A-LEVEL CHEMISTRY • EXERCISE SHEET

1.3 Electrons, energy levels and atomic orbitals

Name: _____ Class: _____ Date: _____ **Total: 10 marks**

KEY WORDS electronic configuration 电子排布 • orbital 轨道 • sub-shell 亚层 • shell 壳层 • spin 自旋

Objective

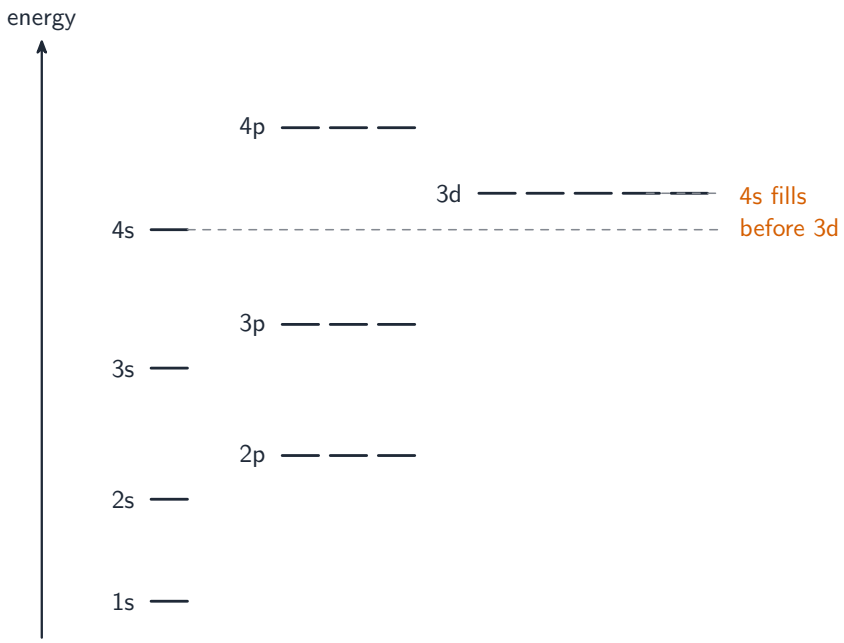
Build the skills to answer exam questions on **electrons, energy levels and atomic orbitals** — **shells, sub-shells and orbitals** 壳层、亚层和轨道, the order of filling, **electronic configurations** 电子排布, and orbital shapes.

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

1 Worked examples

Sub-shells and filling order

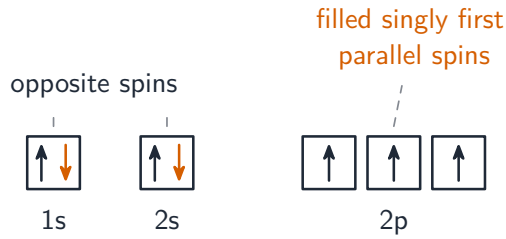


Order of rising energy: 1s < 2s < 2p < 3s < 3p < 4s < 3d < 4p (4s fills before 3d)

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

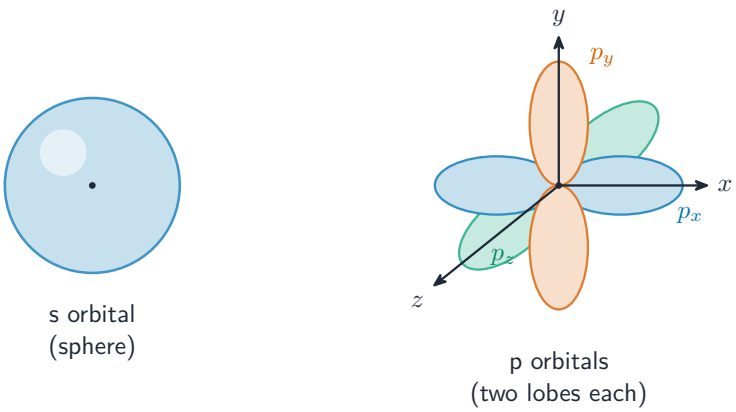
Electronic configuration

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**: $Fe^{3+} = [\mathrm{Ar}]\,3d^5$.



Paired electrons point opposite ways; within a sub-shell, orbitals fill singly first (parallel spins)

Orbital shapes



An s orbital is a sphere; each p orbital is a dumbbell along one axis

2 Practice

2.1 State the maximum number of electrons in (a) a p sub-shell and (b) a d sub-shell. [2]

2.2 Write the full electronic configuration of a calcium atom ($Z = 20$). [1]

3 Exam-style questions

3.1 Which sub-shell is filled **before** the 3d sub-shell? [1]

- **A** 3p
- **B** 4s
- **C** 4p
- **D** 4d

3.2 What is the shape of a p orbital? [1]

- **A** spherical
- **B** dumbbell (two lobes)
- **C** a flat ring
- **D** a cube

3.3 (a) Write the shorthand electronic configuration of an iron atom ($Z = 26$). [1]

(b) Write the electronic configuration of the Fe^{3+} ion, and explain which electrons are lost first. [2]

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

Solutions

2.1 (a) 6; (b) 10.

2.2 $1s^2\,2s^2\,2p^6\,3s^2\,3p^6\,4s^2$.

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

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

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

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