound's percent composition?

$$\frac{part}{whole} \; x \; 100\% = percent$$

Percent Composition from chemical formula

$$\frac{part}{whole}\ x\ 100\% = percent$$

Percent hydrogen in water?

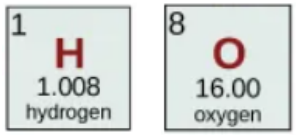
H_2O

2 hydrogens

1 oxygen

$$\frac{part}{whole}\ x\ 100\% = percent \Rightarrow \frac{all\ hydrogens}{the\ whole\ molecule}\ x\ 100\% = \%\ H$$

From the periodic table



$$\frac{(H\ x\ 2)}{(H\ x\ 2) + (O\ x\ 1)}\ x\ 100\% = \%H \Rightarrow \frac{(1.008\ g/mol\ x\ 2)}{(1.008\ g/mol\ x\ 2) + (16.00\ g/mol\ x\ 1)}\ x\ 100\% = \%H \Rightarrow 11.19\% = percent\ H$$

with 4 sigfigs

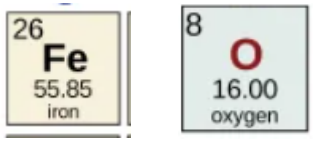
To find the percent oxygen, repeat with 1 oxygen instead of 2 hydrogen.

Alternatively you could take 100% (both hydrogen and oxygen) and subtract 11.19% (hydrogen).

Check Your Learning

To three significant digits, what is the mass percentage of iron in the compound Fe_2O_3?

$$\frac{part}{whole}\ x\ 100\% = percent$$



Determination of Empirical Formula

For brief review: Topic 3, subtopic 3: Molecules, Compounds, and Chemical Formulas

Empirical formula – same ratio of atoms as the molecular formula but lowest subscripts

empirical formula

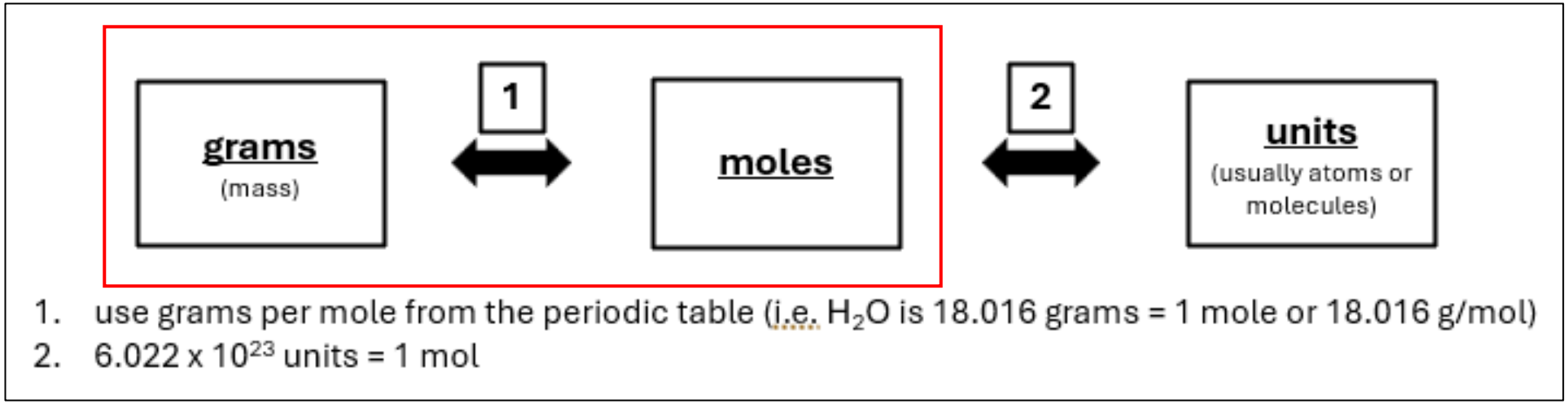
formula showing the composition of a compound given as the simplest whole-number ratio of atoms

Determination of Empirical Formula

Some chemistry experiments will allow us to determine the mass or percent composition of a substance. From this information, we can calculate the empirical formula.

MgO means there is 1 magnesium atom and 1 oxygen atom. This is the "**mole ratio**".

