A-LEVEL CHEMISTRY • EXERCISE SHEET

1.4 Ionisation energy

Name: _____ Class: _____ Date: _____ **Total: 11 marks**

Objective

Build the skills to answer exam questions on **ionisation energy** 电离能—defining the **first ionisation energy** 第一电离能, writing equations, explaining trends, and using **successive ionisation energies** 逐级电离能.

You must be able to:

- define first ionisation energy and write equations for first and successive ionisations
- explain trends across a period (and the dips) and down a group
- deduce electronic configuration and group from successive ionisation energy data

1 Worked examples

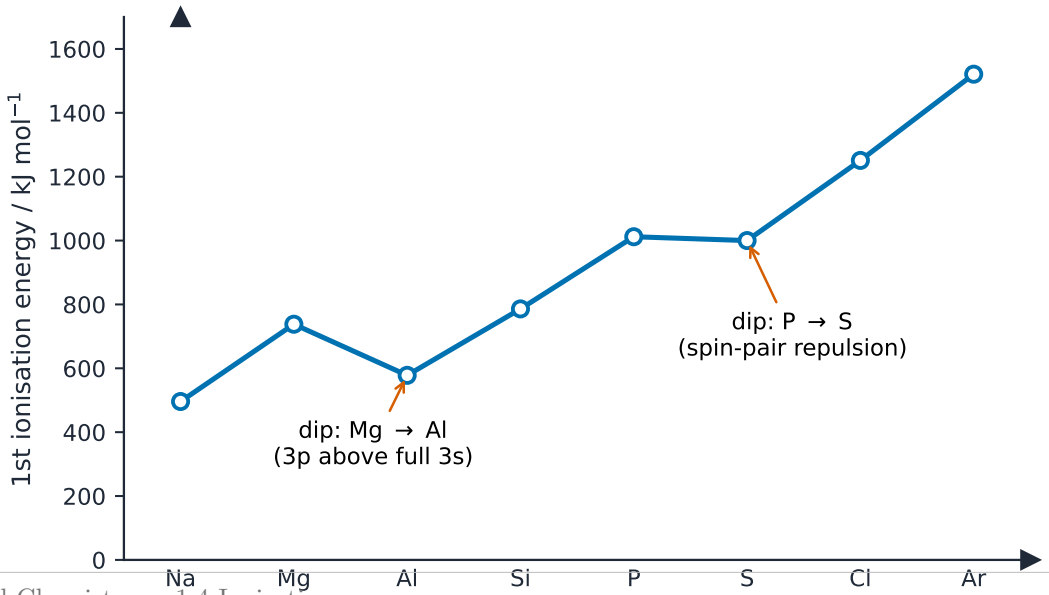
First ionisation energy

The energy to remove one electron from each atom in one mole of **gaseous** atoms, forming one mole of gaseous +1 ions:

$$\mathrm{X(g)} \rightarrow \mathrm{X^{+}(g)} + \mathrm{e^{-}}$$

It depends on **nuclear charge** (more protons → higher), **atomic radius** (further out → lower), and **shielding** (more inner shells → lower).

