

Inside the atom: particles and isotopes

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

Quick answer: An atom has a tiny nucleus of protons and neutrons, with electrons in shells around it. The atomic number is the number of protons, and the mass number is protons plus neutrons. Isotopes are atoms of one element with different numbers of neutrons, and relative atomic mass is their weighted average.

Level: Chemistry grades 9-10 (GCSE · IGCSE · O Level · Class 9-10) · **Curriculum:** HS-PS1-1, GCSE C1

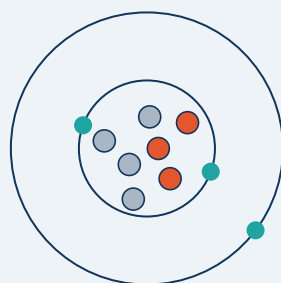
What is inside an atom?

Every atom has a tiny, dense **nucleus** at its centre. The nucleus is built from protons and neutrons. Electrons move around it in shells. Nearly all the mass of an atom sits in the nucleus, but nearly all its volume is empty space where the electrons are found.

Definition

An **atom** is the smallest particle of an element that still has the chemical properties of that element. A neutral atom has the same number of protons as electrons.

Particle	Relative charge	Relative mass	Where it is found
Proton	+1	1	Nucleus
Neutron	0	1	Nucleus
Electron	-1	about 1/1840	Shells around the nucleus



- proton (+1)
- neutron (0)
- electron (-1)

nucleus: tiny and dense
shells: mostly empty space

Lithium-7: 3 protons and 4 neutrons in the nucleus, 3 electrons in shells (2 then 1).

How do atomic number and mass number describe an atom?

Two whole numbers identify any atom. The **atomic number** tells you which element it is, because every atom of an element has the same number of protons. The **mass number** counts all the particles in the nucleus.

Formula

$$A = Z + N, \text{ so } N = A - Z$$

A = mass number, Z = atomic number (number of protons), N = number of neutrons. In a neutral atom the number of electrons equals Z.



Reading the notation: the top number is A, the bottom number is Z.

Worked example 1

Sodium-23 has $Z = 11$ and $A = 23$. Protons = 11. Neutrons = $23 - 11 = 12$. Electrons = 11 because the atom is neutral. Answer: **11 protons, 12 neutrons, 11 electrons**.

Worked example 2

A magnesium ion Mg^{2+} is made from magnesium-24 ($Z = 12$). Protons = 12. Neutrons = $24 - 12 = 12$. The atom lost 2 electrons, so electrons = $12 - 2 = 10$. Answer: **12 protons, 12 neutrons, 10 electrons**.

Common mistake

The mass number is not the relative atomic mass. Mass number is always a whole number counting particles. Relative atomic mass is an average and is often a decimal such as 35.5.

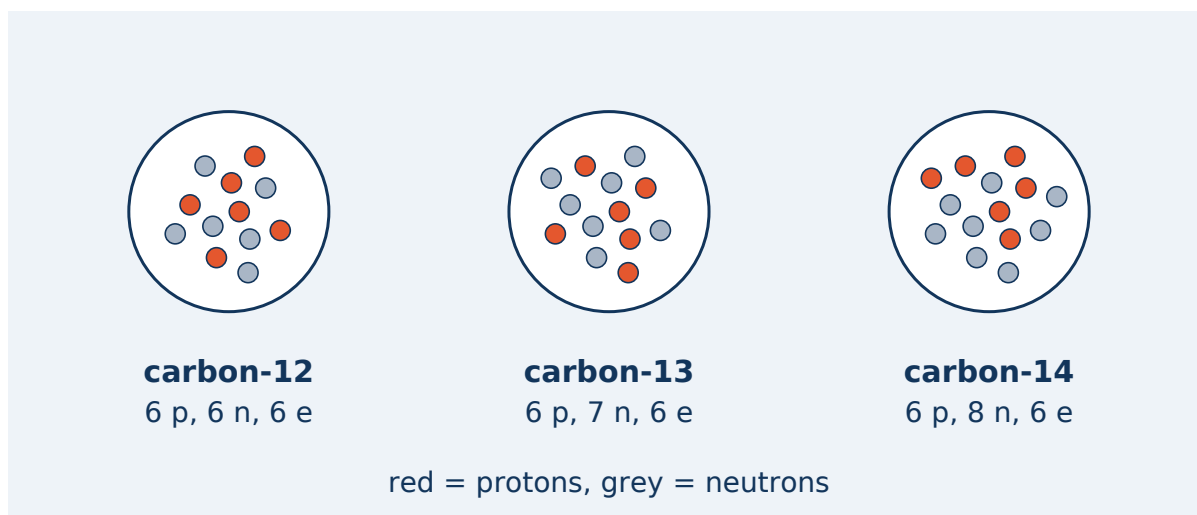
What are isotopes?

Definition

Isotopes are atoms of the same element with the same number of protons but different numbers of neutrons, so they have different mass numbers.

Hydrogen shows the idea well. All three isotopes have one proton and one electron, so they react in the same way. Only the neutron count differs.

Isotope	Protons	Neutrons	Mass number
Hydrogen-1	1	0	1
Hydrogen-2	1	1	2
Hydrogen-3	1	2	3



Carbon isotopes: the proton number stays 6, only the neutron number changes.

