Chemistry Lecture #15: Law of Definite Proportions, Law of Multiple Proportions.

French Chemist Joseph Proust (1754-1826) was the first to observe the Law of Definite Proportions.

Law of Definite Proportions: Specific substances always contain elements in the same ratio by mass.

This means that if a compound is broken into its elements, the ratio of their masses will always be the same.

For example, suppose I break 100 g of water apart into hydrogen and oxygen. I'll end up with 11.11 g of hydrogen and 88.89 g of oxygen.

100 g water = 11.11 g hydrogen + 88.89 g oxygen
(reactant) (products)

If we divide the mass of the products by the smallest mass, we find that the ratio of hydrogen to oxygen is 1 to 8.

11.11/11.11 = 1 88.89/11.11 = 8

Thus, for every 1 g of hydrogen in this sample of water, there will be 8 g of oxygen.

Now suppose I take a different sample of water that has a mass of 254 g, and break it into hydrogen and oxygen. I'll end up with 28.22 g of hydrogen and 225.78 g of oxygen.

254 g water = 28.22 g hydrogen + 225.78 g oxygen.
(reactant) (products)

If we again divide the mass of products by the smallest mass, we find that the ratio of hydrogen to oxygen is 1 to 8.

28.22/28.22 = 1 225.78/28.22 = 8

So in all samples of water, the ratio by mass of hydrogen to oxygen will be 1 to 8.

The fact that specific compounds are made of elements in the same ratio by mass suggests that compounds are made of atoms.

Try this problem: when 120.00 g of salt is broken into sodium and chlorine, we obtain 47.33 g of sodium and 72.90 g of chlorine. Find the ratio by mass of sodium to chlorine.

120 g Salt = 47.33 g sodium + 72.90 g chlorine

47.33/47.33 = 1 72.90/47.33 = 1.54

Thus, for every 1 g of sodium, there will be 1.54 g of chlorine.

English chemist John Dalton (1766-1844) noticed that two elements could form more than one type of compound. He observed that there was a pattern of ratios in how the compounds were formed. This pattern of ratios is called the Law of Multiple Proportions.

Law of Multiple Proportions: The masses of one element that combine with a fixed amount of another element to form more than one compound are in the ratio of small whole numbers.

What the heck does that mean? To explain this, let's first look at two different compounds that are both made of carbon and oxygen: carbon dioxide and carbon monoxide.

Carbon monoxide gas is the pollution produced by cars. If you breath too much of it, you'll die. Carbon dioxide gas is produced by our bodies, and we get rid of it when we exhale.

Suppose we break apart a sample of 28 g of carbon monoxide. We'll end up with 12 g of carbon and 16 g of oxygen.

28 g carbon monoxide = 12 g carbon + 16 g oxygen

Now suppose we break apart a sample of 44 g of carbon dioxide. We'll end up with 12 g of carbon and 32 g of oxygen.

44 g carbon dioxide = 12 g of carbon + 32 g oxygen

I've rigged the problem so that the amount of carbon we obtain is the same for both compounds (12 g).

Let's compare the amount of oxygen in both samples. We have 16 g in one sample, and 32 g in another. 32 is 16 times 2. Or the ratio of oxygens is 16 to 32, or 1 to 2. 32 is a multiple of 16.

As long as the amount of carbon in both samples is the same, the amount of oxygen in carbon dioxide will always be twice as much as the amount of oxygen in carbon monoxide. "Twice" or two is a small whole number. Thus, in comparing compounds, oxygen combines with carbon in ratios of small whole numbers.

This pattern of combinations in small whole numbers suggested to Dalton that matter is made of atoms.

Try this problem: 128.64 g of iron (II) oxide decompose to form 100 grams of iron and 28.64 g of oxygen. 142.97 g of a different compound, iron (III) oxide decomposes to form 100 g of iron and 42.97 g of oxygen. What is the whole number ratio of oxygen between the two compounds?

128.64 g iron (II) oxide = 100 g iron + 28.64 g oxygen

142.97 g iron (III) oxide = 100 g iron + 42.97 g oxygen

28.64/28.64 = 1 42.97/28.64 = 1.5

The ratio of oxygens is 1 to 1.5. If we multiply both numbers by 2, we get a small, whole number ratio of 2 to 3.