Periodic Table

Introduction

Development of Periodic Table

1. Dobereiner's Law of Triads:

This law states that the atomic weight of middle element is arithmetic mean of other two elements which are arranged such that the elements having similar properties are placed in increasing order of atomic weight.

Triad	Atomic Masses
Lithium	6.94
Sodium	22.99
Potassium	39.1

For ex. the atomic mass of sodium is almost equal to the arithmetic mean of the masses of potassium and lithium i.e., 23.02.

Ex Ca, Sr, Ba

P, As, Sb

Cl, Br, I

S, Se, Te

Concept Ladder

Doberenier's law of trids was rejected because in some triads all the three elements possessed nearly the same atomic masses.

Previous Year's Question

Who is called the father of chemistry

[AIPMT]

(1) Faraday
(2) Priestley
(3) Rutherford
(4) Lavoiser

2. Newland's Law of Octaves :

When elements arranged in order of their increasing atomic weights, the properties of every eighth element were similar to those of the first one.

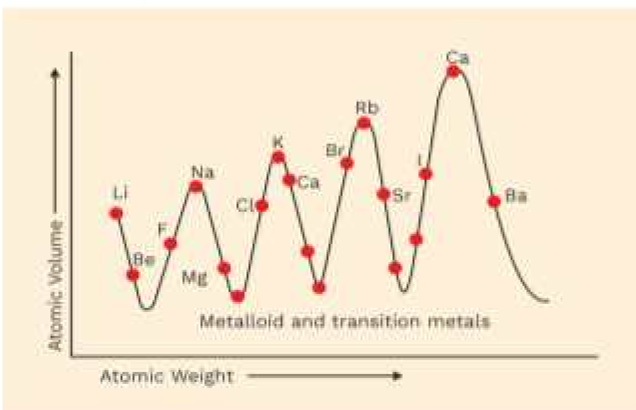
Rack your Brain

Why was the law of octaves discarded?

sa	re	ga	ma	pa	dha	ni	sa
Li	Be	B	C	N	O	F	Na
Na	Mg	Al	Si	P	S	Cl	K

3. Lother Meyer Curve

According to Lother Meyer if a graph is between the atomic volume and atomic weights of the elements and observed that the elements with similar properties occupied similar position on the curve.



(1) The most strongly electropositive alkali metal occupy the peaks on the curve.

(2) The less strongly electropositive alkaline earth metals occupy the descending position on the curve.

(3) The most electronegative elements i.e. halogens occupy the accupy the ascending position on the curve.

Concept Ladder

Lother Meyer proposed that the physical properties of the elements are a periodic function of the atomic weights.

Rack your Brain

Why Lothar Meyer's periodic classification was not that much appreciated.

4. Mendeleev's Periodic Table :

The physical and chemical properties of elements are the periodic function of their atomic weights, i.e., when the elements are arranged in order of their increasing atomic weights, elements with similar properties are repeated after certain regular intervals. It consists of seven horizontal rows called periods. Mendeleev's original talb econsists of 8 vertical columns called groups. Thesea re numbered as I, II, III....VIII. However, 9th vertical column called zero group was added with the discovery of inert gases. Except for 8 and 0, each group is further divided into two sub-group designated as A and B. Group 8 consists of 9 elements arranged in three sets each containing three elements.

Defects :

Position of hydrogen, position of isotopes, position of lanthanides and actinides, anomalous pairs of elements. Few similar elements are placed in different groups while some dissimilar elements are grouped together.

Modern Periodic Law :

- According to this law physical and chemical properties of the elements are a periodic function of their atomic numbers, i.e. elements are arranged in order of their increasing atomic numbers, the elements with similar properties are repeated after certain regular intervals.

Cause of Periodicity :

It is due to repetition of similar outer electronic configurations after certain regular intervals.

Definition

A tabular arrangement of elements in rows and columns, highlighting the regular repetition of properties of elements is called a periodic table.

Concept Ladder

Modern Periodic Table
Mosley's Low

$$\boxed{\sqrt{v} = a(Z-b)}$$

$$\boxed{\sqrt{v} \propto Z}$$

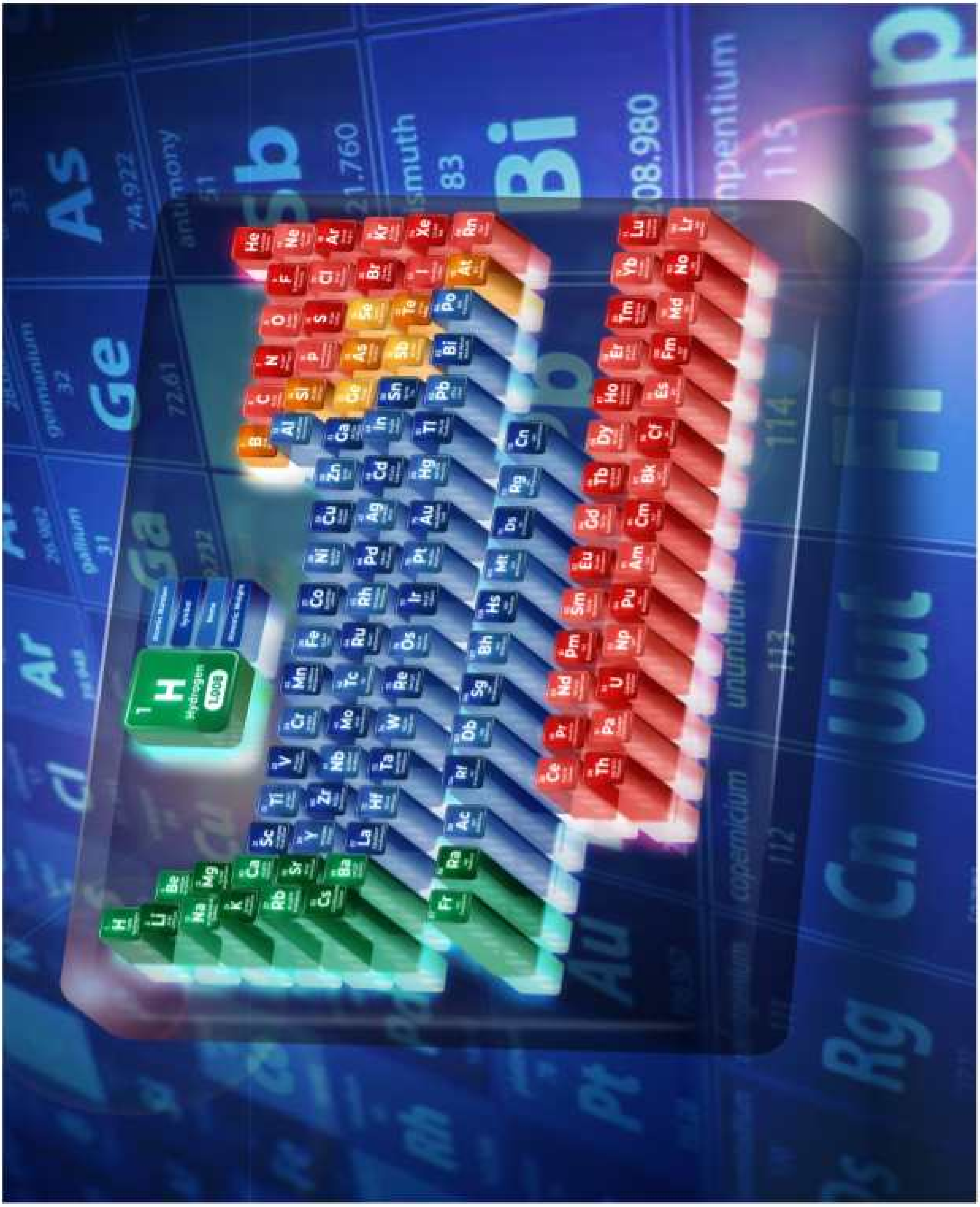
Rack your Brain

Iodine having lower atomic mass than tellurium was placed ahead of tellurium. Why?

Previous Year's Question

The long form of periodic table has **[AIPMT]**

(1) 8 horizontal rows & 7 vertical columns
(2) 7 horizontal rows & 18 vertical columns
(3) 7 horizontal rows & 7 vertical columns
(4) 8 horizontal rows and 8 vertical columns


As
74.922
Ge
germanium
32
Ga
gallium
31
Bi
83
208.980
Cn
copernicium
112
113
114
115
Rg
Uut
Fl
H
hydrogen
1.008

Electronic configuration of elements :

Alkali metals electronic configurations

^{1}H $1s^1$

^{3}Li $1s^2 2s^1$

^{11}Na $1s^2 2s^2 2p^6 3s^1$

^{19}K $1s^2 2s^2 2p^6 3s^2 3p^6 4s^1$

^{37}Rb $1s^2 2s^2 2p^6 3s^2 3p^6 4s^2 3d^{10} 4p^6 5s^1$

^{55}Cs $1s^2 2s^2 2p^6 3s^2 3p^6 4s^2 3d^{10} 4p^6 5s^2 4d^{10} 5p^6 6s^1$

^{87}Fr $1s^2 2s^2 2p^6 3s^2 3p^6 4s^2 3d^{10} 4p^6 5s^2 4d^{10} 5p^6 6s^2 4f^{14} 5d^{10} 6p^6 7s^1$

Alkaline earth metals electronic configurations

^{4}Be $1s^2 2s^2$

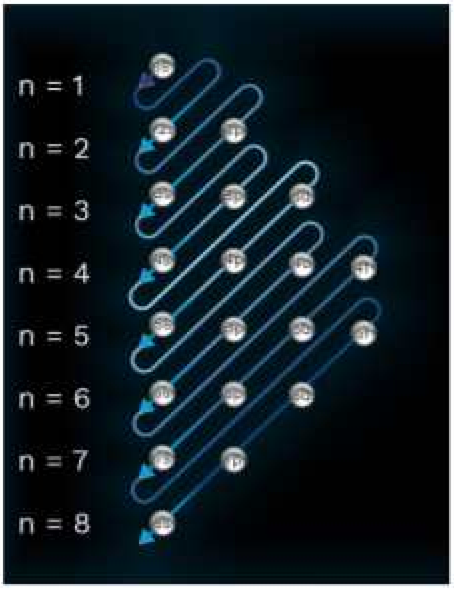
^{12}Mg $1s^2 2s^2 2p^6 3s^2$

^{20}Ca $1s^2 2s^2 2p^6 3s^2 3p^6 4s^2$

^{38}Sr $1s^2 2s^2 2p^6 3s^2 3p^6 4s^2 3d^{10} 4p^6 5s^2$

^{56}Ba $1s^2 2s^2 2p^6 3s^2 3p^6 4s^2 3d^{10} 4p^6 5s^2 4d^{10} 5p^6 6s^2$

^{88}Ra $1s^2 2s^2 2p^6 3s^2 3p^6 4s^2 3d^{10} 4p^6 5s^2 4d^{10} 5p^6 6s^2 4f^{14} 5d^{10} 6p^6 7s^2$



Nomenclature of element with Atomic number (Z) > 100

Digit	Root	Abbreviation	Digit	Root	Abbreviation
0	nil	n	5	pent	p
1	un	u	6	hex	h
2	bi	b	7	sept	s
3	tri	t	8	oct	o
4	quad	q	9	enn	e

Q.1. What is the name of element with atomic number (Z) = 103?

