▶ Video explanation (YouTube Short)

Atomic Size and Ionisation Enthalpy across the 3d Series

From chromium to copper the nucleus gains five protons, yet the metallic radius stays almost the same (129 pm and 128 pm). The reason is **shielding by the inner d electrons**.

1. Why size changes so little (NCERT 4.3.2)

- Across a period the nuclear charge rises by one at each step.
- In a transition series the new electron enters the **inner (n−1)d** subshell, which shields the outer ns electrons.
- The extra pull and the extra shielding nearly balance, so the radius decreases only slightly and stays almost constant in the middle of the series.

	Sc	Ti	V	Cr	Mn	Fe	Co	Ni	Cu	Zn
Metallic radius / pm	164	147	135	129	137	126	125	125	128	137
1st IE / kJ mol^{-1}	631	656	650	653	717	762	758	736	745	906

2. Ionisation enthalpy (NCERT 4.3.3)

The first ionisation enthalpy rises along the series, but slowly: 631 (Sc) → 906 (Zn) kJ/mol. Across period 3 it roughly triples (Na 496 → Ar 1520). Zn is highest because its $3d^{10}\ 4s^2$ configuration is very stable. Small irregularities come from the changing stability of d configurations.

3. Second and third series

Radii increase from 3d to 4d, but the 4d and 5d elements of a group are almost the same size (Zr 160 pm, Hf 159 pm): the lanthanoid contraction.

Solved example

Q. Why does the first ionisation enthalpy increase so little from Sc to Cu?
A. Each added electron enters the inner 3d subshell and shields the 4s electron from the added nuclear charge, so the effective pull on the 4s electron rises only slightly.

Key takeaways

- New electrons enter (n−1)d and shield ns: size and IE change slowly.
- Radius: small fall, nearly constant in the middle.
- IE: slow rise; Zn highest (stable $3d^{10}4s^2$).

Practice questions

1. (MCQ) Across the 3d series, atomic radii: (a) increase sharply (b) decrease sharply (c) change only slightly (d) double

2. (MCQ) The highest first ionisation enthalpy in the 3d series is shown by: (a) Sc (b) Cr (c) Cu (d) Zn
3. (MCQ) Zr and Hf have almost the same radius because of: (a) the inert pair effect (b) lanthanoid contraction (c) hydrogen bonding (d) d-d transitions
4. (Very short) Into which subshell does the added electron go across the 3d series?
5. (Very short) Give the first ionisation enthalpies of Sc and Zn.
6. (Short) Why is the change in atomic radius across a transition series small?
7. (Short) Why is the first ionisation enthalpy of zinc high?
8. (Application) Compare the rise in first IE across the 3d series with that across period 3.

Answer key

1. (c).
2. (d) Zn.
3. (b).
4. The inner 3d subshell.
5. Sc 631, Zn 906 kJ/mol.
6. The added d electron shields the outer 4s electrons, nearly balancing the increased nuclear charge.
7. Its $3d^{10}\ 4s^2$ configuration (full 3d, full 4s) is very stable.
8. 3d: 631 → 906 (about 1.4 times); period 3: 496 → 1520 (about 3 times).

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