s-Block (ns) | d-Block (n – 1)d | p-Block (np)

Transition metals (d-Block)

Period \ Group	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
	IA	IIA	IIIB	IVB	VB	VIB	VIIB	VIII			IB	IIB	IIIA	IVA	VA	VIA	VIIA	VIIIA
1 (1s)	H 1																	He 2
2 (2s, 2p)	Li 3	Be 4											B 5	C 6	N 7	O 8	F 9	Ne 10
3 (3s, 3p)	Na 11	Mg 12											Al 13	Si 14	P 15	S 16	Cl 17	Ar 18
4 (4s, 3d, 4p)	K 19	Ca 20	Sc 21	Ti 22	V 23	Cr 24	Mn 25	Fe 26	Co 27	Ni 28	Cu 29	Zn 30	Ga 31	Ge 32	As 33	Se 34	Br 35	Kr 36
5 (5s, 4d, 5p)	Rb 37	Sr 38	Y 39	Zr 40	Nb 41	Mo 42	Tc 43	Ru 44	Rh 45	Pd 46	Ag 47	Cd 48	In 49	Sn 50	Sb 51	Te 52	I 53	Xe 54
6 (6s, 4f, 5d, 6p)	Cs 55	Ba 56	La 57	Hf 72	Ta 73	W 74	Re 75	Os 76	Ir 77	Pt 78	Au 79	Hg 80	Tl 81	Pb 82	Bi 83	Po 84	At 85	Rn 86
7 (7s, 5f, 6d, 7p)	Fr 87	Ra 88	Ac 89	Rf 104	Db 105	Sg 106	Bh 107	Hs 108	Mt 109	Ds 110	Rg 111	Cn 112	Nh 113	Fl 114	Mc 115	Lv 116	Ts 117	Og 118

The Rare Earths, (n – 2)f

f-Block														
Lanthanide series (4f) Period : 6	Ce 58	Pr 59	Nd 60	Pm 61	Sm 62	Eu 63	Gd 64	Tb 65	Dy 66	Ho 67	Er 68	Tm 69	Yb 70	Lu 71
Actinide series (5f) Period : 7	Th 90	Pa 91	U 92	Np 93	Pu 94	Am 95	Cm 96	Bk 97	Cf 98	Es 99	Fm 100	Md 101	No 102	Lr 103

Class-11th + 12th

Kattar Advanced

EaJEE NOTES

for

INORGANIC CHEMISTRY

JEE Main & Advanced Theory and PYQ's

By Om Pandey
(IIT Delhi)

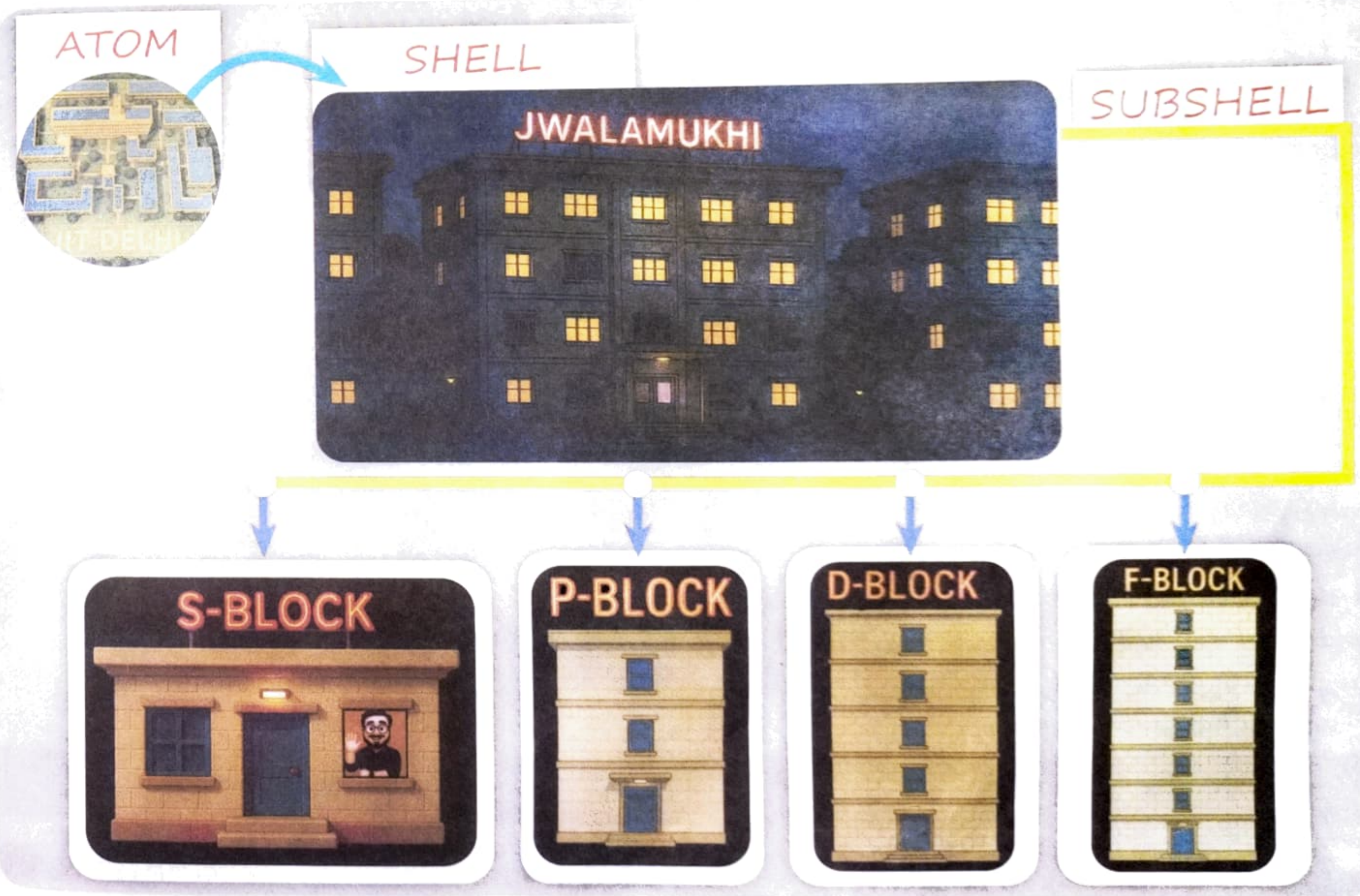
1 Classification of Elements and Periodicity in Properties

Syllabus (JEE Advanced)

Modern periodic law and the present form of periodic table; electronic configuration of elements; periodic trends in atomic radius, ionic radius, ionization enthalpy, electron gain enthalpy, valence, oxidation states, electronegativity, and chemical reactivity.

QUANTUM NUMBERS

The set of four numbers required to defined an electron completely in an atom are called quantum numbers. The first three have been derived from Schrodinger wave equation.

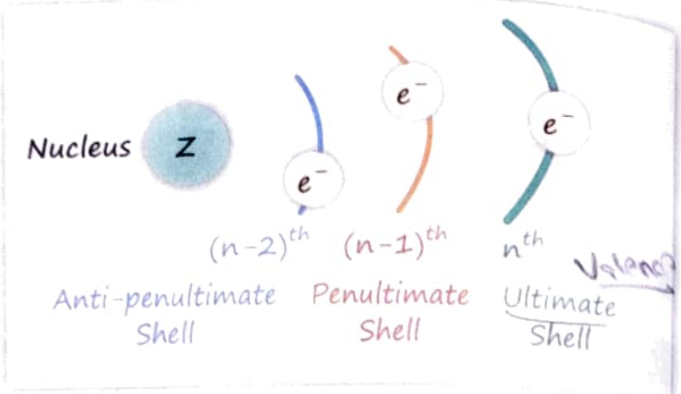


[I] Principal Quantum Number (n)

It describes the size of the electron wave and the total energy of the electron. It has integral values 1, 2, 3, 4... etc. and is denoted by K, L, M, N, ... etc.

Number of subshell present in n^{th} shell = n

n	subshell
1	s
2	s, p
3	s, p, d
4	s, p, d, f



- Number of orbitals present in n^{th} shell = n^2

[II] Azimuthal Quantum Number (ℓ)

It describes the shape of electron cloud and the number of subshells in a shell.

- It can have values from 0 to [n−1].
-

Value of l	Subshell
0 →	s
1 →	p
2 →	d
3 →	f
4 →	g

Note

The notations for the sub-energy levels come from the spectroscopic terms that were used to describe the atomic spectra and have the following full form:

s → sharp	f → fundamental
p → principal	g → generalized
d → diffused	

[III] Magnetic Quantum Number (m)

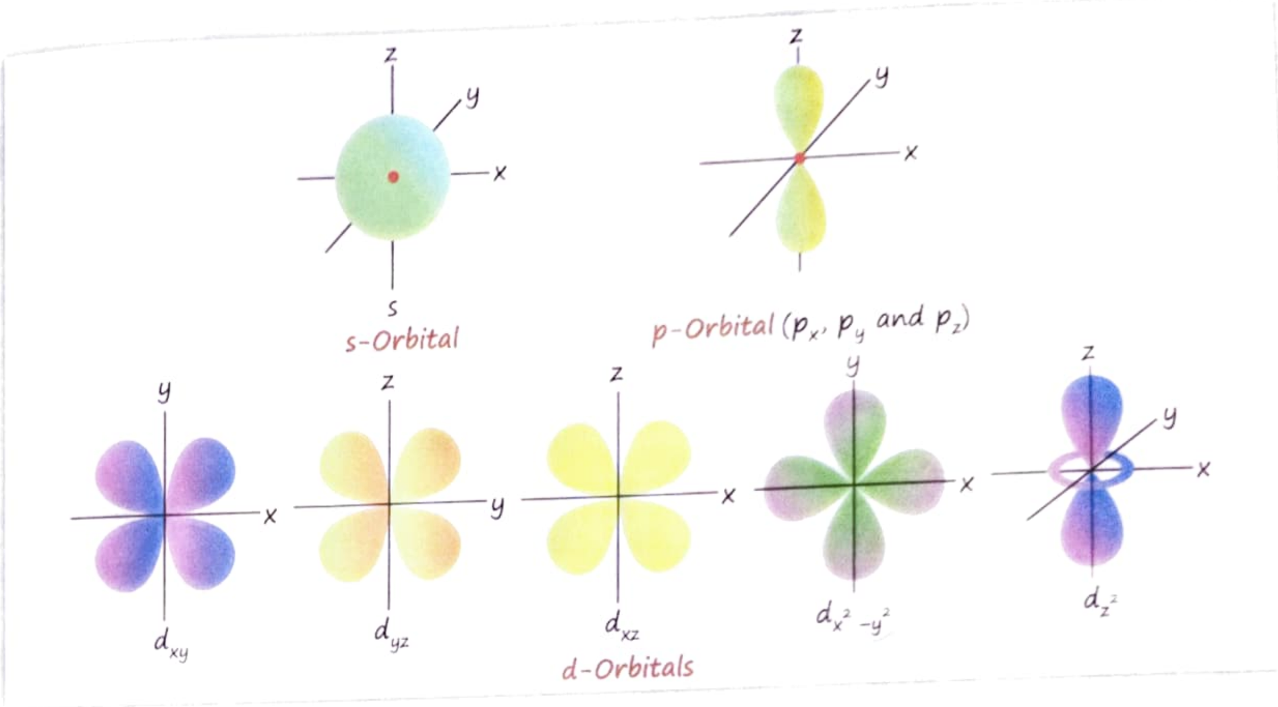
It describes the orientation of an orbital within a subshell. It can have values from $-\ell$ to $+\ell$ including zero, i.e., total $(2\ell + 1)$ values. Each value corresponds to an orbital, s-subshell has one orbital, p-subshell three orbitals (p_x, p_y and p_z), d-subshell five orbitals (d_{xy}, d_{yz}, d_{zx}, $d_{x^2-y^2}$, d_{z^2}) and f-subshell has seven orbitals.

s → $\ell = 0$, m = 0 | 0

p → $\ell = 1$, m = −1, 0, +1 | −1 0 +1

d → $\ell = 2$, m = −2, −1, 0, +1, +2 | −2 −1 0 +1 +2

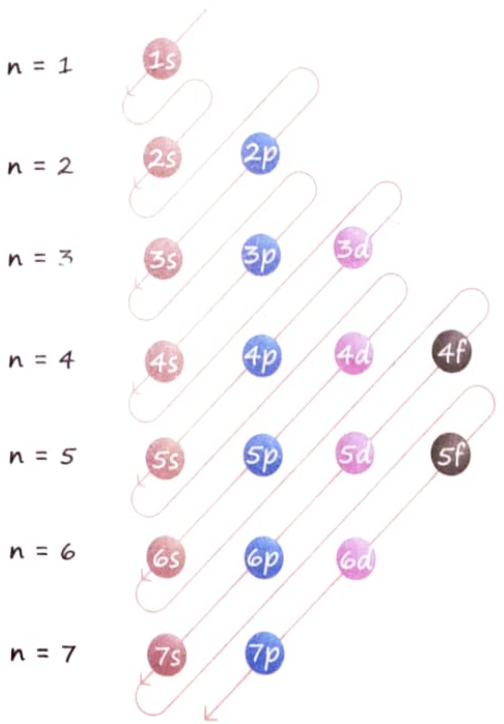
f → $\ell = 3$, m = −3, −2, −1, 0, +1, +2, +3 | −3 −2 −1 0 +1 +2 +3



[IV] Spin Quantum Number (s)

It describes the spin of the electron. It has values +1/2 and −1/2. (+) signifies clockwise spinning and (−) signifies anticlockwise spinning.

n+l RULE AND MODERN PERIODIC TABLE

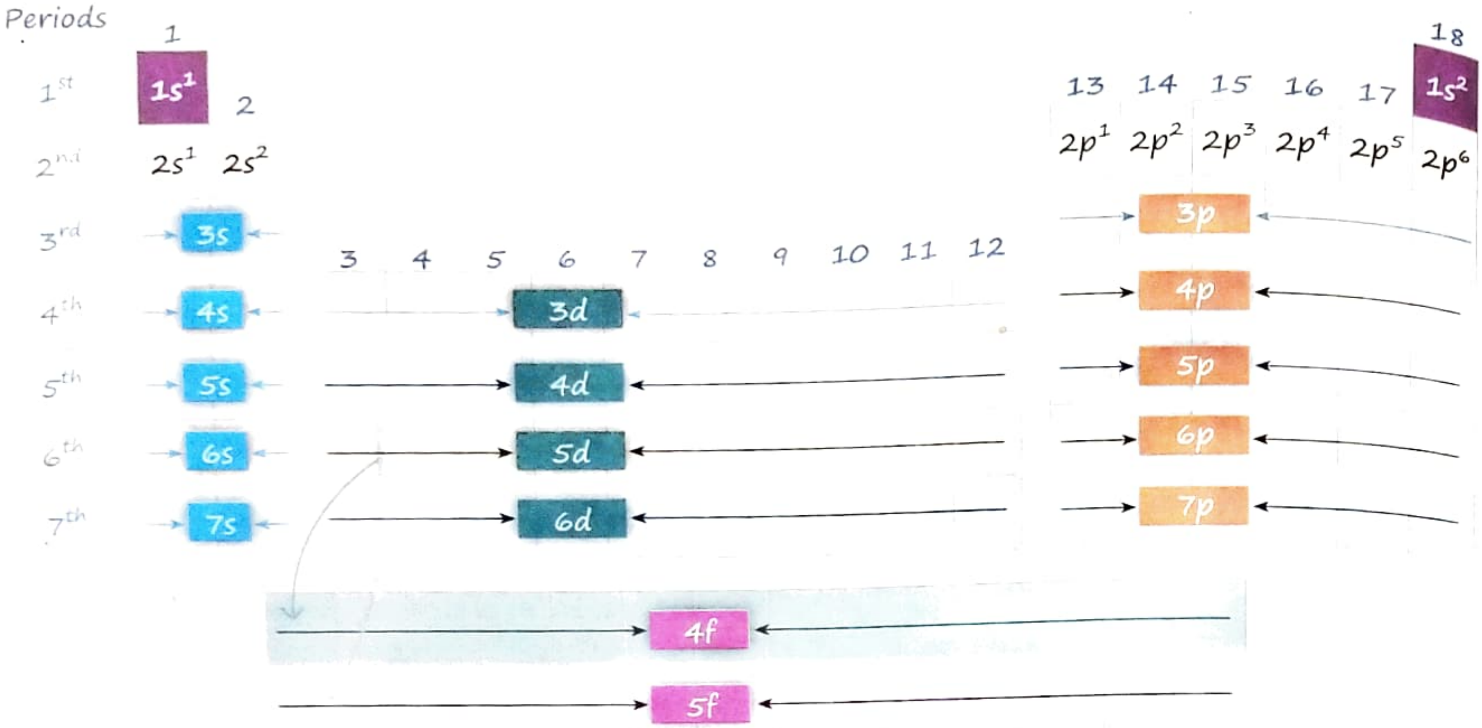


Max. n	Energy Sequence and Set of Subshells				No. of electrons in set of subshell
1	1s				2
2	2s			2p	2 + 6 = 8
3	3s			3p	2 + 6 = 8
4	4s		3d	4p	2 + 10 + 6 = 18
5	5s		4d	5p	2 + 10 + 6 = 18
6	6s	4f	5d	6p	2 + 14 + 10 + 6 = 32
7	7s	5f	6d	7p	2 + 14 + 10 + 6 = 32

