OCR A H432

Atomic Structure II

Specification-led notes

SPEC → CRACK IT → TEST IT → DONE

EVERY SPECIFICATION POINT. EXPLAINED. PRACTISED. CHECKED OFF.

SPECIFICATION COVERAGE

2.2.1(a)	Maximum numbers of electrons in the first four shells
2.2.1(b)	Atomic orbitals; s- and p-orbital shapes; s, p and d subshell capacities
2.2.1(c)	Filling order and electron-in-box diagrams
2.2.1(d)	Electron configurations of atoms to Z = 36 and ions from the s and p blocks

Written by an experienced A-level Chemistry examiner and teacher

Mapped to OCR A Chemistry A H432, specification version 3.1 (2026)

The big picture

THE PROMISE This booklet turns every OCR A Electron structure requirement into something you can recognise, draw, write and check in an exam.

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

OCR A BOUNDARY This pack covers OCR A 2.2.1 Electron structure. First and successive ionisation energies and classification into s, p and d blocks are assessed in OCR A Periodicity 3.1.1. Configurations of transition-metal ions are not required in 2.2.1.

THE ROUTE THROUGH THE TOPIC			
1 LOCATE	**2 FILL**	**3 WRITE**	**4 CHECK**
Connect shells, subshells and orbitals.	Place electrons in increasing energy.	Build configurations for atoms and ions.	Use electron totals and box diagrams.

EXAMINER VIEW OCR can move between words, subshell notation and electrons-in-box diagrams. Treat them as three ways of showing the same electron arrangement.

THE VOCABULARY LADDER			
SHELL	**SUBSHELL**	**ORBITAL**	**ELECTRON**
A main energy level, numbered 1, 2, 3 or 4.	A division of a shell, labelled s, p or d here.	A region holding up to two electrons.	Shown by one arrow in a box diagram.

KEEP THE SCALE CLEAR A shell contains subshells. A subshell contains orbitals. An orbital contains no more than two electrons.

1. The first four electron shells

SPEC 2.2.1(a)

Learners should know the number of electrons that can fill the first four electron shells.

CRACK IT

A shell is a main energy level around the nucleus. Shells are numbered 1, 2, 3 and 4 as their distance and energy generally increase.

Maximum number of electrons in the first four shells

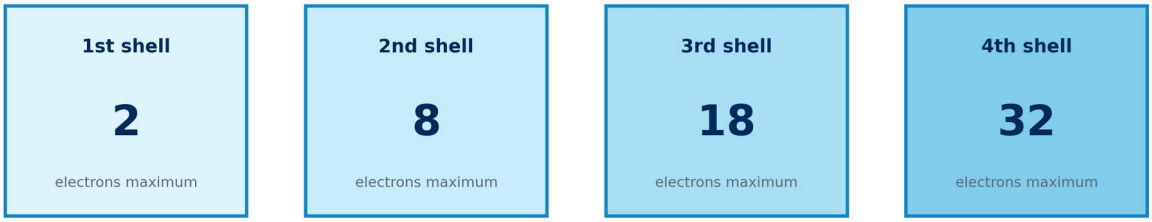

Figure 1. Maximum capacities of the first four shells.

Maximum electrons in a shell = 2 × (shell number)²

Equivalent shorthand: $2n^2$, where n = shell number

WORKED EXAMPLE **Checking the third shell**

QUESTION Use $2n^2$, where n is the shell number, to calculate the maximum number of electrons in the third shell.

1. For the third shell, n = 3.
2. Substitute: $2 \times 3^2 = 2 \times 9$.

ANSWER **The third shell can hold a maximum of 18 electrons.**

EXAM TRAP Shell capacity is not the same as filling order. Potassium places its nineteenth electron in 4s before 3d begins to fill, even though the third shell is not at its maximum capacity.

TEST IT 1 · QUICK CHECK

State the maximum numbers of electrons in the first, second, third and fourth shells. Calculate the fourth-shell capacity using $2n^2$, where n is the shell number. [5]

DONE WHEN: You can recall 2, 8, 18 and 32 and distinguish capacity from filling order.

