Formula Mass and Percent Composition

How do you calculate percent composition?

●○○ Beginner | Reactions & Stoichiometry | Last reviewed 3 October 2026

Before you start: it helps to understand The Mole Concept.

What is it?

Percent composition tells you what percentage of a compound's **mass** comes from each element.

To work it out, you first need the **formula mass**: the sum of the atomic masses of all the atoms in the formula, in atomic mass units (u).

> **KEY IDEA**
>
> Percent composition is about **mass**, not about the number of atoms. A light element can make up most of the atoms in a compound but only a small part of its mass.

Why does it matter?

- **Identifying substances.** Chemists analyse an unknown compound to find the mass of each element it contains. Comparing those percentages with calculated values helps identify the compound, and it is the first step in working out an empirical formula.
- **Checking purity.** If a sample's measured composition doesn't match the expected percentages, it may be impure.
- **Everyday labels.** Products such as fertilisers state their contents as percentages by mass.

How does it work?

1. Find the formula mass

Add the atomic masses of every atom in the formula, using the subscripts to count atoms. For water, $\mathrm{H_2O}$:

$$2(1.008\ \mathrm{u}) + 16.00\ \mathrm{u} = 18.016\ \mathrm{u}$$

A subscript after **parentheses** multiplies everything inside them. Calcium hydroxide, $\mathrm{Ca(OH)_2}$, contains one Ca, two O and two H:

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$$40.08\ \text{u} + 2(16.00\ \text{u} + 1.008\ \text{u})$$
$$= 74.10\ \text{u}$$

For molecules this is also called the **molecular mass**. Ionic compounds like NaCl have no molecules, so we say **formula mass** (the mass of one *formula unit*).

2. Work out each element's share

$$\%\ \text{element} = \frac{n \times A}{\text{formula mass}} \times 100\%$$

where n is the number of atoms of that element in the formula and A is its atomic mass.

The percentages of all the elements in a compound add up to 100% (apart from tiny rounding differences).

3. It doesn't matter how much you have

A pure compound always has the same composition by mass. Every sample of pure water is 11.19% hydrogen by mass, whether it is a drop or a lake. So you can calculate percent composition from the formula alone, using one formula unit or one mole.

THINK OF IT LIKE THIS

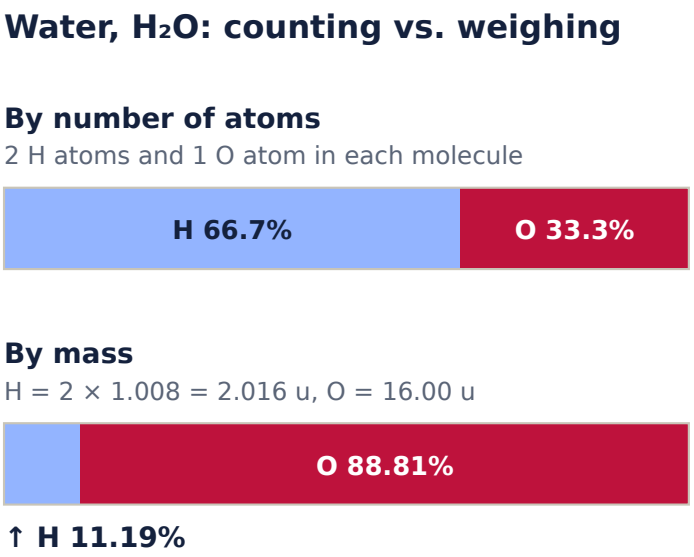
A bag of mixed nuts might contain more peanuts than almonds, but if the almonds are much larger they could still make up most of the bag's *mass*. Percent composition works the same way: it weighs each element's share, it doesn't count atoms.

MORE PRECISELY

The atomic masses on the periodic table are weighted averages of the masses of each element's naturally occurring isotopes. For some elements, IUPAC reports the standard atomic weight as a small range because isotope proportions vary slightly between natural sources. Textbook values such as H = 1.008 are conventional rounded values. They are accurate enough for these calculations.

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Visualise it



In water, two out of three atoms are hydrogen, but hydrogen is only about 11% of the mass.