Block: s, p, d, f

7 Periods: Horizontal Rows

18 Groups: Vertical Columns



ATOMIC NUMBER DISTRIBUTION

Period Number	Range
1	1-2
2	3-10
3	11-18
4	19-36
5	37-54
6	55-86
7	87-118

La_{57} | $Ce_{58} \longrightarrow Lu_{71}$ | Hf_{72}

Ac_{89} | $Th_{90} \longrightarrow Lr_{103}$ | Rf_{104}

Lanthanoid Series	
Period No.	6
Group No.	3

Actinoid Series	
Period No.	7
Group No.	3

MODERN PERIODIC TABLE

s-Block (ns) | d-Block (n – 1)d | p-Block (np)

Transition metals (d-Block)

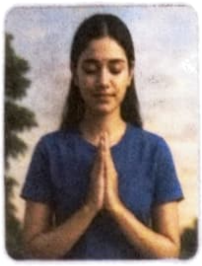
Group / Period	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
	IA	IIA	IIIB	IVB	VB	VIB	VIIB	VIII			IB	IIB	IIIA	IVA	VA	VIA	VIIA	VIIIA
1 (1s)	H																	He
2 (2s, 2p)	Li	Be											B	C	N	O	F	Ne
3 (3s, 3p)	Na	Mg											Al	Si	P	S	Cl	Ar
4 (4s, 3d, 4p)	K	Ca	Sc	Ti	V	Cr	Mn	Fe	Co	Ni	Cu	Zn	Ga	Ge	As	Se	Br	Kr
5 (5s, 4d, 5p)	Rb	Sr	Y	Zr	Nb	Mo	Tc	Ru	Rh	Pd	Ag	Cd	In	Sn	Sb	Te	I	Xe
6 (6s, 4f, 5d, 6p)	Cs	Ba	La	Hf	Ta	W	Re	Os	Ir	Pt	Au	Hg	Tl	Pb	Bi	Po	At	Rn
7 (7s, 5f, 6d, 7p)	Fr	Ra	Ac	Rf	Db	Sg	Bh	Hs	Mt	Ds	Rg	Cn	Nh	Fl	Mc	Lv	Ts	Og

The Rare Earths, (n – 2)f

f-Block															
Lanthanide series (4f) Period : 6	Ce	Pr	Nd	Pm	Sm	Eu	Gd	Tb	Dy	Ho	Er	Tm	Yb	Lu
Actinide series (5f) Period : 7	Th	Pa	U	Np	Pu	Am	Cm	Bk	Cf	Es	Fm	Md	No	Lr

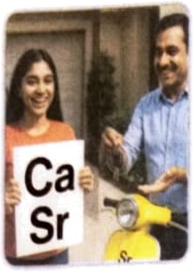
देशी जुगाड़

Alkali Metals (Group-1)



HLiNa ne Ki Rb Cs Fariyad

Alkaline Earth Metals (Group-2)



Beti Mage Car Scooter Baap Razi

Group-13: Boron Family

BAG In thela

Bengan Alu Gajar In Thaila

Group-14: Carbon Family

Cahei Sita Ge Suno Prabhu

Group-15: Nitrogen Family

Nana Patekar Aishwarya Sb Bimar

Group-16: Oxygen Family

O S Se Te Po

Group-17: Halogen Family

Fir Cal* Bahar I Aunty

Group-18: Inert Gas Family

Heena Neena Aur Kareena Xerox Rangeen

1st Transition Series: 3d Series

Science Ticher Very Cruel Mange Fees Copy Niha Cukker Zindabad

2nd Transition Series: 4d Series

Yari Zra Nibhana Mout Tc Rukawat Rah Pde Age Cudo

3rd Transition Series: 5d Series

La HafTa Warna Re Osama Idher Pitayi Aur Hogi

4th Transition Series: 6d Series

Ac Rutherford Dube Sagar me Bohr Hs Mat Darse Royga Caun

Group-3

ScYLa Ac me rahti hai

Group-4

Tina Zor Haaf Rafi* hai

Group-5

Vo Nabab Tha Dabang

Group-6

Crying Moti Wife

Group-7

Maan Tac* Rekha

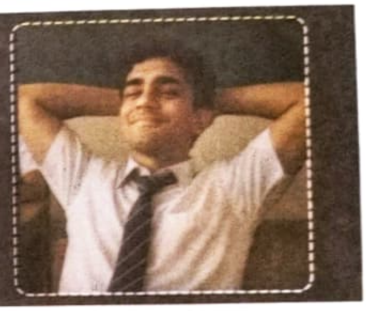
Group-8 and 9

Fer* Rouya Osama Con* Rahega Iran me

Group-10, 11, 12

Nahi Padoge to Pitoge

Cyu Aage Aau



Zindagi Cadbury Hogyi

Lanthanoids → I[st] Inner Transition Series (Part of Group 3)

Cene Pr Nadiyan Prem Ki Samayi Eu Gadgad Tab Dyl Ho gya Engineer Tum Yebhi Lu

Actinoids → II[nd] Inner Transition Series (Part of Group 3)

Thor Ke Papa ne U bola Nepal me Purane Am Cam Bikenge Cafe me jana Ease Farmana Madam Noodles Lare

Place of Hydrogen is not fixed in Periodic Table because it shares properties with both alkali metals and halogens.

IUPAC NAME, COMMON NAME AND POSITION OF ELEMENTS HAVING ATOMIC NUMBER 101 TO 118

Digit	Name	Abbreviation
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

Suffix – ium
101 : Unnilunium (Unu)
102 : Unnilbium (Unb)
105 : Unnilpentium (Unp)
110 : Ununnilium (Uun)
118 : Ununoctium (Uuo)
119 : Ununennium (Uue)

Z = 143
IUPAC Name
↓
Unquadtrium
UQT

Atomic Number 101 to 118

1. Mendeleev [101] ko mila Nobel [102] in Lowrence [103]
2. Rutherford [104] Dube [105] Sea [106] me Bohr [107] Hass [108] Meit [109]
3. Dar [110] se Roe [111] Coper [112]
4. Niho [113] Fle [114] to Mosco [115] to Live [116] Ten [117] Ogan [118]

Atomic Number	Name
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)

Atomic Number	Name
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)

Position in Periodic Table

	101	102	103
Period No. →	7		
Group No. →	3 (Part of actinoids)		

	104	105	106	107	....	118
Group No. →	4th	5th	6th	7th		18th
Period No. →	7					

1. The IUPAC symbol for the element with atomic number 119 would be- [8 April, 2019 (Shift-2)]

(a) Unh (b) Uue (c) Uun (d) Une

Sol. (b)

2. Lanthanoids and Actinoids are present in which of the following group-

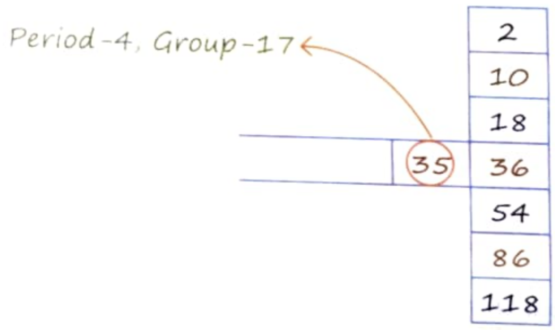
(a) Group 1 (b) Group 3 (c) Group 17 (d) Group 18

Sol. (b)

3. If the atomic number of an element is 35, it will be placed in the periodic table in the-

(a) Group 1 (b) Group 3 (c) Group 17 (d) Group 18

Sol. (c)



[30 Jan, 2023 (Shift-1)]

4. Match List-I with List-II

List-I (Atomic Number)		List-II (Block of Periodic Table)	
(A)	37	(i)	p-block
(B)	78	(ii)	d-block
(C)	52	(iii)	f-block
(D)	65	(iv)	s-block

Choose the correct answer from the options given below:

(a) A-ii, B-iv, C-i, D-iii

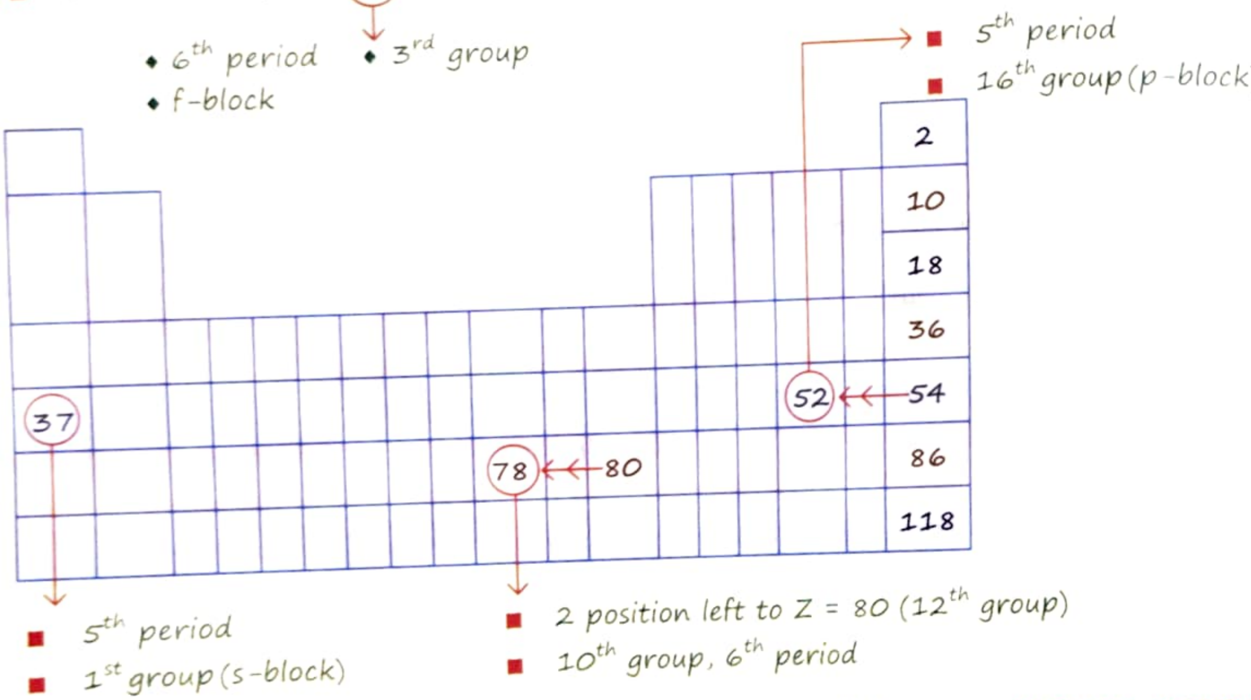
(b) A-i, B-iii, C-iv, D-ii

(c) A-iv, B-iii, C-ii, D-i

(d) A-iv, B-ii, C-i, D-iii

Sol. (d) A-iv, B-ii, C-i, D-iii

- Lanthanoids (58 < 65 < 71)



[30 Jan, 2023 (Shift-1)]

5. The element with atomic number 117, 119, 120, 91 will be-

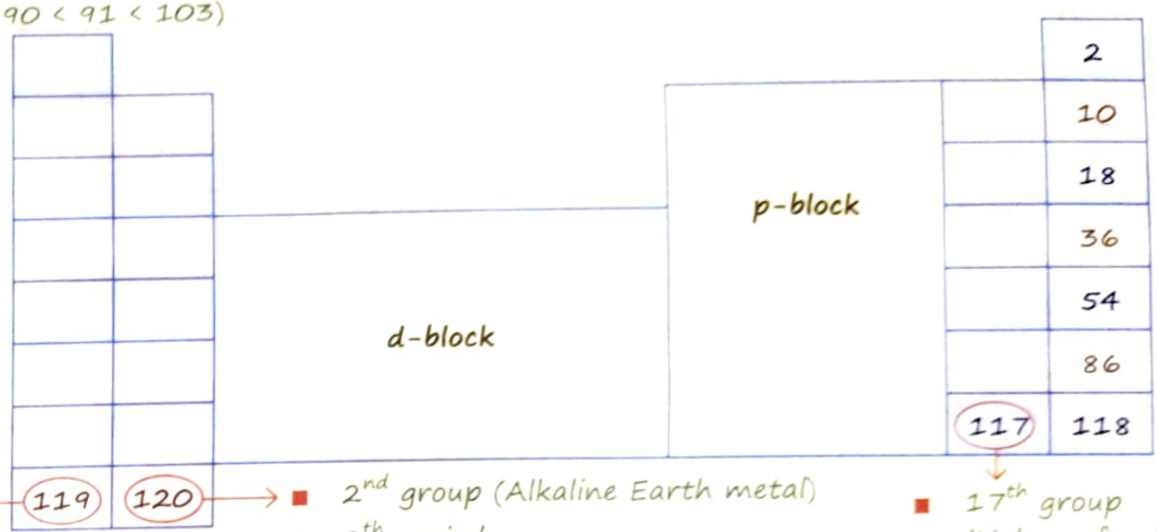
(a) Alkali's

(b) Halogen, Alkali, Alkaline earth metal & Lanthanide

(c) Halogen, Alkali, Alkaline earth metal & Actinide

(d) Transition element, Halogen, Alkali, Alkaline earth metal

Sol. (c) Actinoids (90 < 91 < 103)



- 1^{st} group
- Alkali metals
- 8^{th} period

- 2^{nd} group (Alkaline Earth metal)
- 8^{th} period

- 17^{th} group (Halogen family)
- 7^{th} period

6. **The elements with atomic number 101 and 104 belong to, respectively-** [4 Sept, 2020 (Shift-1)]

(a) Actinoids and Group 4 (b) Group 11 and Group 4
(c) Group 6 and Actinoids (d) Actinoids and Group 6

Sol. (a)

7. **Identify the incorrect match.**

	Name		IUPAC Official Name
(A)	Unnilunium 101	(i)	Mendelevium
(B)	Unniltrium 103	(ii)	Lawrencium
(C)	Unnilhexium 106	(iii)	Seaborgium
(D)	Unununium 111	(iv)	Darmstadtium

(a) A-(i) (b) B-(ii) (c) C-(iii) (d) D-(iv)

Sol. (d) Unununium [111] → Roentgenium

8. **The element with Z = 120 (not yet discovered) will be an/a** [12 Jan, 2019 (Shift-2)]

(a) Transition metal (b) Inner transition metal
(c) Alkaline earth metal (d) Alkali metal

Sol. (c)

METAL, NON-METAL AND METALLOID

Metal

$M \rightarrow M^+ + e^-$

- The metals are characterised by their nature of readily giving up the electron(s) and form shining lustre.
- Metals comprises more than 78% of all known elements and appear on the left hand side of the periodic table.
- Metals are usually solids at room temperature (except Hg, Ga).
- They have high melting and boiling points and are good conductors of heat and electricity.

