Size and mass of atoms

4.1.1.5 · Atomic structure and the periodic table · revision notes

How big atoms and nuclei are, where the mass of an atom is, mass number and isotopes, and how to work out the numbers of protons, neutrons and electrons in an atom or ion. Particle-counting questions and standard form calculations come up on almost every paper.

Key facts

- Radius of an atom ≈ 0.1 nm = 1×10^{-10} m
- 1 nm = 1×10^{-9} m
- Almost all the mass of an atom is in the nucleus
- Neutrons = mass number − atomic number
- Ions: a positive ion has fewer electrons than protons (Al^{3+}: 3 fewer); a negative ion has more (O^{2-}: 2 more)
- Radius of nucleus < 1/10 000 of the atom's radius (≈ 1×10^{-14} m)
- Relative mass: proton 1, neutron 1, electron very small
- Mass number = protons + neutrons
- Isotopes: same number of protons, different numbers of neutrons

Notes

How small atoms are

- Atoms are very small: the radius of an atom is about **0.1 nm** (1×10^{-10} m). 1 nm = 1×10^{-9} m.
- The radius of the nucleus is **less than 1/10 000** of the radius of the atom (about 1×10^{-14} m).
- To picture the scale: if an atom were as wide as a 100 m sports field, its nucleus would be less than 1 cm across.

Where the mass is

- Relative masses: proton **1**, neutron **1**, electron **very small**.
- Protons and neutrons are both in the nucleus, so **almost all the mass** of an atom is in the nucleus.
- The **mass number** is the total number of protons and neutrons in an atom.
- An atom can be written as $^{23}_{11}\mathrm{Na}$: the top number (23) is the mass number and the bottom number (11) is the atomic number.

mass number = protons + neutrons

$^{23}_{11}\mathrm{Na}$ neutrons = 23 − 11 = 12

atomic number = number of protons

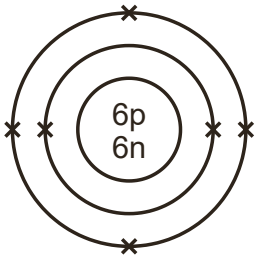
Top number: mass number. Bottom number: atomic number.

Counting the particles

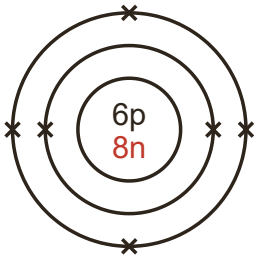
- Protons = atomic number.
- Neutrons = mass number − atomic number. For $^{23}_{11}\mathrm{Na}$: 23 − 11 = 12 neutrons.
- Electrons in an atom = number of protons.
- In an ion, the protons and neutrons are unchanged. A 2+ ion has 2 fewer electrons than protons; a 1− ion has 1 more. For example, Mg^{2+} (atomic number 12) has 12 protons and 10 electrons.

Isotopes

- **Isotopes** are atoms of the same element with different numbers of neutrons.
- Isotopes have the same atomic number but different mass numbers, e.g. $^{35}_{17}\mathrm{Cl}$ has 18 neutrons and $^{37}_{17}\mathrm{Cl}$ has 20 neutrons.



carbon-12
6 protons, 6 neutrons



carbon-14
6 protons, 8 neutrons

Isotopes: same number of protons, different numbers of neutrons.

- Isotopes of an element have the same number of electrons, so they react in the same way.

How to answer each type of question

Work out the numbers of protons, neutrons and electrons

3 to 4 marks | Grade 5

1. Protons = atomic number (the bottom number).
2. Neutrons = mass number − atomic number.
3. Electrons = protons for an atom; adjust for the charge if it is an ion.

Example. An atom of aluminium is represented as $^{27}_{13}\mathrm{Al}$.
(a) Give the numbers of protons, neutrons and electrons in this atom.
(b) Aluminium forms the ion Al^{3+}. Give the number of electrons in this ion.

