Percent composition

(mass percent, percent composition by mass)

$$\text{Mass \%} = \frac{\text{mass of component in substance (grams)}}{\text{mass of substance (grams)}} \times 100$$

What is the mass % composition of 10 g water?

MM (H_2O) = 18.0152 g/mol

MM (H) = 1.0079 g/mol

MM (O) = 15.9994 g/mol

%H in water = 11.21% H

%O in water = 88.79% O

If you have 18.015 g of water, what is the mass % composition of water?

Does mass % composition of a substance depend on the amount of substance you have? Why?

We went from chemical formula (H_2O) to percent composition.

We can also go from percent composition to the chemical formula.

You have 100 grams of a compound, and you find out it has a mass % composition of:
75.7% C
8.8% H
15.5% O.

How many moles of C, H, and O do you have?

Mass % composition of:
75.7% C, 8.8% H, and 15.5% O.

yields these molar ratios …
mol C : mol H : mol O,

which is the same as saying …
atoms C : atoms H : atoms O.

Atoms do not combine as fractions or pieces (0.30, 0.7, 0.969), so we must scale up to reach whole atoms (whole numbers).

Divide by the smallest number to reach 1 for at least one element:

= atom O => mol O

= atoms C => mol C

= atoms H => mol H

mol C : mol H : mol O

Still not whole atoms (6.5 C)! Multiply by 2!
(mol C :   mol H :   mol O) x 2

mol C :   mol H :   mol O
(now a ratio of whole atoms, not fractions)

$C_xH_yO_z$

<u>Empirical formula</u>: a chemical formula with the smallest whole-number ratio of atoms (or moles of atoms), shows the smallest whole-number ratio of atoms in a molecule of the compound.

<u>Molecular formula</u>: a chemical formula with the *actual* whole-number ratio of atoms (or moles), shows the actual number of atoms in a molecule of the compound, not always the smallest ratio.

<u>Example</u>: The molecular formula for hydrogen peroxide (H_2O_2) is x2 the empirical formula (HO).

Practice:

Nicotine has a percent composition of 74.0% C, 8.65% H, and 17.35% N and has a molar mass of 162 g/mol. Determine the (a) empirical and (b) molecular formulas of nicotine.

Conservation of Matter

Example:

$H_2 + Cl_2 \rightarrow HCl$

The starting atoms must equal the final atoms!

A balanced chemical equation is similar to a recipe:

= ratio of ingredients to products (ratio of inputs to outputs).

= can have leftover ingredients (inputs).

Bread example:

2 cups water + 2/3 cup sugar + 1 1/2 tablespoons yeast + 1 1/2 teaspoons salt + 1/4 cup butter + 6 cups bread flour → 2 loaves of bread.

Car example:

4 tires + 1 engine + 2 side mirrors + lots of other parts → 1 car.

Practice:

$H_2 + N_2 \rightarrow NH_3$

Practice:

Titanium (Ti) combines with oxygen (O_2) to form titanium (IV) oxide. Write the balanced equation for this process.

Balancing chemical equations

1. Takes practice to get an intuitive feel for the quickest approach.
2. The quickest approach can vary depending on the specifics of each equation.
3. General guideline: Leave the more complicated formulas (lots of elements, lots of atoms) “as is”, and increase the amount of less complicated formulas to get closer to matching the more complicated formulas. The less complicated formulas are used to try to “fill in” the gaps.

<u>Example</u>:

P_4O_{10} + H_2O $\rightarrow$ H_3PO_4

P_4O_{10} and H_3PO_4 are most complicated formulas (multiple elements, lots of atoms).

Notice that H_3PO_4 has only 1 P atom but P_4O_{10} has 4 P atoms
=> so multiply H_3PO_4 by 4.

Now use H_2O to fill in missing H and O.
=> so multiply H_2O by 6.

Practice:

$Ca(OH)_2 \ + \ H_3PO_4 \ \rightarrow \ H_2O \ + \ Ca_3(PO_4)_2$

(hint: what is the most complicated formula?)

Problem-solving example

Reaction of iodine (I_2) and chlorine (Cl_2) produces I_XCl_Y. Reaction of 0.678 g of iodine with excess chlorine produces 1.246 g of I_XCl_Y. What is the empirical formula of I_XCl_Y?

1. What exactly are you asked to find? (unknown)

2. Search what you are given. (your knowns)

3. Think about how you can connect your knowns to your unknown, in light of what you are studying.

4. Find or obtain additional information to make the connection.

5. Often it helps to draw a picture or diagram.
   Often it helps to write a chemical equation.

6. Work through your solution.

7. Consider if your answer is reasonable.