Non-metal

$N + e^- \rightarrow N^-$

- Non-metals do not lose electrons but take up electrons to form corresponding anions.
- Non-metals are located at the top right hand side of the periodic table.
- Non-metals are usually solids, liquids or gases at room temperature with low melting and boiling points. They are poor conductors of heat and electricity.

Metalloids (Semi-metals)

It has been found that some elements which lie at the border of metallic and nonmetallic behavior, possess the properties that are characteristic of both metals and non-metals. These elements are called semi-metals or metalloids.

Examples - As, Sb, Se, Te, Ge

s-BLOCK

Alkali Metals (Group-1) General electronic configuration ⇒ [Inert gas] ns^1		
n = 2	Li_3	: [He] $2s^1$
n = 3	Na_{11}	: [Ne] $3s^1$
n = 4	K_{19}	: [Ar] $4s^1$
n = 5	Rb_{37}	: [Kr] $5s^1$
n = 6	Cs_{55}	: [Xe] $6s^1$

Alkaline Earth Metals (Group-2) General electronic configuration ⇒ [Inert gas] ns^2	
Be_4	: [He] $2s^2$
Mg_{12}	: [Ne] $3s^2$
Ca_{20}	: [Ar] $4s^2$
Sr_{38}	: [Kr] $5s^2$
Ba_{56}	: [Xe] $6s^2$

When shells upto (n − 1) are completely filled and the last electron enters the s-orbital of the outermost (n^{th}) shell, the elements of this class are called s-block elements.

- Group 1 & 2
- General electronic configuration : [inert gas] ns^{1-2}
- s-block elements lie on the extreme left of the periodic table.
- This block includes metals.

p-BLOCK

Group-13: [Inert Gas] ns^2np^1		Group-14: [Inert Gas] ns^2np^2	
B_5	: [He] $2s^2\ 2p^1$	C_6	: [He] $2s^2\ 2p^2$
Al_{13}	: [Ne] $3s^2\ 3p^1$	Si_{14}	: [Ne] $3s^2\ 3p^2$
Ga_{31}	: [Ar] $4s^2\ 3d^{10}\ 4p^1$	Ge_{32}	: [Ar] $4s^2\ 3d^{10}\ 4p^2$
In_{49}	: [Kr] $5s^2\ 4d^{10}\ 5p^1$	Sn_{50}	: [Kr] $5s^2\ 4d^{10}\ 5p^2$
Tl_{81}	: [Xe] $6s^2\ 4f^{14}\ 5d^{10}\ 6p^1$	Pb_{82}	: [Xe] $6s^2\ 4f^{14}\ 5d^{10}\ 6p^2$
Nh_{113}	: [Rh] $7s^2\ 5f^{14}\ 6d^{10}\ 7p^1$	Fl_{114}	: [Rn] $7s^2\ 5f^{14}\ 6d^{10}\ 7p^2$

Period No. / Group No.	Group 15 (Pnictogens)	Group 16 (Chalcogens)	Group 17 (Halogens)	Group 18 (Inert gas)
1.				He: $1s^2$
2.	N: [He] $2s^2\ 2p^3$	O: [He] $2s^2\ 2p^4$	F: [He] $2s^2\ 2p^5$	Ne: [He] $2s^2\ 2p^6$
3.	P: [Ne] $3s^2\ 3p^3$	S: [Ne] $3s^2\ 3p^4$	Cl: [Ne] $3s^2\ 3p^5$	Ar: [Ne] $3s^2\ 3p^6$
4.	As: [Ar] $4s^2\ 3d^{10}\ 4p^3$	Se: [Ar] $4s^2\ 3d^{10}\ 4p^4$	Br: [Ar] $4s^2\ 3d^{10}\ 4p^5$	Kr: [Ar] $4s^2\ 3d^{10}\ 4p^6$
5.	Sb: [Kr] $5s^2\ 4d^{10}\ 5p^3$	Te: [Kr] $5s^2\ 4d^{10}\ 5p^4$	I: [Kr] $5s^2\ 4d^{10}\ 5p^5$	Xe: [Kr] $5s^2\ 4d^{10}\ 5p^6$
6.	Bi: [Xe] $6s^2\ 4f^{14}\ 5d^{10}\ 6p^3$	Po: [Xe] $6s^2\ 4f^{14}\ 5d^{10}\ 6p^4$	At: [Xe] $6s^2\ 4f^{14}\ 5d^{10}\ 6p^5$	Rn: [Xe] $6s^2\ 4f^{14}\ 5d^{10}\ 6p^6$

When shells upto $(n - 1)$ are completely filled and differentiating electron enters the p-orbital of the n^{th} orbit, elements of this class are called p-block elements.

- Group 13 to 18
- General electronic configuration: [inert gas] $ns^2\ np^{1-6}$
- p-block elements lie on the extreme right of the periodic table.
- This block includes some metals, all non-metals and metalloids.
- Representative Elements: s + p **block elements except inert gas elements.**

d-BLOCK ELEMENTS

Series name ↓ | Group →	3		4	5	6	7	8	9	10	11	12
3d-series	Sc_{21}		Ti_{22}	V	Cr	Mn	Fe	Co	Ni	Cu	Zn_{30}
4d-series	Y_{39}		Zr_{40}	Nb	Mo	Tc	Ru	Rh	Pd	Ag	Cd_{48}
5d-series	La_{57}	4f Series	Hf_{72}	Ta	W	Re	Os	Ir	Pt	Au	Hg_{80}
6d-series	Ac_{89}	5f Series	Rf_{104}	Db	Sg	Bh	Hs	Mt	Ds	Rg	Cn_{112}

Electronic Configuration

3d series: [Ar] 4s 3d

4d series: [Kr] 5s 4d

5d series: [Xe] 6s 5d : for La
[Xe] 6s 5d $4f^{14}$: from Hf → Hg

6d series: [Rn] 7s 6d : for Ac
[Rn] 7s 6d $5f^{14}$: from Rf → Cn

देशी जुगाड़ For Electronic Configuration of 11 Elements

Rahgir(Rg) Kyu(Cu) Aage(Ag) Aau(Au) Pitayi(Pt) Croge(Cr), Nabab(Nb) Mout(Mo) Rukawat(Ru) Rah(Rh) Padegi(Pd)

Rg	Cu	Ag	Au	Pt	Cr	Nb	Mo	Ru	Rh

$\rightarrow ns^1$

Pd $\rightarrow ns^0$

Sc $4s^2\ 3d^1$	Ti $4s^2\ 3d^2$	V $4s^2\ 3d^3$	Cr $4s^1\ 3d^5$	Mn $4s^2\ 3d^5$	Fe $4s^2\ 3d^6$	Co $4s^2\ 3d^7$	Ni $4s^2\ 3d^8$	Cu $4s^1\ 3d^{10}$	Zn $4s^2\ 3d^{10}$
Y $5s^2\ 4d^1$	Zr $5s^2\ 4d^2$	Nb $5s^1\ 4d^4$	Mo $5s^1\ 4d^5$	Tc $5s^2\ 4d^5$	Ru $5s^1\ 4d^7$	Rh $5s^1\ 4d^8$	Pd $5s^0\ 4d^{10}$	Ag $5s^1\ 4d^{10}$	Cd $5s^2\ 4d^{10}$
La $6s^2\ 5d^1$	Hf $6s^2\ 5d^2\ 4f^{14}$	Ta $6s^2\ 5d^3\ 4f^{14}$	W $6s^2\ 5d^4\ 4f^{14}$	Re $6s^2\ 5d^5\ 4f^{14}$	Os $6s^2\ 5d^6\ 4f^{14}$	Ir $6s^2\ 5d^7\ 4f^{14}$	Pt $6s^1\ 5d^9\ 4f^{14}$	Au $6s^1\ 5d^{10}\ 4f^{14}$	Hg $6s^2\ 5d^{10}\ 4f^{14}$
Ac $7s^2\ 6d^1$	Rf $7s^2\ 6d^2\ 5f^{14}$	Db $7s^2\ 6d^3\ 5f^{14}$	Sg $7s^2\ 6d^4\ 5f^{14}$	Bh $7s^2\ 6d^5\ 5f^{14}$	Hs $7s^2\ 6d^6\ 5f^{14}$	Mt $7s^2\ 6d^7\ 5f^{14}$	Ds $7s^2\ 6d^8\ 5f^{14}$	Rg $7s^1\ 6d^{10}\ 5f^{14}$	Cn $7s^2\ 6d^{10}\ 5f^{14}$

- Group : 3 to 12
- General electronic configuration : [inert gas] $ns^{0-2}\ (n-1)d^{1-10}$ (except, Pd : $4d^{10}5s^0$)

When outermost (n^{th}) and penultimate shells $(n-1)^{th}$ shells are incompletely filled and differentiating electron enters the $(n-1)$ d orbitals (d-orbital of penultimate shell) then elements of this class are called d-block elements.

- All the transition elements are metals.

1^{st} Transition Series	2^{nd} Transition Series
3d series	4d series
10 elements	10 elements
Starts from $_{21}Sc - _{30}Zn$.	Starts from $_{39}Y - _{48}Cd$
Filling of electrons takes place in 3d subshell.	Filling of electrons takes place in 4d subshell.

3^{rd} Transition Series	4^{th} Transition Series
5d series	6d series
10 elements	10 elements
Starts from $_{57}La$, $_{72}Hf - _{80}Hg$.	Starts from $_{89}Ac$, $_{104}Rf - _{112}Uub$.
Filling of electrons takes place in 5d subshell.	Filling of electrons takes place in 6d subshell.

Transition Metals

The elements whose atoms or simple ions contain partially filled d-orbitals are called transition metals.

1. Sc is a transition metal because Sc has partially filled d-orbitals.

   Sc : [Ar] $4s^2\ 3d^1$

2. Zn is not a transition metal because Zn and Zn^{2+} both have filled d-orbitals.

   Zn : [Ar] $4s^2\ 3d^{10}$
   Zn^{2+} : [Ar] $3d^{10}$

3. Cu is a transition metal because Cu^{2+} has partially filled d-orbitals.

   Cu : [Ar] $4s^1\ 3d^{10}$
   Cu^{2+} : [Ar] $3d^9$

Note

- Zn, Cd, Hg are not considered as transition elements because they have filled 'd^{10} configuration' in atomic (M) and ionic (M^{2+}) form.
- All transition elements are d-block elements but not all d-block elements are transition elements.
  - Elements in Liquid State at STP - Hg (metal), Br_2 (Non-metal)
  - Metals in Liquid State (at T < 40°C) - Rubi Mar Gayi Fir se
    Rb Hg Ga Fr Cs

f-BLOCK ELEMENTS

The f-block consists of the two series, lanthanoids (the fourteen elements following lanthanum) and actinoids (the fourteen elements following actinium).

Lanthanoids	Ce_{58}	Pr	Nd	Pm	Sm	Eu	Gd	Tb	Dy	Ho	Er	Tm	Yb	Lu_{71}
Actinoids	Th_{90}	Pa	U	Np	Pu	Am	Cm	Bk	Cf	Es	Fm	Md	No	Lr_{103}

- They are metals
- All f-block elements belong to 3^{rd} group.

1^{st} Inner Transition Series - 4f series	2^{nd} Inner Transition Series- 5f series
14 elements - $_{58}Ce$ to $_{71}Lu$	14 elements - $_{90}Th$ to $_{103}Lr$
Filling of electrons takes place in 4f subshell.	Filling of electrons takes place in 5f subshell.

Transuranium Elements $\boxed{Z > 92}$

- The elements coming after uranium are called transuranium elements.

General electronic configuration : [Inert gas] $ns^2\ (n-2)f^{1-14}\ (n-1)d^{0-1}$

- When n, (n−1) and (n−2) shells are incompletely filled and last electron enters into f-orbital of anti-penultimate $(n-2)^{th}$ shell, elements of this class are called f-block elements.
- They are also called as inner transition elements as they contain three incomplete outermost shells and were also referred to as rare earth elements since their oxides were rare in earlier days.

9. The element Z = 114 has been discovered recently. It will belong to which of the following family/group and electronic configuration?

(a) Carbon family, $[Rn]5f^{14}6d^{10}7s^27p^2$
(b) Oxygen family, $[Rn]5f^{14}6d^{10}7s^27p^4$
(c) Nitrogen family, $[Rn]5f^{14}6d^{10}7s^28p^6$
(d) Halogen family, $[Rn]5f^{14}6d^{10}7s^27p^5$

Sol. (a)

10. Which of the following is representative group of elements in the periodic table?

(a) Lanthanum (La)
(b) Argon (Ar)
(c) Chromium (Cr)
(d) Aluminium (Al)

Sol. (d)

11. If Z is given (Z = 32, 57, 71, 87), then what will be Period number, Group number, Block, Family, Electronic Configuration?

Sol. Z = 32
→ p-Block
→ Group Number - 14
→ Period - 4 (Carbon family)
→ EC ≡ $[Ar]\ 4s^2\ 3d^{10}\ 4p^2$

Z = 57
→ d-Block
→ Group Number - 3
→ Period Number - 6
→ EC ≡ $[Xe]\ 6s^2\ 5d^1$

Z = 71
→ f-Block (Lanthanoids)
→ Group Number - 3
→ Period Number - 6
→ EC ≡ $[Xe]\ 6s^2\ 5d^1\ 4f^{14}$

Z = 87
→ Alkali metal
→ s-Block
→ Group 1 [7^{th} Period]
→ EC ≡ $[Rn]\ 7s^1$

Note

If electronic configuration of an element is given and you have to find the position of element in periodic table then add all electrons and find atomic number (**For neutral element → Total no. of electrons = atomic number**).

- Through atomic number, you can find the position of element.

12. The IUPAC nomenclature of an element with electronic configuration $[Rn]5f^{14}6d^{1}7s^{2}$ is : [23 July, 2022 (Shift-1)]

(a) Unnilbium (b) Unnilunium (c) Unnilquadium (d) Unniltrium

Sol. (d) Total number of electrons = 86 + 14 + 1 + 2 = 103 [IUPAC Name - Unniltrium]

13. An atom has electronic configuration $1s^{2}2s^{2}2p^{6}3s^{2}3p^{6}3d^{3}4s^{2}$, you will place it in-

(a) fifth group (b) fifteenth group (c) second group (d) third group

Sol. (a) Total number of electrons = 2 + 2 + 6 + 2 + 6 + 3 + 2 = 23

14. The characteristics of element X, Y and Z with atomic numbers, respectively, 33, 53 and 83 are: [16 March, 2021 (Shift-2)]

(a) X and Y are metalloids and Z is a metal

(b) X is a metalloid, Y is a non-metal and Z is a metal

(c) X, Y and Z are metals.

