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CUET · CHEMISTRY · CLASS XI · CODE 306

Classification of Elements and Periodicity in Properties

CUET unit: Classification of Elements and Periodicity in Properties

By **UniDrill** · NCERT-grounded study material

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📌 Snapshot

- Establishes WHY classification of 114 known elements is necessary and traces the historical evolution from Dobereiner's Triads to Newlands' Octaves to Mendeleev's table and finally the Modern Periodic Law (Moseley).
- Anchors the Modern Periodic Law on atomic number (Z) — the fundamental property — and shows how the long form of the periodic table (7 periods, 18 groups, s/p/d/f blocks) is a direct consequence of electronic configuration.
- Covers IUPAC nomenclature for super-heavy elements ($Z > 100$) using the un-nil-bi-tri root system.
- Develops periodic trends in atomic/ionic radii, ionisation enthalpy, electron gain enthalpy and electronegativity (with their anomalies) and links them to valence, oxidation states and metallic/non-metallic reactivity.
- CUET routinely lifts factual recall (Mendeleev predictions, IUPAC names, block identification) and trend-comparison questions (IE order, radius order, $\Delta_{eg}H$ order) directly from this chapter.

📖 Detailed Notes

2.1 Core concepts

- Need for classification: with 114 known elements (in 1800 only 31, by 1865 = 63), individual study of each element and its compounds is unfeasible; classification rationalises known facts and predicts new ones (NCERT §3.1, p. 74).
- Dobereiner's Triads (early 1800s): groups of three elements where the middle element's atomic weight is approximately the mean of the other two, and its properties also lie in between — e.g., Li(7)/Na(23)/K(39); Ca(40)/Sr(88)/Ba(137); Cl(35.5)/Br(80)/I(127). Worked for only a few sets, dismissed as coincidence (NCERT §3.2, p. 75, Table 3.1).
- De Chancourtois (1862): a French geologist who arranged elements in increasing atomic weight on a cylindrical table — first to notice periodic recurrence; received little attention (NCERT §3.2, p. 75).
- Newlands' Law of Octaves (1865): elements arranged by increasing atomic weight show that every eighth element resembles the first (like musical octaves); valid only up to calcium; Davy Medal awarded 1887 in retrospect after Mendeleev's success (NCERT §3.2, p. 75, Table 3.2).

