CHAPTER 5

Periodic Classification of Elements

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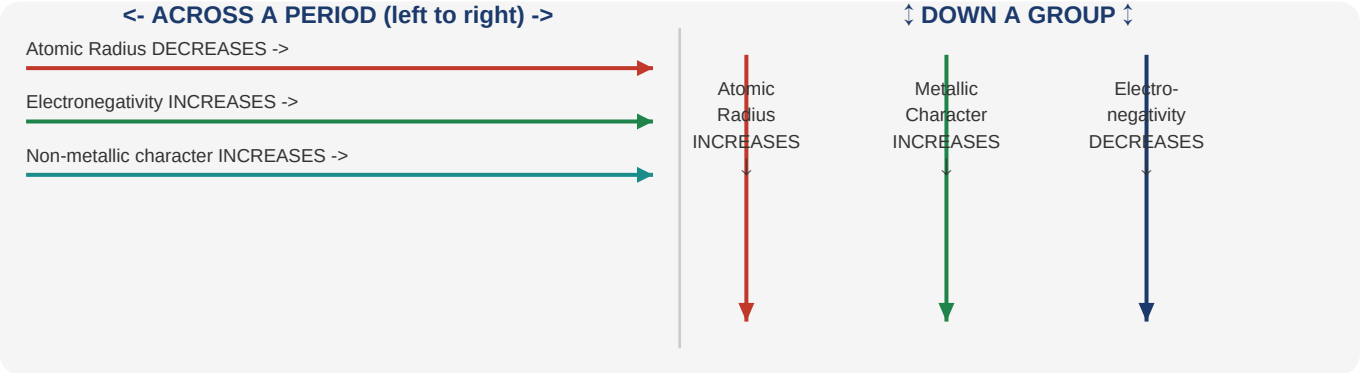
[GLOS] Key Terms / Glossary

Dobereiner's Triads	Groups of three elements with similar properties where the middle element's atomic mass is roughly the average of the other two.
Newlands' Law of Octaves	When elements are arranged by increasing atomic mass, every eighth element has properties similar to the first -- like musical octaves.
Mendeleev's Periodic Law	Properties of elements are a periodic function of their atomic masses.
Modern Periodic Law	Properties of elements are a periodic function of their atomic numbers (Moseley, 1913).
Period	Horizontal row in the periodic table. Elements in the same period have the same number of electron shells.
Group	Vertical column. Elements in the same group have the same number of valence electrons and similar chemical properties.
Atomic Radius	Half the distance between the nuclei of two bonded atoms of the same element; decreases across a period, increases down a group.
Valence Electrons	Electrons in the outermost shell of an atom; determine chemical reactivity.
Electronegativity	Ability of an atom to attract shared electrons; increases across a period, decreases down a group.
Metalloids	Elements with properties intermediate between metals and non-metals (e.g., Si, Ge, As).
Eka-aluminium / Eka-silicon	Names given by Mendeleev to undiscovered elements; later found to be Gallium and Germanium respectively.
Isotopes	Atoms of the same element with the same atomic number but different mass numbers (different neutrons).

■ Periodic Trends at a Glance



SECTION A ❖ Multiple Choice Questions (Q. 1-26)

Q.1. Upto which element was the Law of Octaves found to be applicable?

(a) Oxygen
(b) Calcium
(c) Cobalt
(d) Potassium

[ANS] Answer: (b) Calcium

Newlands' Law of Octaves worked reasonably well only up to **Calcium (Ca, atomic mass 40)**. Beyond calcium, the pattern broke down because Newlands tried to fit too many elements into fixed octave slots, even grouping dissimilar elements together.

[TIP] **Exam Tip:** Remember: Newlands = Octaves = works only up to Calcium. Mendeleev's table came later and was far more successful.

Q.2. According to Mendeleev's Periodic Law, elements were arranged in the periodic table in the order of:

(a) Increasing atomic number
(b) Decreasing atomic number
(c) Increasing atomic masses
(d) Decreasing atomic masses

[ANS] Answer: (c) Increasing atomic masses

Mendeleev arranged elements in order of **increasing atomic masses**. His Periodic Law stated: "The properties of elements are a periodic function of their atomic masses." It was only later (after Moseley's work in 1913) that atomic number replaced atomic mass as the basis.

[TIP] **Exam Tip:** Mendeleev = atomic mass. Modern PT = atomic number. Don't mix them up!

Q.3. In Mendeleev's Periodic Table, gaps were left for undiscovered elements. Which of the following later filled a gap?

(a) Germanium
(b) Chlorine
(c) Oxygen

(d) Silicon

[ANS] Answer: (a) Germanium

Mendeleev predicted an element he called **Eka-silicon**, leaving a blank space for it. When **Germanium (Ge)** was discovered in 1886, its properties matched Mendeleev's predictions almost exactly -- a brilliant triumph for his classification system. Chlorine, Oxygen, and Silicon were all known in Mendeleev's time.

[TIP] **Exam Tip:** Eka = "one beyond" in Sanskrit. Eka-silicon = Germanium, Eka-aluminium = Gallium, Eka-boron = Scandium.

Q.4. Which of the following statement(s) about the Modern Periodic Table are **incorrect**?
(i) Elements arranged by decreasing atomic number
(ii) Elements arranged by increasing atomic masses
(iii) Isotopes placed in adjoining groups
(iv) Elements arranged by increasing atomic number

(a) (i) only
(b) (i), (ii) and (iii)
(c) (i), (ii) and (iv)
(d) (iv) only

[ANS] Answer: (b) (i), (ii) and (iii)

Statements (i), (ii) and (iii) are all **incorrect**:
* (i) WRONG -- elements are arranged by *increasing* atomic number, not decreasing.
* (ii) WRONG -- the Modern PT uses atomic number, not atomic mass.
* (iii) WRONG -- isotopes of an element occupy the *same* position (same group and period) because they have the same atomic number.
Statement (iv) is **correct** -- elements are arranged by increasing atomic number.

[TIP] **Exam Tip:** The Modern Periodic Law (Moseley, 1913): properties are a function of ATOMIC NUMBER, not mass.

Q.5. Which of the following statements about the Modern Periodic Table is correct?

(a) It has 18 horizontal rows known as Periods
(b) It has 7 vertical columns known as Periods
(c) It has 18 vertical columns known as Groups
(d) It has 7 horizontal rows known as Groups

[ANS] Answer: (c) It has 18 vertical columns known as Groups

The Modern Periodic Table has:
* **7 horizontal rows = Periods** (Period 1 has 2 elements, Periods 2 and 3 have 8 each, etc.)
* **18 vertical columns = Groups** (numbered 1 to 18)
Options (a), (b), and (d) incorrectly swap or mislabel these.