(d) X and Z are non-metals and Y is metalloid

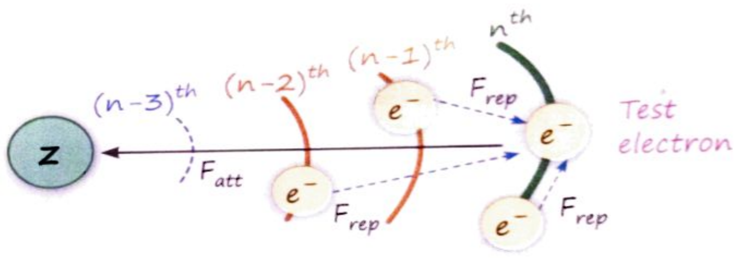
Sol. (b) Metalloid X → 33 [As] Non-metal Y → 53 [I] Metal Z → 83 [Bi]

EFFECTIVE NUCLEAR CHARGE

$F_{effective} = F_{att.} - F_{rep.}$

$Z_{eff} = Z - \sigma$

- Z_{eff} → औकात of Nucleus
- Z → Atomic number
- σ → Shielding constant, Screening constant, Slater's constant



- Number of inner shell electrons ↑ ⇒ σ ↑ ⇒ Z_{eff} ↓

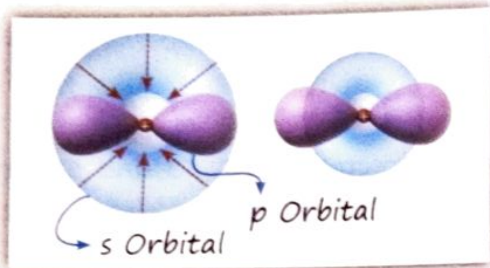
- There is a reduction in nuclear charge due to presence of screen b/w test electron and nucleus.

  Screening/Shielding Effect: The phenomenon where inner electrons in an atom reduce the attractive force of the nucleus on outer electrons. These inner electrons effectively "screen or shield" the outer electrons from the full nuclear charge.

- **Effective nuclear charge (Z_{eff}):** The net positive charge experienced by an electron in a multi-electron atom, which is less than the full nuclear charge due to shielding by inner electrons.

PENETRATION EFFECT

- Penetration Power means the ability of an electron in an orbital to get close to the nucleus.
- The Penetration effect of s-orbital is the maximum because it is closer to the nucleus than the p, d and f-orbitals.



Due to spherical shape of s orbital, it is more attracted towards nucleus (centre of sphere) than p orbital having dumb bell shape.

Closeness to the nucleus : s > p > d > f

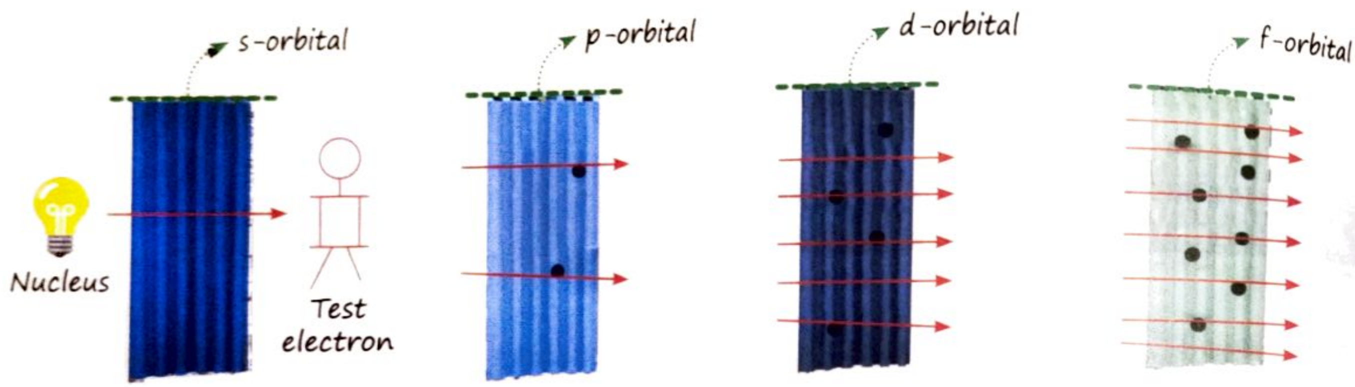
Penetration effect : s > p > d > f

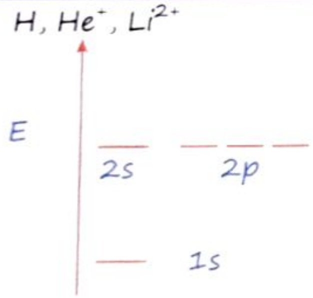
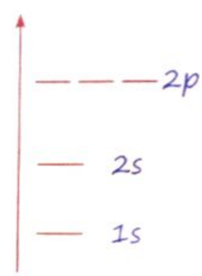
Screening effect/Shielding effect : s > p > $\boxed{d > f}$

Poor shielding

Contribution of subshell in shielding constant (σ) :

ns > np > nd > nf



1 Electron System	More than 1 Electron System
H, He^+, Li^{2+}  2s & 2p subshells are degenerate.	 2s and 2p subshells are non-degenerate

15. The order of screening effect of electrons of s, p, d and f orbitals of a given shell of an atom on its outer shell electrons is :

(a) s > p > d > f (b) f > d > p > s (c) p > d > s > f (d) f > p > s > d

Sol. (a)

16. Screening effect is not observed in :

(a) He^+ (b) Li^{2+} (c) Be^{3+} (d) In all cases

Sol. (d) Screening effect is not observed in 1 electron system.

Variation of Z_{eff} in Periodic Table

$Z_{eff} = Z - \sigma$

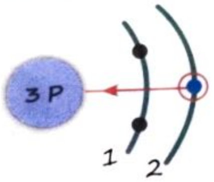
1. $Z_{eff} \propto Z$
2. $Z_{eff} \propto \frac{1}{\sigma} \propto \frac{1}{n_e}$

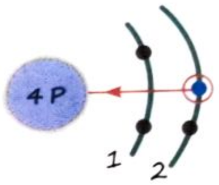
$\boxed{Z_{eff} \propto \frac{Z}{n_e}}$

$n_e \rightarrow$ Total number of electrons in atom

- **Variation in a Period:** Left → Right ⇒ $Z_{eff} \uparrow$ [Generally it is valid in s, p, d and f block]

Li_3 → Be_4





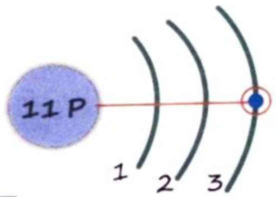
Z_{eff} : Li < Be

- Same shell number
- No. of protons ↑ : $Z_{eff} \uparrow$

- **Variation in a Group:** When we move from top to bottom

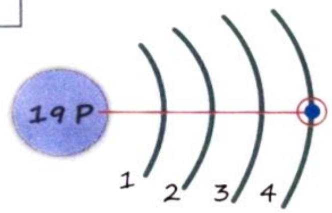
1. Zeff ⇒ Constant [Generally valid in s and p blocks but not always]

Na_{11}



Zeff is constant as no. of proton↑ but distance between nucleus and test electron↑.

K_{19}



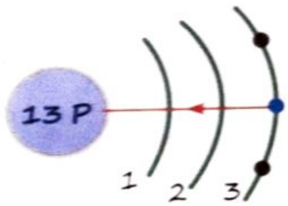
For Example

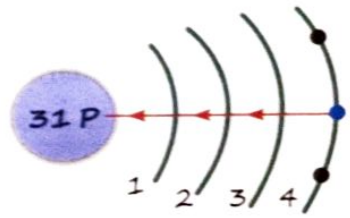
Al_{13} → [Ne] $3s^2$ $3p^1$

Ga_{31} → [Ar] $4s^2$ $\boxed{3d^{10}}$ $4p^1$

Due to poor shielding of $3d^{10}$ electrons, shielding constant σ decreases and $Z_{eff} \uparrow$

Z_{eff} : Al < Ga

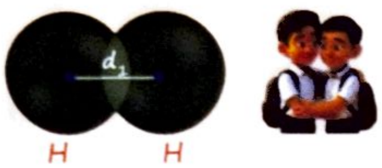
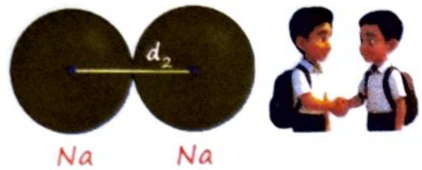
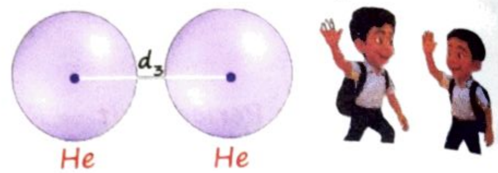




ATOMIC RADIUS

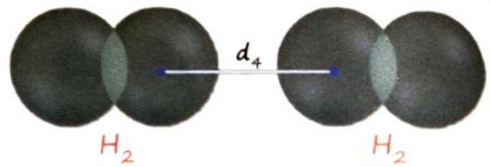
Atomic radius is the average or typical distance from the center of an atom's nucleus to the outermost shell.

$$\text{Atomic Radius} = \frac{\text{Inter-nuclear Distance}}{2}$$

Covalent Radius	Metallic Radius	vander Waal Radius
♦ Covalent Bond ♦ Non metal – non metal (H)	♦ Metallic bond ♦ Metal – metal (Na-Na)	♦ VW – Force of attraction ♦ Inert gas / molecules (He, Ne, Ar) (H_2, Cl_2)
		
$r_c = \frac{d_1}{2}$	$r_M = \frac{d_2}{2}$	$r_{VW} = \frac{d_3}{2}$

- ❑ $d_1 < d_2 < d_3$
- ❑ $r_C < r_M < r_{VW}$

$(r_{VW})_{H_2} = \frac{d_4}{2}$

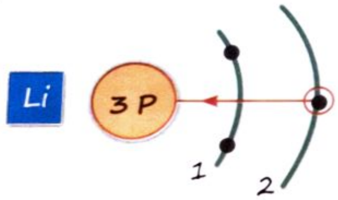


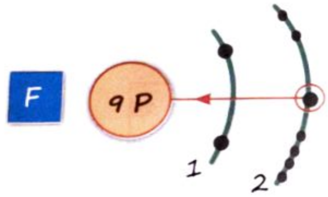
ATOMIC SIZE

❑ **Variation in a Period:** Left → Right ⇒ Z_{eff} ↑ ⇒ Atomic Radius ↓

$_{10}Ne$ > $_3Li$ > Be > B > C > N > O > F : Atomic Radius

vander Waal radii

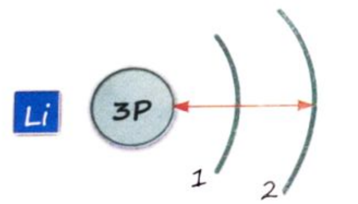


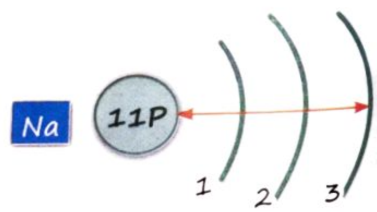


❑ **Variation in a Group:**

Top ↓ Bottom → Z_{eff} ≈ constant
→ Due to addition of new shell ⇒ Atomic Radius ↑

Period No.	Atomic Size
2	Li
	^
3	Na
	^
4	K
	^
5	Rb
	^
6	Cs





Same Period Elements	Different Period Elements
❑ L → R : Atomic Radius ↓	❑ Period Number ↑ : Atomic Radius ↑

♦ $\underbrace{Br}_{n=4} > \underbrace{C > N > F}_{n=2}$ ♦ $\underbrace{C}_{n=2} < \underbrace{S < Al}_{n=3} < \underbrace{Ca}_{n=4}$

♦ $\underset{n=2}{B}$ $\underset{n=3}{P} > \underset{n=3}{S} > \underset{n=3}{Cl}$ $\underset{n=4}{Br}$

B < Cl < S < P < Br → Atomic Size

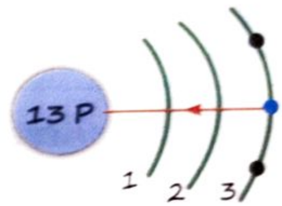
Boron Family

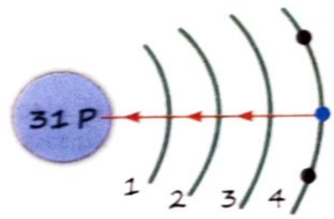
नौटंकी Family

B
^
Al_{13} → [Ne] $3s^2$ $3p^1$
v
Ga_{31} → [Ar] $4s^2$ $\boxed{3d^{10}}$ $4p^1$
^
In
^
Tl

Due to Poor shielding of 3d orbital electrons, Z_{eff} is more in Ga w.r.t Al

→ Z_{eff}↑ : Size↓



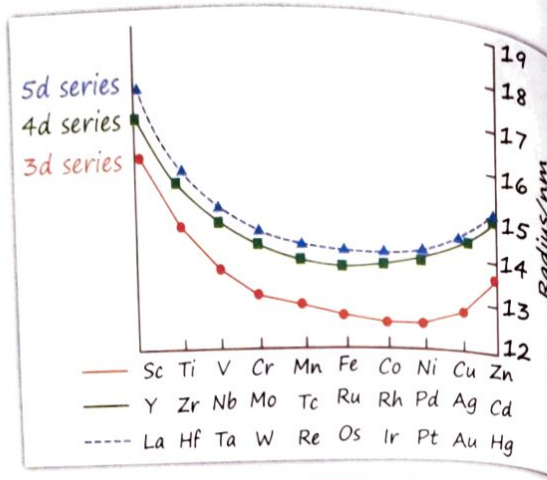


Atomic Size Order in s and p Block

H	
^	
Li	Be
^	^
Na	Mg
^	^
K	Ca
^	^
Rb	Sr
^	^
Cs	Ba

					He
					^
B	C	N	O	F	Ne
^	^	^	^	^	^
Al	Si	P	S	Cl	Ar
v	^	^	^	^	^
Ga	Ge	As	Se	Br	Kr
^	^	^	^	^	^
In	Sn	Sb	Te	I	Xe
^	^	^	^	^	^
Tl	Pb	Bi	Po	At	Rn

Atomic Size of 3d Series



There are two factors in order to decide atomic radius of an element.

1. Nuclear charge [Nuclear charge↑ : size↓]
2. Interelectronic repulsion (IER) [IER↑ : size↑]

Elements	Sc → Ti → V → Cr	Mn → Fe → Co → Ni	Cu → Zn
Size	Decreases	Nearly constant	Slightly increases
Reason	Nuclear charge dominates over IER	Nuclear charge ≈ IER	IER dominates over nuclear charge

Lanthanoid Contraction

- The decrease in atomic or ionic radii from Ce to Lu due to imperfect shielding of 4f e^- from nuclea charge is known as lanthanoid contraction.
- Lanthanoid contraction is similar to that observed in an ordinary transition series and is attribute to the same cause, the imperfect shielding of one electron by another in the same subshell.
- The shielding of one 4f electron by another is less than one d electron by another with the increas in nuclear charge along the series. There is fairly regular decrease in the sizes with increasing atom number.
- Lanthanoid contraction is applicable on both metal (M) and metal ion (M^{+3}) size orders.

Ce → Lu
Ce^{3+} → Lu^{3+}
→ Size decreases

Effect of Lanthanide Contraction on Size of d-Block Elements

3d →	$_{21}Sc$	$_{22}Ti$	V	Cr	Mn	Fe	Co	Ni	Cu	Zn
	∧	∧	∧	∧	∧	∧	∧	∧	∧	∧
4d →	$_{39}Y$	$_{40}Zr$	Nb	Mo	Tc	Ru	Rh	Pd	Ag	Cd
	∧	≈	≈	≈	≈	≈	≈	≈	≈	≈
5d →	$_{57}La$ ($_{58}Ce \longrightarrow {}_{71}Lu$)	$_{72}Hf$	Ta	W	Re	Os	Ir	Pt	Au	Hg

→ Free from effect of Lanthanide contraction

- Due to lanthanoid contraction, radii of the members of 5d series are found to be very similar to those of corresponding members of the 4d series.
- For d-block elements, the trend in atomic radii is: $r_{3d\ series} < r_{4d\ series} \approx r_{5d\ series}$

17. **The lanthanide contraction is responsible for the fact that :**

(a) Zr and Y have about the same radius (b) Zr and Nb have similar oxidation state

(c) Zr and Hf have about the same radius. (d) Zr and Zn have same oxidation state.