2. Atomic orbitals and their shapes

SPEC 2.2.1(b)(i) and 2.2.1(b)(ii)

Learners should know that an atomic orbital is a region around the nucleus that can hold up to two electrons with opposite spins, and know the shapes of s- and p-orbitals.

CRACK IT

OCR DEFINITION An atomic orbital is a region around the nucleus that can hold up to two electrons with opposite spins.

An orbital is not a fixed path followed by an electron. Its shape shows the region where there is a high probability of finding an electron.

One s orbital and the three p orbitals

Figure 2. An s orbital is spherical. Each p orbital has two lobes, often described as a dumb-bell shape.

- **Every s orbital** is spherical.
- **The three p orbitals** have the same shape and energy but point in different directions at right angles.
- **The nucleus** lies at the centre of each orbital.

EXAM TRAP Do not draw a p orbital as a figure of eight orbit around the nucleus. It is a three-dimensional probability region with two lobes.

TEST IT 2 · QUICK CHECK

Define an atomic orbital. State the shape of an s orbital and describe the arrangement of the three p orbitals. [5]

DONE WHEN: You can define an orbital and recognise or draw the required s and p shapes.

3. Subshells, orbitals and capacities

SPEC 2.2.1(b)(iii)

Learners should know the number of orbitals making up s, p and d subshells, and the number of electrons that can fill each subshell.

CRACK IT

Each shell is divided into subshells. A subshell contains one or more orbitals of the same type.

Subshell	Orbitals in the subshell	Electrons per orbital	Maximum electrons
s	1	2	2
p	3	2	6
d	5	2	10

MEMORY HOOK s, p, d have 1, 3, 5 orbitals. Double these numbers to get capacities of 2, 6, 10 electrons.

WORKED EXAMPLE **From orbitals to electrons**

QUESTION Explain why a d subshell can contain ten electrons.

1. A d subshell contains five orbitals.
2. Each orbital holds a maximum of two electrons with opposite spins.
3. Calculate: 5 orbitals × 2 electrons per orbital = 10 electrons.

ANSWER **A d subshell can contain a maximum of ten electrons.**

TEST IT 3 · QUICK CHECK

State the numbers of orbitals and maximum numbers of electrons in s, p and d subshells. Explain the capacity of a p subshell. [8]

DONE WHEN: You can move confidently between a subshell, its orbitals and its electron capacity.

4. Filling orbitals in increasing energy

SPEC 2.2.1(c)(i)

Learners should know how orbitals are filled for the first three shells and the 4s and 4p orbitals in order of increasing energy.

CRACK IT

FILLING PRINCIPLE Electrons fill the available orbitals from lower energy to higher energy.