- Mendeleev (1869, with Lothar Meyer working independently): proposed "the properties of the elements are a periodic function of their atomic weights"; arranged elements in rows and columns by increasing atomic weight, placing elements of similar properties in the same vertical group — even violated atomic-weight order where required (e.g., put iodine after tellurium) and left gaps for undiscovered elements called Eka-aluminium (gallium) and Eka-silicon (germanium) with predicted properties (NCERT §3.2, pp. 76–77, Table 3.3).
- Mendeleev's predictions vs found values — Eka-aluminium: predicted atomic weight 68, density 5.9, oxide E_2O_3, chloride ECl_3; gallium found = 70, 5.94, Ga_2O_3, $GaCl_3$. Eka-silicon: predicted 72, 5.5, EO_2, ECl_4; germanium found = 72.6, 5.36, GeO_2, $GeCl_4$ — remarkable predictive power (NCERT §3.2, p. 76, Table 3.3).
- Defects of Mendeleev's table: anomalous pairs (Ar/K, Co/Ni, Te/I) violate atomic-weight order; H placed in two groups (1 and 17); no place for isotopes; lanthanoids could not be accommodated; reasons unknown until Moseley (NCERT §3.2, p. 77).
- Modern Periodic Law: Henry Moseley (1913) plotted $\sqrt{\nu}$ of characteristic X-rays vs Z and obtained a straight line — showing atomic number, not atomic mass, is the fundamental property. Modern law: "the physical and chemical properties of the elements are periodic functions of their atomic numbers" (NCERT §3.3, p. 78).
- Long form of periodic table: 7 periods and 18 groups (IUPAC numbering 1-18 replaces older IA-VIIA, VIII, IB-VIIB, 0). Periods contain 2, 8, 8, 18, 18, 32, 32 elements; period number = highest n of valence shell; 14 lanthanoids (period 6, Ce-Lu) and 14 actinoids (period 7, Th-Lr) placed in separate panels at the bottom (NCERT §3.3, p. 78).
- Period 1 = 2 elements (H, He); Period 2 = 8 (Li-Ne); Period 3 = 8 (Na-Ar); Period 4 = 18 (K-Kr, includes first transition series 3d); Period 5 = 18 (Rb-Xe, 4d); Period 6 = 32 (Cs-Rn, with 4f and 5d); Period 7 = 32 (Fr-Og, 5f and 6d). Each period begins with an alkali metal (ns^1) and ends at a noble gas (ns^2np^6, except He = $1s^2$).
- IUPAC nomenclature for Z > 100: digit roots — 0=nil(n), 1=un(u), 2=bi(b), 3=tri(t), 4=quad(q), 5=pent(p), 6=hex(h), 7=sept(s), 8=oct(o), 9=enn(e); add suffix "ium". Example: Z = 120 → un-bi-nil-ium = Unbinilium (Ubn) (NCERT §3.4, pp. 80, Table 3.4 and Problem 3.1).
- Permanent names assigned by IUPAC: 101 Mendelevium (Md), 102 Nobelium (No), 103 Lawrencium (Lr), 104 Rutherfordium (Rf), 105 Dubnium (Db), 106 Seaborgium (Sg), 107 Bohrium (Bh), 108 Hassium (Hs), 109 Meitnerium (Mt), 110 Darmstadtium (Ds), 111 Roentgenium (Rg), 112 Copernicium (Cn), 113 Nihonium (Nh), 114 Flerovium (Fl), 115 Moscovium (Mc), 116 Livermorium (Lv), 117 Tennessine (Ts), 118 Oganesson (Og) (NCERT §3.4, p. 80, Table 3.5).
- Electronic configuration determines block: s-block (Groups 1, 2 — ns^1, ns^2), p-block (Groups 13-18 — ns^2np^1 to ns^2np^6), d-block (Groups 3-12 — $(n-1)d^{1-10}\ ns^{0-2}$), f-block (lanthanoids and actinoids — $(n-2)f^{1-14}\ (n-1)d^{0-1}\ ns^2$). Helium is formally s-block ($1s^2$)

but placed with noble gases (Group 18) because of its closed valence shell; hydrogen is unique and placed with Group 1 (NCERT §3.5–§3.6, pp. 81–83).