Sol. (c)

18. **Which of the following has similar atomic radius with respect to Ag :**

(a) La (b) Zn (c) Au (d) Rf

Sol. (c)

IONIC RADIUS

Cation → ⊕ vely charged ion	Anion → ⊖ vely charged ion
$Be \xrightarrow{-e^-} Be^+ \xrightarrow{-e^-} Be^{2+}$	$O \xrightarrow{+e^-} O^- \xrightarrow{+e^-} O^{2-}$
$Z_{eff} \propto \frac{Z}{e} = \frac{4}{4}$ $Z_{eff} \propto \frac{4}{3}$ $Z_{eff} \propto \frac{4}{2}$	$Z_{eff} \propto \frac{8}{8}$ $Z_{eff} \propto \frac{8}{9}$ $Z_{eff} \propto \frac{8}{10}$
Z_{eff} : $Be < Be^+ < Be^{2+}$ Size : $Be > Be^+ > Be^{2+}$: Mother atom > Cation	Z_{eff} : $O > O^- > O^{2-}$ Size : $O < O^- < O^{2-}$: Mother atom < Anion
♦ $Mg > Mg^+ > Mg^{2+}$: Size	♦ $I < I^-$: Size

ISOELECTRONIC SPECIES

- Species having same number of electrons are known as isoelectronic species.
- All ions– C^{4-}, N^{3-}, O^{2-}, F^-, Na^+, Mg^{2+}, Al^{3+} are isoelectronic because they all have 10 electrons.

	C^{4-}		N^{3-}		O^{2-}		F^-		Na^+		Mg^{2+}		Al^{3+}
Number of Electrons :	(6 + 4)		(7+3)		(8+2)		(9+1)		(11-1)		(12-2)		(13-3)
Number of Protons :	6		7		8		9		11		12		13
$Z_{eff} \propto \frac{Z}{e}$:	$\frac{6}{10}$	<	$\frac{7}{10}$	<	$\frac{8}{10}$	<	$\frac{9}{10}$	<	$\frac{11}{10}$	<	$\frac{12}{10}$	<	$\frac{13}{10}$
Size :	C^{4-}	>	N^{3-}	>	O^{2-}	>	F^-	>	Na^+	>	Mg^{2+}	>	Al^{3+}
			→ Anions								→ Cations		

- Si^{4-}, P^{3-}, S^{2-}, Cl^-, K^+, Ca^{2+}, Sc^{3+} → isoelectronic because they all have 18 electrons.

  Size → $Si^{4-} > P^{3-} > S^{2-} > Cl^- > K^+ > Ca^{2+} > Sc^{3+}$

Note

- H_2S, HCl, Ar, SH^- → **Isoelectronic with 18 electrons**
- NH_2^-, NH_3, CH_4, H_2O, OH^-, NH_4^+, NH_2^- → **Isoelectronic with 10 electrons**
- CO_3^{2-}, NO_3^-, BO_3^{3-} → **Isoelectronic with 32 electrons**
- SiO_4^{4-}, PO_4^{3-}, SO_4^{2-}, ClO_4^- → **Isoelectronic with 50 electrons**
- $[Ni(CO)_4]$, $[Co(CO)_4]^-$, $[Fe(CO)_4]^{2-}$, $[Fe(CO)_2(NO)_2]$ → **Isoelectronic with 84 electrons**

$\underbrace{28 + 4(6 + 8)}_{84}$ $\underbrace{27 + 4(6 + 8) + 1}_{84}$ $\underbrace{26 + 4(6 + 8) + 2}_{84}$ $\underbrace{26 + 2(6 + 8) + 2(7 + 8)}_{84}$

Find the order of ionic radius?

- S^{2-} > Cl^- > K^+ > Ca^{2+} : Size
  [16+2] [17+1] [19−1] [20−2] : Number of electrons
- Te^{2-} > I^- : Size
  [52+2] [53+1] : Number of electrons
- Period Number → 2 Period Number → 3
  O^{2-} < N^{3-} < S^{2-} < P^{3-} : Size
- $K^+ > Na^+ > Li^+$: Size [K > Na > Li : Size]
- $F^- < Cl^- < Br^- < I^-$: Size [I > Br > Cl > F : Size]
- $O^{2-} < S^{2-} < Se^{2-} < Te^{2-}$: Size

- Ar > S^{2-} > Cl^- > K^+ > Ca^{2+} : Size
  vander Waal radii

$F^- < H^-$

Note

The smallest anion is F^- and not H^- (ionic radius 208 pm). The radius order of anions is $F^- < Cl^- < Br^- < H^- < I^-$. The exception in the size of H^- is because this is the only anion with z/e ratio = 0.5.

19. Which of the following order is incorrect for size :

(a) Al > Ga (b) $Te^{2-} > I^- > Cs^+ > Ba^{2+}$ (c) $Cr^{3+} < Cr^{6+}$ (d) Pd ≈ Pt

Sol. (c)

20. The ionic radii (in Å) of N^{3-}, O^{2-} and F^- are respectively :

(a) 1.36, 1.40 and 1.71 (b) 1.36, 1.40 and 1.71

(c) 1.71, 1.40 and 1.36 (d) 1.71, 1.36 and 1.40

Sol. (c) $N^{3-} > O^{2-} > F^-$: size

21. **Ionic radii of** **(IIT JEE 1999)**

(a) $Ti^{4+} < Mn^{7+}$ (b) $^{35}Cl^- < ^{37}Cl^-$ (c) $K^+ > Cl^-$ (d) $P^{3+} > P^{5+}$

Sol. (d)

22. **Among $V(CO)_6$, $Cr(CO)_5$, $Cu(CO)_3$, $Mn(CO)_5$, $Fe(CO)_5$, $[Co(CO)_3]^{3-}$, $[Cr(CO)_4]^{4-}$, and $Ir(CO)_3$, the total number of species isoelectronic with $Ni(CO)_4$ is ______.** **(JEE Adv. 2024)**

[Given, atomic number: V = 23, Cr = 24, Mn = 25, Fe = 26, Co = 27, Ni = 28, Cu = 29, Ir = 77]

Sol. [1] Total number of electron in $Ni(CO)_4$ = 84

Species	Total electron
$V(CO)_6$	107
$Cr(CO)_5$	94
$Cu(CO)_3$	71
$Mn(CO)_5$	95

Species	Total electron
$Fe(CO)_5$	96
$[Co(CO)_3]^{3-}$	72
$[Cr(CO)_4]^{4-}$	84
$Ir(CO)_3$	119

Property	Paramagnetic	Diamagnetic
Unpaired Electrons	Have one or more unpaired electrons	All electrons are paired
Magnetic Behavior	Attracted to an external magnetic field	Repelled by an external magnetic field
Magnetic Moment	Has a net magnetic moment	No net magnetic moment
Examples	Fe^{3+}, Mn^{2+} → 23 electrons; NO → 15 electrons Entities having odd number of electrons are always paramagnetic.	He, Ne, Zn^{2+}, Mg

IONISATION ENERGY

Minimum energy required to remove an electron from an isolated gaseous atom is known as ionisation energy (IE).

$$A_{(g)} \xrightarrow{\text{Min. Energy}} A^+_{(g)} + e^-$$

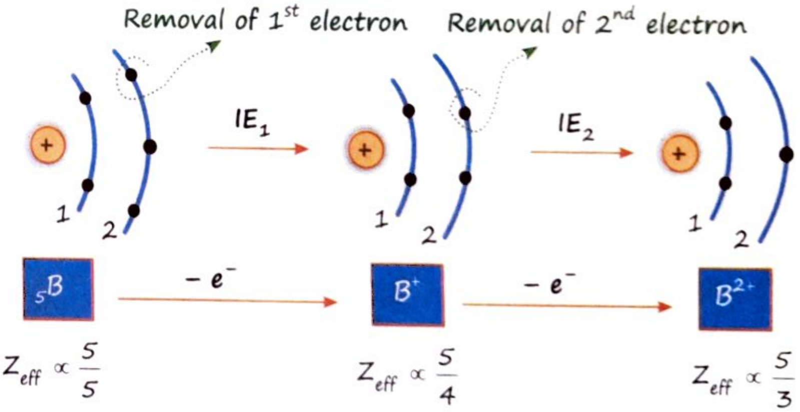
Successive IE :

Z_{eff} : $B < B^+$

IE : $B < B^+$

IE_1 of B < IE_2 of B

- IE_2 of B = IE_1 of B^+
  IE_3 of B = IE_1 of B^{2+}
  = IE_2 of B^+



Factors Affecting I.E.

* L to R :- IE ↑↑
* T to B :- IE ↓↓

1 Z_{eff} Left → Right ⇒ Z_{eff} ↑ : IE ↑

- $_3Li < _4Be$: IE
- B < C : IE
- O < F : IE

2 Size

Top ↓ Bottom → Size ↑ : IE ↓

Li > Na > K > Rb > Cs

As we move from top to bottom: Size ↑ : IE ↓

Metallic Character $M \rightarrow M^+ + e^-$

- Tendency of an element to lose electrons and form positive ions or cations.
- IE ↓ : Metallic character ↑
- Metallic character : Cs > Rb > K > Na > Li

3 Electronic Configuration Half filled / Fully filled subshell → Stable due to high exchange energy.
→ Removal of electron is tough so high IE.

IE : N > O

$2s^2$ $2p^3$ $2s^2$ $2p^4$

Removal of electron from half filled subshell is tough

IE : P > S

$3p^3$ $3p^4$

IE : As > Se

$4p^3$ $4p^4$

In the oxygen atom, two of the four 2p electrons must occupy the same 2p-orbital, resulting in an increased $e^- - e^-$ repulsion. So, it is easier to remove the fourth 2p electron from oxygen than it is to remove one of the three 2p-electrons from nitrogen.

Comparison of 2nd Ionisation Energy

Group-1

Na

[Ne] $3s^1$

$\downarrow IE_1$

$Na^+ \equiv 1s^2\ 2s^2\ 2p^6$ → Removal of electron from 2nd shell is tough.

$\downarrow IE_2$

Na^{2+}

Group-2

Mg

[Ne] $3s^2$

$\downarrow IE_1$

$Mg^+ \equiv [Ne]\ 3s^1$ → Removal of electron from 3rd shell is easy.

$\downarrow IE_2$

Mg^{2+}

IE_1 : group 1 < group 2

IE_2 : group 1 > group 2

- N

$2s^2\ 2p^3$ → Half filled

$\downarrow -e^-$

N^+

$2s^2\ 2p^2$

O

$2s^2\ 2p^4$

$\downarrow -e^-$

O^+

$2s^2\ 2p^3$ → Half filled

$IE_1 : N > O$

$IE_2 : N < O$

$IE : N^+ < O^+$

- Cr

[Ar] $4s^1\ 3d^5$

$-e^-$ → Cr^+ [Ar] $3d^5$

For 2^{nd} IE, removal of e^- from 3^{rd} shell is tough.

Mn

[Ar] $4s^2\ 3d^5$

$-e^-$ → $Mn^+ \equiv$ [Ar] $4s^1\ 3d^5$

For 2^{nd} IE, removal of electron from 4^{th} shell is easy.

$IE_2 : Cr > Mn$

4 Penetration Effect

- Penetration Effect for different subshell: $s > p > d > f$

- Be > B : IE

$2s^2$ $\quad$ $2s^2\ 2p^1$

$-e^-$ → Removal of e^- from 2p subshell is easy with respect to 2s (Be).

The penetration of a 2s -electron to the nucleus is more than that of a 2p electron; hence the 2p electron of B is more shielded from the nucleus by the inner core of electrons than the 2s electrons of Be.

- Mg > Al : IE
- Ca > Ga : IE

23. The correct order of decreasing second ionisation enthalpy of Ti (22), V (23), Cr (24) and Mn (25) is:

energy

(a) Cr > Mn > V > Ti

(b) V > Mn > Cr > Ti

(c) Mn > Cr > Ti > V

(d) Ti > V > Cr > Mn

Sol. (a)

24. Assertion: The first ionization energy of Be is greater than that of B.

Reason: 2p orbital is lower in energy than 2s.

(a) Both Assertion and Reason are true and Reason is the correct explanation of Assertion.

(b) Both Assertion and Reason are true but Reason is not correct explanation of Assertion.

(c) Assertion is true but Reason is false.

(d) Assertion is false but Reason is true.

Sol. (c)

25. **Four successive members of the first row transition elements are listed below with their atomic numbers. Which one of them is expected to have the highest third ionisation enthalpy?**

(a) Vanadium (Z = 23) (b) Chromium (Z = 24)

(c) Iron (Z = 26) (d) Manganese (Z = 25)

Sol. (d) $Mn\ [4s^2 3d^5] \xrightarrow[IE_1]{-e^-} Mn^+\ [4s^1 3d^5] \xrightarrow[IE_2]{-e^-} Mn^{2+}\ [3d^5] \longrightarrow$ Removal of 3^{rd} electron from half filled subshell is tough, so, IE_3 will be highest among all.

26. **The set representing the correct order of first ionisation potential is:**

(a) K > Na > Li (b) Be > Mg > Ca (c) B > C > N (d) Ge > Si > C

Sol. (b)

27. **Reason of lanthanoid contraction is:**

(a) Negligible screening effect of f orbitals (b) Increasing nuclear charge

(c) Decreasing nuclear charge (d) Decreasing screening effect

Sol. (a)

- **Ionisation Energy:** $ns^1 < \underbrace{ns^2 > np^1}_{\text{due to penetration effect}} < np^2 < \underbrace{np^3 > np^4}_{\text{due to stable electronic configuration } [np^3]} < np^5 < np^6$

$$ns^1 < \boxed{np^1 < ns^2} < np^2 < \boxed{np^4 < np^3} < np^5 < np^6 : IE$$

	$2s^1$	$2s^2$	$2p^1$	$2p^2$	$2p^3$	$2p^4$	$2p^5$	$2p^6$
♦	Li	Be	B	C	N	O	F	Ne
♦	Na	Mg	Al	Si	P	S	Cl	Ar
♦	K	Ca	Ga	Ge	As	Se	Br	Kr

Li < B < Be < C < O < N < F < Ne : IE

Na < Al < Mg < Si < S < P < Cl < Ar : IE

K < Ga < Ca < Ge < Se < As < Br < Kr : IE

Boron Family

B_5 : [He] $2s^2\ 2p^1$

∨

Al_{13} : [Ne] $3s^2\ 3p^1$

∧

Ga_{31} : [Ar] $4s^2$ $\boxed{3d^{10}}$ $4p^1$

poor shielding of 3d electrons

∨

In_{49} : [Kr] $5s^2\ 4d^{10}\ 5p^1$

∧

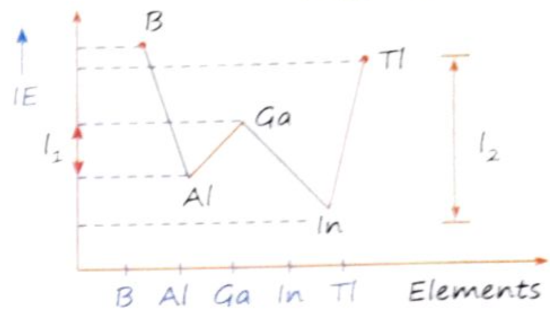
Tl_{81} : [Xe] $6s^2$ $\boxed{4f^{14}}$ $5d^{10}\ 6p^1$

poor shielding of 4f electrons

- B > Tl > Ga ≥ Al > In : IE

$(IE)_{Ga} = 5.99$ eV and

$(IE)_{Al} = 5.98$ eV



- $(IE_{Ga} - IE_{Al} = l_1) < (IE_{Tl} - IE_{In} = l_2)$
- $\Delta IE_{(Ga, Al)} < \Delta IE_{(Tl, In)}$

s Block

Li	Be
∨	∨
Na	Mg
∨	∨
K	Ca
∨	∨
Rb	Sr
∨	∨
Cs	Ba

Highest I.E. : He

Lowest I.E. : Cs

p Block

					He
					∨
B	C	N	O	F	Ne
∨	∨	∨	∨	∨	∨
Al	Si	P	S	Cl	Ar
∧	∨	∨	∨	∨	∨
Ga	Ge	As	Se	Br	Kr
∨	∨	∨	∨	∨	∨
In	Sn	Sb	Te	I	Xe
∧	∧	∨	∨		
Tl	Pb	Bi	Po		

Due to poor shielding of 10 d electrons in Ga

Due to poor shielding of 14 f electrons in Tl & Pb

Size → 4d series ≈ 5d series

4d	$_{39}Y$		$_{40}Zr$	Nb	Mo	Tc	Ru	Rh	Pd	Ag	Cd
	∧		≈	≈	≈	≈	≈	≈	≈	≈	≈
5d	$_{57}La$	$(_{58}Ce \rightarrow {}_{71}Lu)$	$_{72}Hf$	Ta	W	Re	Os	Ir	Pt	Au	Hg

Free from the effect of Lanthanoid contraction

Ionisation Energy → 4d series < 5d series

4d	$_{39}Y$		$_{40}Zr$	Nb	Mo	Tc	Ru	Rh	Pd	Ag	Cd
	∨		∧	∧	∧	∧	∧	∧	∧	∧	∧
5d	$_{57}La$	$(_{58}Ce \rightarrow {}_{71}Lu)$	$_{72}Hf$	Ta	W	Re	Os	Ir	Pt	Au	Hg

The first ionisation energy of 5d elements is higher than that of 4d elements due to a greater Z_{eff} acting on the outer valence electrons, combined with weak shielding by the 4f electrons.

