Exercise walk-through

Electrons, energy levels and atomic orbitals ▪ 1.3

eXercise

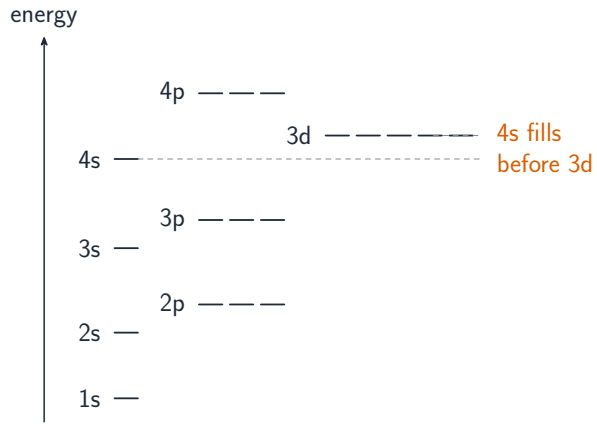
You must be able to

- describe the orbitals and electron capacity of s, p and d sub-shells
- write the electronic configuration of an atom or ion (full and shorthand)
- use the electrons-in-boxes notation and describe s and p orbital shapes

Method — Sub-shells and filling order

sub-shell	orbitals	max electrons
s	1	2
p	3	6
d	5	10

Method — Sub-shells and filling order



An energy-level diagram of the sub-shells from 1s to 4p, with 4s just below 3d

Method — Electronic configuration

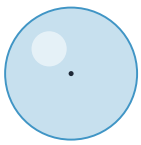
For iron (Fe, $Z = 26$): $1s^2\,2s^2\,2p^6\,3s^2\,3p^6\,3d^6\,4s^2$, or shorthand $[\mathrm{Ar}]\,3d^6\,4s^2$. For a transition-metal ion, remove the **4s electrons first**: $Fe^{3+} = [\mathrm{Ar}]\,3d^5$.

opposite spins

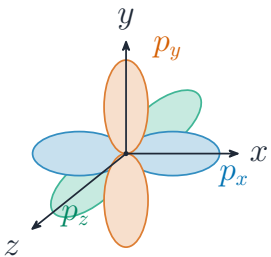
filled singly first, parallel spins

1s 2s 2p

Method — Orbital shapes



s orbital
(sphere)



p orbitals
(two lobes each)

A spherical s orbital and three dumbbell p orbitals along the x, y and z axes

Practice 2.1 ▪ 2 marks

State the maximum number of electrons in (a) a p sub-shell and (b) a d sub-shell.

Solution 2.1

Worked steps

(a) 6; (b) 10 B1 *each*.

Practice 2.2 ▪ 1 mark

Write the full electronic configuration of a calcium atom ($Z = 20$).

Solution 2.2

Method: Electronic configuration

Worked steps

$1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 4s^2$ B1.

Exam-style 3.1 ▪ 1 mark

Which sub-shell is filled **before** the 3d sub-shell?

A 3p

B 4s

C 4p

D 4d

Solution 3.1

Method: Sub-shells and filling order

A 3p

B 4s ✓

C 4p

D 4d

Worked steps

B. 4s is slightly lower in energy than 3d, so it fills first.

Exam-style 3.2 ▪ 1 mark

What is the shape of a p orbital?

A spherical

B dumbbell (two lobes)

C a flat ring

D a cube

Solution 3.2

A spherical

B dumbbell (two lobes) ✓

C a flat ring

D a cube

Worked steps

B. A p orbital is a dumbbell (two lobes).

Exam-style 3.3 ▪ 1 mark

(a) Write the shorthand electronic configuration of an iron atom ($Z = 26$).
(b) Write the electronic configuration of the Fe^{3} ion, and explain which electrons are lost first.

Solution 3.3

Method: Electronic configuration

Worked steps

(a) $[\mathrm{Ar}]\,3\mathrm{d}^6\,4\mathrm{s}^2$ B1.
(b) $[\mathrm{Ar}]\,3\mathrm{d}^5$ B1; the 4s electrons are removed before the 3d electrons B1.

Exam-style 3.4 ▪ 2 marks

Using electrons-in-boxes, explain why the three 2p electrons of nitrogen occupy separate orbitals with parallel spins.

Solution 3.4

Method: Electronic configuration

Worked steps

each electron is negative and they repel M1; occupying separate orbitals keeps them apart, lowering repulsion — the lowest-energy (most stable) arrangement A1.