- s-block: reactive metals, low IE, form 1+ (alkali) or 2+ (alkaline earth) ions; reactivity increases down the group; compounds predominantly ionic (except Li, Be — diagonal relationship with Mg, Al); colour flame tests are typical (NCERT §3.6.1, p. 84).
- p-block: representative elements (with s-block); noble gases (Group 18) ns^2np^6 — chemically inert; halogens (17) and chalcogens (16) have highly negative $\Delta_{eg}H$; non-metallic character increases left→right across period, metallic character increases down a group; oxidation states range from –3 to +5/+6/+7 (NCERT §3.6.2, p. 84).
- d-block (transition elements): Groups 3-12; coloured ions (d-d transitions), variable oxidation states, paramagnetism (unpaired d electrons), catalytic activity (e.g., V_2O_5, Fe, Ni); Zn, Cd, Hg $[(n-1)d^{10}ns^2]$ don't show most transition properties as their d subshells are full in atom and common ions (NCERT §3.6.3, p. 84).
- f-block (inner transition / lanthanoids Z 58-71 and actinoids Z 90-103): outer configuration $(n-2)f^{1-14}\ (n-1)d^{0-1}\ ns^2$; all metals; actinoids are radioactive; elements after uranium (Z > 92) are transuranium elements, all synthetic (NCERT §3.6.4, p. 84).
- Metals/non-metals/metalloids: metals (>78% of elements) on left, usually solids with high m.p./b.p., malleable, ductile, conductors; non-metals on top-right, often solids/gases with low m.p./b.p., brittle, poor conductors; metalloids (Si, Ge, As, Sb, Te) border the zig-zag line with intermediate properties (NCERT §3.6.5, p. 85).
- Atomic radius — covalent radius (half the bond distance of a homonuclear single-bonded molecule, e.g., Cl–Cl = 198 pm → r = 99 pm), metallic radius (half the internuclear distance in metallic crystal, e.g., Cu–Cu = 256 pm → r = 128 pm — metallic radius > covalent radius for the same element), van der Waals radius (for noble gases, monoatomic). Trend: decreases across a period (effective nuclear charge increases) and increases down a group (new shells added, increased shielding) (NCERT §3.7.1(a), pp. 85–87, Tables 3.6a, 3.6b).
- Ionic radius — cation < parent atom (fewer electrons, same nuclear charge, less e-e repulsion); anion > parent atom (added electrons, more repulsion). Isoelectronic species (same number of electrons, e.g., O^{2-}, F^-, Na^+, Mg^{2+} all have 10 electrons): smaller radius for higher positive nuclear charge — $Mg^{2+} < Na^+ < F^- < O^{2-}$ (NCERT §3.7.1(b), p. 87).
- Ionisation enthalpy (Δ_iH): energy to remove the most loosely bound electron from a gaseous atom; $X(g) \rightarrow X^+(g) + e^-$; always positive; expressed in kJ mol⁻¹. IE2 > IE1, IE3 > IE2 etc. because each successive electron is removed from a more positively charged species (NCERT §3.7.1(c), p. 87, Eqs. 3.1–3.2).
- Δ_iH trends: increases across a period (Z increases, atomic size decreases, shielding does not compensate); decreases down a group (size increases, shielding outweighs Z). Maxima at noble gases (closed shells), minima at alkali metals (NCERT §3.7.1(c), pp. 88–89, Figs. 3.5, 3.6).

- ΔiH anomalies in period 2: B (Z = 5) has slightly lower IE1 than Be (Z = 4) — because the 2p electron of B is more shielded than the penetrating 2s electron of Be. O has lower IE1 than N — because nitrogen has three unpaired 2p electrons (half-filled, extra stability); in O, two electrons must pair in one 2p orbital, giving extra e-/e- repulsion (NCERT §3.7.1(c), p. 89). The order is Be > B and N > O.
- Electron gain enthalpy (ΔegH): enthalpy change when a gaseous atom adds an electron — $X(g) + e^- \rightarrow X^-(g)$. Negative if energy is released (halogens, ΔegH = -328 (F), -349 (Cl), -325 (Br), -295 (I), -270 (At) kJ mol^{-1}) — most negative for Cl (not F, due to small 2p orbital → extra electron-electron repulsion). Positive for noble gases (He +48, Ne +116, Ar +96 kJ mol^{-1}) because the added electron must go to the next higher shell (NCERT §3.7.1(d), pp. 89–90, Table 3.7).
- Electronegativity (EN): qualitative ability of a bonded atom to attract shared electrons; NOT a measurable quantity. Scales: Pauling (most widely used, F arbitrarily assigned 4.0), Mulliken-Jaffe, Allred-Rochow. EN increases across a period (Li 1.0 → F 4.0; Na 0.9 → Cl 3.0) and decreases down a group (F 4.0 → At 2.2; Li 1.0 → Cs 0.7). EN is directly proportional to non-metallic character and inversely proportional to metallic character (NCERT §3.7.1(e), pp. 90–92, Tables 3.8a, 3.8b, Fig. 3.7).
- Valence and oxidation state: for representative elements valence = number of valence electrons (Groups 1, 2, 13, 14) OR 8 – number of valence electrons (Groups 15–17); transition elements show variable valences. Oxidation state assigned by electronegativity, e.g., in OF_2 F = –1, O = +2; in Na_2O Na = +1, O = –2 (NCERT §3.7.2(a), pp. 92–93, Table 3.9).
- Anomalous properties of second-period elements: first member of each s/p group (Li, Be, B, C, N, O, F) differs from later members because of (i) small size, (ii) large charge/radius ratio, (iii) high EN, (iv) only 4 valence orbitals (2s, 2p) — no d orbitals — so maximum covalency is 4 (BF_4^-) while later members can expand octet (AlF_6^{3-}). They also show stronger pπ-pπ multiple bonding (C=C, N=N, C=O) (NCERT §3.7.2(b), pp. 93–94).
- Diagonal relationship: Li resembles Mg (chemical similarity, e.g., both form normal oxide Li_2O/MgO not peroxide, both form nitrides with N_2), Be resembles Al (both amphoteric oxides, similar electronegativity 1.5/1.5) — the first member of a group shows similarities with the second member of the next group (NCERT §3.7.2(b), p. 93).
- Periodic trends in reactivity: high chemical reactivity at the two ends of a period (alkali metals lose electrons easily; halogens gain electrons easily); low in the centre. Oxides on extreme left are most basic (Na_2O), extreme right most acidic (Cl_2O_7); middle ones amphoteric (Al_2O_3, As_2O_3) or neutral (CO, NO, N_2O); metallic character increases down a group (NCERT §3.7.3, pp. 94–95).

