SYMBOLS, FORMULAS AND MOLAR MASSES

OBJECTIVES

1. To correctly write and interpret chemical formulas
2. To calculate molecular weights from chemical formulas
3. To calculate moles from grams using chemical formulas

INTRODUCTION

Part I. Symbols and formulas

An element is a homogeneous pure substance made up of identical atoms. All matter is made up of elements and, since chemistry is the study of matter, it is convenient to use symbols to represent the elements rather than using the entire name.

By international agreement, specific symbols are assigned to each element (Note: This means that while names of the elements vary with language, symbols are constant throughout the world.) Each element is assigned a one- or two-letter symbol. The first letter is capitalized, the second (if there is one) is not. While this often seems trivial, it is in fact a very important point. For example, in chemical language Co represents cobalt, which is a metal and an element, while CO represents carbon monoxide, a compound which is a colorless, odorless gas! Even when there is not an obvious correspondence, for instance "MN", it can cause confusion. Do you mean the element manganese? Did you forget a letter and mean something else? Are you using "M" to represent something else entirely? Chemists sometimes use "M" to represent any metal. It is well worth the trouble to memorize the symbols for common elements.

Since compounds consist of elements, the chemical formulas of compounds also consist of elements with subscripts used to denote the number of atoms per molecule. If there is no subscript, it is implied that there is one of that kind of atom. Ones never appear in chemical formulas. Not only do subscripts denote ratios of atoms, they also denote the ratio of moles of element to one mole of compound. Parentheses can be used to show groups of atoms, with the subscripts showing how many groups there are. Parentheses are not used if there is only one group.

Examples: For one mole of the following compounds, how many moles of each element are present?

$MgCl_2$	1 mole Mg, 2 moles Cl
$Mg(NO_3)_2$	1 mole Mg, 2 moles N, 6 moles O
$NaNO_3$	1 mole Na, 1 mole N, 3 mole O
AgCl	1 mole Ag, 1 mole Cl

Part II. Molar Masses

Each atom has a different size and therefore a different mass. The relative masses of each element can be found on the periodic table. For example, one atom of magnesium weighs 24.31 amu (atomic mass units). However, one mole of magnesium weighs 24.31 g. (Moles were planned that way!) Since one mole of $MgCl_2$ consists of one mole of magnesium and two moles of chlorine, the mass of one mole of $MgCl_2$ must be the sum of the masses of the elements. The mass of one mole of a substance is called the molar mass or molecular weight.

Examples: What is the molar mass of the following compounds?

$MgCl_2$	24.31 + 2(35.45) = 95.21 g/mol
$Mg(NO_3)_2$	24.31 + 2(14.01) + 6(16.00) = 148.33 g/mol
$NaNO_3$	23.00 + 14.01 + 3(16.00) = 85.01 g/mol
AgCl	107.9 + 35.45 = 143.4 g/mol

(Note: Yes! You DO have to count significant figures when calculating molecular weight/molar mass. However, the number of significant figures may vary depending on which periodic table you use.)

Chemists are generally interested in number of moles. Unfortunately, it is impossible to measure moles directly. However, masses are easily measured, and if the chemical formula of the compound is known, the molar mass can be used to determine the number of moles. The molar mass is defined as:

molar mass = grams/moles = g/mol (1)

Moles may be calculated by using molar mass as a conversion factor in dimensional analysis where

molar mass in grams = 1 (exactly) mole of compound (2)

This method is used in multi-step calculations. For example, if 0.873 g of $MgCl_2$ is weighed out, it is 9.17×10^{-3} moles.

$$0.873\text{g} \times \frac{1 \text{ mole}}{95.21 \text{ g}} = 9.17 \times 10^{-3} \text{ mol } MgCl_2 \quad (3)$$

However, 0.873 g of AgCl is only 6.09×10^{-3} mol.

$$0.873\text{g} \times \frac{1 \text{ mole}}{143.4 \text{ g}} = 6.09 \times 10^{-3} \text{ mol AgCl} \quad (4)$$

Molar mass may also be used to relate moles to grams. For example, 0.158 mol of $MgCl_2$ is 15.2 g.

$$0.158 \text{ mol} \times \frac{95.21 \text{ g}}{1 \text{ mol}} = 15.2 \text{ g } MgCl_2 \qquad (5)$$

Percent is used to express parts per one hundred. Usually in chemistry, it refers to

$$\frac{\text{g of species of interest}}{\text{g of whole thing}} \times 100 = \% \qquad (6)$$

Example: For the % Mg in $MgCl_2$: In one mole of $MgCl_2$, there are 24.31 g of Mg (molar mass of Mg, the part we are interested in) and 95.21 g of $MgCl_2$ (the whole thing), so %Mg in $MgCl_2$ is

$$(24.31/95.21) \times 100 = 25.53\% \text{ Mg} \qquad (7)$$

PROCEDURE

Work individually.

The formula for calcium phosphate is $Ca_3(PO_4)_2$. Weigh about 2 g of calcium phosphate to the nearest 0.001 g. In other words, you do not have to have exactly 2.000g, but you must know the weight you have exactly. Acceptable results include but are not limited to: 1.985g , 2.035g, 2.314g etc.

Be sure to report all results with the correct number of significant figures and appropriate units!

SYMBOLS, FORMULAS, MOLAR MASSES NAME_____
LABORATORY REPORT DATE_____

Part I. Symbols and Formulas

In one mole of calcium phosphate, how many moles of each element are there?

_____mol Ca _____ mol P _____ mol O

Part II. Molar masses

SHOW ALL CALCULATIONS.

Mass of calcium phosphate sample
plus weighing paper _____

Mass of weighing paper _____

Mass of calcium phosphate sample _____

Molar mass of calcium phosphate _____

Number of moles of calcium phosphate
in your sample _____

Moles of phosphorus in your sample _____

Mass of phosphorus in your sample _____

Percent phosphorus in your sample _____

Percent of phosphorous in one mole
of calcium phosphate _____

Questions

Part I.

1. How many atoms of each element are present in one molecule of the compound?

   a. KNO_3

   b. $(NH_4)_2SO_4$

2. How many moles of each element are present in two moles of the compound?

   a. CH_3COOH

   b. $Al(NO_3)_3$

3. Write the appropriate chemical formulas for compounds with the following ratios of elements.

   a. 1 mole calcium: 1 mole carbon: 3 moles oxygen

   b. 1 molecule iron: 3 molecules chlorine

   c. 1 mole copper: 1 mole sulfur: 4 moles oxygen

Part II.

4. What is the molar mass of each of the following compounds? Show all work.

   a. $Ru(NH_3)_6Cl_3$

   b. WO_2

   c. PbI_2

5. What is the percent of the element which is underlined for each of the following compounds? Show all work.

a. $NaO\underline{H}$

b. $\underline{Al}(NO_3)_3$

6. Calculate the number of moles in the following samples. Show all work.

a. 0.869 g of WO_2

b. 2.200 g of PbI_2

7. Calculate the number of grams in the following samples. Show all work.

a. 0.20 mol of WO_2

b. 0.067 mol of $Ru(NH_3)_6Cl_3$

8. How is the %P in your sample of calcium phosphate related to the %P in one mole of calcium phosphate? Would you expect that relationship to always be true? Why or why not?