In order for us to calculate the empirical formula from the mass or percent data from a chemical experiment we must first convert the mass or percent data to moles. Grams to Moles! (review Topic 6: Dimensional Analysis)



1. use grams per mole from the periodic table (i.e. H_2O is 18.016 grams = 1 mole or 18.016 g/mol)
2. 6.022×10^{23} units = 1 mol

Determination of Empirical Formulas – book way

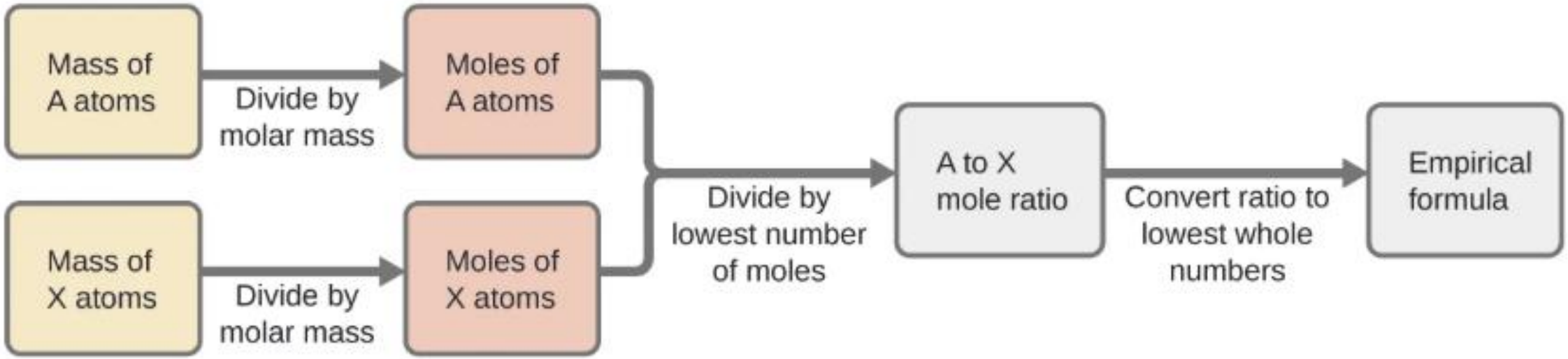
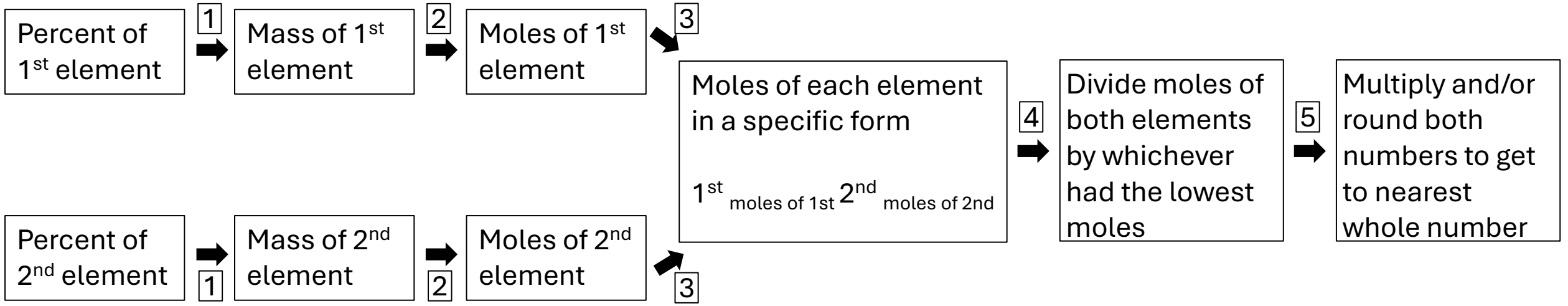


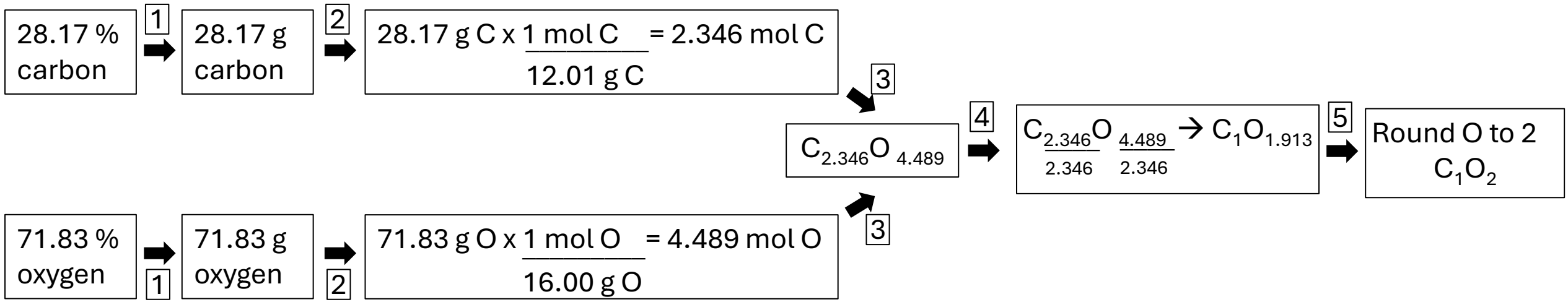
Figure 6.5 The empirical formula of a compound can be derived from the masses of all elements in the sample.

