AQA 7405

Atomic Structure II

Specification-led notes

SPEC → CRACK IT → TEST IT → DONE

EVERY SPECIFICATION POINT. EXPLAINED. PRACTISED. CHECKED OFF.

SPECIFICATION COVERAGE

3.1.1.3	Electron configurations of atoms and ions up to Z = 36; ionisation energies and evidence for shells and sub-shells
3.2.1.1	Classification of elements as s, p, d or f block
3.2.1.2	The trend in first ionisation energy across Period 3
3.2.2	The trend in first ionisation energy down Group 2

Written by an experienced AQA examiner and chemistry teacher

Mapped to AQA Chemistry 7405, version 1.2 (July 2026)

The big picture

THE PROMISE This booklet turns every Atomic Structure II requirement into something you can write, explain or infer from data in an exam.

SPEC	CRACK IT	TEST IT	DONE
This is your target	Unlock what it actually means	Prove you can do it	Mastered

BOUNDARY Atomic Structure I covered fundamental particles, isotopes and mass spectrometry. This pack covers electron configurations and ionisation-energy evidence. Full Period 3 structure, bonding and melting-point trends, and Group 2 reactions and solubility trends, belong in later packs.

THE ROUTE THROUGH THE TOPIC			
1 BUILD	**2 REMOVE**	**3 COMPARE**	**4 INFER**
Write electron configurations of atoms and ions.	Represent first and successive ionisation energies.	Explain trends and anomalies in first ionisation energy.	Use ionisation-energy data as evidence for sub-shells and shells.

EXAMINER VIEW This topic is rarely just recall. AQA commonly gives an unfamiliar electron configuration, graph or data set and expects you to select the right idea: nuclear charge, distance, shielding, sub-shell energy, paired-electron repulsion or a shell jump.

1. Shells, sub-shells and orbitals

SPEC 3.1.1.3

Electron configurations of atoms and ions up to Z = 36 in terms of shells and sub-shells (orbitals) s, p and d.

CRACK IT

Electron structure has three nested levels: principal energy level (shell) → sub-shell → orbital.

1 PRINCIPAL ENERGY LEVEL NUMBER n • GCSE SHELL	What it means: The number n gives the main energy level. In 3p, the 3 is the principal energy level. At GCSE, this is called the shell number.
2 SUB-SHELL LETTER s, p OR d	What it means: The letter identifies the sub-shell within a principal energy level. In 3p, the p is the sub-shell within principal energy level 3.
3 ORBITAL REGION / BOX • MAXIMUM 2 e^-	What it means: An orbital is a region of space that holds up to two electrons. The s, p and d sub-shells contain 1, 3 and 5 orbitals respectively.

Sub-shell	Orbitals in sub-shell	Maximum electrons
s	1	2
p	3	6
d	5	10

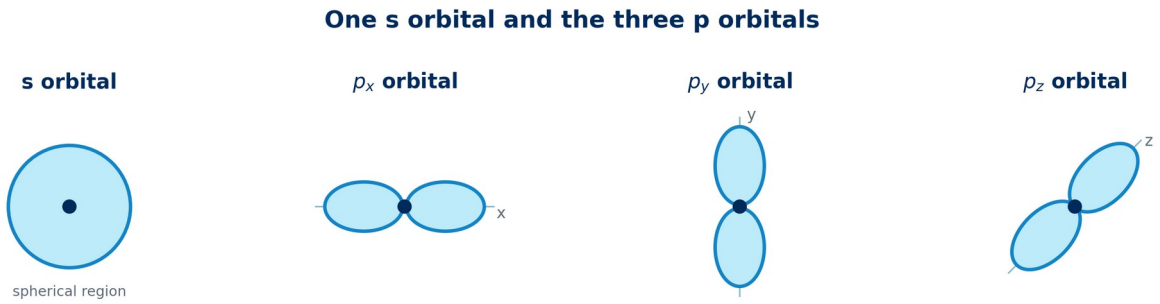


Figure 1. One s orbital and the three p orbitals. The shapes are schematic and not to scale.