Model answer.

(a) protons 13 (1); neutrons 27 − 13 = 14 (1); electrons 13 (1)
(b) 13 − 3 = 10 (1)

Explain why two atoms are isotopes

2 marks | Grade 5

1. Say they have the same number of protons (same atomic number), so they are the same element.
2. Say they have different numbers of neutrons, and give the numbers if you can.

Example. Two atoms are represented as $^{12}_{6}\mathrm{C}$ and $^{14}_{6}\mathrm{C}$.
Explain why these atoms are isotopes of the same element.

Model answer. Both atoms have 6 protons / the same atomic number, so they are the same element (1). They have different numbers of neutrons: 6 and 8 (1).

Calculate with sizes in standard form

2 marks | Grade 7

1. Write down the division: bigger ÷ smaller.
2. Use the $\times 10^{x}$ button on your calculator, or divide the numbers and subtract the powers of 10.
3. Give the answer as an ordinary number or in standard form, as asked.

Example. The radius of a gold atom is 1.4×10^{-10} m. The radius of its nucleus is 7.0×10^{-15} m.
Calculate how many times larger the radius of the atom is than the radius of the nucleus.

Model answer.

$1.4 \times 10^{-10} \div 7.0 \times 10^{-15}$ (1)
$= 20\,000$ (or 2×10^{4}) times (1)

Explain where the mass of an atom is 2 marks **Grade 5**

1. Say protons and neutrons are in the nucleus and each has a relative mass of 1.
2. Say electrons have a very small mass.

Example. Explain why almost all of the mass of an atom is in its nucleus.

Model answer. Protons and neutrons are in the nucleus, and each has a relative mass of 1 (1). The electrons are outside the nucleus and have a very small mass (1).

Don't lose marks

- Adding the two numbers instead of subtracting to find the number of neutrons.
- Changing the number of protons for an ion. Only the number of electrons changes.
- Saying isotopes have different numbers of protons or electrons.
- Writing 1×10^{10} m for the radius of an atom: the power must be negative, 1×10^{-10} m.
- Using a relative atomic mass from the periodic table (e.g. 35.5 for chlorine) as a mass number. Mass numbers are always whole numbers.

More tips

Memory tricks

- In a nuclear symbol the mass number is on top and is never smaller than the atomic number underneath.
- Neutrons = 'top minus bottom'.
- Dividing powers of 10: subtract the powers. $10^{-10} \div 10^{-14} = 10^{4}$.
- Positive ion = electrons lost, so fewer electrons; negative ion = electrons gained, so more.

Exam technique

- Show the subtraction for neutrons (e.g. 27 − 13 = 14) so the examiner can follow your working.
- In standard form, write $a \times 10^{n}$ with a between 1 and 10, unless the question asks for an ordinary number.
- When defining isotopes, include all three ideas: same element, same number of protons, different number of neutrons.

What each grade needs

What you need to be able to do, from the first marks up to the top grade.

Grade 3 **Recall relative masses of subatomic particles**
Proton 1, neutron 1, electron very small.

Grade 4 **Define mass number**
The total number of protons and neutrons in an atom.

Grade 4 **Find protons, neutrons and electrons in atoms**
Protons = electrons = atomic number; neutrons = mass number − atomic number.

Grade 5 **Define isotopes**

Atoms of the same element with different numbers of neutrons: same atomic number, different mass number.

Grade 5

Recall the sizes of atoms and nuclei

Atom radius about 0.1 nm (1×10^{-10} m); nucleus radius less than 1/10 000 of that (about 1×10^{-14} m).

Grade 5

Compare sizes using standard form

Divide one size by the other, e.g. $1 \times 10^{-10} \div 1 \times 10^{-14} = 10\,000$, and relate the scale to everyday objects.

Grade 6

Find protons, neutrons and electrons in ions

Protons and neutrons as in the atom; one electron fewer for each + charge, one more for each − charge.

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