Isotopes have the same chemical properties because chemical reactions depend on electrons, and the electron number is the same. Their physical properties, such as density and mass, are slightly different. Carbon-14 is also radioactive, while carbon-12 and carbon-13 are stable.

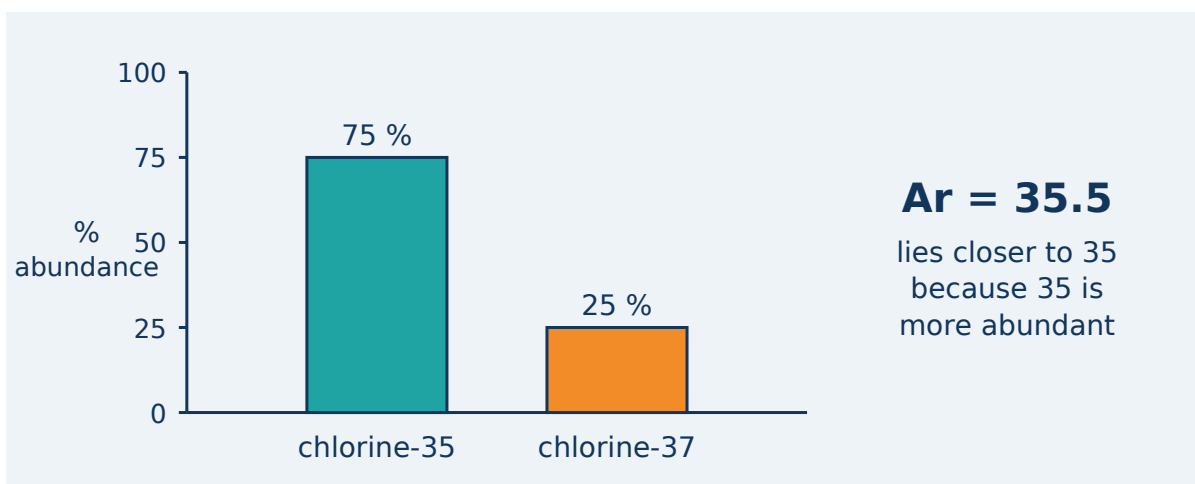
How do you calculate relative atomic mass?

A sample of an element is a mixture of its isotopes. The **relative atomic mass** (A_r) is the weighted average mass of the atoms in that mixture, compared with one twelfth of a carbon-12 atom.

Formula

$$A_r = \Sigma (\text{mass number} \times \text{percentage abundance}) \div 100$$

Add up (mass number $\times$ abundance) for every isotope, then divide by 100. A_r has no unit.



Natural abundance of the two chlorine isotopes.

Ar = 35.5

lies closer to 35
because 35 is
more abundant

Worked example 3

Chlorine is 75 % chlorine-35 and 25 % chlorine-37. $Ar = (35 \times 75 + 37 \times 25) \div 100 = (2625 + 925) \div 100 = 3550 \div 100$. Answer: **Ar = 35.5**.

Worked example 4

Magnesium is 79 % magnesium-24, 10 % magnesium-25 and 11 % magnesium-26. $Ar = (24 \times 79 + 25 \times 10 + 26 \times 11) \div 100 = (1896 + 250 + 286) \div 100 = 2432 \div 100$. Answer: **Ar = 24.3** (3 s.f.).

Lina's tip

Estimate before you calculate. Ar must lie between the lightest and the heaviest isotope, and nearer to the more abundant one. If your answer falls outside that range, you have made a slip.

Key points to remember

- Proton: charge +1, relative mass 1; neutron: charge 0, relative mass 1; electron: charge -1, mass about 1/1840.
- Atomic number Z = number of protons; mass number A = protons + neutrons; neutrons = $A - Z$.
- A neutral atom has electrons = protons; an ion has gained or lost electrons.
- Isotopes have the same Z but different A , so they react the same way but differ in mass.
- $Ar = \Sigma (\text{mass number} \times \% \text{ abundance}) \div 100$; it is usually not a whole number.

Inside the atom: particles and isotopes: frequently asked questions

What is the difference between atomic number and mass number?

The atomic number is the number of protons and identifies the element. The mass number is

the total of protons and neutrons in the nucleus. Subtract the atomic number from the mass number to find the neutrons.

Why do isotopes have the same chemical properties?

Chemical reactions involve the electrons, especially the outer ones. Isotopes of an element have the same number of protons and so the same number of electrons. Extra neutrons change the mass but not the electron arrangement.

Why is relative atomic mass not a whole number?

Most elements are a mixture of isotopes with different mass numbers. Ar is the average of these, weighted by how common each isotope is. That weighted mean is usually a decimal, such as 35.5 for chlorine.

How do you find the number of electrons in an ion?

Start with the atomic number, which is the electron count of the neutral atom. Subtract one electron for each positive charge, or add one for each negative charge. Mg^{2+} has $12 - 2 = 10$ electrons.

Are all isotopes radioactive?

No. Many isotopes are stable, such as carbon-12 and carbon-13. Only some, such as carbon-14, have unstable nuclei that decay. Radioactivity depends on the balance of neutrons and protons, not on having isotopes at all.