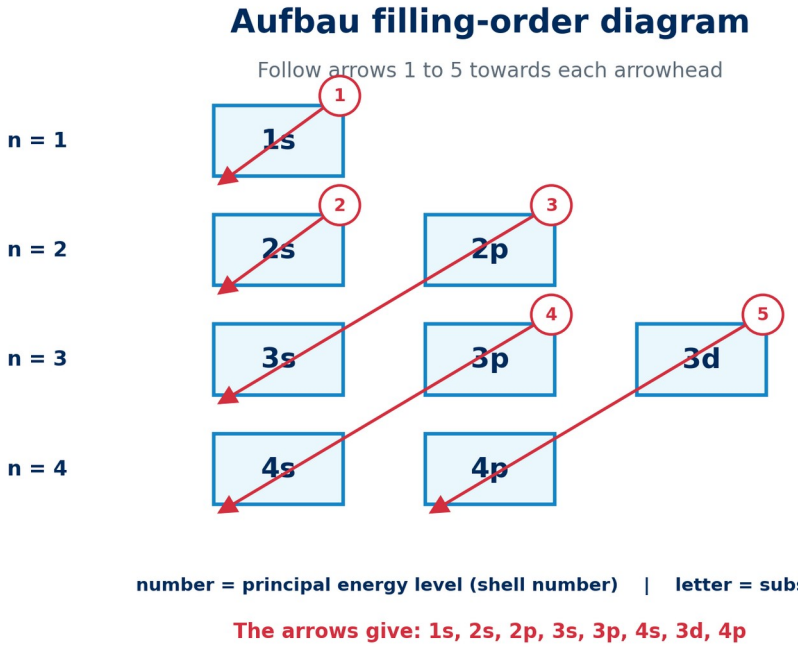

Figure 3. Aufbau diagram showing the OCR A filling order up to the 4p subshell.

1s → 2s → 2p → 3s → 3p → 4s → 3d → 4p

WHY 4S APPEARS EARLY The 4s subshell is lower in energy than 3d while these orbitals are being filled, so 4s fills before 3d.

EXAM TRAP Do not fill all of shell 3 before starting shell 4. After 3p, the next subshell is 4s, not 3d.

TEST IT 4 · QUICK CHECK

Write the filling sequence from 1s to 4p. State which subshell fills immediately before 3d and which fills immediately after 3d. [4]

DONE WHEN: You can reproduce and use the filling order through 4p.

5. Equal-energy orbitals fill singly first

SPEC 2.2.1(c)(ii)

Learners should know that orbitals of the same energy are occupied singly before electron pairing can occur.

CRACK IT

The three orbitals in a p subshell have the same energy. Place one electron in each empty orbital before putting a second electron into any orbital.

Electrons in equal-energy p orbitals

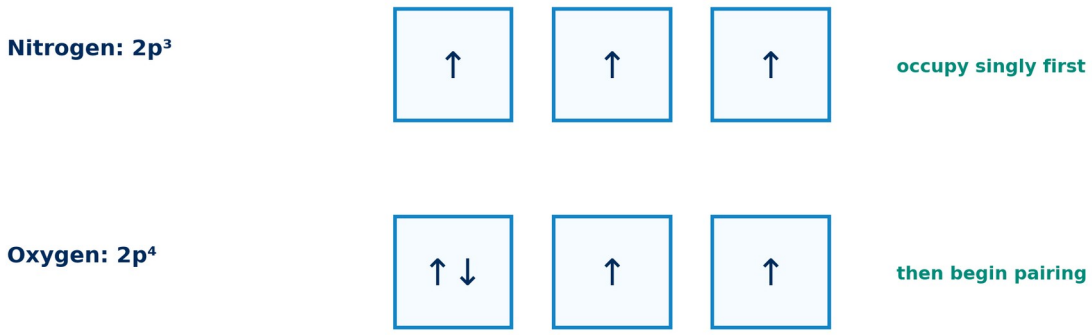

Figure 4. Electrons-in-box diagrams for the 2p electrons in nitrogen and oxygen.

- **One box** represents one orbital.
- **One arrow** represents one electron.
- **Two electrons** in the same orbital must have opposite spins, so the arrows point in opposite directions.

EXAM TRAP For $2p^2$, do not pair both electrons in one box. Put one electron into each of two separate p orbitals.

TEST IT 5 · QUICK CHECK

Draw electrons-in-box diagrams for the 2p electrons in carbon, $2p^2$, and fluorine, $2p^5$. Use arrows to show spin. [4]

DONE WHEN: You can fill equal-energy orbitals singly before pairing and show opposite spins correctly.

6. Electron configurations of atoms up to Z = 36

SPEC 2.2.1(d)(i)

Learners should be able to deduce the electron configurations of atoms up to Z = 36.

CRACK IT

A RELIABLE FOUR-STEP METHOD

1 COUNT	2 FILL	3 STOP	4 CHECK
A neutral atom has Z electrons.	Use the energy order and capacities.	Stop when every electron is placed.	Superscripts must total Z.