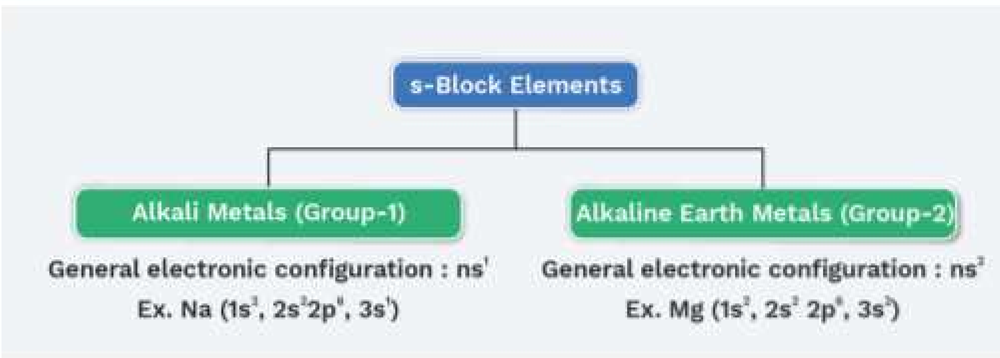
A1. Unniltrium

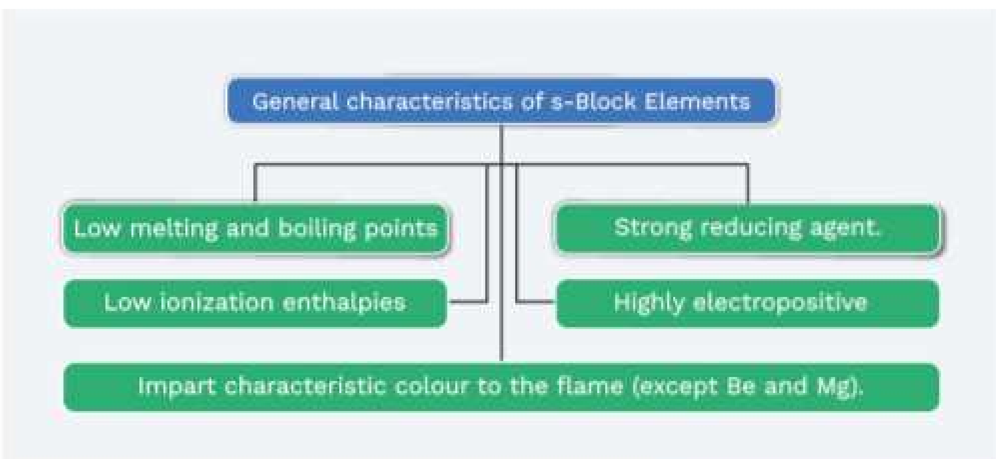
Electronic Configuration of Elements and the Periodic Table

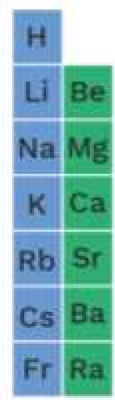
Periodic table is divided into the four blocks viz.

(1) s-Block (2) p-Block (3) d-Block (4) f-Block

s-Block Elements







Rack your Brain

Which elements of s-Block are largely found in biological fluids?

Q.2 Why Be is not a true alkaline earth metal?

A2 Be is not a true alkaline earth metal since its oxide is amphoteric

p-Block Elements

(1) p-block elements are present in right part of the periodic table.

(2) These constituted the groups IIIA to VIIA and zero groups i.e., groups 13 to 18 of the periodic table.

(3) Most of p-block elements are metalloids and non metals but some of them are metals also.

(4) The last electron fills in p-orbital of valence shell.

- **13th group :** Boron family (ns^2np^1)

  Ex :- Al ($1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^1$)

- **14th group :** Carbon family (ns^2np^2)

  Ex :- Si ($1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^2$)

- **15th group :** Nitrogen family "Pnicogen" (ns^2np^3). **Pnico** means Fertilizer and **Gen** means to produce.

  Ex :- P ($1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^3$)

- **16th group :** Oxygen family "Chalcogen" ($ns^2\ np^4$). **Chalco** means Ore and **Gen** means to produce.

  Ex :- S ($1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^4$)

- **17th group :** Halogen family ($ns^2\ np^5$).

  Halo means Salt and **Gen** means to produce.

  Ex :- Cl ($1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^5$)

- **18th group (Zero group) :** Inert/Noble/Rare gas (ns^2np^6)

  Ex :- Ar ($1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6$)

Exception : Helium shows the $1s^2$ electronic configuration.

Concept Ladder

The electronic configuration of valence shell in p-block is ns^2np^{1-6} (n = 2 to 7).

					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	At	Rn

Rack your Brain

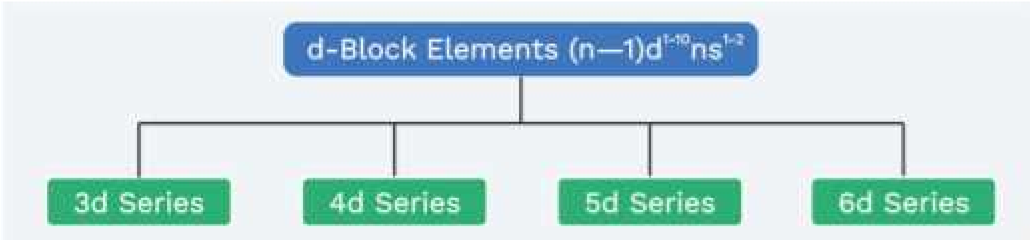
Which element was discovered by marie and pierre curie?

Previous Year's Question

The elements on the right side of the periodic table are **[AIPMT]**

(1) Metals
(2) Metalloids
(3) Non-metals
(4) Transition elements

d-Block Elements (Transition Elements)



(1) These are present in the middle part of the periodic table (between s and p block elements)

(2) These constitute IIIB to VIIB, VII, IB and IIB i.e., 3 to 12 groups of the periodic table.

(3) Filling of electrons takes places in penultimate shell. i.e., (n – 1) shell.

- **3d Series :** Also known as first transition series having 10 elements starting from "Scandium" (Z = 21) to "Zinc" (Z = 30).
  Ex :- Fe : [Ar] $3d^6 4s^2$
- **4d Series :** Also known as second transition series having 10 elements starting from "Yttrium" (Z = 39) to "Cadmium" (Z = 48).
  Ex :- Pd : [Kr] $4d^{10} 5s^0$
- **5d Series :** Also known as third transition series having 10 elements starting from "Lanthanum" (Z = 57) to "Mercury" (Z = 80).
  Ex :- Au : [Xe] $5d^{10} 6s^1$
- **6d Series :** Also known as fourth transition series having 10 elements starting from "Actinium" (Z = 89) to "Copernicium" (Z = 112).
  Ex: Rf : [Rn] $6d^2 7s^2$

Sc	Ti	V	Cr	Mn	Fe	Co	Ni	Cu	Zn
Y	Zr	Nb	Mo	Tc	Ru	Th	Pd	Ag	Cd
La	Hf	Ta	W	Re	Os	Ir	Pt	Au	Hg
Ac	Rf	Db	Sg	Bh	Hs	Mt	Ds	Rg	Cn

Concept Ladder

d-block elements form coloured compounds and coloured complexes. They have vacant orbitals. Electrons take up energy and move to higher energy levels and thus appear coloured.

Previous Year's Question

An atom has electronic configuraiotn $1s^2 2s^2 2p^6 3s^2 3p^6 3d^3 4s^2$, you will place it in

[AIPMT]

(1) 5th gruop
(2) 15th gruop
(3) 2nd group
(4) 3rd group

f-Block Elements (Inner Transition Elements)

f-Block Elements $(n-2)f^{0-14}(n-1)\ d^{0-1}ns^2$

Lanthanoids | Actinoids

Ce	Pr	Nd	Pm	Sm	Eu	Gd	Tb	Dy	Ho	Er	Tm	Yb	Lu
Th	Pa	U	Np	Pu	Am	Cm	Bk	Cf	Es	Fm	Md	No	Lr

(1) All are metals.

(2) They are paramagnetic in nature.

(3) They form coloured compounds.

(4) They have tendency to form complexes.

(5) Filling of electrons takes place in anti-penultimate shell. i.e. (n – 2) shell.

(6) Chemically, lanthanides are very similar. It is difficult to separate them form a mixture by applicaiton of a chemical property. Similary, actinides have similar chemical proper;ties. The members of actinides show the phenomenon of radioactivity.

- **Lanthanoids :** (Atomic number 58–71)
  Lanthanoids belongs to 3rd group (III B group) and VI period having $(n-2)f^{1-14}\ (n-1)d^{0-1}\ ns^2$ electronic configuration.
- **Actinoids :** (Atomic number 90–103)
  Actinoids belongs to 3rd group (III B group) and VII period $(n-2)f^{0-14}\ (n-1)d^{0-1}\ ns^2$ electronic configuration.
- **Hydrogen, Helium, Thorium are exception to block classification.**

Concept Ladder

f-Block show variable valency. The +3 is the most important oxidation state. Few elements show +2 and +4 oxidation states.

Previous Year's Question

Gadolinium belongs to 4f series. Its atomic number is 64. Which of the following is the correct electronic configuration of gadolinium?

[AIPMT-2015]

(1) $[Xe]4f^9 5s^1$ (2) $[Xe]4f^7 5d^1 6s^2$
(3) $[Xe]4f^6 5d^2 6s^2$ (4) $[Xe]4f^8 6d^2$

- Every period starts with the filling of s-orbital & ends with p-orbital.
- Mainly d and f-block elements have exceptions in electronic configuration which is due to orbital contraction.

Magic number :

- They are the set of number after which properties of elements (mainly chemical property) are repeated at regular intervals.

General electronic configuration for various blocks :

(i) **s-block :** $ns^{1,2}$ where $n \geq 1$

(ii) **p-block :** $ns^2\ np^{1-6}$ where $n \geq 2$

(iii) **d-block :** $(n-1)d^{1-10}ns^{1,2}$ where $n \geq 4$

(iv) **f-block :** $(n-2)f^{1-14}(n-1)d^{0}ns^2$ where $n \geq 6$

- Maximum number of electrons in outermost orbit of :

(i) s-block elements = 2

(ii) p-block elements = 8

(iii) d-block elements = 10

(iv) f-block elements = 14

- For Pd the total number of electrons in outermost orbit is 18.

  i.e. Pd – [Kr] $4s^2\ 4p^6\ 4d^{10}$

- Maximum number of electrons in penultimate shell i.e. (n–1) shell.

(i) d-block elements = 18

(ii) f-block elements = 9

- Maximum number of electrons is antipenultimate shell i.e. (n–2) shell of f-block elements 32 range (19 to 32).

Rack your Brain

What are transactinides or Super heavy elements?

Concept Ladder

Values of magic numbers are in gruop.