2.2 Definitions to memorise

Term	Definition	Page
Modern Periodic Law	The physical and chemical properties of elements are periodic functions of their atomic numbers.	p. 78
Mendeleev's Periodic Law	The properties of the elements are a periodic function of their atomic weights.	p. 76
Dobereiner's Triad	Group of three elements where middle atomic weight ≈ mean of the other two (Li-Na-K).	p. 75
Newlands' Octave	Every eighth element resembles the first when arranged by atomic weight (valid up to Ca).	p. 75
Group	A vertical column of the periodic table; elements have similar outer electronic configurations.	p. 78
Period	A horizontal row; the period number equals the highest principal quantum number (n) of its elements.	p. 78
s-block	Groups 1, 2 — outermost ns^1 or ns^2	p. 82
p-block	Groups 13-18 — outermost ns^2np^1 to ns^2np^6	p. 82
d-block	Groups 3-12 — $(n-1)d^{1-10}\ ns^{0-2}$ configurations	p. 82
f-block	Lanthanoids and actinoids — $(n-2)f^{1-14}\ (n-1)d^{0-1}\ ns^2$	p. 82
Covalent radius	Half the distance between the nuclei of two like atoms bonded by a single covalent bond (e.g., Cl–Cl 198 pm → 99 pm).	p. 86
Metallic radius	Half the inter-nuclear distance separating metal cores in the metallic crystal (e.g., Cu–Cu 256 pm → 128 pm).	p. 86
van der Waals radius	Half the distance between nuclei of neighbouring non-bonded atoms in the solid state (used for noble gases).	p. 86
Isoelectronic species	Atoms/ions with the same number of electrons (e.g., O^{2-}, F^-, Na^+, Mg^{2+} all have 10 electrons).	p. 87
Ionisation enthalpy ($\Delta_i H$)	The energy required to remove the most loosely bound electron from an isolated gaseous atom in its ground state — $X(g) \rightarrow X^+(g) + e^-$.	p. 87
Successive ionisation enthalpy	IE2 > IE1, IE3 > IE2 because each subsequent electron is pulled from a more positively charged species.	p. 87
Electron gain enthalpy ($\Delta_{eg}H$)	The enthalpy change when an electron is added to a neutral gaseous atom — $X(g) + e^- \rightarrow X^-(g)$.	p. 89
Electronegativity	A qualitative measure of the ability of an atom in a chemical compound to attract shared electrons to itself; not directly measurable.	p. 90
Valence	Number of valence electrons (Groups 1, 2, 13, 14) or 8 minus the number of valence electrons (Groups 15–17).	p. 92