[TIP] **Exam Tip:** Easy memory trick: 7 Periods (7 horizontal) + 18 Groups (18 vertical). Periods = rows, Groups = columns.

Q.6. Elements A, B, C, D and E have atomic numbers 2, 3, 7, 10 and 30 respectively. Which elements belong to the same period?

(a) A, B, C

(b) B, C, D

(c) A, D, E

(d) B, D, E

[ANS] Answer: (b) B, C, D

Elements in the same period have the same number of electron shells.
* A (Z=2): config 2 -> 1 shell -> Period 1
* B (Z=3): config 2,1 -> 2 shells -> **Period 2**
* C (Z=7): config 2,5 -> 2 shells -> **Period 2**
* D (Z=10): config 2,8 -> 2 shells -> **Period 2**
* E (Z=30): config 2,8,18,2 -> 4 shells -> Period 4

So B, C, and D all have 2 shells and belong to **Period 2**.

[TIP] **Exam Tip:** To find the period: fill electrons shell by shell (K=2, L=8, M=8...) and count how many shells are used.

Q.7. Elements A, B, C, D and E have atomic numbers 9, 11, 17, 12 and 13 respectively. Which pair belongs to the same group?

(a) A and B

(b) B and D

(c) A and C

(d) D and E

[ANS] Answer: (c) A and C

Elements in the same group have the same number of valence electrons.
* A (Z=9, F): config 2,7 -> **7 valence electrons** -> Group 17
* B (Z=11, Na): config 2,8,1 -> 1 valence electron -> Group 1
* C (Z=17, Cl): config 2,8,7 -> **7 valence electrons** -> Group 17
* D (Z=12, Mg): config 2,8,2 -> 2 valence electrons -> Group 2
* E (Z=13, Al): config 2,8,3 -> 3 valence electrons -> Group 13

A and C both have 7 valence electrons -> same group (Group 17 = Halogens).

[TIP] **Exam Tip:** Same group = same number of valence electrons = same outermost shell electron count.

Q.8. Where would you locate the element with electronic configuration 2, 8 in the Modern Periodic Table?

(a) Group 8

(b) Group 2

(c) Group 18

(d) Group 10

[ANS] Answer: (c) Group 18

Electronic configuration 2, 8 means 10 electrons -> element is **Neon (Ne)**.
* Number of shells = 2 -> Period 2
* Valence electrons = 8 -> the outermost shell is completely filled
* Elements with fully filled outermost shells are **Noble Gases** -> Group 18
Neon is a noble gas with zero valency and is chemically inert.

[TIP] **Exam Tip:** Any element with 8 electrons in its outermost shell (or 2 for He) goes in Group 18 (Noble Gases).

Q.9. An element which is an essential constituent of all organic compounds belongs to:

(a) Group 1
(b) Group 14
(c) Group 15
(d) Group 16

[ANS] Answer: (b) Group 14

Carbon (C) is the essential element in all organic compounds. Carbon has atomic number 6 and electronic configuration 2, 4 -> 4 valence electrons -> **Group 14**.
Carbon's unique ability to form 4 covalent bonds and long chains (catenation) makes it the backbone of all organic chemistry.

[TIP] **Exam Tip:** Carbon = Group 14 = 4 valence electrons = tetravalent. Always remember this!

Q.10. Which of the following is the outermost shell for elements of Period 2?

(a) K shell
(b) L shell
(c) M shell
(d) N shell

[ANS] Answer: (b) L shell

Shell names: K (n=1), L (n=2), M (n=3), N (n=4).
Period 2 elements have electrons filling up to the **2nd shell = L shell**.
Examples: Li (2,1), Be (2,2), B (2,3), C (2,4), N (2,5), O (2,6), F (2,7), Ne (2,8).
All Period 2 elements have L as their outermost shell.

[TIP] **Exam Tip:** Period number = highest shell being filled. Period 2 -> L shell (shell 2).

Q.11. Which one of the following elements exhibits the maximum number of valence electrons?

(a) Na
(b) Al
(c) Si

(d) P

[ANS] Answer: (d) P (Phosphorus)

* Na (Z=11): config 2,8,1 -> **1** valence electron
* Al (Z=13): config 2,8,3 -> **3** valence electrons
* Si (Z=14): config 2,8,4 -> **4** valence electrons
* P (Z=15): config 2,8,5 -> **5** valence electrons <- Maximum!

Phosphorus has the most valence electrons among the four options.

[TIP] **Exam Tip:** Going left to right in a period: valence electrons increase 1, 2, 3... 8.

Q.12. Which of the following gives the correct **increasing order** of atomic radii of O, F, and N?

(a) O, F, N
(b) N, F, O
(c) O, N, F
(d) F, O, N

[ANS] Answer: (d) F, O, N

All three elements are in Period 2. Across a period, atomic radius **decreases** as atomic number increases (more protons pull electrons closer).

* N (Z=7): largest (leftmost in the set)
* O (Z=8): medium
* F (Z=9): smallest (rightmost in the set)

So increasing order of atomic radii: **F < O < N**

[TIP] **Exam Tip:** Across a period (left to right): atomic radius DECREASES. More protons = stronger pull on electrons.

Q.13. Which among the following elements has the largest atomic radius?

(a) Na
(b) Mg
(c) K
(d) Ca

[ANS] Answer: (c) K (Potassium)

* Na (Z=11): Period 3, Group 1 -> config 2,8,1
* Mg (Z=12): Period 3, Group 2 -> config 2,8,2
* K (Z=19): Period 4, Group 1 -> config 2,8,8,1 <- **Largest!**
* Ca (Z=20): Period 4, Group 2 -> config 2,8,8,2

K has 4 shells. Na and Mg have 3 shells. Going down a group, radius increases. K is in Period 4 and Group 1 (leftmost), giving it the largest radius.

[TIP] **Exam Tip:** Down a group: atomic radius increases (more shells added). Left to right in a period: radius decreases.

Q.14. Which of the following elements would lose an electron most easily?

(a) Mg

(b) Na

(c) K

(d) Ca

[ANS] Answer: (c) K (Potassium)

The ability to lose an electron depends on ionization energy -- lower ionization energy = easier to lose.
* Metals with the largest atomic radius have the lowest ionization energy
* **K** has the largest radius among the options (Period 4, Group 1)
* Its single valence electron is far from the nucleus and held very loosely
K loses its electron most readily -> most reactive metal in this set.

[TIP] **Exam Tip:** Larger atom = outermost electron further from nucleus = weaker attraction = easier to lose.