1^{st} : I(A)– 2, 8, 8, 18, 18, 32

2^{nd} : II(A)– 8, 8, 18, 18, 32

3^{rd} : III(B)– 18, 18, 32

4^{th} to 12^{th} : 18, 18, 32

13^{th} to 17^{th} : 8, 18, 18, 32, 32

18^{th} : 8, 8, 18, 18, 32

Previous Year's Question

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

[NEET]

(1) Carbon family, [Rn] $f^{14}\ 6d^{10}\ 7s^2\ 7p^2$

(2) Oxygen family, [Rn] $f^{14}\ 6d^{10}\ 7s^2\ 7p^4$

(3) Nitrogen family, [Rn] $f^{14}\ 6d^{10}\ 7s^2\ 7p^6$

(4) Halogen family, [Rn] $f^{14}\ 6d^{10}\ 7s^2\ 7p^5$

Atomic numbers of various inert gases :

First period $\xrightarrow{2}$ He(2)

Second period $\xrightarrow{8}$ Ne(10)

Third period $\xrightarrow{8}$ Ar(18)

Fourth period $\xrightarrow{18}$ Kr(36)

Fifth period $\xrightarrow{18}$ Xe(54)

Sixth period $\xrightarrow{32}$ Rn(86)

Seventh period $\xrightarrow{32}$ Og(118)

Group Identification

$$\boxed{\text{Group No.} = 18 - \left(Z_{\text{inert gas}} - Z_{\text{given}}\right)}$$

Total number of elements in a period :

(i) Total number of elements in a period $= \frac{(n+1)^2}{2}$

When n = 1, 3, 5, ...

(ii) Total number of elements in a period $= \frac{(n+2)^2}{2}$

When n = 2, 4, 6, ...

Previous Year's Question

The electronic configuration of an element is $1s^2 2s^2 sp^6 3s^2 3p^3$. What is the atomic number of the element, which is just below the above element in the periodic table? **[NEET]**

(1) 36 (2) 49

(3) 33 (4) 34

Rack your Brain

Minimum atomic no. which can change the present modal of periodic table?

Q.3 Calculate the total number of elements and total subshell in 7^{th} period.

A.3 For 7^{th} period n = 7 $\therefore$ n = 7 is odd number

$$\frac{(7+1)^2}{2} = \frac{64}{2} = 32 \text{ elements}$$

$$\text{Total subshell in period} = \sqrt{\left(\frac{\text{Total elements}}{2}\right)}$$

$$\sqrt{\frac{32}{2}} = 4(s, p, d, f)$$

Identification of group, block, period in periodic table :

(A) When atomic number is given :

(i) Lanthanoid (Atomic number 58 to 71)

→ 3^{rd} group (III-B)

→ 6^{th} period

→ f-block

(ii) Actinoid (Atomic number 90 to 103)

→ 3^{rd} group (III-B)

→ 7^{th} period

→ f-block

⇒ Atomic number 104 to 118– Last two digit gives group number in periodic table.

Ex Atomic number 115 – group 15. (Last two digit gives group number)

Que. Complete the following table :

S.No.	Atomic no.	Group	Block	Period
1	87			
2	115			
3	52			
4	26			

Sol.

S.No.	Atomic No.	Group	Block	Period
1	87	1^{st}	s	VII^{th}
2	115	15^{th}	p	VII^{th}
3	52	16^{th}	p	V^{th}
4	26	8^{th}	d	IV^{th}

Concept Ladder

Metalloids

Si, Ge, As, Sb, Te, At (universal metalloid)

B or Se is non metal/metalloid

Po is metal/metalloid

Rack your Brain

Noble gases don't have covalent radii. Why ?

Concept Ladder

Total s-block elements

= 14 (12 + H, He)

H and He are exception of block classification on the basis of position in periodic table.

Rack your Brain

What is the total number of liquid metal and non metal elements?

(A) When configuration is given :

$ns \rightarrow (n-2)f \rightarrow (n-1)d \rightarrow np$

- The subshell that receives last electron is block.
- Period number is highest number of orbit.
- Group number can be calculated as follows.

(i) s-block : Group number = Number of outermost s electron.

(ii) p-block : Group number = 12 + Number of outermost p electron.

(iii) d-block : Group number = Number of outermost s electron + Number of Penultimate d electron.

(iv) f-block : Group number for f-block is 3rd group.

Previous Year's Question

The total number of rare-earth elements are

[AIPMT]

(1) 8 (2) 12
(3) 14 (4) 10

Rack your Brain

What is first man made radioactive lanthanoid?

Q.4 Find out group, block & Period.

(a) [He] $2s^2\ 2p^3$ (b) [Rn] $7s^2\ 5f^{14}\ 6d^{10}\ 7p^5$

A.4. (a) 15th group, p-block, IInd period

(b) 17th group, p-block, VIIth period

Bohr's classification :

(I) Inert gases :

→ Outermost orbit complete.
→ Total 7 inert gases are discovered.
→ General configuration is $ns^2np^{0/6}$.

(II) Normal/Representative elements :

→ Last orbit incomplete.
→ s and p-block elements except inert gases are called representative/normal element.
→ General configuration is $ns^{1,2}np^{0-5}$

(III) Transition elements :

- In this case last two orbit are incompleted in its atomic or ionic form.
- d-block elements except 12th group (Zn, Cd, Hg, Uub) are called as transition elements.

Previous Year's Question

The element having the electronic configuraiotn $1s^22s^22p^63s^23p^1$

[AIPMT]

(1) A transition element
(2) A representative element
(3) An inert gas
(4) An inner-transition element

(IV)Inner transition elements :

- In this case last 3 orbits are incompleted in its atomic or ionic form.
- f-block elements are called inner transition elements.

Concept Ladder

Elements of 12^{th} group are not transition elements but they are considered in transition series.

Q.5 Select the set of representative elements.

(1) Atomic number 11, 26, 35, 88 (2) Atomic number 66, 101, 17, 37

(3) Atomic number 19, 38, 15, 7 (4) Atomic number 30, 80, 105, 92

A.5 (3)

Q.6 If an orbital contains 3 electrons or if there are 3 values of spin quantum number, then select the incorrect option.

(1) Na belongs to p-block

(2) (Zinc = 30) changes its block ($1s^3\ 2s^3\ 2p^9\ 3s^3\ 3p^9\ 4s^3$)

(3) Total number of elements in 6^{th} period will be 27

(4) Total number of elements in 3^{rd} period will be 12

(5) Total number of periods in periodic table will be less than total number of periods in modern periodic table.

A.6 (3) Total number of elements in 6^{th} period will be 48.

Typical elements :

- Those elements which explain the properties of there respective group.
- Third period elements except inert gases are called typical elements.
- Elements of 2^{nd} period are not typical elements since they have :

(i) Small size

(ii) High Z_{eff}

(iii) Absence of vacant d-orbitals

Previous Year's Question

The element, with atomic number 118, will be

[AIIMS]

(1) a transition element
(2) an alkali metal
(3) an alkaline earth metal
(4) a noble gas

Bridge elements :

- According to modern periodic table, the elements of 2[nd] period (Li, Be, B) are called as bridge elements.
- According to Mendeleev periodic table, the elements of 3[rd] period (Na, Mg, Al) are called as bridge elements.

Diagonal Relationship :

- Elements of second period are showing properties similar to elements of third period which are diagonally related to them, this is called as diagonal relationship.
- The cause of diagonal relationship is similar value of ionic potential (ϕ).

Transuranic Elements :

- Those elements which are coming after Uranium in periodic table.
- All trans Uranic elements are radioactive and artificial (Man made).
- Total transuranic elements in periodic table are 26.
- First man made element is Technetium(Tc).
- First man made Lanthanoid is Promethium (Pm).
- Total natural elements are 90 (1 to 90).
- Traces of Np, Pu are found in naturally occurring ore of Uranium that is Pitch Blend. (U_3O_8).

Liquid elements :

(i) Liquid at room temperature- Hg, Br

(ii) Liquid around room temperature- Cs, Fr, Ga, Uub

Rack your Brain

What is first man made element?

Concept Ladder

Diagonal Properties

Li → Mg, Be → Al, B → Si

Almost have similarity in properties.

Previous Year's Question

The element, with atomic number 118, will be

[AIIMS]

(1) a transition element
(2) an alkali metal
(3) an alkaline earth metal
(4) a noble gas

Concept Ladder

All actinoids are radioactive but all actinoids are not man made.

Periodicity :

- The causes of periodicity is repetition of general electronic configuration.
- Z_{eff}, ionisation energy, electronegativity, electroaffinity, metallic character etc are periodic properties.

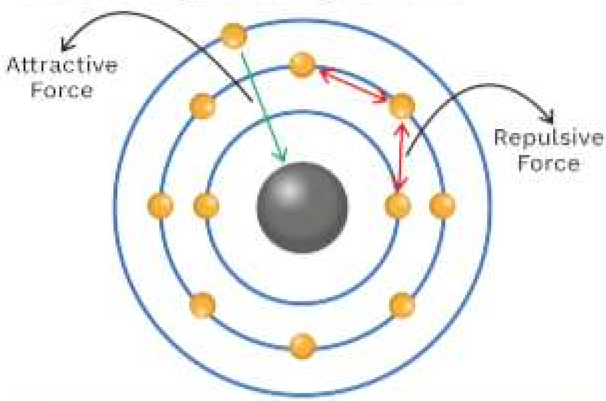
Z_{eff} (Effective nuclear charge)

$$Z_{eff} = Z - \sigma$$

Where,

Z is number of protons

σ is shielding/screening constant



$$Z_{eff} \propto \frac{+\text{ve charge}}{-\text{ve charge}} \quad \text{or} \quad Z_{eff} \propto \frac{p}{e^-}$$

Shielding effect :

(1) It is the phenomenon is which nuclear charge present on outermost electron is decreased by presence of inner or outer electron.

(2) The shielding of electron present in s-orbital is most effective, p-orbital is effective, d-orbital is poor and f-orbital is negligible.
s > p > d > f (shielding effect).

Definition

Regular repetition of properties at fixed intervals is called as periodicity.

Definition

The net positive charge attracting an electron in an atom is known as effective nuclear charge.

Concept Ladder

Shielding effect : s > p > d > f

Rack your Brain

Which element has the highest effective nuclear charge?

Slater's Rule :

(Calculation of σ and z_{eff})

(1) For ns/np electron.

$n^{th} \Rightarrow \sigma = 0.35$

$(n-1) \Rightarrow \sigma = 0.85$

$(n-2)$ or lower $\Rightarrow \sigma = 1.0$

(2) For nd/nf electron.

nd/nf $\Rightarrow \sigma = 0.35$

(3) For 2 electron species (Ex : He, Li^+, Be^{++} etc.)

$\sigma = 0.3$

Concept Ladder

On moving from left to right in s and p-block elements σ is increased by 0.35 and z_{eff} is increased by 0.65.

On moving from left to right in d-block σ is increased by 0.85 and z_{eff} is increased by 0.15.

Examples :

(1) Calculate the σ and z_{eff} for Na.

Sol Na = $1s^2\ 2s^2\ 2p^6\ 3s^1$

$\sigma = 8 \times 0.85 + 2 \times 1.0 = 8.85$

$Z_{eff} = Z - \sigma = 11 - 8.85 = 2.15$

(2) Calculate the σ and z_{eff} for 3s electron of Mg.