Term	Definition	Page
Transuranium elements	Elements with atomic numbers above 92 (after uranium); all man-made and radioactive.	p. 84
Diagonal relationship	Similarity in properties between the first member of a group and the second member of the next group (Li-Mg, Be-Al).	p. 93
Metalloid	Element along the zig-zag line (Si, Ge, As, Sb, Te) with intermediate metallic/non-metallic character.	p. 85
Effective nuclear charge	Net positive charge experienced by valence electrons after accounting for shielding by inner electrons.	p. 87

2.3 Diagrams / processes to remember

- **Fig. 3.1 (p. 77)** — Mendeleev's original Periodic System of the Elements showing groups (I–VIII) and series with horizontal "typical elements" (Mg, P) anchoring each group; useful for spotting the gaps left for Eka-aluminium (between Al and In), Eka-silicon (between Si and Sn) and Eka-boron (between B and Y), all later filled by Ga, Ge, Sc respectively.
- **Fig. 3.2 (p. 79)** — Long form of the modern periodic table with atomic numbers and ground-state outer electronic configurations; IUPAC group numbering 1-18 replacing IA–VIIA, VIII, IB–VIIB and 0; lanthanoids (4f) shown below period 6 row and actinoids (5f) below period 7 — both rows form the f-block and are inserted at the lone "Lanthanoid/Actinoid" cell in the d-block.
- **Fig. 3.3 (p. 83)** — Block classification (s, p, d, f) overlaid with the metal/non-metal/metalloid zig-zag boundary running from B (top) through Si, Ge, As, Sb, Te, Po (bottom right); shows H placed in Group 1, He in Group 18; visualises why p-block elements straddle metal-non-metal divide.
- **Fig. 3.4(a)/(b) (p. 87)** — Atomic radius vs Z plots: (a) sharp decrease across period 2 (Li 152 pm → F 64 pm), (b) regular increase down Group 1 (Li 152 → Cs 244 pm) and Group 17 (F 64 → I 133 pm); each new shell adds significant size.
- **Fig. 3.5 (p. 88)** — First ionisation enthalpy vs Z (Z = 1 to 60): sharp maxima at noble gases (He, Ne, Ar, Kr, Xe — closed shells), deep minima at alkali metals (Li, Na, K, Rb, Cs — single valence electron easy to remove); zig-zag pattern across periods.
- **Fig. 3.6(a)/(b) (p. 88)** — $\Delta_i H$ variation: (a) across period 2 — overall rise from Li to Ne but with dips at B (after Be) and O (after N) due to electronic configuration anomalies; (b) down Group 1 — steady decrease from Li to Cs.
- **Fig. 3.7 (p. 91)** — Summary arrows showing periodic trends across periods and down groups (atomic radius decreases →, increases ↓; IE increases →, decreases ↓; EN increases →, decreases ↓; metallic character decreases →, increases ↓; non-metallic character is the reverse). One-page memory aid.

- **Table 3.6a/3.6b (p. 86)** — Covalent and metallic radii of representative elements in pm; Period 2: Li 152, Be 111, B 88, C 77, N 70, O 66, F 64; Period 3: Na 186, Mg 160, Al 143, Si 117, P 110, S 104, Cl 99.
- **Table 3.7 (p. 90)** — Electron gain enthalpies of halogens (F –328, Cl –349, Br –325, I –295, At –270 kJ/mol) showing Cl > F anomaly.
- **Table 3.8a/3.8b (p. 91-92)** — Pauling electronegativity values; F 4.0 at top right, Cs 0.7 at bottom left.