How to find no. of Valence Shell Electrons?

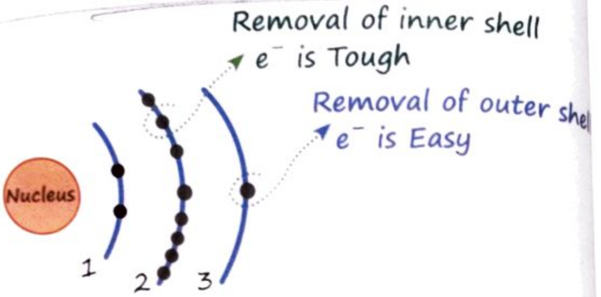
- Removal of electron from valence shell is easy and from inner shell is tough. So there is a large difference in energies required to remove those electrons.
- No. of valence electrons = No. of n^{th} ionisation energy just before SUDDEN JUMP

$$A \xrightarrow{-e^-} A^+ \xrightarrow{-e^-} A^{2+} \xrightarrow{-e^-} A^{3+} \xrightarrow{-e^-} A^{4+}$$

IE_1	IE_2	IE_3	IE_4
5.1	47.2	71.6	98.9

$IE_1 \xrightarrow[\text{Jump}]{\text{Sudden}} IE_2$

No. of valence electron = 1 [large difference b/w IE_1 & IE_2]



Element	IE_1	IE_2	IE_3	IE_4	IE_5	Number of valence electrons
X	5.98	18.22	28.44 $\xrightarrow[\text{Jump}]{\text{Sudden}}$	119.4	–	3
Y	11.26	26.38	47.44	77.41 $\xrightarrow[\text{Jump}]{\text{Sudden}}$	392.07	4

- If the difference in ionisation energy $\Delta(IE_2 - IE_1)$ is greater than 16 eV $atom^{-1}$, then the (+1) oxidation state is stable.

  For Na, $\Delta(IE_2 - IE_1) \approx 41$ eV $atom^{-1} \Rightarrow Na^+$ is more stable.
- If value of $\Delta(IE_2 - IE_1)$ is less than 11 eV $atom^{-1}$ then the (+2) oxidation state is stable.

  For Mg, value of $\Delta(IE_2 - IE_1) \approx 7$ eV $atom^{-1} \Rightarrow Mg^{2+}$ is more stable.

28. Consider the following ionisation enthalpies of two elements 'A' and 'B'. Which of the following statements is correct? [8 April, 2017 (Shift-I)]

Element	Ionization enthalpy (kJ/mol)		
	1^{st}	2^{nd}	3^{rd}
A	899	1757	14847
B	737	1450	7731

(a) Both 'A' and 'B' belong to group-1 where 'B' comes below 'A'

(b) Both 'A' and 'B' belong to group-2 where 'A' comes below 'B'

(c) Both 'A' and 'B' belong to group-2 where 'B' comes below 'A'

(d) Both 'A' and 'B' belong to group-1 where 'A' comes below 'B'

Sol. (c) Both 'A' and 'B' belong to group-2. On moving down the group, the ionisation energy decreases. Since first ionisation energy of B is lower than that of A, 'B' comes below 'A'.

29. Which of the following represents the correct order of metallic character of the given elements? [24 Jan, 2023 (Shift-2)]

(a) Si < Be < Mg < K

(b) Be < Si < Mg < K

(c) K < Mg < Be < Si

(d) Be < Si < K < Mg

Sol. (a)

30. **Outermost electronic configurations of four element A, B, C, D are given below:**

(1) $3s^2$ **(2) $3s^2 3p^1$** **(3) $3s^2 3p^3$** **(4) $3s^2 3p^4$**

The correct order of first ionization enthalpy for them is : [27 July, 2022 (Shift-2)]

(a) (1) < (2) < (3) < (4)

(b) (2) < (1) < (4) < (3)

(c) (2) < (4) < (1) < (3)

(d) (2) < (1) < (3) < (4)

Sol. (b) IE → Al < Mg < S < P

(1) $3s^2$ → Mg (2) $3s^2 3p^1$ → Al (3) $3s^2 3p^3$ → P (4) $3s^2 3p^4$ → S

31. **Statement-I: The decrease in first ionization enthalpy from B to Al is much larger than that from Al to Ga.**

Statement-II: The d orbitals in Ga are completely filled. [29 Jan, 2023 (Shift-II)]

(a) Statement-I is incorrect but Statement-II is correct

(b) Both the Statements-I and II are correct

(c) Statement-I is correct but Statement-II is incorrect

(d) Both the Statements-I and II are incorrect

Sol. (b)

32. **Match List-I with List-II.** [26 Feb, 2021 (Shift-I)]

List-I Electronic configuration of elements		List-II $\Delta_i H$ in kJ mol^{-1}	
A.	$1s^2\ 2s^2$	I.	801
B.	$1s^2\ 2s^2\ 2p^4$	II.	899
C.	$1s^2\ 2s^2\ 2p^3$	III.	1314
D.	$1s^2\ 2s^2\ 2p^1$	IV.	1402

Choose the most appropriate answer from the options given below:

(a) (A)-(II), (B)-(III), (C)-(IV), (D)-(I)

(b) (A)-(I), (B)-(III), (C)-(IV), (D)-(II)

(c) (A)-(I), (B)-(IV), (C)-(III), (D)-(II)

(d) (A)-(IV), (B)-(I), (C)-(II), (D)-(III)

Sol. (a) N > O > Be > B

33. **The five successive ionization enthalpies of an element are 800, 2427, 3658, 25024 and 32824 kJ mol^{-1}. The number of valence electrons in the element is:**

[3 Sept, 2020 (Shift-II)]

(a) 4 (b) 2 (c) 5 (d) 3

Sol. (d) Due to large difference in 3rd and 4th ionisation energies, the number of valence electrons is 3.

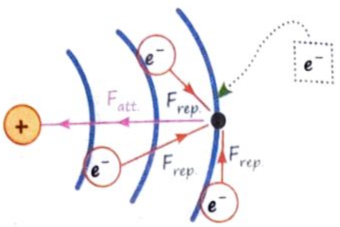
ELECTRON GAIN ENTHALPY

Enthalpy change in addition of an electron in an isolated gaseous atom is known as electron gain enthalpy.

- Electron gain enthalpy provides a measure of the ease with which an atom adds an electron to form anion.
  - $F_{att.} > F_{rep.}$: Release of Energy

    $A \xrightarrow{e^-} A^- + \text{Energy}$
  - $F_{att.} < F_{rep.}$: Absorption of Energy

    $B \xrightarrow[\text{Energy}]{e^-} B^-$



Electron Affinity

Tendency of an isolated gaseous atom to add an electron is known as electron affinity.

- Electron affinity is measured in terms of EGE (ΔH_{eg}).
- More $-ve\ \Delta_{eg}H \Rightarrow$ more electron affinity
- Less $-ve\ \Delta_{eg}H \Rightarrow$ less electron affinity

◆ $H \xrightarrow{+e^-} H^-$ $\Delta_{eg}H = -73$ KJ/mol

$Li \xrightarrow{+e^-} Li^-$ $\Delta_{eg}H = -60$ KJ/mol

→ Electron affinity : H > Li

- **Formation of multiple ⊖ve anion:** Overall energy change during formation of multiple ⊖ve anion is always ⊕ve.

1. $O \xrightarrow{e^-} O^-$ $\Delta H_1 = -141$ KJ/mol (Exo)

   $O^- \xrightarrow[\text{Energy}]{e^-} O^{2-}$ $\Delta H_2 = +844$ KJ/mol (Endo)

   $O \xrightarrow{2e^-} O^{2-}$ $\Delta H_1 + \Delta H_2 = +703$ KJ/mol (Endo)

   ---

2. $N \xrightarrow{3e^-} N^{3-}$ ΔH_{eg} = ⊕ve (Endo)
3. $P \xrightarrow{3e^-} P^{3-}$ ΔH_{eg} = ⊕ve (Endo)

Factor Affecting Electron Affinity

1 Z_{eff} Left → Right : Z_{eff} ↑ : EA ↑ $O_8 < F_9$: EA

2 Size Top ↓ Bottom → Size ↑ → EA ↓ EA : Cl > Br > I > At

3 Electronic Configuration

- Generally for stable electronic configuration (half filled and fully filled) $\Rightarrow \Delta H = \oplus ve$.

- $\underset{(2s^2\,2p^3)}{N} \xrightarrow{e^-} N^-$ $\quad \Delta_{eg}H = \oplus ve$
- $\underset{(2s^2\,2p^6)}{Ne} \xrightarrow{e^-} Ne^-$ $\quad \Delta_{eg}H = \oplus ve$

4 Penetration Effect

Addition of electron in s-orbital is more favorable than p-orbital because s-orbital is near to the nucleus and upcoming electron get more attraction by nucleus.

- EA : K > Ga
  : Rb > In
  : Cs > Tl

$\underset{(2s^1)}{Li} > \underset{(2s^2\,2p^1)}{B}$

$Li \xrightarrow{+e^-} Li^-\ (2s^2)$ $\qquad B \xrightarrow{+e^-} B^-\ (2s^2\,2p^2)$

$\underset{(3s^1)}{Na} > \underset{(3s^2\,3p^1)}{Al}$

Important Points

- Generally For neutral atom : $\Delta_{eg}H \equiv (-)ve$

$O \xrightarrow{e^-} O^-$ (Exo)

$C \xrightarrow{e^-} C^-$ (Exo)

- But For (Be, Mg, N) (Inert Gas) : $\Delta_{eg}H \equiv (+)ve$

$He \xrightarrow{e^-} He^-$ (Endo)

$Ne \xrightarrow{e^-} Ne^-$ (Endo)

$N \xrightarrow{e^-} N^-$ (Endo)

$Be \xrightarrow{e^-} Be^-$ (Endo)

$Mg \xrightarrow{e^-} Mg^-$ (Endo)

- For all cations : $\Delta_{eg}H \equiv (-)ve$

$C^+ \xrightarrow{e^-} C$ (Exo)

$Na^+ \xrightarrow{e^-} Na$ (Exo)

- For all anions : $\Delta_{eg}H \equiv (+)ve$

$O^- \xrightarrow{e^-} O^{2-}$ (Endo)

$N^- \xrightarrow{e^-} N^{2-}$ (Endo)

Adding an electron to a negatively charged ion is more difficult because it requires energy to overcome the repulsion between the negative charge on atom and electron. This makes the second electron gain enthalpy positive (endothermic).

- 1^{st} EGE $[\Delta H_{eg_1}]$ may be +ve/−ve. 2^{nd} EGE $[\Delta H_{eg_2}]$ is always ⊕ve.

♦ $O \xrightarrow{e^-} O^-$	$\Delta H_{eg_1} = \ominus$ ve	♦ $O^- \xrightarrow{e^-} O^{2-}$	$\Delta H_{eg_2} = \oplus$ ve
♦ $N \xrightarrow{e^-} N^-$	$\Delta H_{eg_1} = \oplus$ ve	♦ $N^- \xrightarrow{e^-} N^{2-}$	$\Delta H_{eg_2} = \oplus$ ve

- EA : $\boxed{Ne < Be < N}$ < $\boxed{B < Li < C < O < F}$

  $Ne < Be < N$: $\Delta_{eg}H = \oplus$ve; $B < Li < C < O < F$: $\Delta_{eg}H = \ominus$ve

  $Ar < Mg$: $\Delta_{eg}H = \oplus$ve; $Al < Na < P < Si < S < Cl$: $\Delta_{eg}H = \ominus$ve

- EA : $\boxed{Ar < Mg}$ < $\boxed{Al < Na < P < Si < S < Cl}$

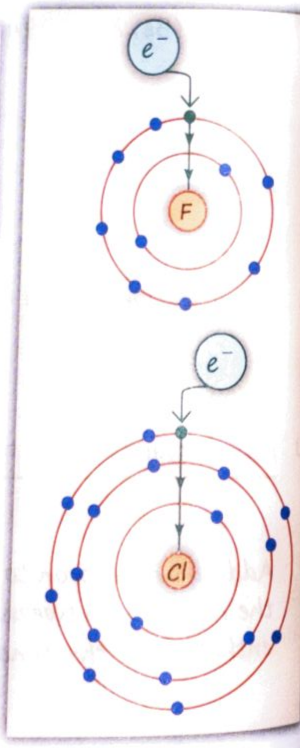
- EA : alkali metals > alkaline earth metals

alkali metals	alkaline earth metals
• $ns^1 \xrightarrow{+e} ns^2$	• $ns^2 \xrightarrow{+e} ns^2\,np^1$
• Fully-filled electronic configuration is achieved	• Fully-filled electronic configuration is disturbed
• $\Delta_{eg}H$ is (−)ve	• $\Delta_{eg}H$ is (+)ve

Comparison b/w Electron Affinity of F & Cl

- $F \xrightarrow{e^-} F^-$ $2s^2\,2p^5 \rightarrow 2s^2\,2p^6$ $\Delta_{eg}H = -328$ KJ/mol
- $Cl \xrightarrow{e^-} Cl^-$ $3s^2\,3p^5 \rightarrow 3s^2\,3p^6$ $\Delta_{eg}H = -349$ KJ/mol

→ EA ≡ Cl > F



- Adding an electron to the 2p-orbital (F) leads to greater repulsion than adding an electron to the larger 3p-orbital (Cl) . Hence electron gain enthalpy of the Cl is more negative than F.