Q.15. Which of the following elements does **NOT** lose an electron easily?

(a) Na

(b) F

(c) Mg

(d) Al

[ANS] Answer: (b) F (Fluorine)

Fluorine is a non-metal with very high electronegativity -- it has a strong tendency to *gain* electrons, not lose them. F has 7 valence electrons and needs just 1 more to complete its shell.
Na, Mg, and Al are all metals with low ionization energies and readily lose electrons.

[TIP] **Exam Tip:** Non-metals GAIN electrons; metals LOSE electrons. F is the most electronegative element -- it never loses electrons!

Q.16. Which of the following are the characteristics of isotopes of an element?

(i) Same atomic masses

(ii) Same atomic number

(iii) Same physical properties

(iv) Same chemical properties

(a) (i), (iii) and (iv)

(b) (ii), (iii) and (iv)

(c) (ii) and (iii)

(d) (ii) and (iv)

[ANS] Answer: (d) (ii) and (iv)

Isotopes are defined as atoms of the same element with the same atomic number but different mass numbers.
* (i) WRONG -- isotopes have *different* atomic masses (different neutrons)
* (ii) CORRECT -- same atomic number (same element, same protons)
* (iii) WRONG -- physical properties (like boiling point, density) can differ due to different masses
* (iv) CORRECT -- chemical properties depend on electron configuration, which is the same for all isotopes
So (ii) and (iv) are correct.

[TIP] **Exam Tip:** Isotopes: same Z (atomic number), same chemical properties, DIFFERENT mass number and physical properties.

Q.17. Arrange the following elements in order of their **decreasing** metallic character: Na, Si, Cl, Mg, Al

(a) Cl > Si > Al > Mg > Na

(b) Na > Mg > Al > Si > Cl

(c) Na > Al > Mg > Cl > Si

(d) Al > Na > Si > Ca > Mg

[ANS] Answer: (b) Na > Mg > Al > Si > Cl

All five elements are in Period 3. Metallic character **decreases** across a period from left to right:
* Na (Group 1) -> most metallic (loses 1 electron very easily)
* Mg (Group 2) -> next
* Al (Group 13) -> less metallic
* Si (Group 14) -> metalloid
* Cl (Group 17) -> non-metal, least metallic
Decreasing order: **Na > Mg > Al > Si > Cl**

[TIP] **Exam Tip:** Period 3 metallic character: Na > Mg > Al > Si > P > S > Cl. Always decreases left to right.

Q.18. Arrange the following elements in order of their **increasing** non-metallic character: Li, O, C, Be, F

(a) F < O < C < Be < Li

(b) Li < Be < C < O < F

(c) F < O < C < Be < Li

(d) F < O < Be < C < Li

[ANS] Answer: (b) Li < Be < C < O < F

Non-metallic character **increases** from left to right across a period.
* Li (Group 1): metal -> least non-metallic
* Be (Group 2): metal
* C (Group 14): non-metal (moderate)
* O (Group 16): non-metal (high)
* F (Group 17): most electronegative element -> most non-metallic!
Increasing non-metallic character: **Li < Be < C < O < F**

[TIP] **Exam Tip:** Non-metallic character increases left to right in a period. F is the most non-metallic element in the entire periodic table!

Q.19. What type of oxide would Eka-aluminium form?

(a) EO_3
(b) E_3O_2
(c) E_2O_3
(d) EO

[ANS] Answer: (c) E2O3

Eka-aluminium is **Gallium (Ga)**, which lies just below Aluminium in Group 13.
Aluminium forms Al_2O_3. Since Eka-aluminium has 3 valence electrons (like Al), it also forms $\mathbf{E_2O_3}$.
This is because the element needs 3 bonds with oxygen (valency = 3), and to balance the charge (O has valency 2), 2 atoms of E combine with 3 atoms of O.

[TIP] **Exam Tip:** Eka-aluminium = Gallium = Group 13 = valency 3 -> oxide formula E2O3 (same as Al2O3).

Q.20. Three elements B, Si and Ge are:

(a) Metals
(b) Non-metals
(c) Metalloids
(d) Metal, non-metal and metalloid respectively

[ANS] Answer: (c) Metalloids

Boron (B), **Silicon (Si)**, and **Germanium (Ge)** are all classic examples of **metalloids** (also called semi-metals).
Metalloids have properties intermediate between metals and non-metals:
* They can conduct electricity under certain conditions (semiconductors)
* Si and Ge are the most important semiconductor materials used in electronics
* They are found along the zig-zag line (staircase) on the periodic table

[TIP] **Exam Tip:** Metalloids along the staircase: B, Si, Ge, As, Sb, Te. Silicon chips in computers = metalloid!

Q.21. Which of the following elements will form an **acidic oxide**?

(a) Atomic number 7
(b) Atomic number 3
(c) Atomic number 12
(d) Atomic number 19

[ANS] Answer: (a) Atomic number 7 (Nitrogen, N)

* Z=7 -> Nitrogen (N): config 2,5 -> Group 15 -> **non-metal** -> forms acidic oxides (e.g., NO_2)
* Z=3 -> Lithium (Li): metal -> basic oxide
* Z=12 -> Magnesium (Mg): metal -> basic oxide
* Z=19 -> Potassium (K): metal -> basic oxide

Non-metals form acidic oxides; metals form basic oxides.

[TIP] **Exam Tip:** Non-metal oxide + water = acid. Metal oxide + water = base. This is a key rule!

Q.22. The element with atomic number 14 is hard, forms acidic oxide and a covalent halide. To which category does it belong?

(a) Metal
(b) Metalloid
(c) Non-metal
(d) Left-hand side element

[ANS] Answer: (b) Metalloid

Z=14 is **Silicon (Si)** with config 2,8,4 -> Group 14.
* It is hard (like a non-metal)
* Forms acidic oxide (SiO_2 is acidic)
* Forms covalent halide ($SiCl_4$)
* But it also has some metallic lustre and is a semiconductor

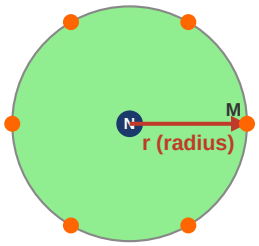
These mixed properties classify Si as a **metalloid**.

[TIP] **Exam Tip:** Silicon (Z=14) = classic metalloid. Forms covalent halides (like non-metals) but also has semi-metallic properties.

Q.23. Which one of the following correctly represents the atomic radius (r) of an atom?
Four diagrams are shown (i) to (iv) depicting atoms with concentric shells K, L, M and a nucleus N. The radius r is drawn differently in each.