In subshell notation, the number identifies the shell, the letter identifies the subshell and the superscript gives the number of electrons in that subshell.

WORKED EXAMPLE **Writing the configuration of selenium**

QUESTION Selenium has atomic number 34. Deduce its electron configuration.

1. A neutral selenium atom has 34 electrons.
2. Fill in order: 1s, 2s, 2p, 3s, 3p, 4s, 3d, 4p.
3. Apply the capacities s^2, p^6 and d^{10}.
4. Check the total: 2 + 2 + 6 + 2 + 6 + 2 + 10 + 4 = 34.

ANSWER **$1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 4s^2\ 3d^{10}\ 4p^4$**

OCR WORDING OCR accepts subshell notation such as $1s^2\ 2s^2\ 2p^4$. Electrons-in-box diagrams may also be used, so be ready to translate between both representations.

SHORTHAND [Ar] represents the complete 18-electron argon core: $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6$. It makes longer configurations easier to read, but the electron total must still be correct.

ORDER OF WRITING Configurations containing both 3d and 4s are often written with 3d before 4s. This does not change the filling rule: 4s fills before 3d.

FAST CHECK For a neutral atom, the superscripts must add to the atomic number.

TEST IT 6 · QUICK CHECK

Deduce the electron configurations of calcium, Z = 20, and krypton, Z = 36. Check each using its electron total. [4]

DONE WHEN: You can build and verify the configuration of any atom from hydrogen to krypton.

7. Chromium and copper

SPEC 2.2.1(d)(i)

Learners should be able to deduce the electron configurations of atoms, given the atomic number, up to Z = 36.

CRACK IT

Chromium (Z = 24) and copper (Z = 29) are within this range. Their observed ground-state configurations differ from the simple filling prediction because the 3d and 4s subshells are very close in energy.

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

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

Atom	Incorrect simple prediction	Correct configuration
Cr	[Ar] $3d^4$ $4s^2$	[Ar] $3d^5$ $4s^1$
Cu	[Ar] $3d^9$ $4s^2$	[Ar] $3d^{10}$ $4s^1$

MEMORY HOOK Cr reaches $3d^5$ and Cu reaches $3d^{10}$. In both atoms, $4s^1$ remains.

EXAM TRAP Do not apply the ordinary pattern blindly to chromium or copper. Learn these two atomic configurations exactly.

TEST IT 7 · QUICK CHECK

Write the electron configurations of chromium and copper using [Ar]. State how each differs from the simple predicted configuration. [4]

DONE WHEN: You can recall both exceptions accurately and distinguish prediction from observation.

8. Electron configurations of s- and p-block ions

SPEC 2.2.1(d)(ii)

Learners should be able to deduce the electron configurations of ions up to Z = 36, limited to ions of elements in the s and p blocks.

CRACK IT

COUNT FIRST, THEN FILL

Species	Electron count	Electron configuration
O^{2-}	8 + 2 = 10	$1s^2\ 2s^2\ 2p^6$
Na^+	11 − 1 = 10	$1s^2\ 2s^2\ 2p^6$
Ca^{2+}	20 − 2 = 18	$1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6$
Br^-	35 + 1 = 36	$1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 4s^2\ 3d^{10}\ 4p^6$

WORKED EXAMPLE **A less familiar p-block ion**

QUESTION Gallium has atomic number 31. Deduce the electron configuration of Ga^{3+}.

1. A neutral gallium atom has 31 electrons: [Ar] $3d^{10}\ 4s^2\ 4p^1$.
2. A 3+ ion has lost three electrons, so Ga^{3+} has 28 electrons.
3. Remove the outer 4p electron and the two 4s electrons.
4. Check: 18 electrons in [Ar] plus 10 in 3d gives 28.

ANSWER **Ga^{3+}: [Ar] $3d^{10}$**

OCR BOUNDARY Do not practise configurations of transition-metal ions such as Fe^{2+} or Fe^{3+} for this specification statement. OCR limits ion configurations here to ions of s- and p-block elements.

