Mass number, atomic number and isotopes

4.4.1.2 · Atomic structure · revision notes

How to use the atomic number and mass number to find the numbers of protons, neutrons and electrons, what isotopes are, and how atoms become positive ions. Expect questions using nuclide notation such as $^{23}_{11}\mathrm{Na}$, tables of particle numbers and the definition of an isotope.

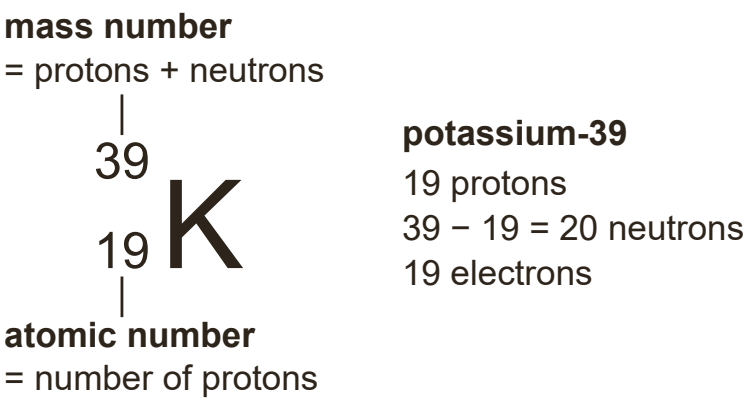
Key facts

- Atomic number = number of protons
- Mass number = number of protons + number of neutrons
- Neutrons = mass number − atomic number
- Neutral atom: number of electrons = number of protons
- $^{A}_{Z}\mathrm{X}$: A = mass number (top), Z = atomic number (bottom)
- Isotopes: same number of protons, different number of neutrons
- Atom loses outer electron(s) → positive ion

Notes

Atomic number and mass number

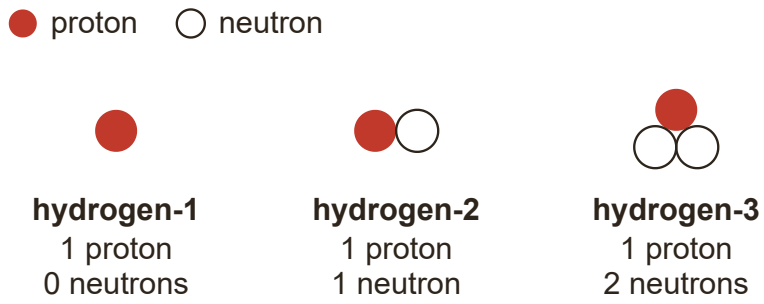
- The **atomic number** is the number of protons in the nucleus. All atoms of the same element have the same number of protons.
- The **mass number** is the total number of protons and neutrons in the nucleus.
- Number of neutrons = mass number − atomic number.
- Atoms have no overall charge, because the number of electrons equals the number of protons.
- In nuclide notation the mass number is at the top left and the atomic number at the bottom left. $^{39}_{19}\mathrm{K}$ has 19 protons, 39 − 19 = 20 neutrons and 19 electrons.



Mass number on top, atomic number underneath. Neutrons = mass number − atomic number.

Isotopes

- **Isotopes** of an element are atoms with the **same number of protons** but a **different number of neutrons**.
- So isotopes have the same atomic number but different mass numbers. $^{12}_{6}\mathrm{C}$ has 6 neutrons and $^{14}_{6}\mathrm{C}$ has 8 neutrons.



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

- An isotope is often named by its mass number, e.g. carbon-14 or uranium-235.
- Some isotopes have unstable nuclei, so they are radioactive (carbon-14 is one).

Ions

- If an atom loses one or more outer electrons, it has more protons than electrons, so it becomes a **positive ion**.
- Losing electrons does not change the nucleus, so the atomic number and mass number stay the same. It is still the same element.
- Nuclear radiation can knock electrons out of atoms, turning them into ions. This is called **ionisation**.

How to answer each type of question

Work out the numbers of particles

1 to 3 marks | **Grade 5**

1. Protons = the bottom number (atomic number).
2. Neutrons = top number − bottom number.
3. Electrons = protons for a neutral atom; subtract any electrons lost for a positive ion.

Example. An atom of iron is represented as $^{56}_{26}\mathrm{Fe}$.
Give the number of (a) protons, (b) neutrons and (c) electrons in this atom.

Model answer.

(a) 26 (1)
(b) 56 − 26 = 30 (1)
(c) 26 (1)

Define and identify isotopes

2 to 3 marks **Grade 4**

1. Find the atoms with the same number of protons.
2. Check that they have different numbers of neutrons.
3. Give both parts of the definition as your reason.

Example. The table gives the particles in the nuclei of three atoms.

Atom	Number of protons	Number of neutrons
A	17	18
B	18	17
C	17	20

(a) Which two atoms are isotopes of the same element? Give a reason. (2 marks)
(b) Give the mass number of atom C. (1 mark)

Model answer.

(a) A and C (1). They have the same number of protons but different numbers of neutrons (1).
(b) 17 + 20 = 37 (1)

Explain how an atom becomes an ion

2 to 3 marks **Grade 4**

1. Say that the atom loses (one or more outer) electrons.
2. Compare the numbers of protons and electrons afterwards.
3. Link this to the overall charge.

Example. An atom of sodium, $^{23}_{11}\mathrm{Na}$, loses one electron.
(a) Explain why the sodium becomes a positive ion. (2 marks)
(b) State the number of electrons the ion has. (1 mark)

Model answer.

(a) It now has fewer electrons than protons (1), so there is more positive charge than negative charge (1).
(b) 10 (1)

Don’t lose marks

- Giving the mass number as the number of neutrons. Subtract the atomic number first.
- Saying isotopes have different numbers of protons. A different number of protons means a different element.
- Saying a positive ion has gained protons or gained electrons. It has lost electrons.
- Swapping the top and bottom numbers in nuclide notation.

More tips

Memory tricks

- The mass number is never smaller than the atomic number, so it is the bigger number (the two are equal only for hydrogen-1).
- The atomic number is the element's ID: change the number of protons and you have a different element.
- 'Iso' means 'same': isotopes are the same element, in the same place in the periodic table, with different masses.
- Quick check: protons + neutrons must add up to the mass number.

Exam technique

- An isotope definition needs both parts: same number of protons AND different number of neutrons.
- For 'explain why an atom has no overall charge', say there are equal numbers of protons and electrons AND that their charges are equal and opposite.
- Write your subtraction for neutrons (e.g. 56 − 26 = 30) so the examiner can follow your method.

What each grade needs

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

Grade 3 — **State what atomic number means**
The atomic number is the number of protons in the nucleus.

Grade 4 — **State what mass number means**
The mass number is the total number of protons and neutrons in the nucleus.

Grade 4 — **Explain why atoms have no overall charge**
An atom has equal numbers of protons and electrons, and their charges are equal and opposite.

Grade 4 — **Define and identify isotopes**
Isotopes are atoms with the same number of protons but different numbers of neutrons.

Grade 4 — **Explain how an atom becomes a positive ion**
Losing one or more outer electrons leaves more protons than electrons, so the particle is positive.

Grade 5 — **Work out protons, neutrons and electrons**
Protons = atomic number; neutrons = mass number − atomic number; electrons = protons in a neutral atom.

Grade 5 — **Identify isotopes and ions from data**
Use particle numbers in a table to decide which atoms are isotopes of the same element and which particles are charged.

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