Options:

(a) (i) and (ii)
(b) (ii) and (iii)
(c) (iii) and (iv)
(d) (i) and (iv)



[ANS] Answer: (b) (ii) and (iii)

The atomic radius is measured from the **centre of the nucleus to the outermost shell**. Diagrams (ii) and (iii) correctly show the arrow r going from the nucleus (N) to the outer boundary of the outermost shell. Diagram (i) shows r only within the nucleus, and (iv) shows r measured from outside, both of which are incorrect representations.

Q.24. Which one of the following does **NOT increase** while moving down the group in the periodic table?

(a) Atomic radius

(b) Metallic character

(c) Valence

(d) Number of shells in an element

[ANS] Answer: (c) Valence

As we move down a group:
* Atomic radius -> **increases** (more shells added)
* Metallic character -> **increases** (electrons held more loosely)
* Number of shells -> **increases** (each new period adds a shell)
* **Valence -> does NOT change** -- all elements in a group have the same number of valence electrons, so their valency stays constant down the group.
For example, Group 1 elements (Li, Na, K...) all have valency = 1.

[TIP] **Exam Tip:** Valence = valency = determined by valence electrons = SAME for all elements in a group. It does not change down the group!

Q.25. On moving from left to right in a period, the size of the atom:

(a) Increases

(b) Decreases

(c) Does not change appreciably

(d) First decreases then increases

[ANS] Answer: (b) Decreases

Moving left to right across a period, the **atomic number increases** (more protons). This increases the nuclear charge (positive), which **pulls the electrons closer** to the nucleus. Since no new shell is added within a period, the atom gets progressively smaller.
This is why F is smaller than Li, even though F has more electrons.

[TIP] **Exam Tip:** Across a period: protons increase -> stronger pull -> electrons drawn closer -> atomic size decreases.

Q.26. Which of the following sets of elements is written in order of their **increasing** metallic character?

(a) Be, Mg, Ca

(b) Na, Li, K

(c) Mg, Al, Si

(d) C, O, N

[ANS] Answer: (a) Be, Mg, Ca

* Be, Mg, Ca are all in Group 2. Going **down a group**, metallic character increases.
-> Be (Period 2) < Mg (Period 3) < Ca (Period 4) OK This is correct increasing order!
* Option (b): Na, Li, K -- Li is Period 2, Na is Period 3, K is Period 4; correct order should be Li < Na < K, not Na < Li < K X
* Option (c): Mg, Al, Si are in Period 3 left to right; metallic character decreases, not increases X
* Option (d): C, O, N are all non-metals X

[TIP] **Exam Tip:** Down a group = increasing metallic character. Be -> Mg -> Ca is the only correct increasing order here.

SECTION B ❖ Short Answer Questions (Q. 27-41)

Q.27. Three elements A, B, and C with similar properties have atomic masses X, Y, and Z respectively. The mass of Y is approximately equal to the average of X and Z. What is this arrangement called? Give one example.

Answer: Dobereiner's Triads

This arrangement is called **Dobereiner's Triads** (proposed by Johann Wolfgang Döbereiner in 1829).
The condition is: Y ~= (X + Z) / 2

Example: Li, Na, K (Group 1 metals)

* Atomic mass of Li = 7
* Atomic mass of Na = 23
* Atomic mass of K = 39

Average of Li and K = (7 + 39) / 2 = 46 / 2 = **23** ~= Atomic mass of Na OK

[TIP] **Exam Tip:** Three other Dobereiner triads: (Cl, Br, I), (Ca, Sr, Ba), (S, Se, Te). Average middle mass is always approx. middle atomic mass.

Q.28. Elements arranged in increasing order of atomic masses: F, Na, Mg, Al, Si, P, S, Cl, Ar, K
(a) Pick two sets of elements with similar properties.
(b) Which law of classification does this sequence represent?

(a) Two sets with similar properties:

* **Set 1: F and Cl** -- both are halogens (Group 17). F is the 1st element, Cl is the 8th element. They are separated by 8 positions -> similar properties.
* **Set 2: Na and K** -- both are alkali metals (Group 1). Na is position 2, K is position 10. They are separated by 8 positions -> similar properties.

(b) Law represented: Newlands' Law of Octaves

This sequence represents **Newlands' Law of Octaves (1865)**, which states that when elements are arranged in increasing order of atomic masses, every 8th element has properties similar to the first element -- just like notes in a musical octave (sa, re, ga, ma, pa, dha, ni, sa).

[TIP] **Exam Tip:** Newlands's law works only upto Calcium. Beyond that, 8th element does not always resemble the first.

Q.29. Can the following groups be classified as Döbereiner's triads?
(a) Na, Si, Cl (b) Be, Mg, Ca
Atomic masses: Be=9, Na=23, Mg=24, Si=28, Cl=35, Ca=40. Explain with reasons.

(a) Na, Si, Cl:

Check condition: Is the atomic mass of Si ~= (Na + Cl) / 2?
Average of Na and Cl = (23 + 35) / 2 = 58 / 2 = **29**
Actual atomic mass of Si = **28**
29 ~= 28 (approximately matches!)
BUT: Na, Si, Cl do **not have similar properties** -- Na is a metal, Si is a metalloid, Cl is a non-metal. So they **CANNOT** be classified as a Dobereiner triad.

(b) Be, Mg, Ca:

Check condition: Is the atomic mass of Mg ~= (Be + Ca) / 2?
Average of Be and Ca = (9 + 40) / 2 = 49 / 2 = **24.5**
Actual atomic mass of Mg = **24**
24.5 ~= 24 OK (very close!)
Also, Be, Mg, Ca are all **alkaline earth metals** with similar properties.
Therefore, Be, Mg, Ca **CAN** be classified as a Dobereiner triad. OK

[TIP] **Exam Tip:** For a valid Dobereiner triad, BOTH conditions must be met: (1) middle mass ~= average of outer masses, AND (2) similar chemical properties.

Q.30. In Mendeleev's Periodic Table, cobalt (atomic mass 58.93) was placed before nickel (atomic mass 58.71), even though cobalt has a higher atomic mass. Give reason.

Answer: Mendeleev prioritised chemical properties over atomic mass in anomalous cases.

In Mendeleev's system, elements were arranged by increasing atomic mass. However, cobalt (58.93 amu) and nickel (58.71 amu) have very similar and nearly equal masses. When Mendeleev found that placing nickel before cobalt would disrupt the periodic pattern of properties, he chose to place **Co before Ni** so that they would fall in the correct groups matching their chemical behaviour.

This was one of the **limitations of Mendeleev's table** -- it could not always correctly order elements based solely on atomic mass. This anomaly was later resolved by Moseley's Modern Periodic Law, which orders elements by **atomic number** (Co=27, Ni=28), giving the correct arrangement.