MEMORY HOOK s has 1 orbital, p has 3 and d has 5. Double the number of orbitals to get the maximum number of electrons: 2, 6 and 10.

TEST IT 1 · QUICK CHECK

State the maximum number of electrons in an s, p and d sub-shell. Explain why a p sub-shell can hold six electrons. [5]

DONE WHEN: You can connect shells, sub-shells, orbitals and the capacities 2, 6 and 10.

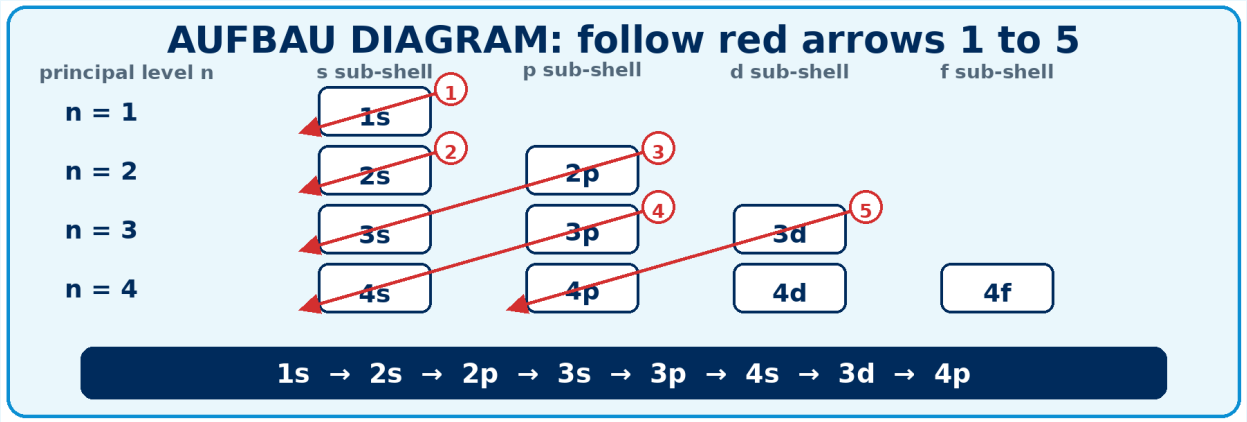
2. Filling sub-shells and writing electron configurations

SPEC 3.1.1.3

Students should be able to write electron configurations of atoms up to Z = 36.

CRACK IT

FILLING ORDER Electrons fill sub-shells in increasing energy. Follow the numbered red arrows from 1 to 5. On each arrow, read towards the arrowhead. Know the order as far as 4p.



- The number gives the principal energy level, n. This is the shell number used at GCSE.
- The letter gives the sub-shell: s, p or d.
- The superscript gives the total number of electrons in that sub-shell, not in one orbital.
- Each orbital holds up to two electrons. Equal-energy orbitals fill singly before electrons pair.

WORKED EXAMPLE **Writing the configuration of bromine**

QUESTION Bromine has atomic number 35. Write its full and shorthand electron configurations.

1. A neutral bromine atom has 35 electrons.
2. Fill the sub-shells in order, respecting the capacities s^2, p^6 and d^{10}.
3. The first 18 electrons form the [Ar] core.
4. Check the superscripts: 18 + 10 + 2 + 5 = 35.

ANSWER **Full: $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 4s^2\ 3d^{10}\ 4p^5$. Shorthand: [Ar] $3d^{10}\ 4s^2\ 4p^5$.**

FAST CHECK For a neutral atom, the superscripts must add to the atomic number. For an ion, they must add to the number of electrons after the charge has been applied.

TEST IT 2 · QUICK CHECK

Write the full electron configuration of selenium, Se, atomic number 34. Then write it using [Ar] shorthand. [2]

DONE WHEN: You can build and check full and shorthand configurations up to krypton.

