InkChemistry

ANSWER BOOK

# Electron configuration: shells, subshells and orbitals

Atomic structure · Unit C01

AQA 3.1.1.3 · OCR A 2.2.1

16 questions · 55 marks

NAVY EDITION

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## SECTION A · Short, 1 to 2 marks

**A1** ECS-Q10

**B1** a positive ion: the potassium ion $K^+$ or the calcium ion $Ca^{2+}$. **B1** a negative ion: the chloride ion $Cl^-$ or the sulfide ion $S^{2-}$. [2]

**A2** ECS-Q20

**B1** $1s^2\ 2s^2\ 2p^2$ is the ground state. **B1** both hold six electrons, but in $1s^2\ 2s^1\ 2p^3$ an electron has moved from 2s to the higher-energy 2p while 2s has room, so it is an excited state. [2]

## SECTION B · Standard, 3 to 5 marks

**B1** ECS-Q1

**B1** an s subshell has one orbital and a p subshell three. **B1** a d subshell has five orbitals, holding up to ten electrons. **B1** an s orbital is spherical, centred on the nucleus. **B1** a p orbital is a dumbbell, two lobes on opposite sides of the nucleus, and the three lie at right angles. [4]

**B2** ECS-Q2

**B1** $Ti^{2+}$ is [Ar] $3d^2$, with 2 unpaired electrons. **B1** $Cr^{3+}$ is [Ar] $3d^3$, with 3 unpaired electrons. **B1** $Ni^{2+}$ is [Ar] $3d^8$: five singles then three pairs, leaving 2 unpaired electrons. **B1** $Zn^{2+}$ is [Ar] $3d^{10}$, with every orbital full and 0 unpaired electrons. [4]

**B3** ECS-Q3

**B1** S is $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^4$. **B1** the shortened form is [Ne] $3s^2\ 3p^4$. **B1** $S^{2-}$ is $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6$, with two electrons added to 3p. **B1** the shortened form of $S^{2-}$ is [Ne] $3s^2\ 3p^6$; allow [Ar]. [4]

**B4** ECS-Q7

**B1** Pauli: an orbital holds at most two electrons, and two in the same orbital have opposite spins. **B1** Hund: electrons occupy the orbitals of a subshell singly, with parallel spins, before any pair, because they repel less in separate orbitals. **B1** carbon, $2p^2$, has one electron in each of two 2p orbitals, with parallel spins, and the third orbital empty. **B1** oxygen, $2p^4$, has one 2p orbital holding a pair of opposite spin and the other two singly occupied. [4]

**B5** ECS-Q11

**B1** a d subshell has five orbitals, each holding two electrons. **B1** ten electrons fill it, one more with each element from scandium to zinc. **B1** potassium is $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 4s^1$, because 4s is lower in energy than 3d. **B1** its outer electron is in the fourth shell, and the period number is the number of the highest occupied shell. [4]

**B6** ECS-Q14

**B1** both ions are [Ar] $3d^5$, with 23 electrons, so they are isoelectronic. **B1** both have one electron in each of the five 3d orbitals, so each has 5 unpaired electrons. **B1** manganese, [Ar] $3d^5\ 4s^2$, loses only its two 4s electrons, while iron, [Ar] $3d^6\ 4s^2$, loses both 4s electrons and one 3d electron. **B1** $Fe^{3+}$ has 26 protons holding the 23 electrons against 25 in $Mn^{2+}$, so its electrons are held more strongly. [4]

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**B7** ECS-Q4
**B1** Cr is $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 3d^5\ 4s^1$; reject $3d^4\ 4s^2$. **B1** Ga is $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 3d^{10}\ 4s^2\ 4p^1$. **B1** $Ga^{3+}$ is $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 3d^{10}$, the 4p and 4s electrons removed. [3]

**B8** ECS-Q5
**B1** the 4s and 3d subshells are very close in energy. **B1** one 4s electron occupies 3d instead, giving a half-filled 3d subshell with one electron in each of the five orbitals. **B1** this arrangement is more stable, lower in energy, than $3d^4\ 4s^2$. [3]

**B9** ECS-Q6
**B1** in potassium and calcium, with 3d empty, 4s is lower in energy than 3d, so it fills first. **B1** once 3d holds electrons, the 4s electrons are the outermost and highest in energy. **B1** so the 4s electrons are removed first: iron, [Ar] $3d^6\ 4s^2$, forms $Fe^{2+}$ as [Ar] $3d^6$. [3]

**B10** ECS-Q9
**B1** the atom has 18 + 10 + 2 + 5 = 35 electrons, so it is bromine. **B1** it is in the p block, because its highest-energy electron is in 4p. **B1** five 4p electrons fill two orbitals and leave one single, so there is 1 unpaired electron. [3]

**B11** ECS-Q12
**B1** a zinc atom is [Ar] $3d^{10}\ 4s^2$. **B1** $Zn^{2+}$ has lost the two 4s electrons and is [Ar] $3d^{10}$. **B1** a third electron would have to come from the full 3d subshell, closer to the nucleus, which needs much more energy. [3]

**B12** ECS-Q16
**B1** the total number of electrons, 23, is right, since iron has 26 and three are lost. **B1** but the three electrons have been taken from 3d, when the 4s electrons are lost first. **B1** the correct configuration is [Ar] $3d^5$. [3]

**B13** ECS-Q18
**B1** in the ground state the outer electron of a sodium atom is in 3s, the lowest-energy arrangement. **B1** energy from the electric discharge promotes the electron to the higher-energy 3p subshell, an excited state. **B1** the electron falls back to 3s and the energy difference is given out as light, of one fixed wavelength because the gap is fixed. [3]

## SECTION C · Long, 6 marks or more

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**C1** ECS-Q15 **Indicative content** [6]

**B1** each shell divides into subshells: the third shell has 3s, 3p and 3d, holding 2, 6 and 10 electrons, 18 in all. **B1** from sodium to argon only the 3s and 3p subshells fill, so argon is 2, 8, 8 with its 3d subshell still empty. **B1** in potassium and calcium the 4s subshell is lower in energy than 3d, so the nineteenth and twentieth electrons go into 4s. **B1** a 4s electron spends part of its time close to the nucleus, inside the inner shells, where it is barely shielded, lowering its energy. **B1** from scandium the 3d subshell fills, so scandium is [Ar] $3d^1\ 4s^2$, with nine electrons in its third shell, not eight. **B1** by zinc the third shell holds eighteen electrons, $2n^2$ for n = 3, so 2, 8, 8 fits only the first twenty elements.

**Levels**

**Level 3 (5–6 marks)** the subshells of the third shell and their capacities, the filling of 4s before 3d in potassium and calcium with the reason in terms of energy and penetration, and the filling of 3d from scandium with the electron configuration are all present.

**Level 2 (3–4 marks)** 4s is said to fill before 3d, so potassium and calcium add electrons to 4s and 3d fills from scandium; the capacities of the subshells, why 4s is lower in energy, or a configuration such as scandium's does not appear.

**Level 1 (1–2 marks)** the third shell is said to be full at eight, or 3d to fill before 4s in potassium, with no energy order and no configurations.

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