Determination of Empirical Formulas – Com's way



1. Just change the % sign to grams. You can do this because if you use 100 g of something it will be the same number. There can be more than two elements as well.
2. Sometimes the problem starts you with mass. Use the periodic table to convert to moles. Multiply the mass by 1 mol/g element (the molar mass in grams per mole from the periodic table with the fraction inverted).
3. Writing it this way helps you keep track of the moles and position (i.e. $Fe_{0.2055}O_{0.3169}$)
4. Which ever moles is lower between the 1st element or 2nd element, divide both the numbers by that same number. This will result in one of your elements being 1 and the other element greater than 1. i.e. $Fe_{\frac{0.2055}{0.2055}}O_{\frac{0.3169}{0.2055}} \rightarrow Fe_1O_{1.542}$
5. The objective is to get your empirical formula which is whole numbers. You can round up or keep the number the same if your number is within 0.19 of a whole number (i.e. 1.81 would be rounded to 2 and something like 3.19 would be rounded down to 3. If they are greater than this, you will have to multiply both numbers by some factor 2, 3, 4, 5 to get close a whole number and then round. $Fe_1O_{1.542} \rightarrow Fe_{1 \times 2}O_{1.542 \times 2}$ (multiply both by 2) $\rightarrow Fe_2O_{3.084} \rightarrow Fe_2O_3$ (rounded).

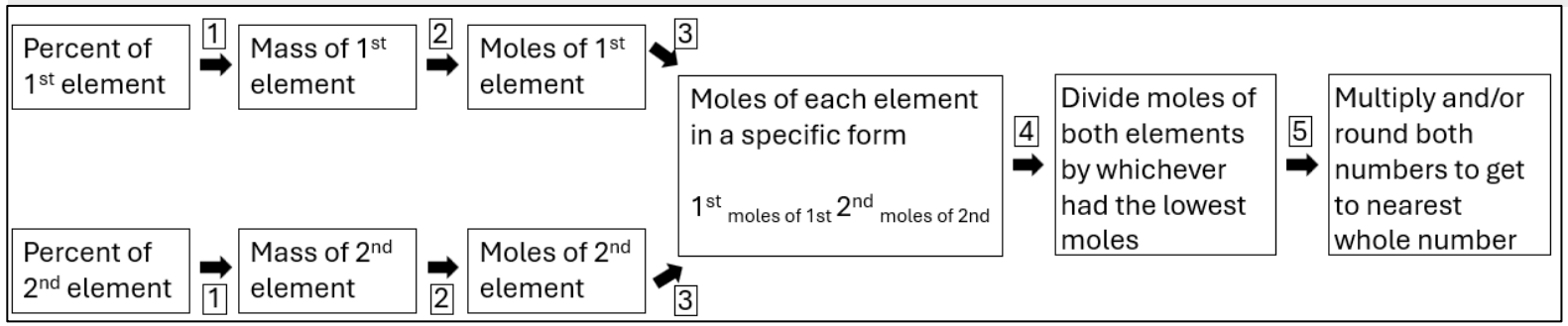
Determination of Empirical Formulas – Com's way



1. Just change the % sign to grams. You can do this because if you use 100 g of something it will be the same number. There can be more than two elements as well.
2. Sometimes the problem starts you with mass. Use the periodic table to convert to moles. Multiply the mass by 1 mol/g element (the molar mass in grams per mole from the periodic table with the fraction inverted).
3. Writing it this way helps you keep track of the moles and position (i.e. $C_{2.346}O_{4.489}$)
4. Which ever moles is lower between the 1st element or 2nd element, divide both the numbers by that same number. This will result in one of your elements being 1 and the other element greater than 1. i.e. $C_{\frac{2.346}{2.346}}O_{\frac{4.489}{2.346}} \rightarrow C_1O_{1.913}$
5. The objective is to get your empirical formula which is whole numbers. You can round up or keep the number the same if your number is within 0.19 of a whole number (i.e. 1.81 would be rounded to 2 and something like 3.19 would be rounded down to 3. If they are greater than this, you will have to multiply both numbers by some factor 2, 3, 4, 5 to get close a whole number and then round. $C_1O_{1.913} \rightarrow C_1O_2$ (rounded).

Check Your Learning

What is the empirical formula of a compound if a sample contains 0.130 g of nitrogen and 0.370 g of oxygen?



Check Your Learning

What is the empirical formula of a compound containing 40.0% C, 6.71% H, and 53.28% O?