3. The chromium and copper exceptions

SPEC 3.1.1.3

Electron configurations up to Z = 36 include the experimentally observed configurations of chromium and copper.

CRACK IT

Chromium and copper do not use the simplest predicted arrangements. A half-filled or completely filled 3d sub-shell is especially stable.

Cr: [Ar] $3d^5$ $4s^1$

Cu: [Ar] $3d^{10}$ $4s^1$

EXAM TRAP Do not write chromium as [Ar] $3d^4$ $4s^2$ or copper as [Ar] $3d^9$ $4s^2$. These are the two configurations that must be learned.

TEST IT 3 · QUICK CHECK

Write the shorthand electron configurations of chromium and copper. State the feature of the 3d sub-shell in each atom. [4]

DONE WHEN: You can recall Cr and Cu correctly without applying the ordinary filling pattern blindly.

4. Electron configurations of ions

SPEC 3.1.1.3

Students should be able to write electron configurations of ions formed by elements up to Z = 36.

CRACK IT

MAIN-GROUP IONS Add or remove electrons from the highest occupied shell until the total matches the ionic charge.

TRANSITION-METAL IONS Remove the 4s electrons before the 3d electrons, even though the 4s sub-shell filled first.

Species	Electron configuration	What changed?
O^{2-}	$1s^2$ $2s^2$ $2p^6$	2 electrons gained
Ca^{2+}	[Ar]	$4s^2$ removed
Fe	[Ar] $3d^6$ $4s^2$	neutral atom
Fe^{2+}	[Ar] $3d^6$	$4s^2$ removed first
Fe^{3+}	[Ar] $3d^5$	$4s^2$, then one 3d electron removed

WORKED EXAMPLE **Working backwards from an ion**

QUESTION An ion X^{3+} has electron configuration [Ar] $3d^2$. Identify X and write the configuration of the neutral atom.

1. X^{3+} contains 18 + 2 = 20 electrons.
2. The neutral atom contains three more electrons, so X has 23 electrons and proton number 23.
3. Element 23 is vanadium.
4. The ion was formed by removing two 4s electrons and one 3d electron. Reconstruct the atom by adding one electron to 3d and two to 4s.

ANSWER **X is V. The neutral atom is [Ar] $3d^3$ $4s^2$.**

TEST IT 4 · QUICK CHECK

Write the electron configurations of S^{2-}, Fe^{2+} and Fe^{3+}. For the iron ions, state which sub-shell loses electrons first. [4]

DONE WHEN: You can count electrons, apply charge and remove 4s before 3d for transition-metal ions.

5. Electron configuration and the Periodic Table

SPEC 3.2.1.1

An element is classified as s, p, d or f block according to its position in the Periodic Table, which is determined by its proton number.

CRACK IT

The block is named after the type of sub-shell receiving the highest-energy electron. This makes electron configuration and position in the Periodic Table two views of the same pattern.

WHAT DOES n MEAN? Here, n is the principal energy level number of the outer shell, equivalent to the shell number used at GCSE. An s- or p-block ending uses n; a d-block ending is one level lower, (n − 1)d; and an f-block ending is two levels lower, (n − 2)f.

Block	Where it appears	Typical ending
s	Groups 1 and 2, plus helium	ns^1 or ns^2
p	Groups 13 to 18	np^1 to np^6
d	central transition block	$(n - 1)d^1$ to $(n - 1)d^{10}$
f	two rows shown below the main table	$(n - 2)f^1$ to $(n - 2)f^{14}$

USEFUL DISTINCTION AQA requires electron configurations only up to Z = 36, so you need s, p and d configurations here. You should still recognise the f block from its position in the Periodic Table.

WORKED EXAMPLE **Identifying the block**

QUESTION An element has electron configuration [Ar] $3d^5$ $4s^2$. State its block.

