

An Example of the Law of Multiple Proportions

Problem 2-14

Phosphorus forms two compounds with chlorine. In the first compound, 1.000 g of phosphorus is combined with 3.433 g of chlorine, and in the second, 2.500 g phosphorus is combined with 14.306 g chlorine. Show that these results are consistent with Dalton's law of multiple proportions.

Solution:

To demonstrate the law of multiple proportions, all that needs to be demonstrated is that the mass ratio of the phosphorus atoms and the chlorine atoms when comparing the two compounds are each a simple whole number ratio.

First things first: let's normalize the chlorine to phosphorus ratio in the two compounds to the same amount of phosphorus – 1 g.

Compound 1:

$$\frac{m_{\text{Cl}}}{m_{\text{P}}} = \frac{3.433 \text{ g Cl}}{1.000 \text{ g P}} = 3.433 \frac{\text{g Cl}}{\text{g P}}$$

Compound 2:

$$\frac{m_{\text{Cl}}}{m_{\text{P}}} = \frac{14.308 \text{ g Cl}}{2.500 \text{ g P}} = 5.7232 \frac{\text{g Cl}}{\text{g P}}$$

The ratio of phosphorus in the two compounds is 1:1. So, what is the ratio of the chlorines?

$$\frac{m_{\text{Cl}}^2}{m_{\text{Cl}}^1} = \frac{5.7232 \text{ g Cl}}{3.433 \text{ g P}} = 1.6671 \frac{\text{g Cl in compound 2}}{\text{g Cl in compound 1}}$$

But how does this demonstrate the law of multiple proportions? 1.6671 doesn't look much like a ratio of simple whole numbers. Or does it?

$$1.6671 \frac{\text{g Cl in compound 2}}{\text{g Cl in compound 1}} \text{ looks a little like } \frac{5}{3} = 1.667$$

Thus, the ratio of phosphorus atoms between the two compounds is 1:1 while the ratio of chlorine atoms is 5:3.