

Counting atoms with the mole

Chemistry grades 9-10 (GCSE · IGCSE · O Level · Class 9-10) · Lesson

Quick answer: The mole is the chemist's counting unit: one mole contains 6.02×10^{23} particles, the Avogadro constant. The mass of one mole, the molar mass M in g/mol, equals the relative formula mass. Use $n = m \div M$ to convert between mass and moles, and $N = n \times 6.02 \times 10^{23}$ for particle numbers.

Level: Chemistry grades 9-10 (GCSE · IGCSE · O Level · Class 9-10) · **Curriculum:** HS-PS1-7, GCSE C3

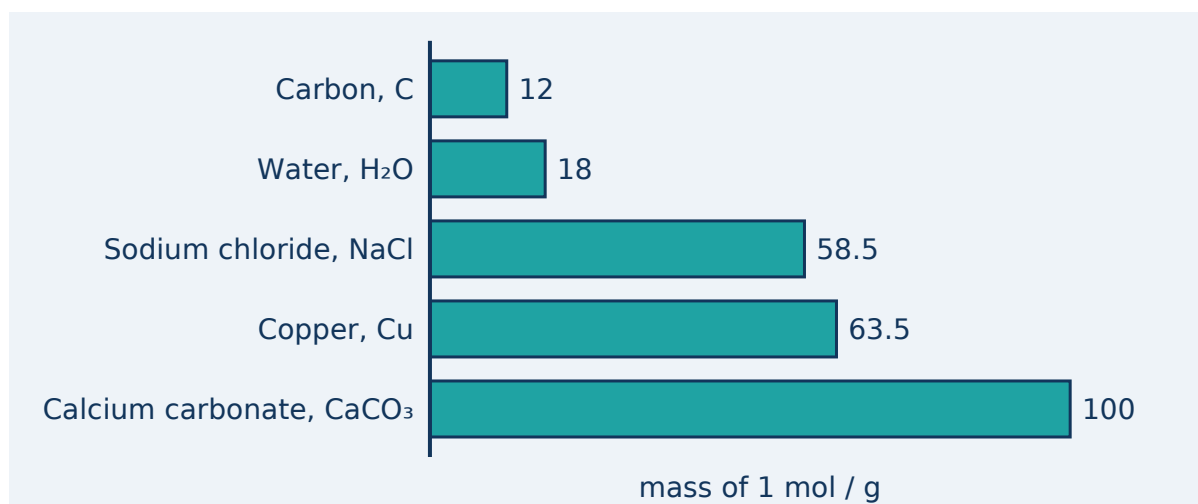
What is a mole?

Atoms and molecules are far too small to count one by one, so chemists count them in huge, fixed groups called moles. A dozen means 12 of something; a mole means 6.02×10^{23} of something.

Definition

One **mole** of a substance contains 6.02×10^{23} particles (atoms, molecules or ions). The number 6.02×10^{23} per mole is the **Avogadro constant**. The symbol for amount of substance is n and the unit is mol.

One mole of carbon atoms has a mass of 12 g, and one mole of water molecules has a mass of 18 g. The mass of one mole is called the *molar mass*, M , in g/mol. It equals the relative atomic mass or relative formula mass in grams.



One mole of each substance contains the same number of particles but has a different mass.

Why use moles at all? A balanced equation compares numbers of particles, but a balance measures mass. Moles let you move from the grams on the balance to the particle ratio in the equation and back again.

How do you find relative formula mass?

Add the relative atomic masses (A_r) of all the atoms in the formula. Multiply by the number outside brackets. Use these values: H 1, C 12, N 14, O 16, Na 23, Mg 24, Al 27, S 32, Cl 35.5, Ca 40, Fe 56, Cu 63.5.

Worked example

Calculate the relative formula mass of calcium hydroxide, $\text{Ca}(\text{OH})_2$.

$$M_r = 40 + 2 \times (16 + 1) = 40 + 34 = 74.$$

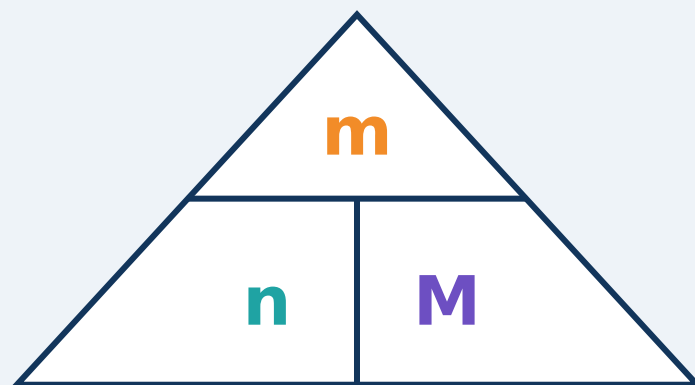
Answer: $M_r = 74$, so $M = 74 \text{ g/mol}$.