1. Look for the sub-shell receiving the differentiating electron.
2. The configuration contains a partially filled 3d sub-shell.

ANSWER **The element is in the d block.**

TEST IT 5 · QUICK CHECK

State the block of each element with the following final sub-shells: $3s^2$, $3p^4$ and $3d^7$. Explain how the block name is chosen. [4]

DONE WHEN: You can infer s, p, d or f block from an electron configuration or Periodic Table position.

6. First and successive ionisation energies

SPEC 3.1.1.3

Students should be able to define first ionisation energy and write equations for first and successive ionisation energies.

CRACK IT

DEFINITION The first ionisation energy is the energy required to remove one electron from each atom in one mole of gaseous atoms to form one mole of gaseous 1+ ions.

$$X(g) \rightarrow X^+(g) + e^-$$

Ionisation energies are endothermic and are measured in kJ mol^{-1}.

DEFINITION CHECKLIST one mole of gaseous atoms | one electron removed from each atom | one mole of gaseous 1+ ions formed

Equations for successive ionisation energies

Each equation starts with a gaseous ion and increases its charge by exactly one.

$$\text{1st: } Mg(g) \rightarrow Mg^+(g) + e^-$$

$$\text{2nd: } Mg^+(g) \rightarrow Mg^{2+}(g) + e^-$$

$$\text{3rd: } Mg^{2+}(g) \rightarrow Mg^{3+}(g) + e^-$$

EXAM TRAP For the third ionisation energy, begin with a 2+ gaseous ion and form a 3+ gaseous ion. Do not begin with the neutral atom.

TEST IT 6 · QUICK CHECK

Define first ionisation energy. Then write an equation, including state symbols, for the third ionisation energy of aluminium. [5]

✓ **DONE WHEN: You can give the exact definition and write any successive-ionisation equation with correct charges and state symbols.**

7. What controls ionisation energy?

SPEC 3.1.1.3

Students should use ionisation-energy evidence to explain electron configuration in sub-shells and shells.

CRACK IT

Factor	Change	Effect on ionisation energy
Nuclear charge	more protons	stronger attraction, so ionisation energy increases
Distance	electron further from nucleus	weaker attraction, so ionisation energy decreases
Shielding	more inner-shell electrons	weaker attraction, so ionisation energy decreases
Sub-shell energy	electron in a higher-energy sub-shell	easier to remove, so ionisation energy decreases
Electron pairing	two electrons in one orbital repel	one becomes easier to remove

BUILD EVERY EXPLANATION AS A CAUSE-AND-EFFECT CHAIN

structural change → attraction to the electron changes → energy needed changes

EXAM WORDING Never stop at “the atom is bigger” or “there is more shielding”. Finish the explanation by stating how the attraction changes and therefore how the energy needed changes.

TEST IT 7 · QUICK CHECK

State the three main factors controlling attraction between the nucleus and the electron being removed. Explain why removing an electron from a higher-energy sub-shell requires less energy. [5]

✓ **DONE WHEN: You can select the correct factor and finish with attraction and energy, rather than naming a factor only.**

8. First ionisation energy across Period 3

SPEC 3.1.1.3 + 3.2.1.2

Students should explain how first ionisation energies across Period 3 give evidence for electron configuration in sub-shells and explain the trend in first ionisation energy.