Note

♦ B   C   N   O   F   (Period 2)

^   ^   ^   ^   ^

♦ Al   Si   P   S   Cl   (Period 3)

Group 1	$\Delta_{eg}H$	Group 16	$\Delta_{eg}H$	Group 17	$\Delta_{eg}H$	Group 0	$\Delta_{eg}H$
						He	+48
H	−73						
Li	−60	O	−141	F	−328	Ne	+116
Na	−53	S	−200	Cl	−349	Ar	+96
K	−48	Se	−195	Br	−325	Kr	+96
Rb	−47	Te	−190	I	−295	Xe	+77
Cs	−46	Po	−174	At	−270	Rn	+68

- Order of (−)ve electron gain enthapy : H > Li > Na > K > Rb > Cs

  $\underbrace{K > Rb > Cs}_{\text{approx. same value}}$

- Order of (−)ve electron gain enthalpy: S > Se > Te > Po > O

  Cl > F > Br > I > At

- Order of (+)ve electron gain enthalpy: Ne > Ar = Kr > Xe > Rn > He

Noble gases have (+)ve electron gain enthalpy as they have completely filled orbitals of valence shell.

Note

- Cl has most (−)ve ΔH_{eg} and Ne has most (+)ve ΔH_{eg} among all elements.
- Oxygen has min. EGE in family. EA : S > Se > Te > Po > O
- Halogen family has max. EGE in periodic table.
- Any element from G-17 has higher EGE wrt other element in periodic table. EA : I > S

34. Find the order of electron affinity in following:

(a) Cl, Br, S, O (b) O, S, Se, I (c) Li, B (d) F, Cl, O, N (e) P, S, Cl, F

Sol. (a) Cl > Br > S > O : ΔH_{eg} (more negative) or electron affinity

(b) I > S > Se > O

(c) Li > B

(d) Cl > F > O > N

(e) Cl > F > S > P

35. In which of the following pairs, electron gain enthalpies of constituent elements are nearly the same or identical? [28 July, 2022 (Shift-1)]

1. Rb and Cs 2. Na and K 3. Ar and Kr 4. I and At

Choose the correct answer from the options given below :

(a) 1 and 2 only (b) 2 and 3 only (c) 1 and 3 only (d) 3 and 4 only

Sol. (c)

36. **Inert gases have positive electron gain enthalpy. Its correct order is :** [24 Jan, 2023 (Shift-1)]

(a) Xe < Kr < Ne < He
(b) He < Ne < Kr < Xe
(c) He < Xe < Kr < Ne
(d) He < Kr < Xe < Ne

Sol. (c)

37. **The first electron gain enthalpy (ΔH_{eg}) of oxygen is −141 kJ/mol, its second electron gain enthalpy is :**

(a) Almost the same as that of the first
(b) a more negative value than the first
(c) negative, but less negative than the first
(d) a positive value

Sol. (d)

38. **The formation of the oxide in O^{2-} requires first an exothermic and then an endothermic step as shown below :**

$O \longrightarrow O^-$ $\quad \Delta H_1 = -141$ kJ / mol

$O^- \longrightarrow O^{2-}$ $\quad \Delta H_2 = +844$ kJ / mol

This is because:

(a) Oxygen is more electronegative
(b) Oxygen has high electron affinity.
(c) O^- ion will tend to resist the addition of another electron.
(d) O^- ion has comparatively larger size than oxygen atom.

Sol. (c)

39. **For electron gain enthalpies of the elements denoted as $\Delta_{eg}H$, the incorrect option is:** [1 Feb, 2023 (Shift-II)]

(a) $\Delta_{eg}H(Cl) < \Delta_{eg}H(F)$
(b) $\Delta_{eg}H(Se) < \Delta_{eg}H(S)$
(c) $\Delta_{eg}H(I) < \Delta_{eg}H(At)$
(d) $\Delta_{eg}H(Te) < \Delta_{eg}H(Po)$

Sol. (b) $\Delta_{eg}H$ (S) is more (−)ve value than $\Delta_{eg}H$ (Se).

40. **The process that is NOT endothermic in nature is:** [4 Sept, 2020 (Shift-II)]

(a) $H_{(g)} + e^- \rightarrow H^-_{(g)}$
(b) $O^-_{(g)} + e^- \rightarrow O^{2-}_{(g)}$
(c) $Na_{(g)} \rightarrow Na^+_{(g)} + e^-$
(d) $Ar_{(g)} + e^- \rightarrow Ar^-_{(g)}$

Sol. (a)

[IIT JEE 2002]

41. **Identify the least stable ion amongst the following:**

(a) Li^-
(b) Be^-
(c) B^-
(d) C^-

Sol. (b) Be^- ion is formed by absorption of energy, so they have high energy → means least stable.

Relation Between I.E. & E.G.E.

- $A \underset{EGE}{\overset{IE}{\rightleftharpoons}} A^{+} + e^{-}$

$\boxed{\text{IE of A} \equiv |\text{EGE of } A^{\oplus}|}$

Order of IE : F > Cl

Order of EA : $F^{+} > Cl^{+}$

$$Na \underset{-5.1\ eV}{\overset{5.1\ eV}{\rightleftharpoons}} Na^{+} + e^{-}$$

5.1 eV → IE of Na

−5.1 eV → EGE of Na^{+}

- $A^{-} \underset{\Delta H_{eg} \text{ of A}}{\overset{\text{IE of } A^{-}}{\rightleftharpoons}} A + e^{-}$

$\boxed{\text{IE of } A^{-} = |\Delta_{eg}H \text{ of A}|}$

- $F^{-} \underset{\text{EA of F}}{\overset{\text{IE of } F^{-}}{\rightleftharpoons}} F + e^{-}$
- $Cl^{-} \underset{\text{EA of Cl}}{\overset{\text{IE of } Cl^{-}}{\rightleftharpoons}} Cl + e^{-}$

EA ≡ Cl > F

IE ≡ $Cl^{-} > F^{-}$

Note

If energy is released when an electron is added to an atom, the electron affinity is taken as positive, contrary to thermodynamic convention. If energy has to be supplied to add an electron to an atom, then the electron affinity of the atom is assigned a negative sign. However, electron affinity is defined as absolute zero and, therefore at any other temperature (T) heat capacities of the reactants and the products have to be taken into account in $\Delta_{eg}H = -A_e - 5/2\ RT$.

ELECTRONEGATIVITY

- Tendency of an atom to attract shared pair of electrons in a covalent bond is known as electronegativity.

−δ : partial ⊖ve charge

$\overset{-\delta}{A}$—(:)—$\overset{+\delta}{B}$

Z_{eff} : A > B ⇒ EN : A > B

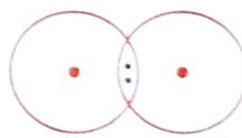
1. Z_{eff} ↑ : EN ↑

$(Z_{eff})_A > (Z_{eff})_B$

$(EN)_A > (EN)_B$

Left → Right ⇒ EN ↑

B < C < N < O < F : EN



$A^{-\delta}$ —— $B^{+\delta}$

2. Size ↑ : EN ↓

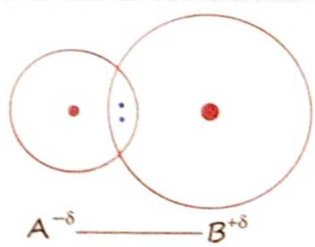
$(Size)_A < (Size)_B$

Top ↓ Bottom

→ Size ↑

→ EN ↓

F > Cl > Br > I



$A^{-\delta}$ —— $B^{+\delta}$

Scale for Electronegativity

- Pauling Scale
- Mulliken Scale
- Allred Rochow Scale

Pauling Scale

CIS (2.5)
HP (2.1)

H 2.1													
Li 1		Be 1.5		B 2		C 2.5		N 3		O 3.5		F 4	
Na 0.9	→ 0.3	Mg 1.2	→ 0.3	Al 1.5	→ 0.3	Si 1.8	→ 0.3	P 2.1	→ 0.4	S 2.5	→ 0.5	Cl 3	
												Br 2.8	
												I 2.5	

- Most electronegative element : F
- Second most electronegative element : O
- It is based on an empirical relation between energy of a bond and electronegativity.

$\boxed{\chi_A - \chi_B = 0.208\sqrt{\Delta}\ \text{kcal mol}^{-1}}$ $\qquad \Delta = E_{A-B} - \sqrt{E_{A-A} \times E_{B-B}}$

Δ = Extra bond Energy

= Actual bond Energy (A – B) – Calculated bond energy for 100% covalent bond (A – B)

$$\chi_A - \chi_B = 0.208\sqrt{E_{A-B} - \sqrt{E_{A-A} \cdot E_{B-B}}}$$

$\boxed{\chi_A - \chi_B = 0.101\sqrt{\Delta}\ \text{kJ mol}^{-1}}$

42. Calculate electronegativity of carbon on Pauling scale given that E_{H-H}, E_{C-C} and E_{C-H} are 104.2, 83.1, 98.8 kcal / mol respectively, also electronegativity of Hydrogen atom is 2.1.

Sol. (2.59) $\chi_C - \chi_H = 0.208\sqrt{\Delta}$, $\qquad (\Delta = E_{C-H} - \sqrt{E_{C-C} \cdot E_{H-H}} = 98.8 - \sqrt{104.2 \times 83.1})$

$\chi_C = \chi_H + 0.208\sqrt{\Delta}$

$= 2.1 + 0.49$ $\boxed{\chi_C = 2.59}$

43. The correct option with respect to the Pauling electronegativity values of the elements is :

(a) Te > Se (b) Ga < Ge (c) Si < Al (d) P > S

Sol. (b)

Mulliken Scale

$$\chi_M = \frac{\text{I.E.} + \text{E.A.}\ (\text{eV/atom})}{2}$$

$$\chi_M = 2.8\ \chi_P$$

I.E. ⟶ Ionisation energy of an element in eV/atom.

E.A ⟶ Electron affinity of an element in eV/atom.

χ_M ⟶ Electronegativity of an element on Mulliken scale

χ_P ⟶ Electronegativity of an element on Pauling scale

Allred Rochow Scale

Electronegativity as the electrostatic force of attraction exerted by the nucleus of an atom on the valence electrons.

$$\chi_{AR} = \left(\frac{0.359 \times Z^*}{r^2}\right) + 0.744$$

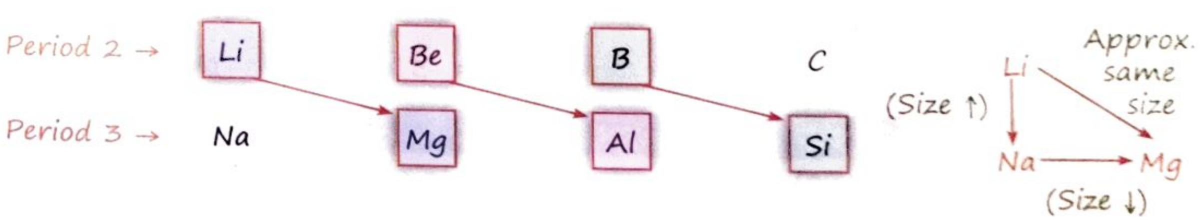
Where Z^* = Effective nuclear charge

r = Covalent radius of atom in Å.

DIAGONAL RELATIONSHIP

- Some elements of certain groups of second period resemble much in properties with the elements of third period, which are diagonally related in properties.
- Diagonal relationship arises because of similar size of atom and ions.

For Example: Atomic size : Li ≈ Mg



44. The set of elements that differ in mutual relationship from those of the other sets is : [17 March, 2021 (Shift-2)]

(a) Li – Mg (b) B – Si (c) Be – Al (d) Li – Na

Sol. (d)

45. Match List-I with List-II

List-I (Elements)		List-II (Properties in their respective groups)	
A.	Cl, S	I.	Elements with highest electronegativity
B.	Ge, As	II.	Elements with largest atomic size
C.	Fr, Ra	III.	Elements which show properties of both metal and non metal
D.	F, O	IV.	Elements with highest negative electron gain enthalpy

[08 April, 2024 (Shift-I)]

Choose the correct answer from the options given below:

(a) A-II, B-III, C-IV, D-I
(b) A-III, B-II, C-I, D-IV
(c) A-IV, B-III, C-II, D-I
(d) A-II, B-I, C-IV, D-III

Sol. (c)

OXIDATION STATE

The oxidation state of an atom in a molecule or in an ion is the charge the atom would have if the electr[ons] in each bond were located on the more electronegative atom.

Rule :

1.	F : −1	(Li → Cs) Group 1 : +1	(Be → Ra) Group 2: +2	Zn : +2 Al, Sc, Ga : +3
2.	H : +1			
3.	O : −2			
4.	N : −3			
5.	Cl, Br, I : −1			

- Elements in rule −1 ALWAYS show fix oxidation state in all molecules.
- Elements in rules 2, 3, 4, and 5 generally show the listed oxidation state but can also exhibit variable oxidation states in different compounds.
- **Priority of rule: 1 > 2 > 3 > 4 > 5**

Na^+	N^{3-}	NO_3^-	NH_4^+
$x = +1$	$x = -3$	$x + 3(-2) = -1$ then $x = +5$	$x + 4(+1) = +1$ then $x = -3$

LiH	H_2SO_4	Na_2O	Na_2O_2
$(+1) + x = 0$ then $x = -1$	$2(+1) + x + 4(-2) = 0$ then $x = +6$	$2(+1) + x = 0$ then $x = -2$	$2(+1) + 2x = 0$ then $x = -1$

OXIDES & HYDROXIDES

Basic Oxides: Na_2O (Basic Oxide) $+ 2HCl$ (Acid) $\longrightarrow 2NaCl$ (Salt) $+ H_2O$

Acidic Oxides: CO_2 (Acidic Oxide) $+ 2NaOH$ (Base) $\longrightarrow Na_2CO_3$ (Salt) $+ H_2O$

Amphoteric Oxides:

$ZnO \xrightarrow{2HCl} ZnCl_2 + H_2O$

$ZnO \xrightarrow{2NaOH} Zn(OH)_2 \xrightarrow[NaOH]{Excess} Na_2[Zn(OH)_4]$

Neutral Oxides: CO (Carbon monoxide) / N_2O (Nitrous oxide) / NO (Nitric oxide)

Amphoteric Oxides

- As(+3) Aas, Sb(+3) Sab, Cr(+3) Car, V(+5) Vento, Te(+4) Tera
- Zn Zaan, Sn Suno, Be Be, Al Aaliya, Pb Pub, Ga Gayi

Amphoteric but predominantly acidic: $\overset{+5}{V_2O_5}$

Example → $\overset{+3}{As_2O_3}$, $\overset{+3}{Sb_2O_3}$, $\overset{+3}{Cr_2O_3}$, $\overset{+5}{V_2O_5}$, $\overset{+4}{TeO_2}$

ZnO, BeO, Al_2O_3, Ga_2O_3, SnO, SnO_2, PbO, PbO_2, Pb_3O_4, Pb_3O_2

Basic Oxides

- Most common oxidation states for metals are +1, +2 and +3.
- Generally oxide of metals are basic in nature but some oxides are amphoteric and acidic also.

Metals

- +1 / +2 / +3 → Basic Oxides: $\overset{+2}{CaO}$, $\overset{+1}{Li_2O}$, $\overset{+2}{MgO}$, $\overset{+3}{V_2O_3}$, $\overset{+2}{CrO}$, $\overset{+2}{MnO}$
- +4 → Amphoteric oxides: $\overset{+4}{TiO_2}$, $\overset{+4}{MnO_2}$, $\overset{+4}{ZrO_2}$
- +6 / +7 → Acidic Oxides: $\overset{+6}{CrO_3}$, $\overset{+7}{Mn_2O_7}$

Acidic Oxides

- Generally non-metal oxides are acidic except some neutral oxide [CO, NO, N_2O].
- Metalloid oxides are acidic except those which are considered already in amphoteric.

