1. Introduction and Position in the Periodic Table

The **d-block elements** (Groups 3 to 12) occupy the large middle section of the periodic table, flanked by s- and p-blocks. The name "transition metals" refers to their position and the transition of properties between the highly reactive s-block metals and the elements of the p-block.

The **f-block elements** (Lanthanoids and Actinoids) are placed in a separate panel at the bottom of the periodic table. They are also known as "inner transition metals."

2. Electronic Configurations

- **d-block elements:** The general outer electronic configuration is $(n-1)d^{1-10}ns^{1-2}$
  (Exceptions occur, such as Cr and Cu in the 3d series, due to the extra stability of half-filled and fully-filled d-orbitals).
- **f-block elements:** The general outer electronic configuration is $(n-2)f^{1-14}(n-1)d^{0-1}ns^2$

3. General Properties of Transition Elements (d-block)

Physical Properties

Nearly all transition elements display typical metallic properties: high tensile strength, ductility, malleability, high thermal and electrical conductivity, and metallic luster. They generally have high melting and boiling points due to strong metallic bonding involving $(n-1)d$ electrons in addition to ns electrons.

Atomic and Ionic Sizes & Lanthanoid Contraction

- Generally, atomic radii decrease moving left to right in a series until near the end, where electron-electron repulsion causes a slight increase.
- **Lanthanoid Contraction:** The nearly identical atomic and ionic radii of the elements of the 4d and 5d series (e.g., Zr and Hf). This occurs due to the imperfect shielding of one 4f electron by another in the same subshell, causing a steady decrease in size across the lanthanoid series.

Ionisation Enthalpies

Ionisation enthalpies generally increase from left to right across a given transition series due to the increasing nuclear charge. However, the trend is irregular due to the varying stabilities of different d-orbital configurations.

Oxidation States

Transition elements exhibit a large variety of oxidation states in their compounds due to the small energy difference between $(n-1)d$ and ns orbitals.

- The highest oxidation state shown by any transition element is +8 (e.g., Os and Ru).
- **Stability of Higher Oxidation States:** The highest oxidation states are usually stabilized by highly electronegative elements like oxygen and fluorine (e.g., OsO_4, V_2O_5).

Standard Electrode Potential ($E^\ominus$)

- **Trend in M^{2+}/M:** Generally becomes less negative across the series, though Cu has a positive $E^\ominus$ value ($+0.34\ \text{V}$), meaning it cannot displace hydrogen from acids.
- **Trend in M^{3+}/M^{2+}:** A low value indicates high stability of the M^{3+} state (e.g., Fe^{3+} is stable due to its d^5 configuration, so its reduction potential is relatively high compared to Cr^{3+}).

Magnetic Properties

Substances with unpaired electrons are **paramagnetic** (attracted by a magnetic field). The magnetic moment (μ) is calculated using the "spin-only" formula:

$$\mu = \sqrt{n(n+2)} \text{ B.M.}$$

Where n is the number of unpaired electrons, and B.M. is the Bohr Magneton unit.

Formation of Coloured Ions

Most transition metal compounds are colored in their solid or solution states. This is primarily due to **d-d transitions**. When light falls on a transition metal complex, electrons are excited from lower energy d-orbitals to higher energy d-orbitals, absorbing specific wavelengths of light. The transmitted light shows the complementary color.

Catalytic, Interstitial, and Alloy Formation

- **Catalytic Properties:** They are excellent catalysts (e.g., V_2O_5 in the Contact Process, finely divided Fe in Haber's Process) due to their ability to adopt multiple oxidation states and form complexes.
- **Interstitial Compounds:** Small atoms like H, C, or N get trapped inside the crystal lattices of metals. These are generally non-stoichiometric, chemically inert, and very hard.
- **Alloy Formation:** Because the atomic radii of transition metals are very similar, they can easily replace each other in the crystal lattice, forming solid solutions (alloys) like brass, bronze, and steel.

4. Nature of Oxides & Oxoanions

- Oxides in lower oxidation states are generally **basic**.
- Oxides in intermediate oxidation states are **amphoteric** (e.g., Cr_2O_3).
- Oxides in the highest oxidation states are **acidic** (e.g., Mn_2O_7, CrO_3). They dissolve in water to form oxoacids.

5. Important Compounds of Transition Elements

Potassium Dichromate ($K_2Cr_2O_7$)

A very strong oxidizing agent, heavily used in volumetric analysis.

- **Structure:** The dichromate ion consists of two tetrahedral CrO_4 units sharing one corner.
- **Oxidizing Action (Acidic Medium):** $Cr_2O_7^{2-} + 14H^+ + 6e^- \rightarrow 2Cr^{3+} + 7H_2O$
  It oxidizes iodides to iodine, sulfides to sulfur, and Iron(II) to Iron(III).

Potassium Permanganate ($KMnO_4$)

A dark purple crystalline solid and a powerful oxidizing agent.

- **Structure:** The manganate and permanganate ions are tetrahedral.
- **Oxidizing Action (Acidic Medium):** $MnO_4^- + 8H^+ + 5e^- \rightarrow Mn^{2+} + 4H_2O$

- **Oxidizing Action (Neutral or Faintly Alkaline Medium):** $MnO_4^- + 2H_2O + 3e^- \rightarrow MnO_2 + 4OH^-$

6. f-block Elements: Lanthanoids & Actinoids

Lanthanoids (4f series)

- **General Properties:** Silvery-white soft metals that tarnish rapidly in air.
- **Oxidation States:** The most common and stable oxidation state is **+3**. However, +2 and +4 are also exhibited by some elements to achieve stable f^0, f^7, or f^{14} configurations (e.g., Ce^{4+}, Eu^{2+}).
- **Atomic & Ionic Sizes:** Exhibit lanthanoid contraction (steady decrease in size).

Actinoids (5f series)

- **General Properties:** All are radioactive. The earlier members have relatively long half-lives, but later members are highly radioactive with very short half-lives.
- **Oxidation States:** Show a greater range of oxidation states compared to lanthanoids because the 5f, 6d, and 7s levels are of comparable energies. The +3 state is common, but higher states like +4, +5, +6, and +7 are heavily utilized.

Comparison of Actinoids with Lanthanoids

1. **Contraction:** The "actinoid contraction" from element to element is greater than the lanthanoid contraction due to poorer shielding by 5f electrons compared to 4f electrons.
2. **Oxidation States:** Actinoids exhibit a larger number of variable oxidation states.
3. **Radioactivity:** All actinoids are radioactive; among lanthanoids, only Promethium is radioactive.
4. **Complex Formation:** Actinoids have a much higher tendency to form complexes than lanthanoids.

7. Applications of d- and f-Block Elements

- **Iron and Steel:** Construction materials.
- **Catalysts:** TiO_2 (Ziegler-Natta catalyst), V_2O_5 (oxidation of SO_2), $PdCl_2$ (Wacker process).
- **Coinage Metals:** Cu, Ag, Au.
- **Photography:** $AgBr$ is a light-sensitive material.
- **Nuclear Energy:** Uranium and Plutonium (actinoids) are used as nuclear fuels.
- **Mischmetall:** An alloy of lanthanoids used to produce bullets, shells, and lighter flints.