CRACK IT

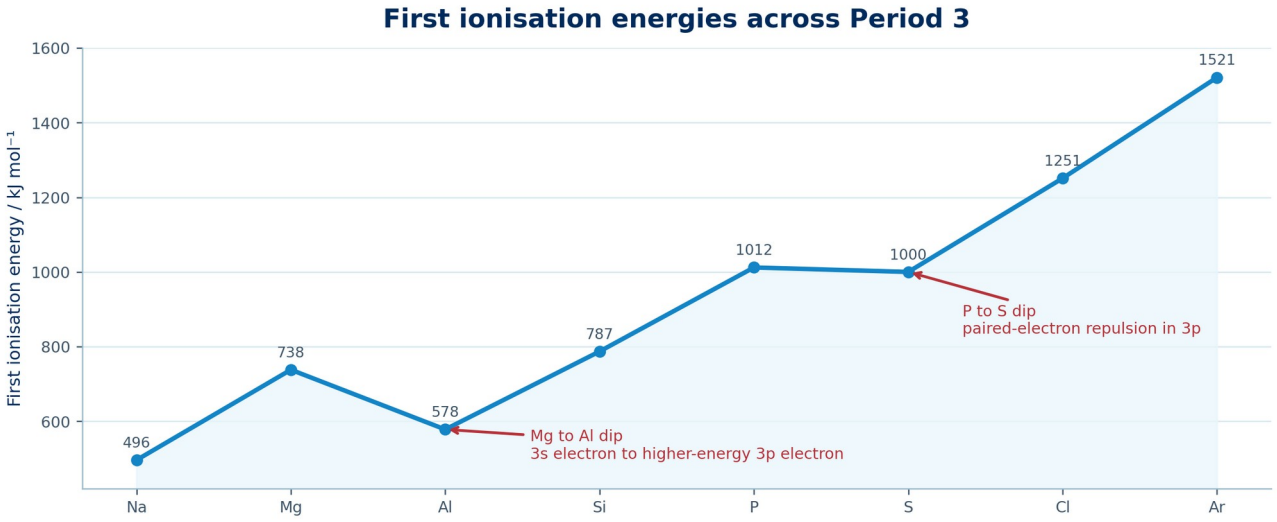


Figure 2. Rounded first ionisation energies for the Period 3 elements.

GENERAL TREND First ionisation energy generally increases from sodium to argon. Nuclear charge increases, electrons are added to the same principal shell and inner-shell shielding is broadly similar. Atomic radius decreases, attraction becomes stronger and more energy is required.

Why the trend is not perfectly smooth

Dip	Electron configurations	Explanation
Mg to Al	Mg: [Ne] $3s^2$ Al: [Ne] $3s^2$ $3p^1$	The electron removed from Al is in the higher-energy 3p sub-shell and is slightly more shielded, so it is easier to remove.
P to S	P: [Ne] $3s^2$ $3p^3$ S: [Ne] $3s^2$ $3p^4$	One 3p orbital in S contains a pair. Repulsion within the pair makes one electron easier to remove.

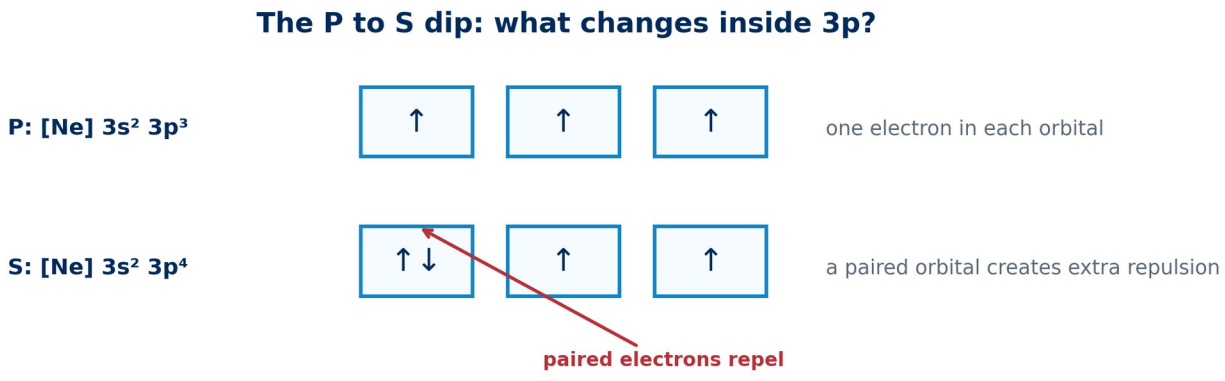


Figure 3. The 3p orbital occupancy that explains the small decrease from phosphorus to sulfur.