Sol. Mg = $1s^2\ 2s^2\ 2p^6\ 3s^2$

$\sigma = 1 \times 0.35 + 8 \times 0.85 + 2 \times 1.0 = 9.15$

$Z_{eff} = Z - \sigma = 12 - 9.15 = 2.85$

- From top to bottom Z_{eff} value is

  Li = 1.30

  Na = 2.20

  K = 2.20

  Rb = 2.20

Rack your Brain

If Z_{eff} of carbon is x than find out the value of Z_{eff} of oxygen?

Concept Ladder

On moving from top to bottom z_{eff} is increased by 0.9 in IInd & IIIrd period. Thereafter it remains constant.

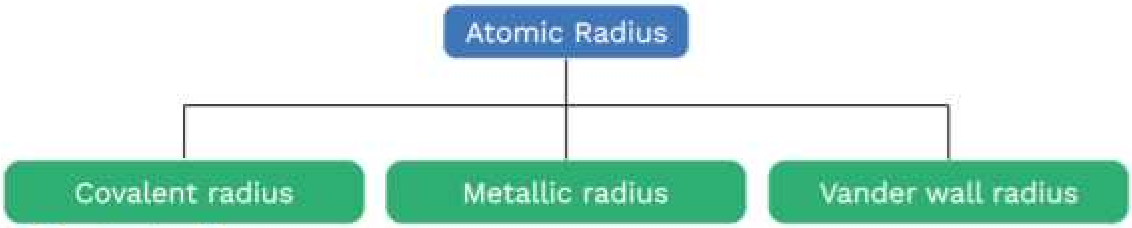
Note :

Slater's rule is never used for comparing various periodic properties.

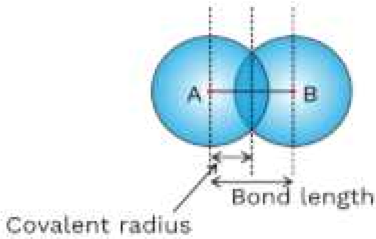
Rack your Brain

Total number of liquid elements are?

Atomic Radius:



(a) Covalent radius :



It is defined as one-half the distance between the nuclei of two covalently bonded atoms of the same element in a molecule. This is generally used for non-metals.

$$r_{\text{covalent radius}} = \frac{1}{2}(\text{Bond length})$$

For Homoatomic molecule : $d_{A-B} = r_A + r_B$

For Heteroatomic

$d_{A-B} = r_A + r_B - 0.09\ |\Delta EN|$ (Stevenson and Schoemaker formula)

(b) Metallic radius : (Crystal radius)

- It is half of internuclear distance present between the two adjacent metal ions in the metallic lattice.
- Covalent radius is always lower than metallic radius since in case of metallic radius no overlapping takes place.
- Kernel is the part left after separation of outermost orbit.
- Generally metallic radius is present between two metal atoms.

Concept Ladder

For non-metal

$$r_{\text{covalent}} = \frac{d}{2}$$

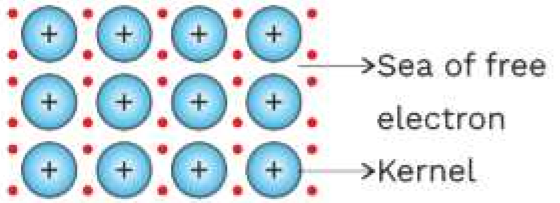
Rack your Brain

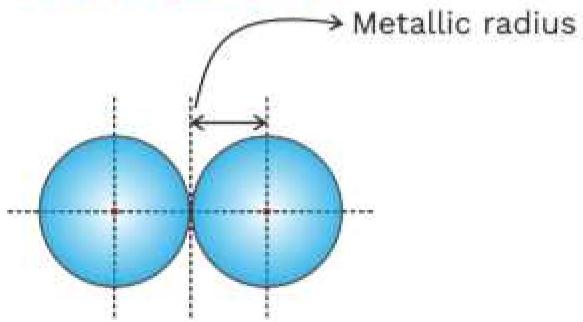
How covalent bonds are broken?

Concept Ladder

For metal

$$r_{\text{metallic}} = \frac{d}{2}$$





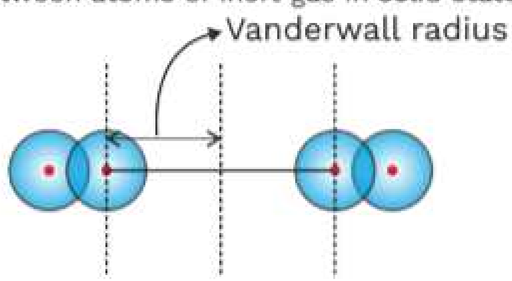
> **Rack your Brain**
>
> Which metal would form a strong metallic bond?

> **Previous Year's Question**
>
> Largest difference in radii is found in case of the pair **[AIIMS]**
>
> (1) Li, Na (2) Na, K
> (3) K, Rb (4) Rb, Cs

> **Concept Ladder**
>
> For metal
>
> $$r_{vwf} = \frac{d}{2}$$

(c) Van der Walls radius :

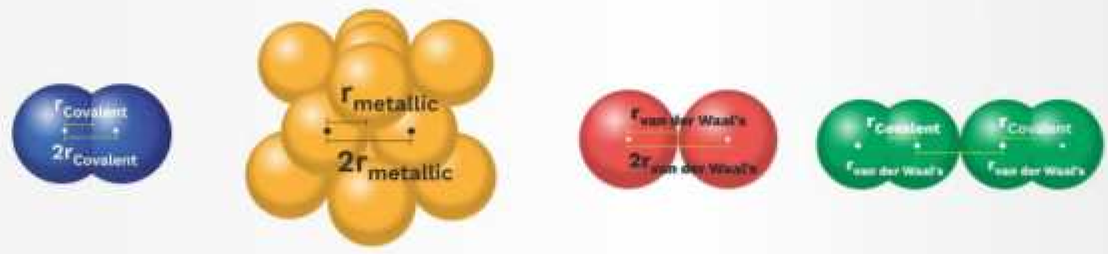
- It is half of internuclear distance between nuclei of two non-bonded isolated atoms or adjacent atoms belonging to neighbouring molecules.
- It is also defined with respect to inert gases, it is half of the internuclear distance present between atoms of inert gas in solid state.



> **Rack your Brain**
>
> Why is van der Walls radius greater than covalent radius?

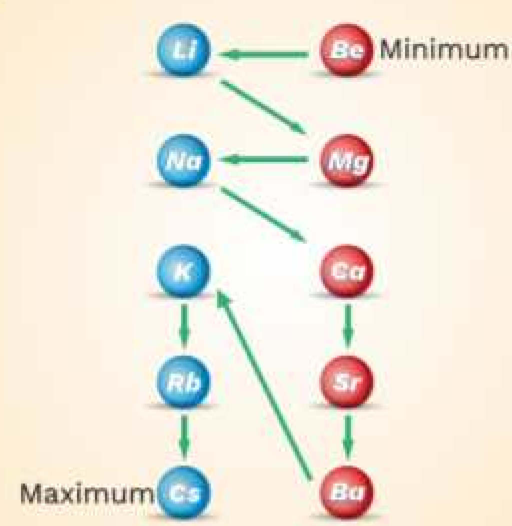
Q.7 Inert gases have maximum size. Why ?

A.7 In case of inert gases, we consider Vanderwaal radius and Vanderwaal radius is greater than that of metallic and covalent radius.



Block-wise comparison of elements:

(I) s-block : The atomic or ionic size of s-block elements is given as follows :



In the above figure Be and Cs has minimum and maximum atomic radius respectively.

Note : -

(i) Ionic radius Li^{+}(76 pm) ≥ Mg^{2+}(72 pm) and Na^{+} (102 pm) ≥ Ca^{2+} (100 pm).

(ii) Metallic bond strength of Ba is higher than K due to metallic radius of Ba is lower than K.

(II) p-block : Generally on moving along period from left to right size of elements decreases and on moving from top to bottom size of elements increases.

- In boron family the trend in atomic size is given as :

$$B < \underbrace{Al \geq Ga}_{\text{Transition contraction}} < \underbrace{In \leq Tl}_{\text{Lanthanoid contraction}}$$

Previous Year's Question

Which of the following atoms will have the smallest size?

[AIIMS]

(1) Mg (2) Na
(3) Be (4) Li

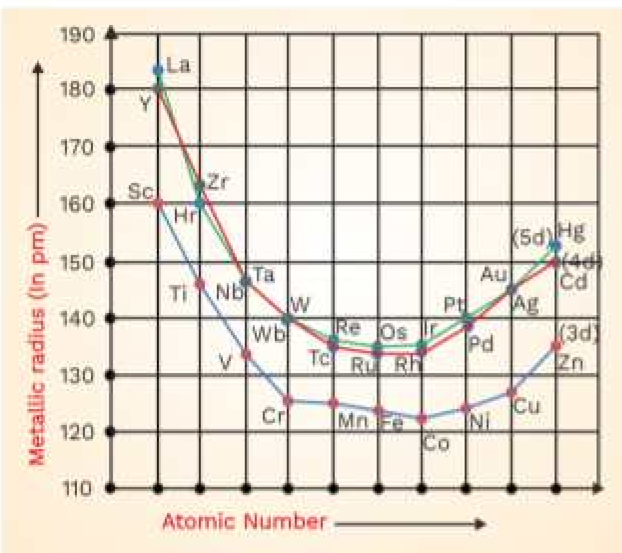
- In carbon family the trend in atomic size is given as :

$$C < \underbrace{Si \leq Ge}_{\text{Weak Transition contraction}} < \underbrace{Sn \leq Tl}_{\text{Weak Lanthanoid contraction}}$$

- In nitrogen and oxygen families there is general trend for atomic size that is from top to bottom it increases.

(III)d-block : Generally on moving top to bottom size increases.

Note : (From left to right)



Order of size of 3d series :

(i) Covalent radius :

$$\underbrace{Sc \geq Ti \geq V \geq Cs \geq Mn}_{Z_{eff} > \sigma} \geq \underbrace{Fe \approx Co \approx Ni}_{Z_{eff} \approx \sigma} \leq \underbrace{Cu \leq Zn}_{Z_{eff} < \sigma}$$

Previous Year's Question

Which is correct regarding size of atom?

[AIIMS]

(1) N < O
(2) B < Ne
(3) V > Ti
(4) Na > K

Concept Ladder

Transition metal show similarity in properties in both horizontal and vertical direction due to comparable size.

Rack your Brain

Why d-block elements are highly reactive?