2.4 Common confusions / NTA trap points

- "Modern Periodic Law is based on atomic mass" — WRONG; it is based on atomic number (Moseley, 1913). Mendeleev's law was based on atomic mass (p. 78).
- "F has the most negative $\Delta_{eg}H$" — WRONG; Cl (-349) is more negative than F (-328) because the small 2p orbital of F creates greater electron-electron repulsion (p. 90, Table 3.7).
- "IE1 of B > IE1 of Be" — WRONG; IE1 of B is slightly LESS than IE1 of Be (2p electron more shielded than 2s) (p. 89).
- "IE1 of O > IE1 of N" — WRONG; IE1 of N > IE1 of O (half-filled $2p^3$ in N is extra stable) (p. 89).
- "Noble gases have negative $\Delta_{eg}H$" — WRONG; noble gases have LARGE POSITIVE $\Delta_{eg}H$ (He +48, Ne +116) because the added electron must enter the next higher shell (p. 90).
- "Helium is in s-block" — Technically yes ($1s^2$), but placed in p-block (Group 18) with other noble gases because it has a completely filled valence shell (p. 82).
- IUPAC name confusion: for Z = 120, it is UN-BI-NIL-ium (Unbinilium, Ubn) — students often forget the "nil" for 0 (p. 80, Problem 3.1).
- "Lanthanoids are d-block" — WRONG; they are f-block (4f filling), placed in a separate panel of the table. The same for actinoids (5f) (p. 82).
- "Zn is a transition metal" — depends on definition; NCERT Class XI does include it in d-block but in Class XII §4 notes it does not show typical transition properties (d^{10} in atom and ions) (p. 84). Watch for which standard is invoked.
- "Atomic radius increases down a group always" — WRONG for d-block: Zr ≈ Hf and Mo ≈ W due to lanthanoid contraction (covered in detail in Class XII §4.5.2).
- "Cation is bigger than parent atom" — WRONG; cations are SMALLER than parent atoms (one fewer shell often, no e-e repulsion); anions are LARGER (p. 87).
- "$\Delta_{eg}H$ of N is more negative than of C" — WRONG; $\Delta_{eg}H$ of N is positive (or weakly negative) because adding an electron to the half-filled $2p^3$ of N forces pairing — N rejects the extra electron more than C does.

🎯 Practice MCQs

Q1. **According to the Modern Periodic Law proposed after Moseley's work, the physical and chemical properties of elements are a periodic function of their:**

A. atomic weights

B. atomic numbers

C. atomic volumes

D. atomic radii

Q2. **Mendeleev predicted properties of Eka-aluminium, which was later identified as gallium. Which set of predicted/found values is correctly matched?**

A. Predicted atomic weight 72; found (Ga) 70

B. Predicted density 5.5 g/cm^3; found (Ga) 5.94 g/cm^3

C. Predicted formula of oxide E_2O_3; found Ga_2O_3

D. Predicted formula of chloride ECl_4; found $GaCl_3$

Q3. **According to the IUPAC nomenclature for elements with Z > 100, the systematic name and symbol of the element with atomic number 120 is:**

A. Ununennium, Uue

B. Unnilbium, Unb

C. Unbinilium, Ubn

D. Ununbium, Uub

📊 PYQ Alignment

> This chapter is a perennial favourite in CUET (UG) Chemistry — roughly 6–8 MCQs per paper across 2023-25, dominated by (i) periodic trend comparisons (IE order in period 2 with Be/B and N/O anomalies, $\Delta_{eg}H$ order in halogens, atomic/ionic radius order among

isoelectronic species), (ii) direct factual recall (Mendeleev's predictions for Eka-aluminium/Eka-silicon, Moseley's contribution, IUPAC names for Z > 100), and (iii) electronic-configuration-to-block matching. Assertion-reason questions on diagonal relationship and anomalous behaviour of second-period elements appear in almost every year.