[TIP] **Exam Tip:** Similar anomaly: Argon (39.9) placed before Potassium (39.1) in Mendeleev's table. Resolved by atomic number ordering.

Q.31. "Hydrogen occupies a unique position in the Modern Periodic Table." Justify this statement.

Hydrogen's Dual Nature:

Hydrogen (H) has electronic configuration 1 -- just 1 electron in its outermost shell.

Similarities with Alkali Metals (Group 1):

* Like alkali metals, H has 1 valence electron
* Like alkali metals, H can lose 1 electron to form H^+ ion
* H forms similar types of compounds (e.g., HCl similar to NaCl)

Similarities with Halogens (Group 17):

* Like halogens, H needs 1 electron to complete its shell (duplet)
* Like halogens, H can gain 1 electron to form H^- (hydride ion)
* H exists as a diatomic molecule (H_2), like halogens (Cl_2, F_2)

Because of this dual resemblance, hydrogen is placed **separately at the top** of the periodic table, sometimes shown between Group 1 and Group 17, indicating its unique nature.

[TIP] **Exam Tip:** In exams, mention BOTH similarities: with alkali metals AND with halogens. 3 points each for 6 marks.

Q.32. Write the formulae of chlorides of Eka-silicon and Eka-aluminium predicted by Mendeleev.

Eka-silicon = Germanium (Ge), Group 14, valency = 4

Chloride formula: **$GeCl_4$** (Eka-silicon tetrachloride)

Eka-aluminium = Gallium (Ga), Group 13, valency = 3

Chloride formula: **$GaCl_3$** (Eka-aluminium trichloride)

Mendeleev predicted these formulae from the known chlorides of neighbouring elements. When Ge and Ga were actually discovered, their chloride formulae matched perfectly -- a remarkable validation of Mendeleev's classification.

[TIP] **Exam Tip:** Eka-silicon (Ge) valency=4 -> GeCl4. Eka-aluminium (Ga) valency=3 -> GaCl3. Valency = group number for main group elements.

Q.33. Three elements A, B, and C have 3, 4, and 2 electrons respectively in their outermost shell. Give their group numbers and valencies.

Element A: 3 valence electrons

Group Number = **13** (Group 13 has 3 valence electrons)
Valency = 3 (needs to lose 3 electrons to empty outermost shell, or gain 5 -- losing is easier for metals)
Example: Aluminium (Al) has config 2,8,3

Element B: 4 valence electrons

Group Number = **14**
Valency = 4 (neither easily gains 4 nor loses 4 -> forms 4 covalent bonds)
Example: Carbon (C) or Silicon (Si)

Element C: 2 valence electrons

Group Number = **2**
Valency = 2 (loses 2 electrons to achieve noble gas configuration)
Example: Magnesium (Mg) has config 2,8,2

[TIP] **Exam Tip:** Rule: For Groups 1-13, valency = number of valence electrons. For Groups 14-17, valency = 8 minus valence electrons (for gaining). Group 14 valency = 4.

Q.34. If an element X is placed in Group 14, what will be the formula and nature of bonding of its chloride?

Group 14 -> Valency = 4

Formula of chloride: **XCl_4**

Nature of bonding: Covalent bond
Elements in Group 14 (C, Si, Ge) are non-metals or metalloids with 4 valence electrons. They share electrons rather than transfer them. When X combines with Cl (also a non-metal), they form a **covalent compound** by sharing electron pairs.

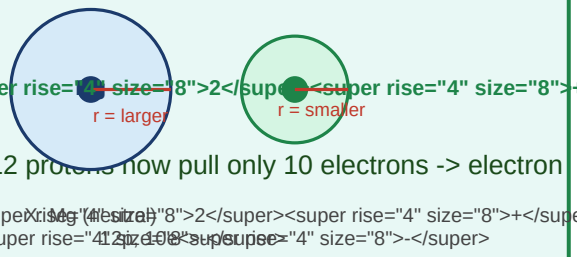
Example: Carbon tetrachloride CCl_4 -- 4 covalent bonds between C and 4 Cl atoms.

[TIP] **Exam Tip:** Group 14 elements form covalent chlorides (XCl_4). Metallic elements (Groups 1, 2) form ionic chlorides. Non-metals form covalent chlorides.

Q.35. Compare the radii of two species X and Y:
(a) X has 12 protons and 12 electrons
(b) Y has 12 protons and 10 electrons

Answer: Radius of X > Radius of Y

X is **Mg (neutral atom)** -- 12 protons, 12 electrons, config 2,8,2
Y is **Mg^{2+} (cation)** -- 12 protons, only 10 electrons, config 2,8



Reason: In Y (Mg^{2+}), the atom has lost 2 electrons. The same 12 protons now pull only 10 electrons -> electron cloud contracts -> radius decreases significantly.

Also, the outermost shell of Y is the L shell (2 shells), while X has 3 shells -> X is larger than Y.

[TIP] **Exam Tip:** Cation (positive ion) is SMALLER than the parent atom. Anion (negative ion) is LARGER. Same element, different charges = different radii.

Q.36. Arrange the following elements in increasing order of their atomic radii.
(a) Li, Be, F, N
(b) Cl, At, Br, I

(a) Li, Be, F, N -- all in Period 2 (same period):

Moving left to right in Period 2, atomic radius decreases.
Li (Group 1) > Be (Group 2) > N (Group 15) > F (Group 17)
Increasing order: F < N < Be < Li

(b) Cl, At, Br, I -- all in Group 17 (same group):

Moving down a group, atomic radius increases (more shells added).
Cl (Period 3) < Br (Period 4) < I (Period 5) < At (Period 6)
Increasing order: Cl < Br < I < At

[TIP] **Exam Tip:** Same period = decreasing radius left to right. Same group = increasing radius top to bottom. Identify same-period or same-group first!

Q.37. Identify and name the metals from the following electronic configurations:
(a) 2,8,2 (b) 2,8,1 (c) 2,8,7 (d) 2,1

(a) 2, 8, 2 -> Magnesium (Mg), Z=12 -> **Metal** (Group 2, Period 3, 2 valence electrons)

(b) 2, 8, 1 -> Sodium (Na), Z=11 -> **Metal** (Group 1, Period 3, 1 valence electron)

(c) 2, 8, 7 -> Chlorine (Cl), Z=17 -> **Non-metal** (Group 17, Period 3, 7 valence electrons) -- NOT a metal!

