Chemical compounds

Chemical compounds are a great real-world illustration of ratio and proportion. A chemical compound like water, H_2O, is made up of two hydrogen atoms and one oxygen atom, and in these kinds of chemical compound problems, we can figure out the proportion of the hydrogen compared to the entire compound, or the proportion of oxygen compared to the entire compound.

In other words, in this lesson we'll learn how to find the molar mass of a chemical compound given the molar masses of the elements (of the periodic table) that make up the compound, and how to find the molar mass of an individual element in a compound given the molar mass of the compound. We'll also learn how to find the weight of an element in a compound given the molar mass and weight of a compound.

The molar mass of a compound is the sum of products of the atomic weight of each element that make up the compound and the numbers of atoms of the corresponding element in one molecule of that compound.

Molar mass is measured in **grams per mole**, which is often abbreviated g/mol.

Let's look at a few examples.

Example

Find the molar mass of table sugar.

Table sugar has the molecular formula $C_{12}H_{22}O_{11}$.

Carbon has a molar mass of 12.01 g/mol.

Hydrogen has a molar mass of 1.01 g/mol.

Oxygen has a molar mass of 16.00 g/mol.

We can see that one molecule of table sugar $C_{12}H_{22}O_{11}$ has 12 carbon atoms, 22 hydrogen atoms, and 11 oxygen atoms, which means the ratio of atoms is $12:22:11$.

Multiply the numbers of atoms by the corresponding molar masses, and add them up.

carbon: $12(12.01) = 144.12$ g in 1 mole of table sugar

hydrogen: $22(1.01) = 22.22$ g in 1 mole of table sugar

oxygen: $11(16.00) = 176.00$ g in 1 mole of table sugar

Find the total.

$$144.12 + 22.22 + 176.00 = 342.34 \text{ g in } 1 \text{ mole of table sugar}$$

Therefore, the molar mass of table sugar is 342.34 g/mol.

Let's look at an example where we know the molar mass of a compound and we want the molar mass of an individual element in that compound.

Example

What is the mass of cadmium in one mole of cadmium carbonate?

Cadmium carbonate is made of cadmium, carbon, and oxygen; its molecular formula is $CdCO_3$

$CdCO_3$ has a molar mass of about 172.42 g/mol.

Carbon has a molar mass of 12.01 g/mol.

Oxygen has a molar mass of 16.00 g/mol.

We can see from the molecular formula that the ratio of atoms is $1:1:3$. We haven't been told the molar mass of cadmium, so we'll use the variable x for that unknown quantity.

Let's summarize the information we have about cadmium carbonate.

cadmium: $1x = x$ g in 1 mole of cadmium carbonate

carbon: $1(12.01) = 12.01$ g in 1 mole of cadmium carbonate

oxygen: $3(16.00) = 48.00$ g in 1 mole of cadmium carbonate

$CdCO_3$: 172.42 g/mol

Now let's set up an equation to solve for the molar mass of cadmium.

$$x + 12.01 + 48.00 = 172.42$$

$$x + 60.01 = 172.42$$

$$x = 112.41 \text{ g/mol}$$

In this case we know that the mass of cadmium in one mole of cadmium carbonate is 112.41 g, because there is only one cadmium atom in a molecule of cadmium carbonate.

Let's do another example.

Example

Imagine we have 250 g of sodium hydrocarbonate, $NaHCO_3$, and we want to know the combined mass of sodium and carbon in this compound.

Sodium hydrocarbonate is made of sodium, hydrogen, carbon, and oxygen; its molecular formula is $NaHCO_3$

$NaHCO_3$ has a molar mass of about 84.007 g/mol.

Sodium has a molar mass of 22.989769 g/mol.

Carbon has a molar mass of 12.01 g/mol.

First, calculate the combined molar mass of the sodium and carbon.

$$22.989769 + 12.01 = 34.999769 \text{ g/mol.}$$

Let's use x as a combined mass of sodium and carbon in sodium hydrocarbonate. We can now set up the proportion which consists of two ratios. The first is the ratio of the combined molar mass of sodium and carbon to the molar mass of the sodium hydrocarbonate, and the second is the ratio of the combined mass of sodium and carbon, x, to the mass of the sodium hydrocarbonate. Therefore, we have

$$\frac{34.999769}{84.007} = \frac{x}{250}$$

$$x = \frac{250(34.999769)}{84.007} \approx 104 \text{ g}$$

The combined mass of sodium and carbon in 250 g of sodium hydrocarbonate is approximately 104 g.