How do you convert between mass and moles?

Formula

$$n = m \div M$$

n = amount of substance in mol, m = mass in g, M = molar mass in g/mol.



cover the quantity you want: $n = m \div M$, $m = n \times M$, $M = m \div n$

The formula triangle for amount, mass and molar mass.

Worked example

How many moles are in 5.85 g of sodium chloride, NaCl ?

$$M = 23 + 35.5 = 58.5 \text{ g/mol. } n = 5.85 \div 58.5 = 0.100.$$

Answer: 0.100 mol.

Worked example

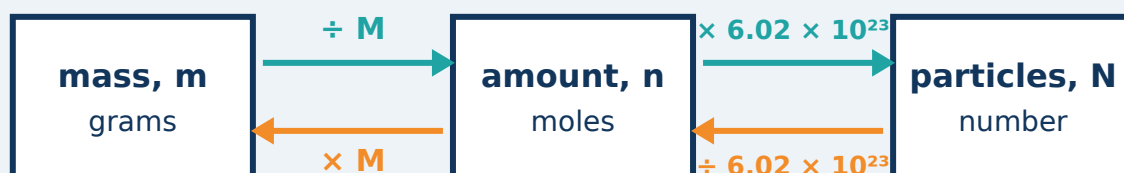
Calculate the mass of 0.25 mol of calcium carbonate, CaCO_3 .

$$M = 40 + 12 + 3 \times 16 = 100 \text{ g/mol. } m = n \times M = 0.25 \times 100 = 25.$$

Answer: 25 g.

How do you count particles?

Multiply the amount in moles by the Avogadro constant to find the number of particles: $N = n \times 6.02 \times 10^{23}$. Divide by the constant to go back from particles to moles.



Moles are the bridge between mass and number of particles.

Moles link mass and number of particles.

Quantity	Symbol	Unit
Amount of substance	n	mol
Mass	m	g
Molar mass	M	g/mol
Number of particles	N	none (a count)

Worked example

How many molecules are in 9.0 g of water?

$$n = 9.0 \div 18 = 0.50 \text{ mol. } N = 0.50 \times 6.02 \times 10^{23} = 3.01 \times 10^{23}.$$

Answer: 3.0×10^{23} molecules.

Particle numbers are huge, so write them in standard form and keep the same number of significant figures as the data in the question, usually two or three.

Common mistake

Use the molar mass of the whole particle, not of one atom. Hydrogen gas is H_2 , so $M = 2 \text{ g/mol}$, not 1 g/mol . Likewise oxygen gas O_2 has $M = 32 \text{ g/mol}$.

Lina's tip

Write the units in your calculation. Grams divided by grams per mole gives moles. If the units do not give the quantity you want, you have turned the formula upside down.

Key points to remember

- $1 \text{ mol} = 6.02 \times 10^{23}$ particles (Avogadro constant).
- Molar mass M (g/mol) has the same number as the relative formula mass M_r .
- $n = m \div M$, so $m = n \times M$ (n in mol, m in g, M in g/mol).

- Number of particles $N = n \times 6.02 \times 10^{23}$.
- Use the whole particle: $M(\text{H}_2) = 2 \text{ g/mol}$, $M(\text{O}_2) = 32 \text{ g/mol}$.

Counting atoms with the mole: frequently asked questions

What is the Avogadro constant?

The Avogadro constant is the number of particles in one mole, 6.02×10^{23} per mole. It applies to atoms, molecules, ions or any other particles.

How do you calculate the number of moles from mass?

Divide the mass in grams by the molar mass in g/mol: $n = m \div M$. For example, 36 g of water is $36 \div 18 = 2.0 \text{ mol}$.

What is the difference between relative formula mass and molar mass?

Relative formula mass has no unit and is found by adding relative atomic masses. Molar mass has the same value but with the unit g/mol, and it is the mass of one mole.

Why do equal moles of different substances have different masses?

A mole always contains the same number of particles, but the particles have different masses. One mole of carbon is 12 g, whereas one mole of copper is 63.5 g.

How do you find the number of atoms in a molecule sample?

First find the number of molecules by multiplying moles by 6.02×10^{23} . Then multiply by the number of atoms in one molecule, for example 3 for water.