TEST IT 8 · QUICK CHECK

Describe and explain the general trend in first ionisation energy across Period 3. Then explain both the Mg to Al and P to S decreases. [10]

DONE WHEN: You can explain the overall trend and both anomalies using the correct sub-shell and pairing language.

9. First ionisation energy down Group 2

SPEC 3.1.1.3 + 3.2.2

Students should explain how first ionisation energies down Group 2 give evidence for electron configuration in shells and explain the trend in first ionisation energy.

CRACK IT

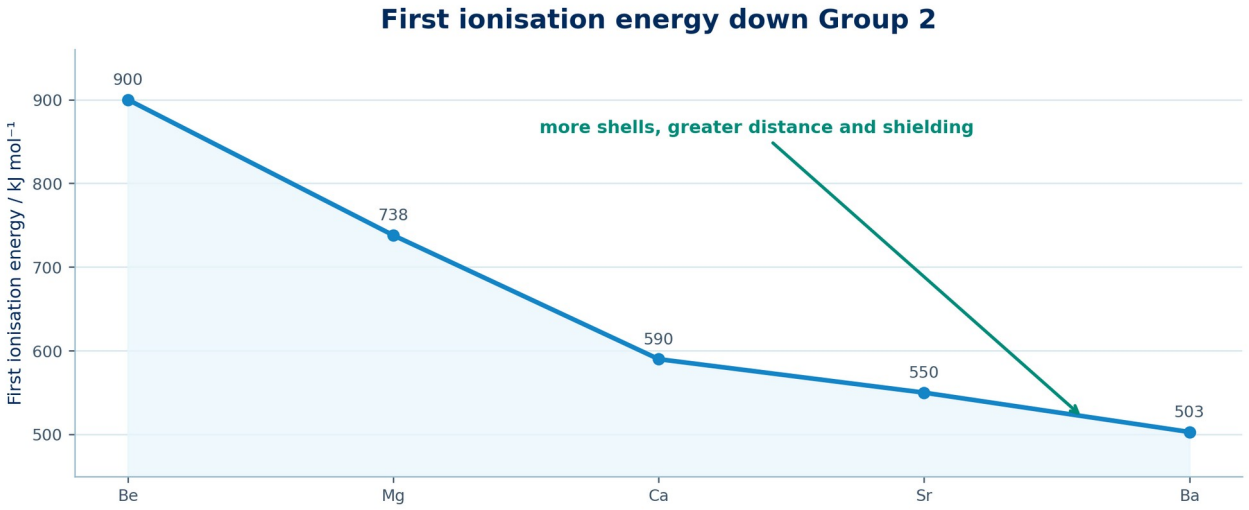


Figure 4. Rounded first ionisation energies for the Group 2 elements from Be to Ba.

THE CHAIN Down Group 2 there are more occupied shells. The outer electron is further from the nucleus and experiences more shielding. These effects outweigh the increase in nuclear charge, so attraction is weaker and first ionisation energy decreases.

EVIDENCE FOR SHELLS The repeating decrease when a new shell is occupied supports the shell model of electron configuration.

EXAM TRAP Do not say only that there are more electrons or that the atom is larger. State greater distance and shielding, then weaker attraction and lower ionisation energy.

TEST IT 9 · QUICK CHECK

The first ionisation energies of Be, Mg, Ca, Sr and Ba are 900, 738, 590, 550 and 503 kJ mol^{-1}. Describe and explain the trend. [4]

DONE WHEN: You can explain the Group 2 trend using distance, shielding, nuclear charge and attraction.

10. Successive ionisation energies and shell structure

SPEC 3.1.1.3

Students should explain how successive ionisation energies in Period 3 and Group 2 give evidence for electron configuration in shells.