(d) 2, 1 -> Lithium (Li), Z=3 -> **Metal** (Group 1, Period 2, 1 valence electron)

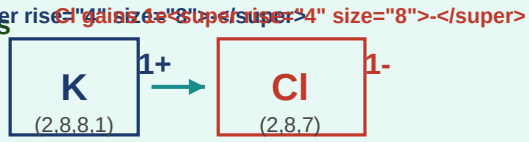
Metals identified: Mg, Na, Li

[TIP] **Exam Tip:** Metals typically have 1, 2, or 3 valence electrons. Non-metals have 4-7. 7 valence electrons = halogen = non-metal!

Q.38. Write the formula of the product when element A (Z=19) combines with element B (Z=17). Draw its electron dot structure. What is the nature of the bond formed?

A = Potassium (K), Z=19, config 2,8,8,1 -> 1 valence electron

B = Chlorine (Cl), Z=17, config 2,8,7 -> 7 valence electrons



Product: KCl (Potassium Chloride)

K loses 1 electron -> K^+

Cl gains 1 electron -> Cl^-

Electrostatic attraction between K^+ and Cl^- forms the bond.

Nature of Bond: Ionic (electrovalent) bond

Formed by complete transfer of electron from K to Cl.

[TIP] **Exam Tip:** Metal + Non-metal -> Ionic bond (electron transfer). Non-metal + Non-metal -> Covalent bond (electron sharing).

Q.39. Arrange the following elements in increasing order of their metallic character: Mg, Ca, K, Ge, Ga

Step 1: Identify positions in the periodic table:

* Ge (Z=32): Period 4, Group 14 -> metalloid (weakest metallic character)
* Ga (Z=31): Period 4, Group 13 -> metal (more metallic than Ge)
* Mg (Z=12): Period 3, Group 2
* Ca (Z=20): Period 4, Group 2 -> more metallic than Mg (same group, lower period)
* K (Z=19): Period 4, Group 1 -> most metallic (leftmost in Period 4)

Increasing metallic character: Ge < Ga < Mg < Ca < K

[TIP] **Exam Tip:** Compare by position: same group -> lower is more metallic. Same period -> further left is more metallic.

Q.40. Identify the elements with the following properties and arrange them in increasing order of reactivity:
(a) A soft and reactive metal
(b) The metal which is an important constituent of limestone
(c) The metal which exists in liquid state at room temperature

(a) Soft, reactive metal = Sodium (Na)
Na is a Group 1 alkali metal. It is very soft (can be cut with a knife), highly reactive with water and air.

(b) Metal in limestone = Calcium (Ca)
Limestone is calcium carbonate ($CaCO_3$). Ca is in Group 2, Period 4.

(c) Metal in liquid state at room temp = Mercury (Hg)
Mercury is the only metal liquid at room temperature (melting point = -39 degC).

Reactivity order (increasing): Hg < Ca < Na

Mercury is a transition metal with low reactivity. Calcium reacts with water but slowly. Sodium reacts vigorously -- even explosively -- with water.

[TIP] **Exam Tip:** Reactivity of metals: the easier an element loses electrons, the more reactive it is. Group 1 metals (Na, K) are most reactive.

Q.41. Where would you locate the following elements in the periodic table?
(a) Soft metal stored under kerosene
(b) Element with variable valency, stored under water
(c) Tetravalent element forming basis of organic chemistry
(d) Inert gas with atomic number 2
(e) Element whose thin oxide layer is used for anodising

(a) Soft metal stored under kerosene = Sodium (Na)
-> Group 1 (alkali metals), Period 3
Na reacts violently with air/water, so stored under kerosene.

(b) Variable valency, stored under water = Phosphorus (P)
-> Group 15, Period 3
White phosphorus is highly reactive with air, stored under water. Phosphorus can show valencies of 3 and 5.

(c) Tetravalent, basis of organic chemistry = Carbon (C)
-> Group 14, Period 2
Carbon's valency of 4 allows it to form long chains, rings, and complex molecules.

(d) Inert gas, atomic number 2 = Helium (He)
-> Group 18, Period 1
He has config 2 (full K shell), completely inert.

(e) Thin oxide layer used for anodising = Aluminium (Al)
-> Group 13, Period 3
Al_2O_3 forms a thin, protective oxide layer on Al surface. Anodising thickens this layer to make Al more corrosion resistant.

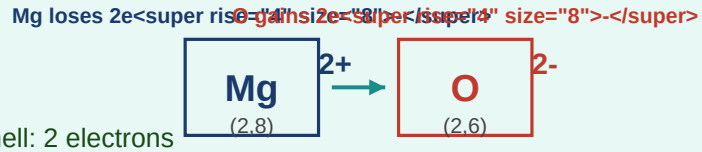
[TIP] **Exam Tip:** Anodising = electrolytic process to thicken the oxide layer on Aluminium. Common exam fact!

SECTION C ❖ Long Answer Questions (Q. 42-52)

Q.42. An element is in Group 2 and Period 3. It burns in oxygen to form a basic oxide.
(a) Identify the element (b) Write electronic configuration
(c) Balanced equation: burns in air (d) Equation: oxide dissolves in water
(e) Draw electron dot structure for the oxide

(a) Element: Magnesium (Mg)

Group 2, Period 3 -> Mg (Z = 12)



(b) Electronic Configuration: 2, 8, 2

K shell: 2 electrons | L shell: 8 electrons | M shell: 2 electrons
2 valence electrons -> Group 2

(c) Mg burns in air (oxygen):

2Mg + O2 -> 2MgO
(Magnesium burns with a bright white flame to form magnesium oxide)

(d) MgO dissolves in water:

MgO + H2O -> Mg(OH)2
Magnesium hydroxide [Mg(OH)2] is a basic solution (turns red litmus blue)

[TIP] **Exam Tip:** MgO is an IONIC compound. Mg^{2+} and O^{2-} ions. Metal oxide + water = basic/alkali. MgO is amphoteric in some sources but primarily basic.

