Exercise walk-through

Ionisation energy ▪ 1.4

eXercise

You must be able to

- define first ionisation energy and write equations for first and successive ionisations
- explain trends across a period (and the dips) and down a group
- deduce electronic configuration and group from successive ionisation energy data

Method — First ionisation energy

The energy to remove one electron from each atom in one mole of **gaseous** atoms, forming one mole of gaseous $+1$ ions:

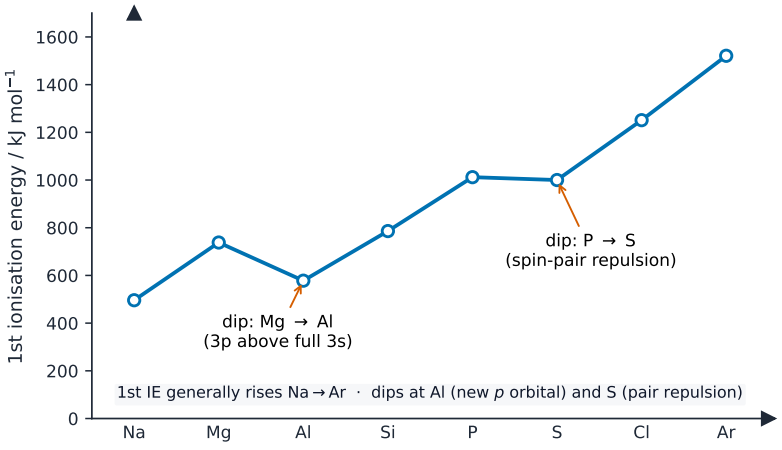
$$\mathrm{X(g)} \rightarrow \mathrm{X^{+}(g)} + \mathrm{e^{-}}$$

It depends on **nuclear charge** (more protons $\rightarrow$ higher), **atomic radius** (further out $\rightarrow$ lower), and **shielding** (more inner shells $\rightarrow$ lower).

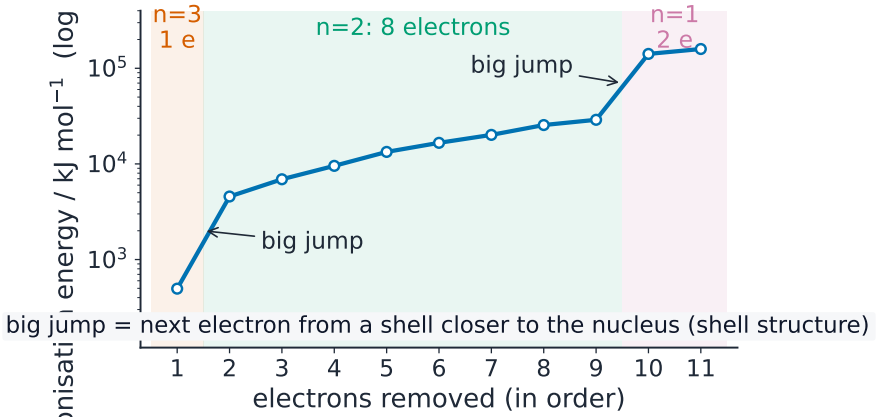
Method — Trends across Period 3

It rises across a period (rising nuclear charge, similar shielding) and falls down a group (more shielding, larger radius). The two dips: **Mg→Al** (Al's electron is in a higher 3p sub-shell) and **P→S** (S has a paired 3p electron, so spin-pair repulsion makes it easier to remove).

Method — Trends across Period 3



Method — Successive ionisation energies



big jump = next electron from a shell closer to the nucleus (shell structure)

Practice 2.1 ▪ 2 marks

Write an equation, with state symbols, for the first ionisation energy of magnesium.

Solution 2.1

Worked steps

$\mathrm{Mg(g)} \rightarrow \mathrm{Mg^{+}(g)} + \mathrm{e^{-}}$ **M1** **A1** *correct species, state symbols.*

Practice 2.2 ▪ 2 marks

State **two** factors that affect the size of an ionisation energy.

Solution 2.2

Worked steps

any two: nuclear charge; atomic radius; shielding; (spin-pair repulsion) **B1** *each, max 2.*

Exam-style 3.1 ▪ 1 mark

Why is the second ionisation energy of an element always larger than the first?

A the atom is now a gas

B the electron is removed from a more positive ion

C there are more neutrons

D shielding increases

Solution 3.1

Method: Trends across Period 3

A the atom is now a gas

B the electron is removed from a more positive ion ✓

C there are more neutrons

D shielding increases

Worked steps

B. The electron is pulled from a more positive ion, needing more energy.

Exam-style 3.2 ▪ 1 mark

The first ionisation energy of sulfur is lower than that of phosphorus because:

A sulfur has fewer protons

B sulfur's removed electron is one of a pair in a 3p orbital (spin-pair repulsion)

C sulfur is in a different period

D sulfur has more shielding

Solution 3.2

Method: First ionisation energy

A sulfur has fewer protons

B sulfur's removed electron is one of a pair in a 3p orbital (spin-pair repulsion) ✓

C sulfur is in a different period

D sulfur has more shielding

Worked steps

B. The paired 3p electron in sulfur is easier to remove (spin-pair repulsion).

Exam-style 3.3 ▪ 3 marks

Explain why the first ionisation energy decreases down Group 2.

Solution 3.3

Method: Trends across Period 3

Worked steps

down the group each element has more shells M1, so more shielding and a larger atomic radius M1; the outer electron is held less tightly, so it is easier to remove A1.

Exam-style 3.4 ▪ 2 marks

The first six ionisation energies of an element (kJ mol ^{1}) are: 590, 1150, 4940, 6480, 8120, 10500. Deduce which group the element is in, and explain your answer.

Solution 3.4

Method: Successive ionisation energies

Worked steps

Group 2 **M1**; there is a large jump between the 2nd and 3rd ionisation energies, showing 2 easily-removed outer electrons before reaching a full inner shell **A1**.