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Pandemonium Pesticide: A Simple Demonstration Illustrating Some Fundamental Chemical Concepts

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Because many students perform chemical calculations by rote, we have used the following lecture demonstration to illustrate several fundamental chemical concepts in a striking, humorous, and concrete manner. Its visual "hands-on" impact is particularly suitable for students still working at the Piagetian concrete operational level, yet, with modification, it can be used with more advanced classes as a starting point for a discussion of ideas more abstract than those exemplified here, e.g., determination of the molecular masses used in the final problem or determination of the atomic masses used. The demonstration-activity leads students to understand that calculations are a logical consequence of Dalton's atomic theory and simply involve the relationships between *physical* units of mass (grams) and *chemical* units of number (atoms or molecules.)[1]

Pandemonium and Pesticine

An announcement is made in lecture of a recent discovery of two new elements which are unusual in that their atoms are very large, heavy, and readily visible to the naked eye. Atoms of the two elements—the metal pandemonium, Pn (hard rubber balls), and the nonmetal pesticine, Pe (tennis balls)—are exhibited and shown to have different properties (e.g., color, size, mass, and "bounceability"). At the same time, atoms of the same element are shown to be identical in these properties. (The balls of each particular element have been preselected for identical masses, or their masses have been made identical by adding or scraping material from the balls.)

Atomic Mass

Since atomic masses are the masses of each atom relative to the mass of a ${}^{12}_{6}C$ or C-12 atom taken as 12.000, the atomic masses of pandemonium (23.1 g) and pesticine (54.8 g) are determined directly in front of the class by weighing an atom of each on a balance.[2]

Molecular Mass

Since the molecular mass of a compound equals the sum of the atomic masses of its constituent atoms, each multiplied by the number of such atoms, it may be determined by weighing on the balance. For example, for dipandemonium tripesticide, Pn_2Pe_3:

$$2 \times \text{Pn} = 2 \text{ atoms} \times 23.1 \text{ g/atom} = 46.2 \text{ g}$$

$$3 \times \text{Pe} = 3 \text{ atoms} \times 54.8 \text{ g/atom} = \underline{164.4 \text{ g}}$$
$$\text{molecular mass} = 210.6 \text{ g}$$

Since the mass of the molecule is independent of how the atoms are arranged, it should be emphasized that the molecular mass is the same for ionic or covalent substances of the same formula as well as for isomers (substances with the same molecular formula but different arrangements of the atoms in the molecule).

Percentage Composition from Formula

If the pesticine atoms are first removed from the balance and the pandemonium atoms are weighed and if next the pandemonium atoms are removed and the pesticine atoms are replaced and weighed, the masses obtained are the masses of the pandemonium atoms and pesticine atoms, respectively, in a molecule of dipandemonium tripesticide, Pn_2Pe_3.

$$\text{wt. of Pn atoms} = 2 \text{ atoms} \times 23.1 \text{ g/atom} = 46.2 \text{ g}$$

$$\text{wt. of Pe atoms} = 3 \text{ atoms} \times 54.8 \text{ g/atom} = 164.4 \text{ g}$$

Since the entire molecule weighs 210.6 g, the percentages of pandemonium atoms and pesticine atoms can be obtained by dividing the above figures by the molecular weight and multiplying by 100%.

$$\%\text{Pn} = \frac{46.2 \text{ g}}{210.6 \text{ g}} \times 100\% = 21.9\%$$

$$\%\text{Pe} = \frac{164.4 \text{ g}}{210.6 \text{ g}} \times 100\% = \frac{78.1\%}{100.0\%}$$

Empirical Formula from Percentage Composition

The instructor surreptitiously places four pandemonium atoms and ten pesticine atoms in a bag or box, reports the percentage composition (Pn, 14.5%; Pe, 85.5%) to the class, and asks the students to calculate the formula of the compound in the bag or box. If the students encounter difficulty, he may ask them first to calculate the numbers of pandemonium atoms and pesticine atoms, assuming that we have 100 g of the compound.

$$\text{no. of Pn atoms} = \frac{14.5 \text{ g}}{23.1 \text{ g/atom}} = 0.628 \text{ atoms}$$

$$\text{no. of Pe atoms} = \frac{85.5 \text{ g}}{54.8 \text{ g/atom}} = 1.573 \text{ atoms}$$

The ratios are then calculated and the simplest whole number ratio determined.

$$\frac{\text{Pn atoms}}{\text{Pe atoms}} = \frac{0.628/0.628}{1.573/0.628} = \frac{1 \text{ atom}}{2.50 \text{ atoms}} = \frac{2 \text{ atoms}}{5 \text{ atoms}} \qquad \therefore Pn_2Pe_5$$

Molecular Formula

When the atoms are removed from the bag or box, the class is surprised to learn that the compound is tetrapandemonium decapesticide, Pn_4Pe_{10}, rather than dipandemonium pentapesticide, Pn_2Pe_5, as predicted. When the class is

[1] Kauffman, G. B., J. CHEM. EDUC., **53,** 470 (1976).

[2] The masses and numbers in this article are those obtained with the particular balls that we used. Different sized balls, of course, will yield different numbers.

asked how they would have been able to have predicted this correctly, they quickly realize that the molecular mass of the unknown substance is required. This is determined by weighing the bag or box empty and then with the constituent atoms.

$$4 \times \mathrm{Pn} = 4 \text{ atoms} \times 23.1 \text{ g/atom} = 92.4 \text{ g}$$

$$10 \times \mathrm{Pe} = 10 \text{ atoms} \times 54.8 \text{ g/atom} = \frac{548.0 \text{ g}}{640.4 \text{ g}}$$

$$= \text{molecular mass of unknown}$$

$$2 \times \mathrm{Pn} = 2 \text{ atoms} \times 23.1 \text{ g/atom} = 46.2 \text{ g}$$

$$5 \times \mathrm{Pe} = 5 \text{ atoms} \times 54.8 \text{ g/atom} = \frac{274.0 \text{ g}}{320.2 \text{ g}}$$

$$= \text{empirical mass of } \mathrm{Pn_2Pe_5}$$

$$\frac{\text{molecular mass}}{\text{empirical mass}} = \frac{640.4 \text{ g}}{320.2 \text{ g}} = 2 \qquad \therefore 2 \times \mathrm{Pn_2Pe_5} = \mathrm{Pn_4Pe_{10}}$$

Conclusion

We have found that this demonstration, which requires only 15 to 20 minutes of class time, gives a good introduction, review, and reinforcement of basic concepts and simple mathematical tools frequently employed in chemistry, especially the use of ratios in physical/chemical relationships. It requires immediate conclusions during class from the students, who react well to their active participation in the learning process. They also appreciate the humor involved and the change of pace provided by its concrete illustration of abstract concepts.