Previous Year's Question

Among the elements Ca, Mg, P and Cl, the order of increasing atomic radii is

[AIPMT-2010]

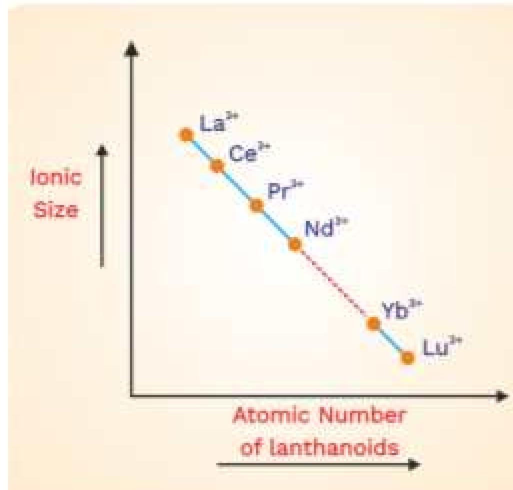
(1) Mg < Ca < Cl < P
(2) Cl < P < Mg < Ca
(3) P < Cl < Ca < Mg
(4) Ca < Mg < P < Cl

(ii) Metallic radius:

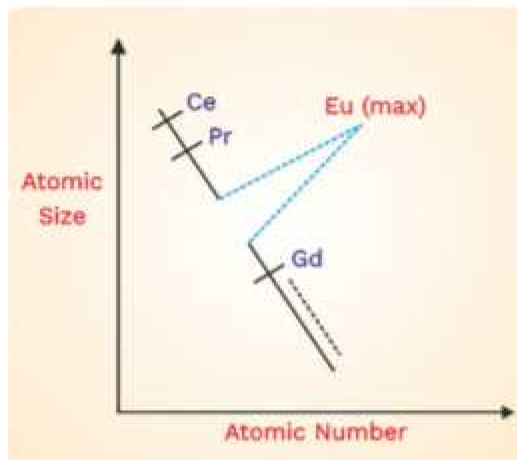
$$Sc \geq Ti \geq V \geq Cr < Mn > Fe \approx Co \approx Ni \leq Cu \leq Zn$$

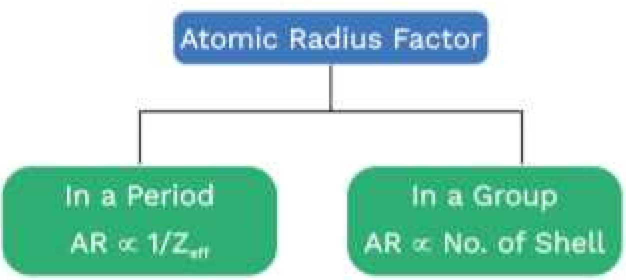
The variation in covalent and metallic radius of Cr and Mn is due to the fact that in case of Mn two electrons participate in metallic bond formation whereas in case of Cr three electrons participate in formation of metallic bond, that is why metallic bond strength of Cr is high and its metallic radius is low.

(IV) f-block : The order of ionic size of lanthanoid series elements is shown as follows :



- The metallic radius/atomic radius of Eu is maximum in lanthanoids series since, in case of Eu two electrons are participating in metallic bond but in case of other metals of lanthanoid series three electrons are participating in metallic bond due to which their metallic bond strength is high and their metallic radius is low.





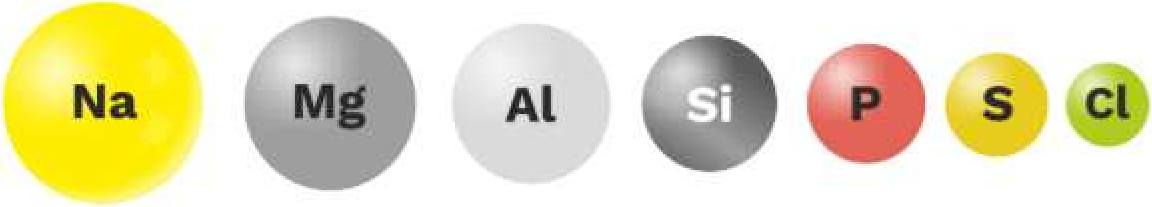
Atomic Size (Period Trends) :

$$\text{Atomic Radius} \propto \frac{1}{Z_{eff}}$$

Concept Ladder

Maximum and minimum atomic radius along the period are inert gases and halogens.

- In a period, electrons are in the same energy level but there is more nuclear charge.
- Outermost electrons are pulled closer.



Ex (i) Li > Be > B > C > N > O > F << Ne

(ii) Na > Mg > Al > Si > P > S > Cl << Ar

Atomic Size (Group Trends) :

Atomic Radius ∝ No. of shell

- As we increase the atomic number (or go down a gorup).
- Each atom has another energy level, so the atoms get bigger.

Ex : (i) F < Cl < Br < I

(ii) Be < Mg < Ca < Sr < Ba

(iii) N < P < As < Sb < Bi

(iv) Li < Na < K < Rb < Cs ≈ Fr (Lanthanoid contraction)

(v) V < Nb ≈ Ta

Concept Ladder

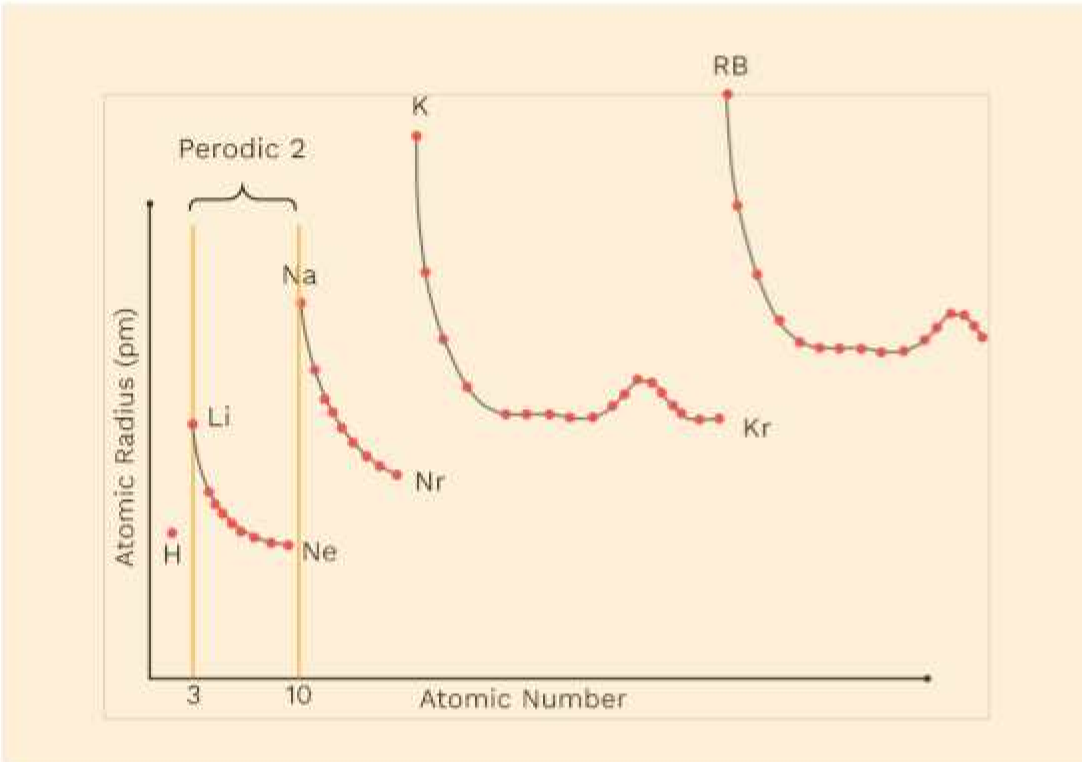
Size of an atom depends upon effective nuclear charge and screening effect. Therefore, when we move from left to right of periodic table atomic size decreases

Previous Year's Question

Arrange the following in increasing order of their atomic radius : Na, K, Mg, Rb

[AIPMT]

(1) Mg < K < Na < Rb
(2) Mg < Na < K < Rb
(3) Mg < Na < Rb < K
(4) Na < K < Rb < Mg



Size order of Isoeletronic species Ions of element

$$\text{Ionic Radius} \propto \frac{1}{Z_{eff}} \propto \frac{-\text{ve charge}}{+\text{ve charge}}$$

Ionic Size (Group Trends) :

- Energy leve is added on each step down a group.
- Therefore, ions get bigger as we go down, because of the additional energy level.

Ex: (i) $F^- < Cl^- < Br^- < H^-$

(ii) $I^- > I > I^+$

(iii) $S^{-2} > Cl^- > Ar > K^+ > Ca^{+2}$ (isoelectronic)

(iv) $NaH > H_2 > HCl$ (H-radius)

Ionic Size (Period Trends) :

- Across the period from left to right, the nuclear charge increases so they get smaller.
- Notice the energy level charges between anions and cations.

Rack your Brain

Does the radius of an atom or ion depend upon electron-proton ratio?

Q.: Correct order of radius is :

(1) $K > K^{\oplus}$

(2) $Cl < Cl^{\ominus}$

(3) $H^+ > H$

(4) $I^{\oplus} < I < I^{\ominus}$

(VWR) (CR)

(5) Cr > Mn (Covalent)

(6) Cr < Mn (Metallic-R)

(7) $MnO_2 > KMnO_4$ (Radius of Mn)

(+4) (+7)

(8) $N_2O < NH_3$ (Radius of N)

(+1) (–3)

(9) $Li^+ < Na^+ < K^+ < Rb^+ < Cs^+$

(10) N < P < As < Sb < Bi

(11) He < Ne < Ar < Kr < Xe < Rn

(12) $C < Si \leq Ge < Sn \leq Pb$

Previous Year's Question

The radii of F, F^-, O and O^{-2} are in the order of

[AIPMT]

(1) $O^{2-} > F^- > O > F$

(2) $O^{2-} > F^- > F > O$

(3) $F^- > O^{2-} > F > O$

(4) $O^{2-} > O > F^- > F$

Previous Year's Question

Which of the following order of ionic radii is corrctly represented

[AIPMT-2014]

(1) $F^- > O^{2-} > Na^+$

(2) $Al^{3+} > Mg^{2+} > N^{3-}$

(3) $H^- > H > H^+$

(4) $Na^+ > F^- > O^{2-}$

Ionisation energy (IP or IE) :

Ex Which of the following represents IP_1.