Q.43. Element X (Z=17) reacts with element Y (Z=20) to form a divalent halide.
(a) Where are X and Y in the periodic table? (b) Classify as metal/non-metal/metalloid
(c) Nature of oxide of Y and nature of bonding (d) Electron dot structure of divalent halide

X (Z=17) = Chlorine (Cl), config 2,8,7

Period 3, Group 17 (Halogens) | Non-metal | 7 valence electrons

Y (Z=20) = Calcium (Ca), config 2,8,8,2

Period 4, Group 2 (Alkaline Earth Metals) | Metal | 2 valence electrons

(b) Classification: X (Cl) = Non-metal; Y (Ca) = Metal

(c) Oxide of Ca = CaO (Calcium oxide)

CaO + H2O -> Ca(OH)2 (Calcium hydroxide -- strongly basic, turns litmus blue)
Nature: **Basic oxide**
Metal + Non-metal -> **Ionic bond** in CaCl2 (Ca gives $2e^-$ to 2 Cl atoms)

(d) Divalent halide = CaCl2 (Calcium Chloride)

Ca loses 2 electrons; each Cl gains 1 electron.
Ca -> $Ca^{2+} + 2e^-$
$Cl + e^- \rightarrow Cl^-$ (x2)
Result: CaCl2 with ionic bonds between Ca^{2+} and 2 Cl^- ions.
Electron dot: [Ca^{2+}] [Cl^-] [Cl^-] -- each Cl has 8 electrons in outer shell (octet complete)

Q.44. Atomic numbers given: 10, 20, 7, 14. Identify elements and find their group, period, configuration, and valency.

Z	Element	Config	Group	Period	Valency
10	Neon (Ne)	2, 8	18	2	0
20	Calcium (Ca)	2, 8, 8, 2	2	4	2
7	Nitrogen (N)	2, 5	15	2	3
14	Silicon (Si)	2, 8, 4	14	3	4

Note on valency:
* Neon (Z=10): noble gas, completely inert -> valency = 0
* Ca: 2 valence electrons -> loses 2 -> valency = 2
* N: 5 valence electrons -> gains 3 to complete octet -> valency = 3
* Si: 4 valence electrons -> forms 4 covalent bonds -> valency = 4

Q.45. Crossword Puzzle -- Solutions

Across:

(1) Atomic number 12 -> **MAGNESIUM**
(3) Metal in cans, Group 14 -> **TIN (Sn, Z=50)**
(4) Lustrous non-metal with 7 outermost electrons -> **IODINE (I, Group 17, Period 5)**

Down:

(2) Soft, reactive metal, yellow flame, stored in kerosene -> **SODIUM**
(5) First element of 2nd Period -> **LITHIUM (Li, Z=3)**
(6) Used in fluorescent bulbs, Group 18, 2nd member -> **NEON (Ne, Z=10)**
(7) Radioactive, last halogen -> **ASTATINE (At, Z=85)**
(8) Constituent of steel, forms rust -> **IRON (Fe)**
(9) First metalloid, fibres in bullet-proof vests -> **BORON (B, Z=5)**

Q.46. The ladder shows: Mg, O, Na, C, Cl, Be, Si, Ne, P, F, N, Ar, B, Al, H, Ca, K, Li, S, He.
(a) Arrange in increasing order of atomic number.
(b) Also arrange in order of their group.

(a) Increasing atomic number order:

H, He, Li, Be, B, C, N, O, F, Ne, Na, Mg, Al, Si, P, S, Cl, Ar, K, Ca

Group 1	Group 2	Group 13	Group 14	Group 15	Group 16	Group 17	Group 18
H, Li Na, K	Be Mg, Ca	B Al	C Si	N P	O S	F Cl	He, Ne Ar

Q.47. Mendeleev predicted Eka-silicon and Eka-aluminium.
(a) Name the elements (b) Group and Period in Modern PT
(c) Metals/non-metals/metalloids? (d) How many valence electrons?

(a) Eka-silicon = Germanium (Ge); Eka-aluminium = Gallium (Ga)

(b) Position in Modern Periodic Table:
* Germanium: Group 14, Period 4
* Gallium: Group 13, Period 4

(c) Classification:
* Germanium -> **Metalloid** (properties between metal and non-metal; used in semiconductors)
* Gallium -> **Metal** (low melting point, soft; melts in your hand at ~29.8 degC!)

(d) Valence electrons:
* Germanium (Group 14): **4 valence electrons**
* Gallium (Group 13): **3 valence electrons**

[TIP] **Exam Tip:** Mendeleev's predictions were astoundingly accurate. Gallium (discovered 1875) and Germanium (1886) matched his predictions almost perfectly in density, melting point, and formulae.

Q.48. Based on periodic trends (given), answer about elements with Z = 3 to 9:
(a) Most electropositive (b) Most electronegative (c) Smallest atomic size

(d) The metalloid (e) Element with maximum valency

Elem	Z	Config	Group	Type	Valency
Li	3	2,1	Group 1	Metal	1
Be	4	2,2	Group 2	Metal	2
B	5	2,3	Group 13	Metalloid	3
C	6	2,4	Group 14	Non-metal	4
N	7	2,5	Group 15	Non-metal	3
O	8	2,6	Group 16	Non-metal	2
F	9	2,7	Group 17	Non-metal	1

(a) Most electropositive = Lithium (Li)
Li is in Group 1 and leftmost in this set. It loses electrons most easily.

(b) Most electronegative = Fluorine (F)
F (Z=9) is the most electronegative element in the entire periodic table.

(c) Smallest atomic size = Fluorine (F)
Across Period 2, radius decreases. F is rightmost -> smallest.

(d) Metalloid = Boron (B)
B (Z=5) is the only metalloid in this range. It is hard, has a high melting point, and shows intermediate properties.

(e) Maximum valency = Carbon (C) -- valency = 4
C (Group 14) has 4 valence electrons. It forms 4 covalent bonds -> valency = 4, which is the highest in this set.

Q.49. An element X is a yellow solid at room temperature, shows catenation and allotropy. X forms two oxides (also formed during thermal decomposition of ferrous sulphate crystals) that are major air pollutants.
(a) Identify X (b) Electronic configuration
(c) Balanced equation for thermal decomposition of FeSO4 crystals
(d) Nature of oxides (e) Position in Modern PT

(a) Element X = Sulfur (S), Z = 16

Sulfur is a yellow solid, shows catenation (S8 rings) and allotropy (rhombic and monoclinic forms). Its oxides SO2 and SO3 are major air pollutants and are also produced when FeSO4 is heated.

(b) Electronic Configuration: 2, 8, 6

6 valence electrons -> Group 16

(c) Thermal decomposition of ferrous sulphate (FeSO4 . 7H2O):

Equation: 2FeSO4 -> Fe2O3 + SO2 + SO3
Step by step:
* Ferrous sulphate crystals first lose water of crystallisation on gentle heating
* On strong heating: 2FeSO4 -> Fe2O3 + SO2↑ + SO3↑
* Iron(III) oxide (Fe2O3) is a reddish-brown solid residue
* SO2 and SO3 are gases that smell pungent

(d) Nature of oxides: Acidic

SO2 + H2O -> H2SO3 (sulphurous acid -- acidic)
SO3 + H2O -> H2SO4 (sulphuric acid -- strongly acidic)
Both are acidic oxides as Sulfur is a non-metal.