EXAM TRAP Apply the charge before writing the configuration. A 2− ion has two more electrons than the neutral atom; a 2+ ion has two fewer.

TEST IT 8 · QUICK CHECK

Deduce the electron configurations of Al^{3+}, S^{2-} and Br^-. Show the electron count for each species. [6]

DONE WHEN: You can count electrons and deduce configurations for ions of s- and p-block elements up to Z = 36.

9. Pulling the ideas together

SPEC 2.2.1(a) to 2.2.1(d)

This section applies OCR A 2.2.1(a)–(d): shell capacities, orbital diagrams and subshell configurations.

CRACK IT

THE DECISION ROUTE First identify what representation is shown. Next count the electrons. Then apply filling order, capacities and the singly-before-pairing rule. Finally check the total and any ionic charge.

TEST IT 9 · QUICK CHECK

An ion formed by a p-block element has 18 electrons and a 2− charge. Identify the element, write the electron configuration of the ion and draw the electrons-in-box diagram for its 3p subshell. [6]

✓ **DONE WHEN: You can select and combine the correct electron-structure ideas without being told which rule to use.**

Final mastery check

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

☐	Recall the maximum electron capacities of the first four shells.
☐	Define an atomic orbital and state that paired electrons have opposite spins.
☐	Recognise and draw the required shapes of s and p orbitals.
☐	Recall the numbers of orbitals and electron capacities in s, p and d subshells.
☐	Use the filling order from 1s to 4p, including 4s before 3d.
☐	Draw electrons-in-box diagrams with singly occupied orbitals before pairing.
☐	Deduce and check electron configurations of atoms up to Z = 36.
☐	Recall the observed configurations of chromium and copper.
☐	Deduce configurations of ions of s- and p-block elements up to Z = 36.
☐	Recognise that ionisation energies, block classification and transition-metal ion configurations are outside OCR A 2.2.1.

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	First shell: 2; second: 8; third: 18; fourth: 32. For n = 4, $2n^2 = 2 \times 4^2 = 32$ electrons. [5]
2	An atomic orbital is a region around the nucleus that can hold up to two electrons with opposite spins. An s orbital is spherical. The three p orbitals have dumb-bell shapes and point in different directions at right angles. [5]
3	s: 1 orbital and 2 electrons; p: 3 orbitals and 6 electrons; d: 5 orbitals and 10 electrons. A p subshell contains three orbitals, each holding a maximum of two electrons, so its capacity is six. [8]
4	1s → 2s → 2p → 3s → 3p → 4s → 3d → 4p. The subshell immediately before 3d is 4s; the one immediately after 3d is 4p. [4]
5	Carbon, $2p^2$: [↑] [↑] [ ] Fluorine, $2p^5$: [↑↓] [↑↓] [↑]. Equivalent placement of the singly occupied orbital is acceptable. [4]
6	Ca: $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 4s^2$, total 20. Kr: $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 4s^2\ 3d^{10}\ 4p^6$, total 36. [4]
7	Cr: [Ar] $3d^5\ 4s^1$ rather than [Ar] $3d^4\ 4s^2$. Cu: [Ar] $3d^{10}\ 4s^1$ rather than [Ar] $3d^9\ 4s^2$. [4]
8	Al^{3+} has 13 − 3 = 10 electrons: $1s^2\ 2s^2\ 2p^6$. S^{2-} has 16 + 2 = 18 electrons: $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6$. Br^- has 35 + 1 = 36 electrons: $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 4s^2\ 3d^{10}\ 4p^6$. [6]
9	The neutral atom has 18 − 2 = 16 electrons, so it is sulfur. The ion is S^{2-} with configuration $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6$. Its 3p diagram is [↑↓] [↑↓] [↑↓]. [6]

FINAL CHECK If you missed a mark, identify the missing chemistry rather than copying the model answer. Every mark in this topic comes from a precise definition, capacity, filling rule, electron count or configuration.