(1) $Na(s) \longrightarrow Na^+(g)$
(Sublimation Energy + IP_1)

(2) $K(g) \longrightarrow K^+(g)$

(3) $Cl_2(g) \longrightarrow Cl^+(g)$

(4) $Mg(g) \longrightarrow Mg^{2+}(g)$ $(IP_1 + IP_2)$

Sol.(2)

Note :

- Successive IP :

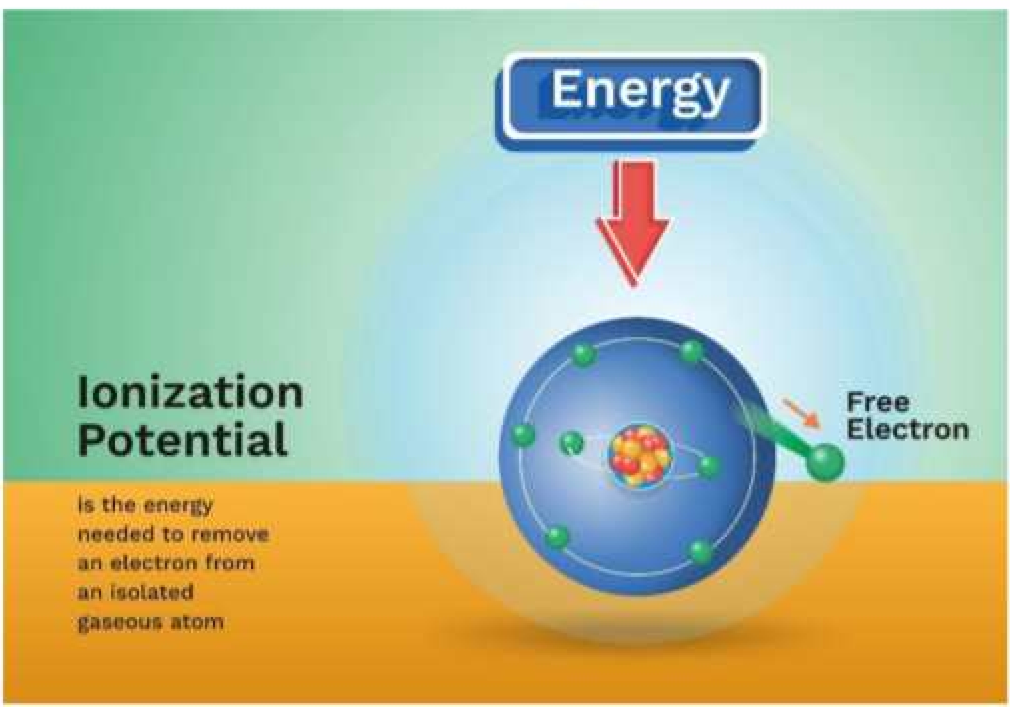
- $IP_2 = IP_1$ (Neutral atom) ($Ag^+(g)$)
- $IP_3 = IP_1 + IP_2$ (Neutral atom) ($Ag^{2+}(g)$)($Ag^+(g)$)

Definition

The amount of energy required to remove an electron from an isolated gaseous atom.

Concept Ladder

When an electron is being removed from an atom having half-filled or full-filled orbitals, the amount of energy required is maximized.



Factor affecting IP

- $Z_{eff} \propto IP$
- $Size \propto \frac{1}{IP}$ IP
- Charges $\left(\frac{+ve}{-ve}\right) \propto IP$
- Stable configuration $\propto$ IP
- Penetration effect $\propto$ IP; Order of penetration effect – s > p > d > f

Important points :

- The concept of Z_{eff} is used when we compare IP of same elements/isoelectronic species.

Ex Order of IP :

(1) $Cl(g) > Cl^{-}(g)$

(2) $Al^{3+} > Mg^{2+} > Na^{+} > F^{-} > O^{2-} > N^{3-}$

(3) $Ne^{+}(g) > Ne(g)$

(4) $Mg^{2+}(g) > Mg^{+}(g) > Mg(g)$

(5) $Al^{3+}(g) > Al^{2+}(g) > Al^{+}(g) > Al(g)$

- The concept of half filled/full filled configuration is applicable in the following 2 cases.

(a) Case-I : On moving left to right in a periodic table.

It is applicable when difference in atomic number is one and in all the other cases Z_{eff} is use.

Ex

(b) Case-II : On moving top to bottom in a periodic table.

The concept of half-filled is applicable till 4th period after that Z_{eff} is used.

Previous Year's Question

Which of the order for ionisation energy is correct.

[AIPMT]

(1) Be > B > C > N > O

(2) B < Be < C < O < N

(3) B < Be < C < N < O

(4) B < Be < N < C < O

Rack your Brain

Successive electron gain enthalpies are always positive. Why?

Half filled electronic configuration is used
- II: N > O
- III: P > S
- IV: As > Se

Z_{eff} is used (since orbital contraction)
- V: Sb < Te
- VI: Bi < Po

Penetration Effect ($ns^2 > ns^2np$)

2^{nd} and 13^{th} group

Till 4th period

		ns^2		ns^2np^1
Penetration effect	II	Be	>	B
	III	Mg	>	Al
	IV	Ca	>	Ga
Z_{eff} (orbital concentration)	V	Sr	<	In
	VI	Ba	<	Tl

12^{th} and 13^{th} group

Always applicable

$(n-1)d^{10}ns^2$		ns^2np^1
Be	>	B
Mg	>	Al
Ca	>	Ga

Concept of exchange energy :

Configuration	p^1	p^2	p^3	p^4	p^5	p^6
Exchanges	0	1	3	3	4	6

Stability order :

Configuration : $p^6 > p^5 > p^3 > p^4 > p^2 > p^1$

(Ne) (F) (N) (O) (C) (B)

Left to Right

$p^6 > p^5 > p^3 > p^4 > p^2 > s^2 > p^1 > s^1$

(Ne) (F) (N) (O) (C) (Be) (B) (Li)

$s^2 > p^1$ → Pentration effect

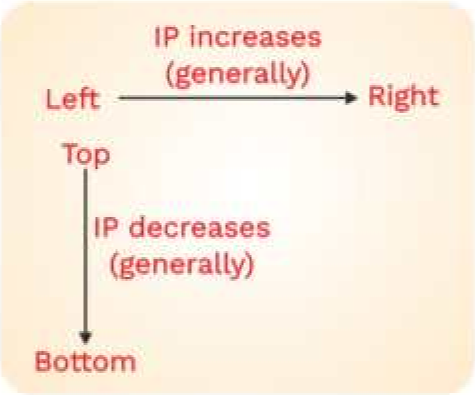
Note :

- Maximum IP in any period — Inert gas.
- Minimum IP in any period — Alkali metal.
- Maximum IP in periodic table — Helium(He).
- Minimum IP in periodic table — Cesium(Cs).

Rack your Brain

Why ionisation enthalpy is always calculated in gaseous state?

Periodicity :



Previous Year's Question

For the second period elements the correct increasing order of first ionization enthalpy is

[NEET-2019]

(1) Li < Be < B < C < O < N < F < Ne
(2) Li < Be < B < C < N < O < F < Ne
(3) Li < B < Be < C < O < N < F < Ne
(4) Li < B < Be < C < N < O < F < Ne

Block -wise comparison :

(I) s-block element :

Li > Na > K > Rb > Cs

Be > Mg > Ca > Sr > Ba < Ra

Lanthanoid contraction

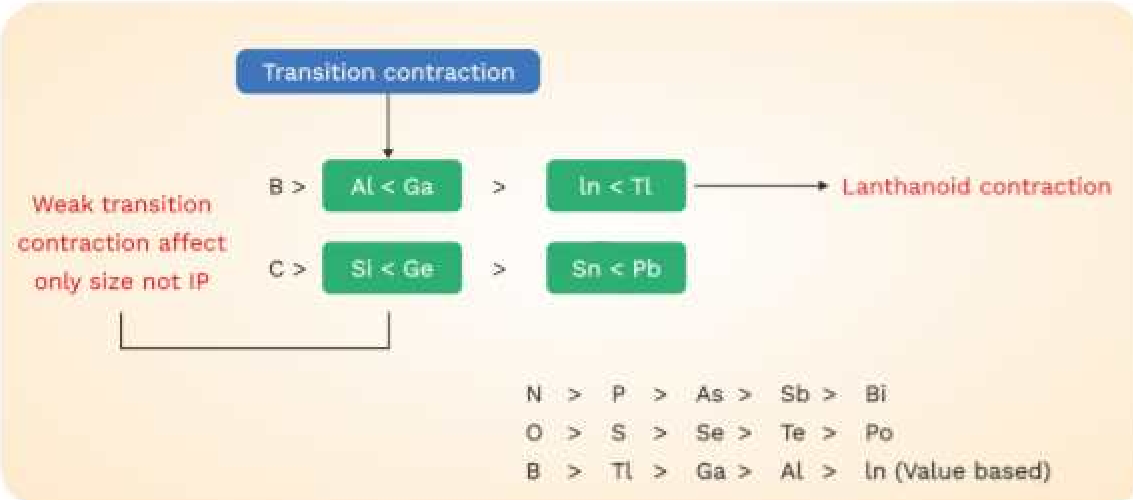
On moving down a group, if size is same or almost same due to lanthanoid or transition contraction then I.P. increases because z_{eff} increases.

Concept Ladder

If difference between two successive I.P. values is less than 11 eV then higher oxidation state is more stable.

If difference between two successive I.P. values is greater then 16 eV then lower oxidation state is more stable.

(II) p-block element :



(III) d-block element :

The order of IP moving from left to right in d-block is shown as follows :

3d series	Sc	Ti	V	Cr	Mn	Fe	Co	Ni	Cu	Zn
4d series	Y	Zr	Nb	Mo	Tc	Ru	Rh	Pd	Ag	Cd
5d series	La	Hf	Ta	W	Re	Os	Ir	Pt	Au	Hg

Note :

There are various exceptions in the IP of d-block elements which is due to the following reasons.

(1) Exceptional electronic configuration.

(2) Irregular variation in size and Z_{eff}.

(3) When e^- is removed from ns orbital then remaining e^- is shifted to (n-1) orbital due to which the no. of exchanges are changed and IP also changes.

- On moving from top to bottom in d-block Z_{eff} is dominating factor.

Previous Year's Question

Which of the following has the highest first ionisation energy **[AIPMT]**

(1) Li (2) Be
(3) B (4) C

- Order of IP of 3d series will be:-

Sc < Ti > V < Cr < Mn < Fe > Co > Ni < Cu < Zn

Note

- 2^{nd}, 6^{th} & 7^{th} group IP decreases & in rest of all groups IP increases.
- From top to bottom.

Previous Year's Question

Which of the following element has maximum first ionisation potential? **[AIIMS]**

(1) V (2) Ti
(3) Cr (4) Mn

3rd group : Sc (3d) > Y (4d) > La (5d) < Ac (6d)

(La (5d) < Ac (6d)) → Poor shielding of f-electrons

For the group no. 4, 5, 6, 10

3d < 4d < 5d

For all groups

4d < 3d < 5d

- The above 2 orders are not valid for 3^{rd} group.

Rack your Brain

Why hydrogen has high ionisation energy compare to ionic metals?

(IV) f-block

In case of Lanthanoids i.e. 4f-series

4f ; $\sigma \downarrow$, Z_{eff}, $\uparrow$, IP $\uparrow$

Application of IP

- **Metallic & Non-metallic character**
  - Metallic character $\propto \frac{1}{I.P}$
  - Non - metallic character $\propto$ I.P
- **Basic & Acidic nature of oxide/hydroxide**
  - Basic nature of oxide / hydroxide $\propto \frac{1}{IP}$
  - Acidic nature of oxide / hydroxide $\propto$ IP
- **To decide stable oxidation state**
  - (a) $\Delta IP \leq 11eV$ (Higher oxidation state stable)
  - (b) $\Delta IP \geq 16eV$ (Lower oxidation state stable)

Ex. (1) Na^{+} is more stable than Na^{2+} since $E^{\circ}_{cell} - \frac{2.303RT}{nF}\log Q$

(2) Mg^{2+} is more stable than Mg^{+} since $E^{\circ}_{cell} - \frac{0.0591}{n}\log Q$

Stability : $Al^{3+} > Al^{+} > Al^{2+}$ (Governed By Configuration)

IP : $Al^{3+} > Al^{2+} > Al^{+}$ (Governed By Z_{eff})

(iv) To decide valence electron

Ex: $IP_1 = 12$

$IP_2 = 27$

$IP_3 = 39$

$IP_4 = 169$

- The above element may be Al.
- Oxide of above element may be amphoteric.
- The above element is a metal.
- Outermost electron (valency) = 3

Previous Year's Question

In which of the following options the order of arrangement does not agree with the variation of property indicated against it?

