The Law of Multiple Proportions

The Law of Multiple Proportions states that "*When two elements form a series of compounds, the ratios of the masses of one element that combine with 1 gram of the other element can always be reduced to small whole numbers.*"

A Chem 11 student wishes to determine whether two compounds, copper (I) nitrite and copper (II) nitrate, obey the Law of Multiple Proportions. In addition to copper, each compound contains both nitrogen and oxygen. A 100.0 g sample of copper (I) nitrite is found to contain 58.00 g of copper and 12.78 g of nitrogen, whereas a 100.0 g sample of copper (II) nitrate is found to contain 33.88 g of copper and 14.94 g of nitrogen.

1. Show that the two compounds obey the Law of Multiple Proportions.

2. Based on the names of the compounds, write down their formulas.

3. What relationship, if any, is there between the ratios determined in #1 and the ratios of atoms in the compounds, based on the formulas found in #2?

Evaluating Avogadro's Hypothesis of Diatomic Elemental Gases

Amedeo Avogadro made two hypotheses that were essential for interpreting the experimental data that led to a determination of the relative atomic masses of the elements. The first hypothesis states that at constant temperature and pressure, equal volumes of two different gases contain equal numbers of particles. Here we will examine in detail the reasoning that led to the second hypothesis, which states that gaseous elements are diatomic: for example, hydrogen gas has the formula H_2 and oxygen gas has the formula O_2.

The following volume data was observed by Joseph Gay-Lussac:

2 volumes of hydrogen + 1 volume of oxygen $\rightarrow$ 2 volumes of water vapor (gas)

The following questions will lead you from Avogadro's first hypothesis and Dalton's atomic theory to Avogadro's second hypothesis. They will also lead you to the formulas of all of the substances involved in the reactions. You should *not* make any *a priori* assumptions about what the specific formulas of any of the substances might be, or about what the relative masses of the elements are – these are precisely the types of conclusions Avogadro was hoping to draw *after* having made his two hypotheses.

For the purposes of this exercise, we will use the following definitions:

Atom – the smallest amount of an element that retains the characteristics of that element (same as we have defined it in lecture)

Molecule – a bonded collection of two or more atoms of the same or different elements

Particle – a general term for either an atom or a molecule, whichever is the smallest independently moving unit of matter in the gas in question

1. For the given reaction, state what Avogadro's first hypothesis implies about the relative numbers of particles of hydrogen, nitrogen, and ammonia that are involved in the reaction.

2. Based on this reaction, provide a rationale for why oxygen must be thought of as the diatomic molecule, O_2. Hint: it may be helpful to consider the reaction on the smallest possible scale, using the minimum possible number of particles.

3. Based on this reaction, provide a rationale for why hydrogen must be thought of as the diatomic molecule, H_2.

4. Determine the formula of water, and explain your rationale.