▶ Video explanation (YouTube Short)

Why Transition Metals Show Variable Oxidation States

Manganese alone shows every oxidation state from +2 to +7. The reason: **the ns and (n−1)d electrons are close in energy, so both can take part in bonding**.

1. The reason (NCERT 4.3.4)

An atom can lose (or share) its ns electrons and then, one at a time, its (n−1)d electrons. Each extra electron used raises the oxidation state by one.

2. Manganese: +2 to +7

Mn = [Ar] $3d^5$ $4s^2$: seven electrons available. Losing the two 4s gives Mn^{2+} (+2); using all seven gives +7, as in $KMnO_4$. Examples: Mn^{2+} salts (+2, pale pink), MnO_2 (+4, dark solid), $KMnO_4$ (+7, purple).

3. Across the 3d series

Sc	Ti	V	Cr	Mn	Fe	Co	Ni	Cu	Zn
+3	+2 to +4	+2 to +5	+2 to +6	+2 to +7	+2, +3, +4, +6	+2 to +4	+2 to +4	+1, +2	+2

- The **most** oxidation states are near the **middle** (Mn). At the start, Sc has few electrons to use (only +3); at the end, Zn's full d^{10} leaves only +2.
- Up to Mn, the highest state = number of 4s + 3d electrons: Sc +3, Ti +4, V +5, Cr +6, Mn +7.

4. Steps of one

Oxidation states of transition elements differ by **one** (Fe^{2+}/Fe^{3+}, Cu^{+}/Cu^{2+}, V +2, +3, +4, +5). In the p-block they usually differ by **two** (Sn^{2+}/Sn^{4+}, Pb^{2+}/Pb^{4+}).

Solved example

Q. Find the oxidation state of Mn in $KMnO_4$.
A. K is +1 and each O is −2: (+1) + x + 4(−2) = 0, so x = +7.

Key takeaways

- ns + (n−1)d electrons both bond → variable oxidation states.
- Most in the middle (Mn +2 to +7); Sc +3, Zn +2 only.
- States change in steps of one.

Practice questions

1. (MCQ) The element showing the most oxidation states in the 3d series is: (a) Sc (b) Mn (c) Cu (d) Zn
2. (MCQ) The oxidation state of Mn in MnO_2 is: (a) +2 (b) +3 (c) +4 (d) +7

3. (MCQ) Zinc shows only: (a) +1 (b) +2 (c) +3 (d) +4
4. (Very short) Why can transition metals use both ns and (n−1)d electrons?
5. (Very short) What is the highest oxidation state of vanadium?
6. (Short) Why does Sc show only +3?
7. (Short) How does the variability of oxidation states differ between transition and p-block elements?
8. (Application) Find the oxidation state of Cr in $K_2Cr_2O_7$.

Answer key

1. (b) Mn.
2. (c) +4.
3. (b) +2.
4. The ns and (n−1)d orbitals are very close in energy.
5. +5 ($3d^3\ 4s^2$: five electrons).
6. Sc ($3d^1\ 4s^2$) has only three electrons to lose; Sc^{3+} then has the stable argon configuration.
7. Transition elements: states differ by one; p-block: usually by two.
8. 2(+1) + 2x + 7(−2) = 0, so x = +6.

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