CRACK IT

Successive ionisation energies increase because each electron is removed from an increasingly positive ion. The remaining electrons experience stronger attraction to the nucleus.

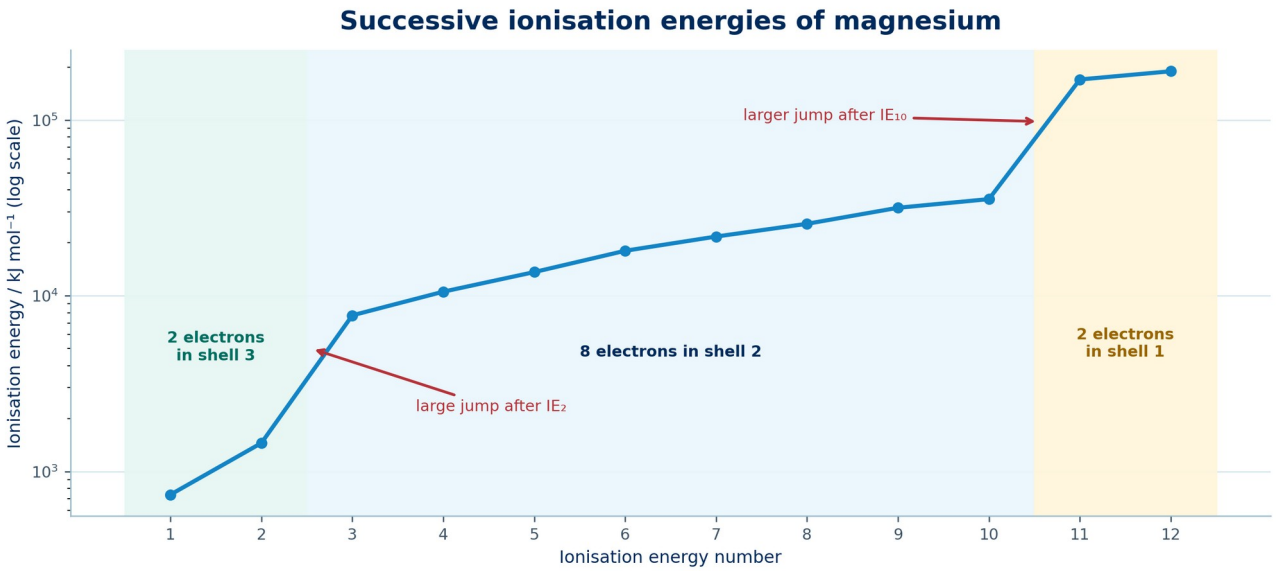


Figure 5. Successive ionisation energies of magnesium. A log scale makes both major shell jumps visible.

HOW TO READ THE GRAPH A large jump means the next electron is being removed from a new inner shell. Count the electrons removed before the first large jump to find the number of outer-shell electrons and, for a main-group element, its group.

MAGNESIUM EVIDENCE The first jump is after IE_2, showing two outer-shell electrons. The second major jump is after IE_{10}, giving the shell arrangement 2,8,2. Across Group 2, the first major jump always occurs after the second electron.

The Period 3 pattern

Element	Na	Mg	Al	Si	P	S	Cl	Ar
First major jump after	IE_1	IE_2	IE_3	IE_4	IE_5	IE_6	IE_7	IE_8

WORKED EXAMPLE **Identifying a Period 3 element from successive values**

QUESTION A Period 3 element has successive ionisation energies of 578, 1817, 2745 and 11 578 kJ mol^{-1}. Identify the element and explain your answer.

1. Find the large jump: it is between the third and fourth ionisation energies.
2. Three outer-shell electrons are removed before an inner-shell electron must be removed.
3. The element is therefore in Group 13.
4. The Period 3 Group 13 element is aluminium.