(e) Position of Sulfur in Modern PT:
Group 16 (Chalcogens), Period 3

Q.50. Element X (Group 15) exists as diatomic molecule and combines with H at 773 K (with catalyst) to form ammonia (pungent smell).
(a) Identify X and its valence electrons
(b) Electron dot structure of X2 and bond type
(c) Electron dot structure of ammonia and bond type

(a) X = Nitrogen (N), Z=7, config 2,5

Valence electrons = 5

N2 + 3H2 -> 2NH3 (at 773 K, Fe catalyst) -- Haber Process

Each N has 3 bond pairs + 1 lone pair

:N=N:

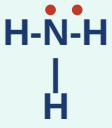
(Triple covalent bond)

(b) N2 electron dot structure:

N=N (triple bond)
Each N contributes 3 electrons to 3 bond pairs.
Each N also has 1 lone pair remaining.
Bond type: Covalent (triple bond)
Very strong bond; high bond dissociation energy (945 kJ/mol)

(c) NH3 (Ammonia) dot structure:

N forms 3 single bonds with 3 H atoms.
N still has 1 lone pair of electrons.
Bond type: Covalent bonds
Pyramidal shape due to lone pair repulsion.



(Pyramidal structure, 3 bond + 1 lone pair)

Q.51. Which group of elements could be placed in Mendeleev's Periodic Table without disturbing the original order? Give reason.

Answer: Noble Gases (Group 18) -- He, Ne, Ar, Kr, Xe, Rn

Reason:

* Noble gases were discovered much later (Argon by Rayleigh and Ramsay in 1894).
* They could be added as a new group (Group 0 / Group 18) between the Halogens (Group 17) and Alkali Metals (Group 1) without disturbing the existing order.
* Their atomic masses also fit between the halogens and alkali metals of each period.
* No properties of other elements were disrupted -- noble gases simply formed an entirely separate, self-consistent group.

This was a **great credit to Mendeleev's system** -- it was flexible enough to accommodate an entirely new group without needing reorganisation.

[TIP] **Exam Tip:** Noble gases were not known to Mendeleev! They were discovered around 1894-1900. Their addition as Group 18 (or Group 0) didn't disturb the periodic table at all.

Q.52. Give an account of the process adopted by Mendeleev for classification of elements. How did he arrive at "Periodic Law"?

Mendeleev's Classification Process:

Step 1: Data Collection
Mendeleev studied the properties of all 63 elements known at the time. He wrote the symbol, atomic mass, and properties of each element on separate cards.

Step 2: Observation of Patterns
When he arranged elements by increasing atomic mass, he noticed a pattern: certain properties repeated at regular intervals. For example, every few elements, a reactive alkali metal appeared, followed by a reactive non-metal.

Step 3: Grouping by Properties
He grouped elements with similar chemical properties together in vertical columns. He also related the properties of elements to their formulae with common compounds (oxides and hydrides).

Step 4: Leaving Gaps for Undiscovered Elements
When an element did not fit a group, Mendeleev boldly left a blank space rather than forcing a fit. He predicted the properties of the missing elements (Eka-boron, Eka-aluminium, Eka-silicon).

Mendeleev's Periodic Law:

"The properties of elements are a periodic function of their atomic masses."

This means: when elements are arranged in order of increasing atomic mass, elements with similar properties recur after a fixed interval -- this regular recurrence is called periodicity.

Achievements:
* Successfully predicted undiscovered elements (Ga, Ge, Sc found later)
* Provided a systematic framework for all known elements
* Accommodated noble gases without structural changes

Limitations:
* Could not explain position of isotopes (same element, different masses)
* Cobalt and Nickel anomaly (Co placed before Ni despite higher mass)
* Hydrogen's position remained ambiguous
* No theoretical basis (why does periodicity occur?)

[TIP] **Exam Tip:** For 5-mark questions: mention the process (5 steps), the law itself, 2 achievements, AND 2 limitations.

[WARN] Common Mistakes & Exam Tips

[ERR] Mendeleev vs Modern PT

Mendeleev = atomic MASS. Modern PT = atomic NUMBER. Never swap these in exams!

[ERR] Valency vs Valence electrons

Valence electrons = electrons in outermost shell. Valency = combining capacity. Group 16 elements have 6 valence electrons but valency = 2 (they gain 2).

[ERR] Period vs Group

Period = HORIZONTAL row. Group = VERTICAL column. Same period = same number of shells. Same group = same valence electrons.

[ERR] Atomic radius trend

Across period: DECREASES (more protons). Down group: INCREASES (more shells). Don't confuse these two directions!

[ERR] Noble gases in Mendeleev's table

Noble gases were NOT known to Mendeleev. When discovered, they fit as Group 0 without disrupting the existing order.

[ERR] Cation vs Anion size

Cation (loses e^-) -> SMALLER than atom. Anion (gains e^-) -> LARGER than atom.

[ERR] Eka-silicon vs Eka-aluminium

Eka-silicon = Germanium (Ge). Eka-aluminium = Gallium (Ga). Students often mix these up!

[ERR] Ionic vs Covalent bond

Metal + Non-metal = Ionic. Non-metal + Non-metal = Covalent. Group 14 chlorides (e.g., CCl_4) are covalent!

[REV] Quick Revision Table -- Chapter 5 at a Glance

Scientist	Contribution	Basis	Limitation
Döbereiner (1829)	Triads of elements	Atomic mass (average)	Only 3 elements per group
Newlands (1865)	Law of Octaves	Atomic mass (every 8th)	Works only up to Ca
Mendeleev (1869)	Periodic Table (63 elements)	Atomic mass	Isotopes, Co-Ni anomaly
Moseley (1913)	Modern Periodic Law	Atomic number	None significant

[KEY] MCQ Answer Key Summary (Q. 1-26)

Q.No	Ans	Q.No	Ans	Q.No	Ans	Q.No	Ans
Q.1	**(b)**	Q.2	**(c)**	Q.3	**(a)**	Q.4	**(b)**
Q.5	**(c)**	Q.6	**(b)**	Q.7	**(c)**	Q.8	**(c)**
Q.9	**(b)**	Q.10	**(b)**	Q.11	**(d)**	Q.12	**(d)**
Q.13	**(c)**	Q.14	**(c)**	Q.15	**(b)**	Q.16	**(d)**
Q.17	**(b)**	Q.18	**(b)**	Q.19	**(c)**	Q.20	**(c)**
Q.21	**(a)**	Q.22	**(b)**	Q.23	**(b)**	Q.24	**(c)**
Q.25	**(b)**	Q.26	**(a)**				

✥ Study hard, revise smart, score high! ✥