Percent Composition

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CONCEPT 1

Percent Composition

Lesson Objectives

The student will:

- calculate the percent composition by mass given the masses of elements in a compound.
- calculate the percent composition by mass given the formula or name of a compound.

Vocabulary

- percent composition

Introduction

Metals useful to man are typically extracted from ore. The ore is removed from the mine and partially purified by washing away dirt and other materials not chemically bound to the metal of interest. This partially purified ore is then treated chemically in smelters or other purifying processes to separate pure metal from the other elements. The value of the original ore is very dependent on how much pure metal can eventually be separated from it. High-grade ore and low-grade ore command significantly different prices. The ore can be evaluated before it is mined or smelted to determine what percent of the ore can eventually become pure metal. This process involves determining what percentage of the ore is metal compounds and what percentage of the metal compounds is pure metal.

Percent Composition from Masses

Compounds are made up of two or more elements. The law of definite proportions tells us that the proportion, by mass, of elements in a compound is always the same. Water, for example, is always 11% hydrogen and 89% oxygen by mass. The **percentage composition** of a compound is the percentage by mass of each element in the compound.

Percentage composition can be determined experimentally. To do this, a known quantity of a compound is decomposed in the laboratory. The mass of each element is measured and then divided by the total mass of the original compound. This tells us what fraction of the compound is made up of that element. The fraction can then be multiplied by 100% to convert it into a percent.

Example:

Laboratory procedures show that 50.0 grams of ammonia, NH_3, yields 41.0 grams of nitrogen and 9.00 grams of hydrogen upon decomposition. What is the percent composition of ammonia?

Solution:

$$\% \text{ nitrogen} = \left(\frac{41.0 \text{ grams}}{50.0 \text{ grams}}\right) \cdot (100\%) = 82\%$$

$$\%\ \text{hydrogen} = \left(\frac{9.00\ \text{grams}}{50.0\ \text{grams}}\right) \cdot (100\%) = 18\%$$

Example:

The decomposition of 25.0 grams of $Ca(OH)_2$ in the lab produces 13.5 grams of calcium, 10.8 grams of oxygen, and 0.68 grams of hydrogen. What is the percent composition of calcium hydroxide?

Solution:

$$\%\ \text{calcium} = \left(\frac{13.5\ \text{grams}}{25.0\ \text{grams}}\right) \cdot (100\%) = 54.0\%$$
$$\%\ \text{oxygen} = \left(\frac{10.8\ \text{grams}}{25.0\ \text{grams}}\right) \cdot (100\%) = 43.2\%$$
$$\%\ \text{hydrogen} = \left(\frac{0.68\ \text{grams}}{25.0\ \text{grams}}\right) \cdot (100\%) = 2.8\%$$

You should note that the sum of the percentages always adds to 100%. Sometimes, the sum may total to 99% or 101% due to rounding, but if it totals to 96% or 103%, you have made an error.

Percent Composition from the Formula

Percent composition can also be calculated from the formula of a compound. Consider the formula for the compound iron(III) oxide, Fe_2O_3. The percent composition of the elements in this compound can be calculated by dividing the total atomic mass of the atoms of each element in the formula by the formula mass.

Example:

What is the percent composition of iron(III) oxide, Fe_2O_3?

Solution:

Element	Atomic Mass	Number of Atoms per Formula	Product
Fe	55.8 daltons	2	111.6 daltons
O	16.0 daltons	3	48.0 daltons
		Formula mass =	159.6 daltons

$$\%\ \text{iron} = \left(\frac{111.6\ \text{daltons}}{159.6\ \text{daltons}}\right) \cdot (100\%) = 69.9\%$$
$$\%\ \text{oxygen} = \left(\frac{48.0\ \text{daltons}}{159.6\ \text{daltons}}\right) \cdot (100\%) = 30.1\%$$

Example:

What is the percent composition of aluminum sulfate, $Al_2(SO_4)_3$?

Solution:

The formula mass of $Al_2(SO_4)_3$ is: $2 \cdot (27.0\ \text{daltons}) + 3 \cdot (32.0\ \text{daltons}) + 12 \cdot (16.0\ \text{daltons}) = 342.0\ \text{daltons}$

$$\%\ \text{aluminum} = \left(\frac{54.0\ \text{daltons}}{342\ \text{daltons}}\right) \cdot (100\%) = 15.8\%$$
$$\%\ \text{sulfur} = \left(\frac{96.0\ \text{daltons}}{342\ \text{daltons}}\right) \cdot (100\%) = 28.1\%$$
$$\%\ \text{oxygen} = \left(\frac{192\ \text{daltons}}{342\ \text{daltons}}\right) \cdot (100\%) = 56.1\%$$

Lesson Summary

- The percent composition of a compound is the percent of the total mass contributed by each element in the compound.
- Percent composition can be determined either from the masses of each element in the compound or from the formula of the compound.

Further Reading / Supplemental Links

This website has solved example problems for a number of topics covered in this lesson, including the calculation of percent composition by mass.

- http://www.sciencejoywagon.com/chemzone/05chemical-reactions/

The website below reviews how to calculate percent composition.

- http://www.ausetute.com.au/percentc.html

Review Questions

Determine the percent composition of the following compounds.

1. BF_3
2. $Ca(C_2H_3O_2)_2$
3. FeF_3
4. $CrCl_3$
5. $(NH_4)_3PO_4$