[NEET-2016]

(1) I < Be < Cl < F (increasing electron gain enthalpy)

(2) Li < Na < K < Rb (increasing metallic radius)

(3) $Al^{3+} < Mg^{2+} < Na^{+} < F^{-}$ (increasing)

(4) B < C < N < O (increasing first ionization enthalpy)

Q.8 Given following values of IP in [eV]

IP_1	IP_2	IP_3	IP_4.....
12	127	139	167.........

Select the correct option :

(1) Element may be Na. (2) Element may be Li.

(3) Element is a metal. (4) Both (1) & (3)

A.8 (4) Element may be Li is incorrect because 3 electrons are present in Li

Rack your Brain

Why IP values of lanthanoids generally increases from Ce to Lu?

Note- Isotopes have similar values of size & IP.

Ex. Correct order of IPs are

(1) $N^{3-} < O^{2-} < F^{-} < Na^{+} < Mg^{2+} < Al^{3+}$

(2) $I^{+}(g) > I(g) > I^{-}(g)$

(3) $Be^{2+} > La^{+} > He$

(4) Sc > Y > La < Ac

(5) Ni < Pd < Pt (10^{th} group)

(6) Rn > W > Hg > La

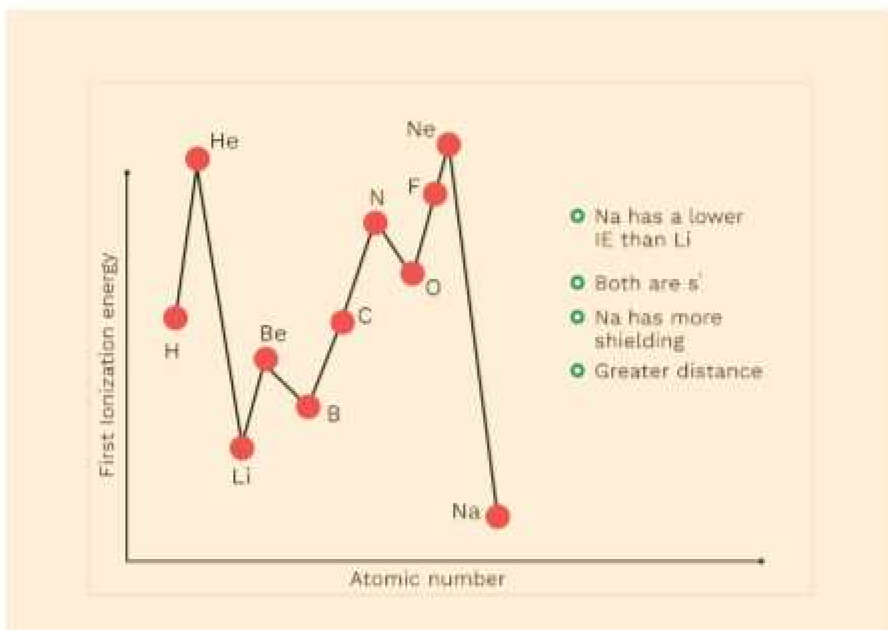
(7) Zn > Fe > Sc

(8) Order of IP_1 of 2^{nd} period elements

Ne > F > N O > C > Be > B > Li

(9) Order of IP_2 of 2^{nd} period elements

Li > Ne > O > F > N > B > C > Be



	Group 1	2	13	14	15	16	17	18
			H 1310					He 2370
2	Li 519	Be 900	B 799	C 1090	N 1400	O 1310	F 1680	Ne 2080
3	Na 494	Mg 736	Al 577	Si 786	P 1011	S 1000	Cl 1255	Ar 1520
4	K 418	Ca 590	Ga 577	Ge 784	As 947	Se 941	Br 1140	Kr 1350
5	Rb [illegible]	Sr [illegible]	In [illegible]	Sn [illegible]	Sb [illegible]	Te [illegible]	I 1008	Xe 1170

Ionisation energy ($kJ\text{-}mol^{-1}$)

2001-2500

1501-2000

1001-1500

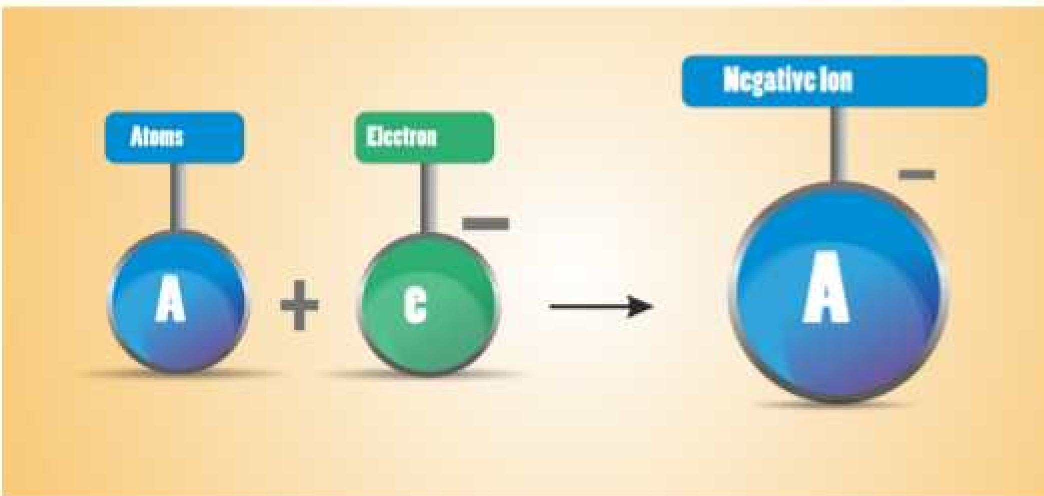
Electron Affinity/ Electron gain enthalpy :

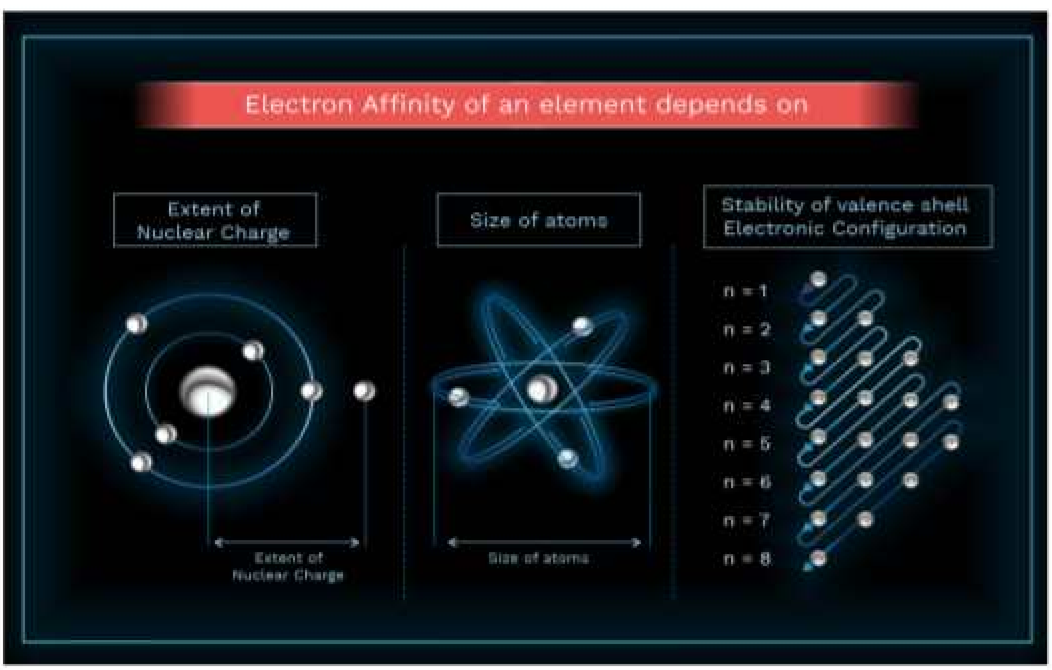
- Electron gain enthalpy is the enthalpy change in the above process.

–0 0.0591. [P]

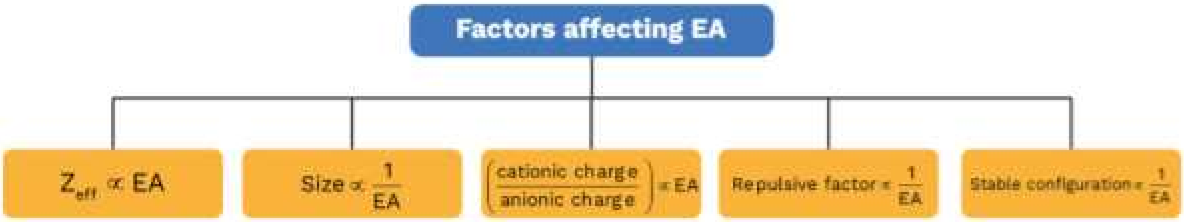
Definition

Electron Affinity is amount of energy released when electron is added to isolated gaseous atom in its ground state.





• **For exothermic ΔH is negative and for endothermic ΔH is positive.**



Relation between IP & EA

$X(g) + e^- \underset{IP}{\overset{EA}{\rightleftharpoons}} X^-(g)$ $\qquad$ $M(g) \underset{IP}{\overset{EA}{\rightleftharpoons}} M^+(g) + e^-$

$IP_{(x^-)} = EA_{(x)}$ $\qquad$ $IP_{(M)} = EA_{(M^+)}$

(i) Ionisation Potential of monoanion is always equal to EA of neutral atom.

(ii) Similarly, Ionisation Potential of neutral atom is always equal to EA of monocation.

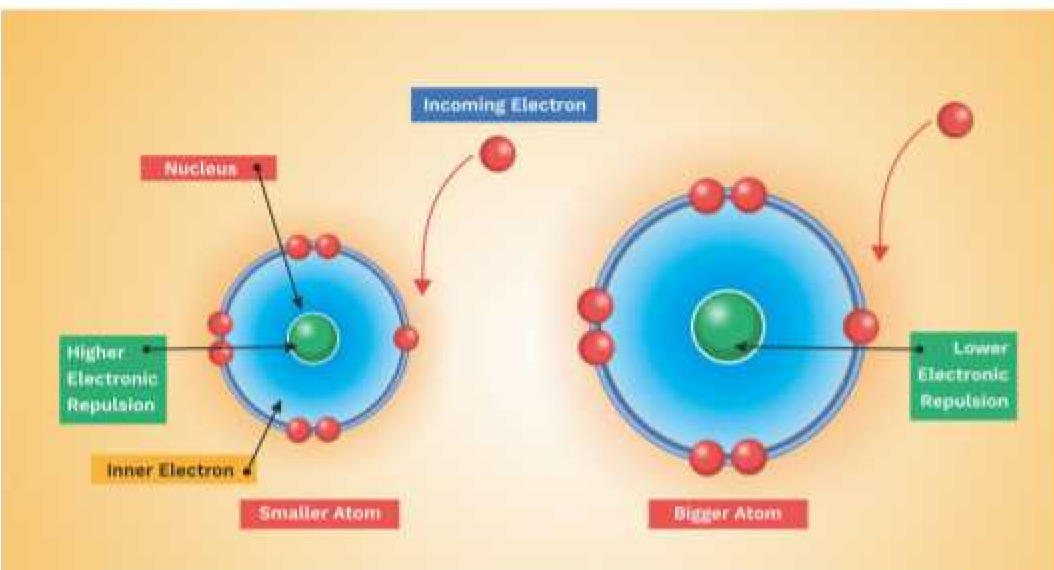
Important Points

- The formation of poly -ve anion is always endothermic process.