Non-metal Oxide

Acidic	Neutral
B_2O_3	CO
CO_2	NO
N_2O_5	N_2O
P_2O_5	
Cl_2O_7	

Metalloid Oxide

As, Sb, Se, Te, Ge

- As_2O_3 (+3) : Amphoteric
  As_2O_5 (+5) : Acidic
- Sb_2O_3 (+3) : Amphoteric
  Sb_2O_5 (+5) : Acidic
- TeO_2 (+4) : Amphoteric
- TeO_3 (+6) : Acidic

Acidic Nature of Oxides

- In an oxide, as oxidation state of element increases, acidic nature of oxides increases.

  - $\overset{+1}{Li_2O} < \overset{+2}{BeO} < \overset{+3}{B_2O_3} < \overset{+4}{CO_2} < \overset{+5}{N_2O_5}$
  - $\overset{+2}{CO} < \overset{+4}{CO_2}$
  - $\overset{+1}{Na_2O} < \overset{+2}{MgO} < \overset{+3}{Al_2O_3} < \overset{+4}{SiO_2} < \overset{+5}{P_2O_5} < \overset{+6}{SO_3} < \overset{+7}{Cl_2O_7}$
  - $\overset{+4}{SO_2} < \overset{+6}{SO_3}$
  - $\overset{+1}{N_2O} < \overset{+2}{NO} < \overset{+3}{N_2O_3} < \overset{+4}{NO_2} < \overset{+5}{N_2O_5}$

Note

M—O—H like compound will **act as acid or as base** can be predicted very easily.

a. **Acts as a base when**

$M{-}O{-}H \rightleftharpoons M^+ + OH^-$

$|\chi_O - \chi_M| > |\chi_O - \chi_H|$

- Cs—O—H is a base because

$\chi_O - \chi_{Cs} = 3.5 - 0.7 = 2.8$

$\chi_O - \chi_H = 3.5 - 2.1 = 1.4$

b. **Acts as an acid when**

$M{-}O{-}H \rightleftharpoons MO^- + H^+$

$|\chi_O - \chi_H| > |\chi_O - \chi_M|$

- Cl—O—H is an acid because

$\chi_O - \chi_{Cl} = 3.5 - 3.1 = 0.34$

$\chi_O - \chi_H = 3.5 - 2.1 = 1.4$

Basic Oxide	Basic hydroxide	Acidic oxide	Acidic hydroxide	Amphoteric oxide	Amphoteric hydroxide
Na_2O	$NaOH$	SiO_2	$Si(OH)_4$	Al_2O_3	$Al(OH)_3$
MgO	$Mg(OH)_2$	B_2O_3	$B(OH)_3$	ZnO	$Zn(OH)_2$
MnO	$Mn(OH)_2$	N_2O_5	HNO_3	BeO	$Be(OH)_2$
CuO	$Cu(OH)_2$	CO_2	H_2CO_3	PbO	$Pb(OH)_2$

46. Three elements X, Y and Z are in the 3rd period of the periodic table. The oxides of X, Y and Z, respectively, are basic, amphoteric and acidic. The correct order of the atomic numbers of X, Y and Z is: [2 Sept, 2020 (Shift-II)]

(a) $X < Z < Y$ (b) $Z < Y < X$ (c) $X < Y < Z$ (d) $Y < X < Z$

Sol. (c)

GENESIS OF PERIODIC CLASSIFICATION

1. Dobereiner's Traids
2. Newland's Law of Octaves
3. Lothar Meyer Classification
4. Mendeleev's Periodic Table
5. Modern Periodic Table

Dobereiner's Traids

3 elements → A, B, C

$$M_B = \frac{M_A + M_C}{2}$$

M_A = atomic mass of A
M_B = atomic mass of B
M_C = atomic mass of C

Dobereiner arranged certain elements with similar properties in groups of three (Triad) in such a way that the atomic mass of the middle element was nearly the same the average atomic masses of the first and the third elements.

Elements	Atomic weight	Element	Atomic weight	Element	Atomic weight
Li	7	Ca	40	Cl	35.5
Na	23	Sr	88	Br	80
K	39	Ba	137	I	127

Be	8
Mg →	24
Ca	40

S	32
Se →	79
Te	127

P	31
As →	75
Sb	120

H	1
F →	19
Cl	35.5

Sc : x

Y → $y = \frac{x + z}{2}$

La : z

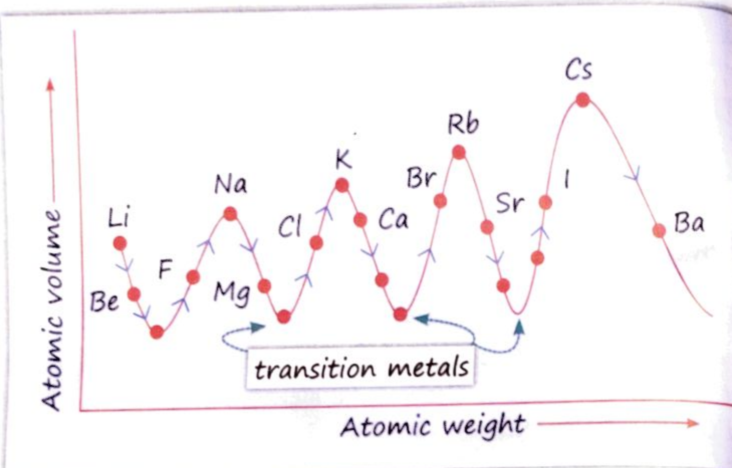
Newland's Law of Octaves

- When elements are arranged in order of increasing atomic masses, every 8^{th} element has properties similar to the first. Newlands called it law of octaves because similar relationship exists in the musical notes also.

sa		re		ga		ma		pa		da		ni
H	→	Li	→	Be	→	B	→	C	→	N	→	O
F		Na		Mg		Al		Si		P		S
Cl		K		Ca		Cr		Ti		Mn		Fe
Co and Ni		Cu		Zn		Y		In		As		Se
Br		Rb		Sr		Ce and La		Zr		–		–

Lothar Meyer Classification

- He calculated the atomic volumes by dividing atomic masses with their densities in solid states.
- He plotted a graph between atomic masses against their respective atomic volumes for a number of elements.
- Elements with similar properties occupied similar positions on the curve.
- Atomic volumes (a physical property) of the elements are the periodic functions of their atomic masses.
- Alkali metals (Li, Na, K, Rb, Cs) having larger atomic volumes occupied the crests.
- Alkaline earth metals (Be, Mg, Ca, Sr, Ba) occupied the positions at about the mid points of the descending portions of the curve.
- The halogens (F, Cl, Br, I) occupied the ascending portions of the curve before the inert gases.
- Transitions elements occupied the troughs.



Mendeleev's Periodic Table

Characteristic of Mendeleev's Periodic Table :

(i) It is based on atomic weight.

(ii) 63 elements were known, noble gases were not discovered.

(iii) He was the first scientist to classify the elements in a systematic manner (in horizontal rows and in vertical columns).

(iv) Horizontal rows are called periods and there were 7 periods in Mendeleev's Periodic table.

(v) Vertical columns are called groups and there were 8 groups in Mendeleev's Periodic table.

(vi) Each group upto VIIth is divided into A & B subgroups. 'A' sub group element are called normal element and 'B' sub groups elements are called transition elements.

(vii) The VIIIth group was consist of 9 elements in three rows (Transition metals group).

Fe	Co	Ni
Ru	Rh	Pd
Os	Ir	Pt

(viii) The elements belonging to same group exhibit similar properties.

Series	Groups of Elements								
	0	I	II	III	IV	V	VI	VII	VIII
1	-	H 1.008	-	-					
2	He 4.0	Li 7.03	Be 9.1	B 11.0	C 12.0	N 14.04	O 16.00	F 19.0	
3	Ne 19.9	Na 23.5	Mg 24.3	Al 27.0	Si 28.4	P 31.0	S 32.06	Cl 35.45	
4	Ar 38	K 39.1	Ca 40.1	Sc 44.1	Ti 48.1	V 51.4	Cr 52.1	Mn 55.0	Fe 55.9 Co 59 Ni 59 (Cu)
5		Cu 63.6	Zn 65.4	Ga 70.0	Ge 72.3	As 75	Se 79	Br 79.95	
6	Kr 81.8	Rb 85.4	Sr 87.6	Y 89.0	Zr 90.6	Nb 94.0	Mo 96.0	-	Ru 101.7 Rh 103.0 Pd 106.5 (Ag)
7		Ag 107.9	Cd 112.4	In 114.0	Sn 119.0	Sb 120.0	Te 127.6	I 126.9	
8	Xe 128	Cs 132.9	Ba 137.4	La 139	Ce 140	-	-	-	
9		-	-	-	-	-	-	-	
10	-	-	-	Yb 173	-	Ta 183	W 184	-	Os 191 Ir 193 Pt 194.9 (Au)
11		Au 197.2	Hg 200.0	Tl 204.1	Pb 206.9	Bi 208	-	-	
12	-	-	Ra 224	-	Th 232	-	U 239		
	R	R_2O	RO	R_2O_3	Higher Saline Oxides: RO_2	R_2O_5	RO_3	R_2O_7	RO_4
					Higher Gaseous Hydrogen Compounds: RH_4	RH_3	RH_2	RH	

Merits of Mendeleev Periodic Table :

- It has simplified and systematized the study of elements and their compounds.
- It has helped in predicting the discovery of new elements on the basis of the blank spaces given in its periodic table.
- Mendeleev predicted the properties of those missing elements from the known properties of the other elements in the same group.

Eka-aluminium – Ga
Eka-silicon – Ge

- Later, it was found that properties predicted by Mendeleev for these elements and those found experimentally were almost similar.

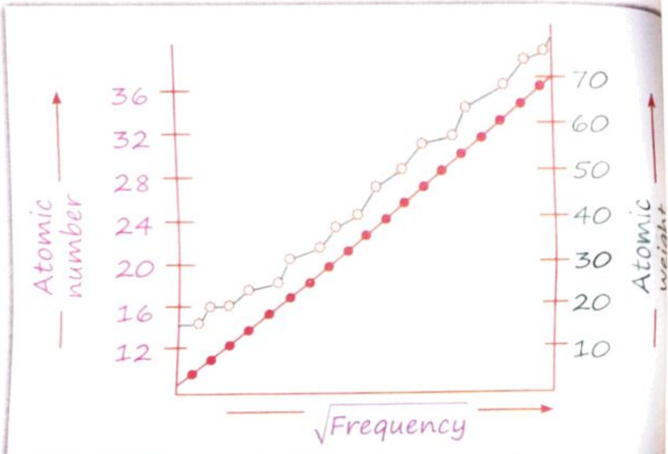
Demerits in Mendeleev's Periodic Table :

- Position of hydrogen is uncertain. It has been placed in IA and VIIA groups because of its resemblance with both the groups.
- No separate positions were given to isotopes.
- Anomalous positions of lanthanides and actinides in periodic table.
- Order of increasing atomic weights is not strictly followed.
  Te (127.6) is placed before I (126.9)
- Similar elements were placed in different groups (Cu in IB and Hg in IIB) and similarly the elements with different properties were placed in same groups (alkali metals in IA and coinage metals in IB)

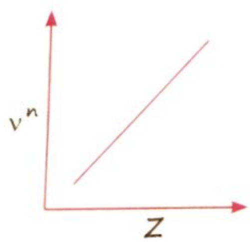
Modern Periodic Table

- Henry Moseley observed regularities in the characteristic X-ray spectra of the elements. A plot of $\sqrt{\nu}$ (where ν is frequency of X-rays emitted) against atomic number (Z) gave a straight line and not the plot of $\sqrt{\nu}$ vs atomic mass.
  - $\sqrt{\nu} \propto Z$

  $\boxed{\sqrt{\nu} = a(Z - b)}$ (a, b : constant)



47. It is observed that characteristic X-ray spectra of elements show regularity. When frequency to the power 'n' i.e. ν^n of X-rays emitted is plotted against atomic number 'Z', following graph is obtained. [24 Jan, 2023 (Shift-I)]

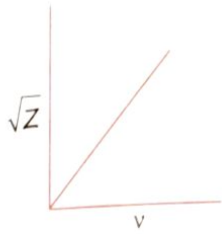


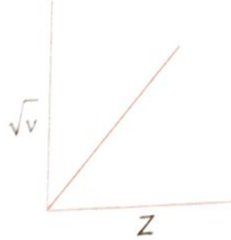
The value of 'n' is

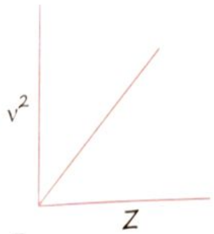
(a) 1 (b) 2 (c) 1/2 (d) 3

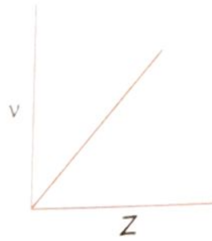
Sol. (c)

48. Henry Moseley studied characteristic X-ray spectra of elements. The graph which represents his observation correctly is:
(Given: ν = frequency of X-ray emitted; Z = atomic number) [8 April, 2023 (Shift-II)]

(a) 

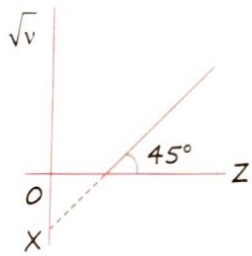
(b) 

(c) 

(d) 

Sol. (b) $\sqrt{\nu} \propto Z$

49. **In the graph between $\sqrt{\nu}$ and Z for the Moseley's equation, the intercept OX is −1 on $\sqrt{\nu}$ axis. What will be in Frequency when atomic number (Z) is 51?**



(a) 50 Hz (b) 100 Hz (c) 2500 Hz (d) None

Sol. (c)

$\sqrt{\nu} = a(z-b)$ $\sqrt{\nu} = az - ab$ $y = mx + c$	Slope (m) = a = tan 45° = 1 $-ab = -1$ $-1.b = -1$ then b = 1	a = 1 & b = 1 $\sqrt{\nu} = a(z-b)$ $\sqrt{\nu} = 1(z-1)$ $= 51 - 1 = 50$	$\nu = (50)^2 = 2500$ Hz

50. **The increasing order of atomic radii of the following Group 13 elements is:** **(JEE Adv. 2016)**

(a) Al < Ga < In < Tl
(b) Ga < Al < In < Tl
(c) Al < In < Ga < Tl
(d) Al < Ga < Tl < In

Sol. (b)

51. **The option(s) with only amphoteric oxides is (are)** **(JEE Adv. 2020)**

(a) NO, B_2O_3, PbO, SnO_2
(b) Cr_2O_3, CrO, SnO, PbO
(c) Cr_2O_3, BeO, SnO, SnO_2
(d) ZnO, Al_2O_3, PbO, PbO_2

Sol. (c) and (d)

52. The 1^{st}, 2^{nd} and the 3^{rd} ionisation enthalpies I_1, I_2 and I_3, of four atoms with atomic numbers n, n + 1, n + 2 and n + 3, where n < 10, are tabulated below. (JEE Adv. 2020)

What is the value of n?

Atomic number	Ionisation Enthalpy (kJ/mol)		
	I_1	I_2	I_3
n	1681	3374	6050
n + 1	2081	3952	6122
n + 2	496	4562	6910
n + 3	738	1451	7733

Sol. [9]

By observing the values of different ionisation energies for atomic number (n + 2), it is observed that there is very large difference between I_2 and I_1.

This indicates that number of valence shell electrons is 1 and atomic number (n + 2) should be an alkali metal.

Also for atomic number (n + 3), $I_3 >> I_2$. This indicates that it will be an alkaline earth metal which suggests that atomic number (n + 1) should be a noble gas and atomic number (n) should belong to halogen family. Since, n < 10; hence, n = 9 (F atom)