## Section 3: Observation 1: Mass relationships during chemical reactions (In Progress)

The Law of Conservation of Mass, by itself alone, does not require an atomic view of the elements. Mass could be conserved even if matter were not atomic. The importance of the Law of Conservation of Mass is that it reveals that we can usefully measure the masses of the elements which are contained in a fixed mass of a compound. As an example, we can decompose copper carbonate into its constituent elements, copper, oxygen, and carbon, weighing each and taking the ratios of these masses. The result is that every sample of copper carbonate is 51.5% copper, 38.8% oxygen, and 9.7% carbon. Stated differently, the masses of copper, oxygen, and carbon are in the ratio of 5.3 : 4 : 1, for every measurement of every sample of copper carbonate. Similarly, lead sulfide is 86.7% lead and 13.3% sulfur, so that the mass ratio for lead to sulfur in lead sulfide is always 6.5 : 1. Every sample of copper carbonate and every sample of lead sulfide will produce these elemental proportions, regardless of how much material we decompose or where the material came from. These results are examples of a general principle known as the Law of Definite Proportions.

Law of Definite Proportions

When two or more elements combine to form a compound, their masses in that compound are in a fixed and definite ratio.

These data help justify an atomic view of matter. We can simply argue that, for example, lead sulfide is formed by taking one lead atom and combining it with one sulfur atom. If this were true, then we also must conclude that the ratio of the mass of a lead atom to that of a sulfur atom is the same as the 6.5 : 1 lead to sulfur mass ratio we found for the bulk lead sulfide. This atomic explanation looks like the definitive answer to the question of what it means to combine two elements to make a compound, and it should even permit prediction of what quantity of lead sulfide will be produced by a given amount of lead. For example, 6.5g of lead will produce exactly 7.5g of lead sulfide, 50g of lead will produce 57.7g of lead sulfide, etc.

There is a problem, however. We can illustrate with three compounds formed from hydrogen, oxygen, and nitrogen. The three mass proportion measurements are given in the following table. First we examine nitric oxide, to find that the mass proportion is 8 : 7 oxygen to nitrogen. If this is one nitrogen atom combined with one oxygen atom, we would expect that the mass of an oxygen atom is 8/7=1.14 times that of a nitrogen atom. Second we examine ammonia, which is a combination of nitrogen and hydrogen with the mass proportion of 7 : 1.5 nitrogen to hydrogen. If this is one nitrogen combined with one hydrogen, we would expect that a nitrogen atom mass is 4.67 times that of a hydrogen atom mass. These two expectations predict a relationship between the mass of an oxygen atom and the mass of a hydrogen atom. If the mass of an oxygen atom is 1.14 times the mass of a nitrogen atom and if the mass of a nitrogen atom is 4.67 times the mass of a hydrogen atom, then we must conclude that an oxygen atom has a mass which is $1.14 \times 4.67 = 5.34$ times that of a hydrogen atom.

But there is a problem with this calculation. The third line of the following table shows that the compound formed from hydrogen and oxygen is water, which is found to have mass proportion 8:1 oxygen to hydrogen. Our expectation should then be that an oxygen atom mass is 8.0 times a hydrogen atom mass. Thus the three measurements in the following table appear to lead to contradictory expectations of atomic mass ratios. How are we to reconcile these results?

**UNFINISHED, FIGURE OUT WAY TO INSERT TABLE HERE**

One possibility is that we were mistaken in assuming that there are atoms of the elements which combine to form the different compounds. If so, then we would not be surprised to see variations in relative masses of materials which combine.

Another possibility is that we have erred in our reasoning. Looking back, we see that we have to assume how many atoms of each type are contained in each compound to find the relative masses of the atoms. In each of the above examples, we assumed the ratio of atoms to be 1:1 in each compound. If there are atoms of the elements, then this assumption must be wrong, since it gives relative atomic masses which differ from compound to compound. How could we find the correct atomic ratios? It would help if we knew the ratio of the atomic masses: for example, if we knew that the oxygen to hydrogen mass ratio were 8:1, then we could conclude that the atomic ratio in water would be 1 oxygen and 1 hydrogen. Our reasoning seems to circular: to know the atomic masses, we must know the formula of the compound (the numbers of atoms of each type), but to know the formula we must know the masses.

Which of these possibilities is correct? Without further observations, we cannot say for certain whether matter is composed of atoms or not.

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