Worked example

WORKED EXAMPLE: Percent composition of glucose

Question: Calculate the percent composition by mass of glucose, $C_6H_{12}O_6$. (C = 12.01 u, H = 1.008 u, O = 16.00 u)

Step 1 Mass of each element in one formula unit: C: 6 × 12.01 u = 72.06 u; H: 12 × 1.008 u = 12.096 u; O: 6 × 16.00 u = 96.00 u

Step 2 Formula mass: 72.06 u + 12.096 u + 96.00 u = 180.156 u

Step 3
$$\%\ \mathrm{C} = \frac{72.06\ \mathrm{u}}{180.156\ \mathrm{u}} \times 100\% = 40.00\%$$

Step 4
$$\%\ \mathrm{H} = \frac{12.096\ \mathrm{u}}{180.156\ \mathrm{u}} \times 100\% = 6.71\%$$

Step 5
$$\%\ \mathrm{O} = \frac{96.00\ \mathrm{u}}{180.156\ \mathrm{u}} \times 100\% = 53.29\%$$

The units of u cancel in each fraction, leaving a percentage.

Answer: glucose is **40.00% C, 6.71% H and 53.29% O** by mass. Check: 40.00% + 6.71% + 53.29% = 100.00%.

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WORKED EXAMPLE: Mass of an element in a sample

Question: What mass of iron is contained in 50.0 g of iron(III) oxide, $\mathrm{Fe_2O_3}$? (Fe = 55.85 u, O = 16.00 u)

Step 1 Formula mass: 2(55.85 u) + 3(16.00 u) = 111.70 u + 48.00 u = 159.70 u

Step 2 Fraction of the mass that is iron: $\frac{111.70\ \text{u}}{159.70\ \text{u}} = 0.6994$ (that is, 69.94% Fe; the units of u cancel)

Step 3 Mass of iron: $0.6994 \times 50.0\ \text{g} = 35.0\ \text{g}$

Answer: 50.0 g of $\mathrm{Fe_2O_3}$ contains **35.0 g of iron**.

Common mistake

COMMON MISTAKE: Ignoring subscripts and parentheses

In $\mathrm{Fe_2O_3}$ there are **two** iron atoms, so iron contributes 2 × 55.85 u = 111.70 u, not 55.85 u. Leaving out the 2 gives half the correct mass of iron (17.5 g instead of 35.0 g in the example above).

In $\mathrm{Ca(OH)_2}$, the 2 applies to both O and H: the formula mass is 74.10 u, not 58.10 u.

COMMON MISTAKE: Counting atoms instead of weighing them

Two-thirds of the atoms in water are hydrogen, but hydrogen is **not** 66.7% of water. Percent composition is by mass: hydrogen is 11.19% of water's mass.

COMMON MISTAKE: Rounding too early

If you round water's formula mass to 18.02 u before dividing, you get 11.19% H and 88.79% O, which add up to only 99.98%. Keep extra digits (18.016 u) until the final step to get 11.19% and 88.81%.

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NOTATION NOTE

Different textbooks use different names for the same quantity:

- **Formula weight** and **molecular weight** are traditional names; **formula mass** and **molecular mass** are more common in newer texts. All are given in u (also written amu or Da).
- Some courses use **relative formula mass**, M_r. It has the same number but no units, because it is measured relative to $\frac{1}{12}$ of the mass of a carbon-12 atom.
- Percent composition is sometimes called **mass percent** or **percentage by mass**.

Remember this

REMEMBER THIS

- **Formula mass = sum of the atomic masses of all atoms in the formula (watch subscripts and parentheses).**
- **% element = (atoms of element × atomic mass) ÷ formula mass × 100%.**
- **Percent composition is by mass, and it is the same for any sample of a pure compound.**
- **Keep extra digits until the end; the percentages should add to 100%.**

References

1. Brown, T. L.; LeMay, H. E., Jr.; Bursten, B. E.; Murphy, C. J.; Woodward, P. M.; Stoltzfus, M. W. Chemistry: The Central Science, 15th ed.; Pearson, 2022.

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