The nuclear atom

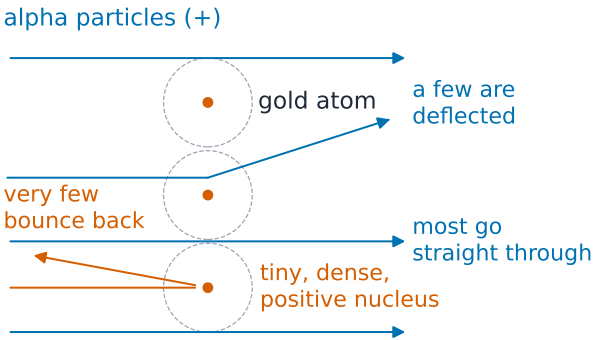
Structure 1.2 · SL and AHL

What did Rutherford see?

> Distinguish an observation from the model used to explain it.

- Geiger–Marsden scattering supplied evidence for Rutherford's nuclear model.
- A small fraction undergo large deflections; the fraction depends on conditions.
- This unit: nuclear particles $\rightarrow$ symbols $\rightarrow$ isotopes $\rightarrow$ weighted means.

The gold-foil experiment

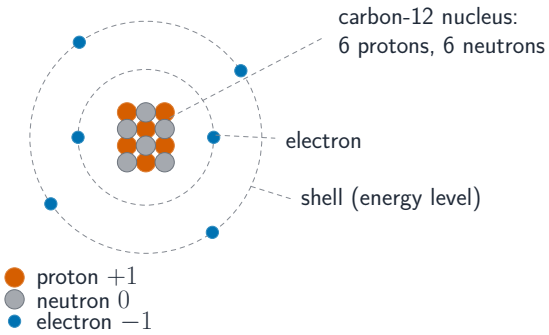


The **nucleus** is much smaller than the atomic **electron** region.

Protons, neutrons and electrons

Particle	Relative mass	Relative charge
proton	1	$+1$
neutron	1	0
electron	$1/1836$	-1

Count a neutral carbon-12 model



Equal **proton** and **electron** counts give zero overall charge.

Nuclear symbols

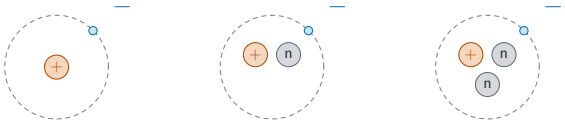
1. $^{23}_{11}\mathbf{Na}$**.** 11 protons, 12 neutrons, 11 electrons
2. $^{23}_{11}\mathbf{Na}^{+}$**.** 11 protons, 12 neutrons, 10 electrons
3. $^{32}_{16}\mathbf{S}^{2-}$**.** 16 protons, 16 neutrons, 18 electrons

Decision

An **ion** changes only its electrons.

Isotopes

Hydrogen isotopes (not to scale)



hydrogen-1	hydrogen-2	hydrogen-3
$^{1}_{1}\mathrm{H}$	$^{2}_{1}\mathrm{H}$	$^{3}_{1}\mathrm{H}$
1 proton	1 proton	1 proton
0 neutrons	1 neutron	2 neutrons
1 electron	1 electron	1 electron

Similar bonding behaviour does not make every measured property identical.

Relative atomic mass

- Weighted mean relative to one-twelfth of a carbon-12 atom's mass; no unit.
- Use supplied approximate chlorine masses and abundances.

$$A_r = \frac{35 \times 75.8 + 37 \times 24.2}{100} = 35.5$$

Unrounded mean 35.484; no individual atom needs fractional nucleons.

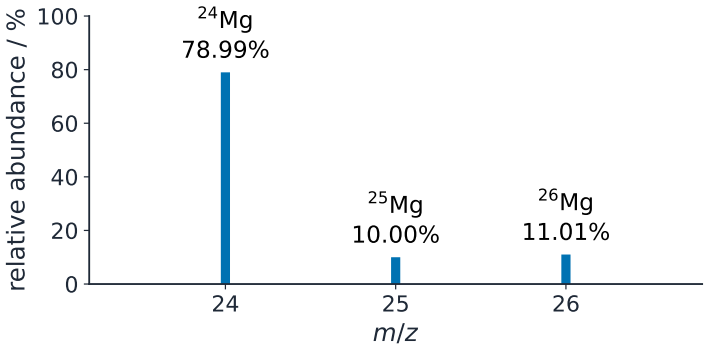
Check: copper isotopes

Your turn

What percentage of copper is ^{63}Cu (using whole-number masses)?

A. 27.5%
B. 50.0%
C. 63.5%
D. 72.5%

AHL: Mass spectrum of magnesium



Whole-number isotope masses give mean 24.3202, reported 24.32.

AHL: Heights that are not percentages

- Divide by the sum of the heights, not by 100.
- Lines at 10 (height 23) and 11 (height 100).

$$A_r = \frac{10 \times 23 + 11 \times 100}{23 + 100} = 10.8$$

Assigned elemental peaks give 10.813008… before rounding.

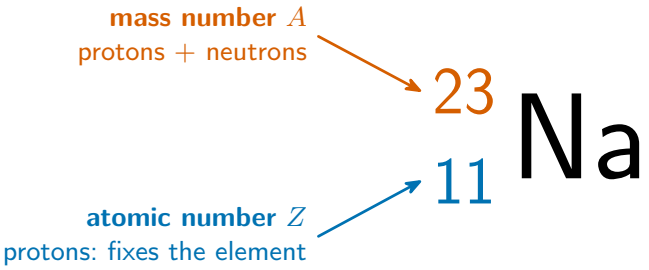
Charge, isotope and element

1. **Data.** 17 protons, 20 neutrons, 18 electrons
2. **Nucleus.** Z $=$17, A $=$37: chlorine-37
3. **Charge.** $17-18=-1$: chloride **ion**

Decision

Losing one **electron** gives neutral chlorine-37; the **nucleus** stays unchanged.

Reading a nuclear symbol



Mass number minus **atomic number** gives the neutrons

A three-isotope weighted mean

1. **Inputs.** 20 at 90.5%; 21 at 0.3%; 22 at 9.2%
2. **Mean.** $20\times0.905 + 21\times0.003 + 22\times0.092 = 20.187$
3. **Report.** 20.19 to two decimal places; no unit

Decision

The small middle-isotope contribution is included.

Recover an isotope abundance

1. **Model.** $64\mathrm{f} + 66(1-\mathrm{f}) = 64.60$
2. **Solve.** $\mathrm{f} = 0.700$, hence 70.0% lighter and 30.0% heavier
3. **Check.** $64 \times 0.70 + 66 \times 0.30 = 64.60$

Decision

The mean lies nearer the more abundant isotope.

AHL: Mass is not always m/z

1. **Single.** Relative mass 24, charge $+1$: m/z $\approx$24
2. **Double.** Relative mass 24, charge $+2$: m/z $\approx$12

Decision

Check charge before converting a peak position into an isotope mass.

Exam tips

> Check that A_r lies nearer the more abundant isotope.

- Z identifies the element; A counts nucleons in one nuclide.
- An **ion** changes electrons; an isotope changes neutrons.
- Use stated mass precision and the sum of **abundance** weights.

Check yourself

Try these

Give the particles in $^{40}_{20}Ca^{2+}$ and $^{19}_{9}F^{-}$.

Calculate A_r of neon from 90.5% ^{20}Ne, 0.3% ^{21}Ne, 9.2% ^{22}Ne.

Find the abundances of ^{69}Ga and ^{71}Ga when $A_r = 69.8$.

AHL. Explain the lines at m/z 70, 72 and 74 for Cl_2.