The Mole Concept

What is a mole in chemistry?

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

What is it?

A **mole** is a counting unit for particles. One mole of anything contains **6.022×10^{23}** of those things. The particles can be atoms, molecules, ions or formula units.

The number 6.022×10^{23} is called **Avogadro's number**. The symbol for "one mole" is **mol**.

> **KEY IDEA**
>
> A mole is a *number* of particles: 1 mol = 6.022×10^{23} particles. Chemists use it because atoms are far too small and numerous to count one by one.

Why does it matter?

Atoms and molecules are extremely small. A single drop of water (about 0.05 g) contains roughly 1.7×10^{21} water molecules. Nobody can count particles like that, but we *can* weigh substances on a balance.

The mole is the bridge between the two worlds:

- **The particle world**, where reactions happen one atom or molecule at a time.
- **The laboratory world**, where we measure grams.

Balanced chemical equations are written in particles, and therefore in moles. For example,

$$2\,H_2 + O_2 \longrightarrow 2\,H_2O$$

means 2 molecules of hydrogen react with 1 molecule of oxygen. It equally means **2 mol of H_2 react with 1 mol of O_2** to form 2 mol of H_2O. The mole lets you turn that ratio into masses you can actually weigh out. This is the basis of all stoichiometry.

How does it work?

1. The mole is a counting number

Just as "a dozen" always means 12, "a mole" always means 6.022×10^{23}. A mole of carbon atoms, a mole of water molecules and a mole of sodium ions all contain the same number of particles.

© 2026 Chemistry Clarity · chemistryclarity.com · Free for personal and classroom use. Not for resale.

THINK OF IT LIKE THIS

A dozen eggs and a dozen watermelons contain the same *number* of items, but they have very different *masses*. In the same way, one mole of carbon atoms (12.01 g) and one mole of gold atoms (196.97 g) contain exactly the same number of atoms. Gold atoms are simply heavier.

2. Molar mass links moles to grams

The **molar mass** (symbol M) is the mass of one mole of a substance, in grams per mole (g/mol).

Conveniently, the molar mass in g/mol has the **same number** as the atomic mass or formula mass in atomic mass units (u):

Substance	Mass of one particle	Molar mass
Carbon atom, C	12.01 u	12.01 g/mol
Water molecule, $\mathrm{H_2O}$	2(1.008 u) + 16.00 u = 18.02 u	18.02 g/mol
Sodium chloride, NaCl	22.99 u + 35.45 u = 58.44 u	58.44 g/mol

To find a molar mass, add up the atomic masses of all the atoms in the formula, taking account of the subscripts.

3. Two conversions do almost everything

Between mass and moles:

$$n = \frac{m}{M}$$

where n is the amount in moles, m is the mass in grams, and M is the molar mass in g/mol.

Between moles and number of particles:

$$N = n \times N_\mathrm{A}$$

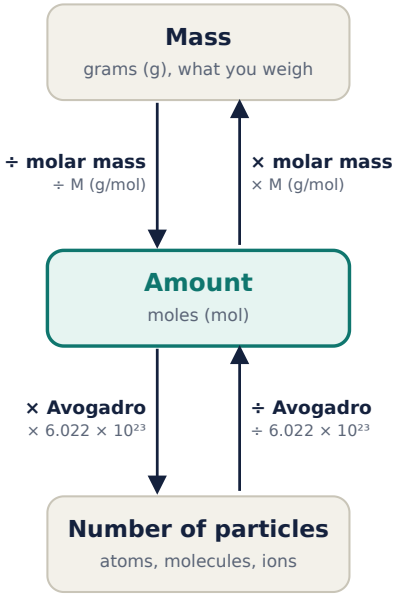
where N is the number of particles and $N_\mathrm{A} = 6.022 \times 10^{23}\ \mathrm{mol^{-1}}$ is the Avogadro constant.

MORE PRECISELY

Since 20 May 2019, the mole has been defined by fixing the Avogadro constant at **exactly** 6.022 140 76 × 10^{23} $\mathrm{mol^{-1}}$. Before that, one mole was defined as the number of atoms in exactly 12 g of carbon-12. Under today's definition, one mole of carbon-12 has a mass extremely close to 12 g, but not exactly 12 g. For school and introductory university calculations, 6.022 × 10^{23} is precise enough.