ANSWER **The element is aluminium, Al.**

EXAM TRAP A large jump is not just a normal increase. It is evidence that the next electron is closer to the nucleus and less shielded because it occupies an inner shell.

TEST IT 10 · QUICK CHECK

An element has successive ionisation energies of 580, 1820, 2750, 11 600 and 14 800 kJ mol^{-1}. State its group, identify the Period 3 element and write its electron configuration. Explain your reasoning. [6]

DONE WHEN: You can use large jumps to determine outer-shell electron number, group, element and shell structure.

Final mastery check

THE RULE Tick a statement only when you can do it without looking back at the notes.

☐	State the relationship between shells, sub-shells and orbitals, and recall s, p and d capacities.
☐	Write and check full and shorthand electron configurations up to Z = 36.
☐	Recall the chromium and copper exceptions.
☐	Write configurations of main-group and transition-metal ions, removing 4s before 3d.
☐	Use electron configuration to identify s, p, d and f blocks.
☐	Define first ionisation energy precisely and write first and successive equations.
☐	Use nuclear charge, distance, shielding, sub-shell energy and pairing correctly.
☐	Explain the Period 3 trend and the Mg to Al and P to S dips.
☐	Explain the first-ionisation-energy trend down Group 2.
☐	Use successive ionisation energies to infer outer-shell number, group and shell structure.

TEST IT answers

USE THESE PROPERLY Attempt every TEST IT question first. Then compare your answer with the chemistry below and return to the exact specification point if anything is missing.

TEST IT	CHECK ANSWER
1	s: 2 electrons; p: 6; d: 10. A p sub-shell contains three orbitals and each orbital holds a maximum of two electrons, so 3 × 2 = 6. [5]
2	Se: $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 4s^2\ 3d^{10}\ 4p^4$. Shorthand: [Ar] $3d^{10}\ 4s^2\ 4p^4$. The superscripts total 34. [2]
3	Cr: [Ar] $3d^5\ 4s^1$, with a half-filled 3d sub-shell. Cu: [Ar] $3d^{10}\ 4s^1$, with a full 3d sub-shell. [4]
4	S^{2-}: $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6$ or [Ar]. Fe^{2+}: [Ar] $3d^6$. Fe^{3+}: [Ar] $3d^5$. The 4s electrons are removed before the 3d electrons. [4]
5	$3s^2$ is s block; $3p^4$ is p block; $3d^7$ is d block. The block is named after the type of sub-shell receiving the highest-energy electron. [4]
6	The first ionisation energy is the energy required to remove one electron from each atom in one mole of gaseous atoms to form one mole of gaseous 1+ ions. Third IE of aluminium: $Al^{2+}(g) \rightarrow Al^{3+}(g) + e^-$. [5]
7	Nuclear charge, distance from the nucleus and shielding by inner electrons. An electron in a higher-energy sub-shell is easier to remove, so less energy is required. [5]
8	First ionisation energy generally increases across Period 3 because nuclear charge increases, electrons are added to the same principal shell, shielding is broadly similar and atomic radius decreases. Attraction becomes stronger. Al is lower than Mg because a higher-energy, slightly more shielded 3p electron is removed rather than a 3s electron. S is lower than P because S has a pair in one 3p orbital; paired-electron repulsion makes one electron easier to remove. [10]
9	First ionisation energy decreases from Be to Ba. Down the group the outer electron is further from the nucleus and experiences more shielding. These effects outweigh the increased nuclear charge, so attraction is weaker and less energy is required. [4]
10	The large jump is between the third and fourth values, so three outer-shell electrons are removed before an inner-shell electron. The element is in Group 13. The Period 3 element is aluminium. Electron configuration: $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^1$ or [Ne] $3s^2\ 3p^1$. [6]

FINAL CHECK If you missed a mark, identify the missing chemistry rather than merely copying the model answer. Every mark in this topic comes from a specific idea, equation, state symbol or cause-and-effect link.