Determining Formula and Molar Masses

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CONCEPT 1

Determining Formula and Molar Masses

Lesson Objectives

The student will:

- calculate the formula mass of a compound given its name and a periodic table.

Vocabulary

- formula mass
- molecular mass

Introduction

When atoms of one element chemically combine with atoms of another element, a compound is formed. Compounds have names and formulas associated with them. The formula of a compound contains chemical symbols that tell us what elements are in the compound. The subscripts in the formula tell us the ratios of the elements present. For example, the formula $MgCl_2$ tells us that this compound is composed of the elements magnesium and chlorine, which combine in the ratio of two atoms of chlorine for each atom of magnesium. Using the formula of the compound and the relative masses of elements from the periodic table, we can then calculate the relative formula mass for the compound.

Formula Mass

The periodic table tells us the relative masses of all the elements. Looking at the squares for carbon and helium, we can see that a carbon atom has about three times the mass of a helium atom. In this way, we can compare the relative masses of any two atoms in the table. By looking at the chemical formulas and the relative atomic masses, we can also compare the masses of different compounds. The **formula mass** of a compound is the sum of all the atomic masses in the formula. The formula for water, for example, is H_2O. This formula tells us that water is composed of hydrogen and oxygen and has a ratio of two hydrogen atoms for each oxygen atom. We can determine the formula mass for water by adding up the atomic masses of its components.

Example:

What is the formula mass of H_2O?

Solution:

Element	Atomic Mass	Number of Atoms per Formula	Product
H	1.0 daltons	2	2.0 daltons
O	16.0 daltons	1	16.0 daltons
			18.0 daltons

The formula mass of $H_2O = 18.0$ daltons.

Example:

What is the formula mass of $Ca(NO_3)_2$?

Solution:

Element	Atomic Mass	Number of Atoms per Formula	Product
Ca	40.0 daltons	1	40.0 daltons
N	14.0 daltons	2	28.0 daltons
O	16.0 daltons	6	96.0 daltons
			164.0 daltons

The formula mass of $Ca(NO_3)_2 = 164.0$ daltons.

These formula masses are in the same units as atomic masses and therefore are exactly comparable. For example, the atomic mass of an oxygen atom is 16 daltons, the atomic mass of a fluorine atom is 19 daltons, and the formula mass of a water molecule is 18 daltons. This means that a water molecule is slightly more massive than an oxygen atom and slightly less massive than a fluorine atom.

Terminology

Since ionic compounds do not form individual molecules, the term formula mass is the only proper term to describe this relative mass. In comparison, the formula mass for covalent compounds may also be called the **molecular mass** because covalent compounds do form molecules. While it is important to understand this distinction, no professional chemists have had their degrees in chemistry recalled when they referred to the "molecular mass" of NaCl due to a slip of the tongue.

Lesson Summary

- The molecular mass of a molecule is found by adding the atomic masses of all the atoms in one molecule.
- Not all substances exist as molecules, so the term molecular mass is not used for all substances. The masses of ionic compounds and empirical formulas are called formula mass.

Review Questions

1. Calculate the formula mass for each of the following.
    a. K_2SO_4
    b. CuO
    c. $Mg_3(AsO_4)_2$
    d. $Ca_3(PO_4)_2$

e. Fe_2O_3
f. $Al(OH)_3$
g. $(NH_4)_2S$
h. $C_{12}H_{22}O_{11}$

2. On average, how many times heavier are bromine atoms than neon atoms?
3. An unknown element, M, combines with oxygen to form a compound with a formula of MO_2. If 25.0 grams of the unknown element combines with 4.50 grams of oxygen, what is the atomic mass of M?