A Demonstration of the Law of Multiple Proportions

> The law of multiple proportions says that if more than one compound can be made from the same elements, the ratio of masses of one of the elements, at a fixed mass of the other, will be a ratio of simple whole numbers.

The following data were obtained for compounds of nitrogen and hydrogen for the mass of nitrogen given:

Compound	Mass of Nitrogen (g)	Mass of Hydrogen (g)
A	0.500	0.108
B	1.000	0.0720
C	0.750	0.108

a. Show that these data are consistent with the law of multiple proportions.

b. If the formula of compound B is N_2H_2, what are the formulas of compounds A and C?

Solution:

a. To demonstrate the law of multiple proportions, the mass of one of the elements must be normalized to a constant value. A good value for this is 1, so normalize, say, the mass of nitrogen in each case to 1. At the same time, recalculate the mass of hydrogen for the normalized mass of nitrogen

Compound	Mass of Nitrogen (g)	Mass of Nitrogen Normalized to 1	Mass of Hydrogen (g)	Mass of Hydrogen Normalized to Nitrogen
A	0.500	0.500/0.500	0.108	0.108/0.500
B	1.000	1.000/1.000	0.0720	0.0720/1.000
C	0.750	0.750/0.750	0.108	0.108/0.750

Compound	Mass of Nitrogen (g)	Mass of Hydrogen (g)
A	1.000	0.216
B	1.000	0.0720
C	1.000	0.144

Now show that the ratios of hydrogen are simple whole number ratios:

$$\frac{A}{B} = \frac{0.216}{0.0720}\left(= 3\right) = \frac{3}{1}$$

$$\frac{B}{C} = \frac{0.0720}{0.144}\left(= 0.5\right) = \frac{1}{2}$$

$$\frac{A}{C} = \frac{0.216}{0.144}\left(= 1.5\right) = \frac{3}{2}$$

It would work equally well normalizing the mass of hydrogen to 1.

b. The solution can be determined mathematically relatively easily. Alternatively, it can solved by inspection:

Compound B = N_2H_2

Compound C has twice as many hydrogens as compound B at the same amount of nitrogen.

Compound C = N_2H_4 (= empirical formula NH_2)

Compound A has 6 times as many hydrogens as compound B at the same amount of nitrogen.

Compound A = N_2H_6 = NH_3