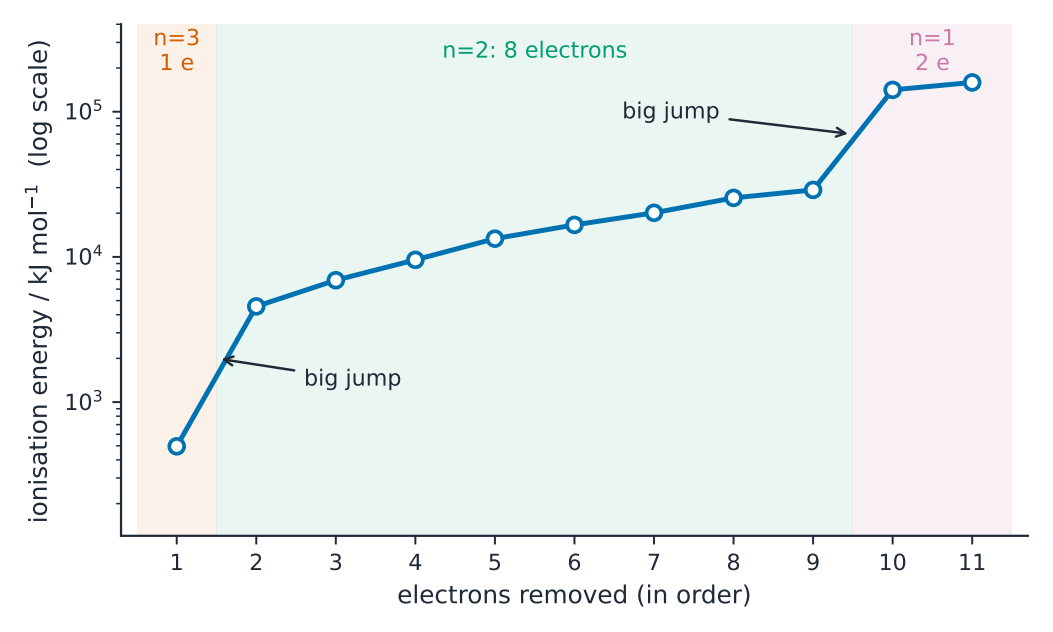
Trends across Period 3



IE rises across the period but dips at Al (3p above 3s) and at S (spin-pair repulsion) —evidence for sub-shells

It rises across a period (rising nuclear charge, similar shielding) and falls down a group (more shielding, larger radius). The two dips: **Mg→Al** (Al's electron is in a higher 3p sub-shell) and **P→S** (S has a paired 3p electron, so spin-pair repulsion makes it easier to remove).

■ **Successive ionisation energies**



Big jumps reveal the shell structure (Na = 2,8,1); the electrons removed before the first big jump = the group number

2 Practice

2.1 Write an equation, with state symbols, for the first ionisation energy of magnesium. [2]

2.2 State **two** factors that affect the size of an ionisation energy. [2]

3 Exam-style questions

3.1 Why is the second ionisation energy of an element always larger than the first? [1]

- **A** the atom is now a gas
- **B** the electron is removed from a more positive ion
- **C** there are more neutrons
- **D** shielding increases

3.2 The first ionisation energy of sulfur is lower than that of phosphorus because: [1]

- **A** sulfur has fewer protons
- **B** sulfur's removed electron is one of a pair in a 3p orbital (spin-pair repulsion)
- **C** sulfur is in a different period
- **D** sulfur has more shielding

3.3 Explain why the first ionisation energy decreases down Group 2. [3]

3.4 The first six ionisation energies of an element (kJ mol ^{1}) are: 590, 1150, 4940, 6480, 8120, 10500. Deduce which group the element is in, and explain your answer. [2]

4 Go further

You are now ready for the real exam questions on this subtopic. Open the **1.4 Ionisation energy** past-paper sheet in the Library, or try these in **Practice mode**:

- 9701/11 N25 —Q2 (ionisation energy)
- 9701/12 N25 —Q7 (ionisation energy trends)
- 9701/13 N25 —Q2 (successive ionisation energies)

Solutions

2.1 $Mg(g) \rightarrow Mg^{+}(g) + e^{-}$.

2.2 any two: nuclear charge; atomic radius; shielding; (spin-pair repulsion).

3.1 B. The electron is pulled from a more positive ion, needing more energy.

3.2 B. The paired 3p electron in sulfur is easier to remove (spin-pair repulsion).

3.3 down the group each element has more shells, so more shielding and a larger atomic radius; the outer electron is held less tightly, so it is easier to remove.

3.4 Group 2; there is a large jump between the 2nd and 3rd ionisation energies, showing 2 easily-removed outer electrons before reaching a full inner shell.