© 2026 Chemistry Clarity · chemistryclarity.com · Free for personal and classroom use. Not for resale.

Visualise it



The mole map: moles sit in the middle. Every conversion goes through moles.

Worked example

WORKED EXAMPLE: From grams to moles to molecules

Question: How many moles of water, and how many water molecules, are in 36.0 g of water? (H = 1.008 g/mol, O = 16.00 g/mol)

Step 1 Find the molar mass of $\mathrm{H_2O}$: $M = 2(1.008\ \mathrm{g/mol}) + 16.00\ \mathrm{g/mol} = 18.02\ \mathrm{g/mol}$

Step 2 Convert mass to moles: $n = \dfrac{36.0\ \mathrm{g}}{18.02\ \mathrm{g/mol}} = 2.00\ \mathrm{mol}$

Step 3 Convert moles to molecules: $N = 2.00\ \mathrm{mol} \times 6.022 \times 10^{23}\ \mathrm{mol^{-1}} = 1.20 \times 10^{24}$ molecules.

Answer: 36.0 g of water is **2.00 mol**, which is **1.20×10^{24} molecules**.

Check the units: g ÷ (g/mol) leaves mol, and mol × $\mathrm{mol^{-1}}$ leaves a pure number of molecules.

© 2026 Chemistry Clarity · chemistryclarity.com · Free for personal and classroom use. Not for resale.

WORKED EXAMPLE: From moles to grams

Question: What is the mass of 0.250 mol of sodium chloride, NaCl? (Na = 22.99 g/mol, Cl = 35.45 g/mol)

Step 1 Find the molar mass: $M = 22.99\ \mathrm{g/mol} + 35.45\ \mathrm{g/mol} = 58.44\ \mathrm{g/mol}$

Step 2 Rearrange $n = \dfrac{m}{M}$ to give $m = n \times M$.

Step 3 Substitute: $m = 0.250\ \mathrm{mol} \times 58.44\ \mathrm{g/mol} = 14.6\ \mathrm{g}$

Answer: 0.250 mol of sodium chloride has a mass of **14.6 g**.

Common mistake

COMMON MISTAKE: Mixing up atoms and molecules

One mole of oxygen *gas*, $\mathrm{O_2}$, contains 6.022×10^{23} **molecules** but twice as many **atoms** (1.204×10^{24}), because each molecule has two oxygen atoms. Its molar mass is 2 × 16.00 g/mol = **32.00 g/mol**, not 16.00 g/mol.

Always ask: *a mole of what?* Atoms, molecules or ions? Write the formula and count the atoms in it.

COMMON MISTAKE: Multiplying when you should divide

Students often multiply mass by molar mass to get moles. Let the units guide you: to cancel grams, you must *divide* by g/mol. If your answer's units don't come out as mol, the setup is upside down.

NOTATION NOTE

Textbooks use slightly different names and symbols for the same ideas:

- **Amount of substance** (n) is the quantity measured in moles. "Number of moles" means the same thing.
- **Atomic mass unit**: many textbooks write **amu**. The symbol accepted in the SI is **u** (also called the dalton, Da).
- **Formula weight** and **molecular weight** are older textbook names for the mass of one formula unit or molecule in u. Many textbooks now say formula *mass* and molecular *mass* instead.
- The **Avogadro constant**, $N_\mathrm{A} = 6.022 \times 10^{23}\ \mathrm{mol^{-1}}$, has units. **Avogadro's number** is the same value written as a plain number.

© 2026 Chemistry Clarity · chemistryclarity.com · Free for personal and classroom use. Not for resale.

Remember this

REMEMBER THIS

- 1 mol = 6.022×10^{23} particles.
- Molar mass (g/mol) has the same number as the atomic or formula mass (u).
- moles = mass ÷ molar mass, and particles = moles × 6.022×10^{23}.
- Always ask: a mole of *what*?

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.
2. Bureau International des Poids et Mesures (BIPM). The International System of Units (SI), 9th ed.; BIPM, 2019. Link

---

Practise this topic with flashcards and a quiz at chemistryclarity.com/chemistry/mole-concept/

© 2026 Chemistry Clarity · chemistryclarity.com · Free for personal and classroom use. Not for resale.