$O_{(g)} + e^- \rightarrow O^-_{(g)}$ $\quad (\Delta H = -141\ kJ/mol)$ $\quad$ (Exothermic)

$O^-_{(g)} + e^- \rightarrow O^{2-}_{(g)}$ $\quad (\Delta H = +744\ kJ/mol)$ $\quad$ (Endothermic)

$O_{(g)} + 2e^- \rightarrow O^{2-}_{(g)}$ $\quad (\Delta H = +603\ kJ/mol)$ $\quad$ (Endothermic)



REPRESENTATION OF ELECTRON AFFINITY

- Concept of repulsion factors is applicable when we compare EA of 2nd & 3rd period elements.

$F + 1e^- \longrightarrow F^-$ and $Cl + 1e^- \longrightarrow Cl^-$

- Electron affinity of Cl is more than F (2nd period element < 3rd period element)
- **Order of EA**

  F < Cl > Br > I

  N < P > As > Sb > Bi

  O < S > Se > Te

  EA of oxygen is minimum in chalcogens

Ex: IP (Cs) > EA (Cl)

Order of EA

Family	Halogen >	Chalogen >	Pnicogen	Always valid
Config.	p^5	p^4	p^3	

Previous Year's Question

Which one of the following arrangements represents the correct order of electron gain enthalpy (with negative sign) of the given atomic species

[AIPMT-2010]

(1) Cl < F < S < O (2) O < S < F < Cl
(3) S < O < Cl < F (4) F < Cl < O < S

Q.9 EA of Cl is maximum in Periodic Table.

A.9 If we consider Cl

$Cl(g) + e^- \rightarrow Cl^-(g) + 350\ KJ/mol$

EA = +350 KJ/mol

EGE = -350 KJ/mol

EA >> EGE

Rack your Brain

Which group has the highest electronaffinity?

Order of EA

(I) 2nd period elements

Element	Li	Be	B	C	N	O	F	Ne
Configuration	$2s^1$	$2s^2$	$2p^1$	$2p^2$	$2p^3$	$2p^4$	$2p^5$	$2p^6$

Ne < Be < N (Endothermic) < B < Li < C < O < F (Exothermic)

Q.10 **Assertion :** Addition of one electron in nitrogen is endothermic where as in phosphorus is exothermic.

Reason : Nitrogen doesn't contain vacant d-orbital but phosphorus contains d-orbital.

A.10 Assertion and Reason both are true and Reason is the correct explanation of the Assertion.

(II) 3rd period element

Element	Na	Mg	Al	Si	P	S	Cl	Ar
Configuration	$3s^1$	$3s^2$	$3p^1$	$3p^2$	$3p^3$	$3p^4$	$3p^5$	$2p^6$

Ar < Mg <   Al < Na < P < So < S < Cl

Endothermic   Exothermic

- **Exothermic/ Endothermic**

(1) Stable configuraiton of atom $\xrightarrow{+e^-}$ endothermic
$(1s^2/np^6/2s^2/3s^2/2p^3) \approx$ $\boxed{EA = 0}$

(2) Unstable configuration of atom $\xrightarrow{+e^-}$ exothermic

(3) Poly negative anion formation $\longrightarrow$ endothermic

(4) Neutral atom $\xrightarrow{-e^-}$ endothermic (IP)

Examples for endothermic/ exothermic :

(1) $Cl_{(g)} \longrightarrow Cl^-_{(g)}$ (exothermic)

(2) $K_{(g)} \longrightarrow K^+_{(g)}$ (endothermic)

(3) $Na_{(g)} \longrightarrow Na^+_{(g)}$ (endothermic)

(4) $Cl_{2(g)} \longrightarrow Cl^+_{(g)}$ (endothermic)

Previous Year's Question

Fluorine has low electron affinity than chlorine because of **[AIPMT]**

(1) Smaller radius of fluorine, high density

(2) Smaller radius of chlorine, high density

(3) Bigger radius of fluorine, less density

(4) Smaller radius of chlorine, less density

- **Order of electron affinity of various species :**

(1) $I^+ > I > I^-$ (2) Cl > F > S > O

(3) F > O > N > Be > Ne (4) Cl > P > Na > Al > Ar

(5) Cl > F > P > N (6) Cl > F > Br > I

1A	2A	3A	4A	5A	6A	7A	8A
H -73							He >0
Li -60	Be >0	B -27	C -122	N >0	O -141	F -328	Ne >0
Na -53	Mg >0	Al -43	Si -134	P -72	S -200	Cl -349	Ar >0
K -48	Ca -2	Ga -30	Ge -119	As -78	Se -195	Br -325	Kr >0
Rb -47	Sr -5	In -30	Sn -107	Sb -103	Te -190	I -295	Xe >0

- In general, electron affinity becomes more exothermic as from you go left to right across a row.
- Added electron must go in p- Orbital, not s- orbital. Electron is farther from nucleus and feels repulsion from s- electrons.

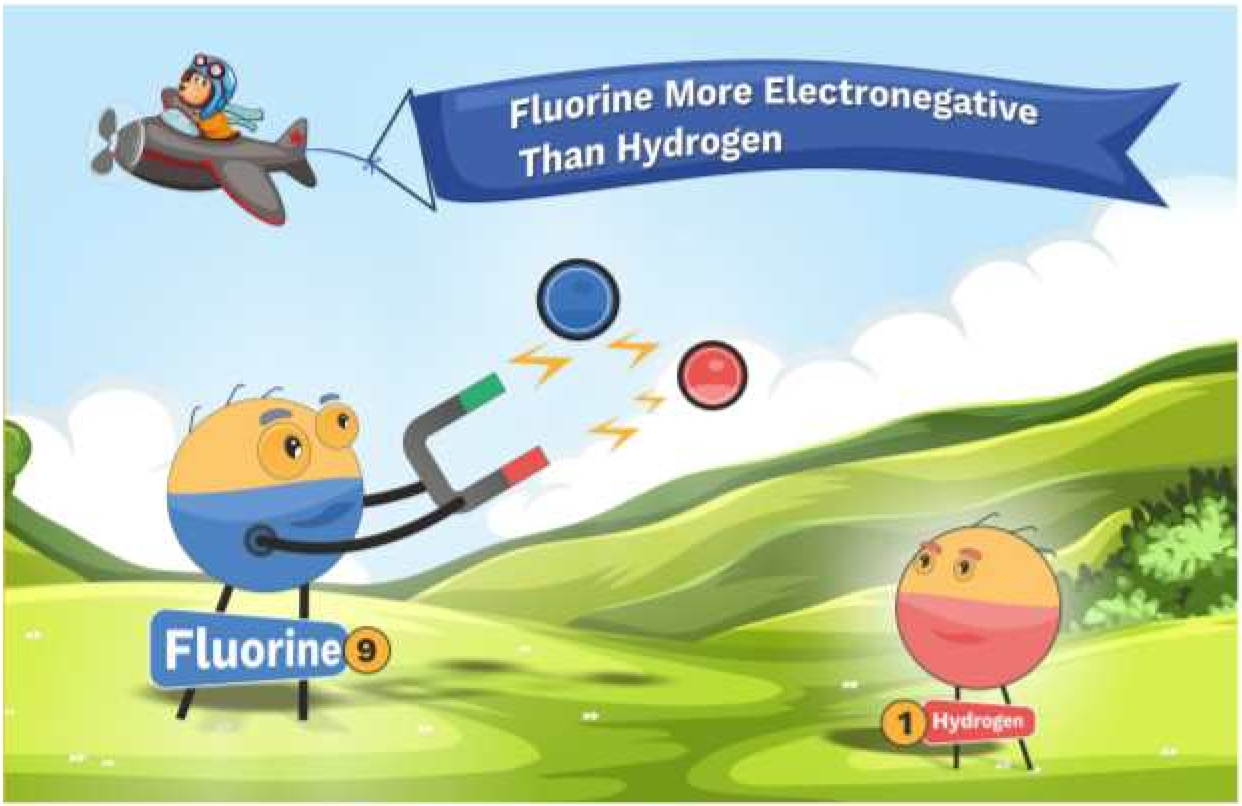
Electronegativity

- The concept of EN is independent of configuration factor and it is a relative concept.
- Partial charges are developed by EN & it has no unit.

[P]

Definition

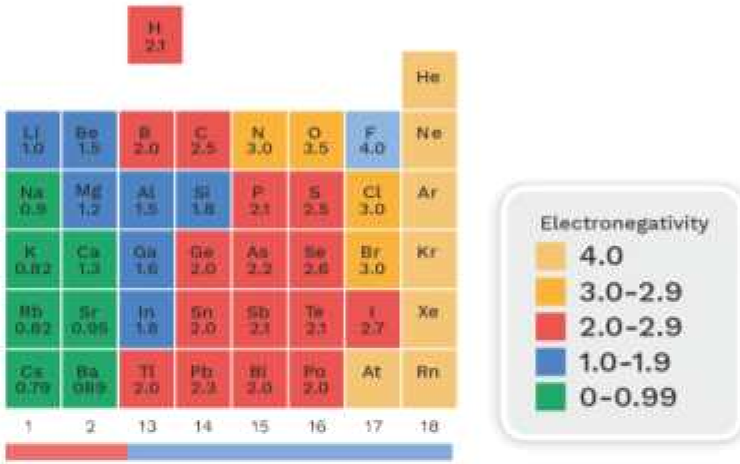
It is the tendency of atom in a molecule by which it attracts shared pair of electrons towards itself



Factors affecting EN

- $EN \propto Z_{eff}$ (In a period)
- $EN \propto \frac{1}{Size}$ (In a group)
- $EN \propto$ %s-character
- $EN \propto \frac{+ve\ oxidation\ state}{-ve\ oxidation\ state}$

S.No.	Character	CH≡CH	$CH_2 = CH_2$	$CH_3 - CH_3$
(1)	Hybridisation	sp	sp^2	sp^3
(2)	% s-character	50 %	33.33 %	25 %
(3)	% p-character	50 %	66.7 %	75 %
(4)	EN value	3.25	2.75	2.5



Ex: (1) C < N < O < F

(2) F > Cl > Br > I

(3) $SbF_5 > SbF_3$

Scale of EN

(I) Pauling's scale

$$X_A - X_B = 0.208\sqrt{\Delta_{A-B}}$$

$$\text{Or } \Delta_{A-B} = 23.06\left(X_A - X_B\right)^2$$

X_A = EN of A

X_B = EN of B

Δ_{AB} = Resonance energy in Kcal/mol^{-1}

Resonance Energy $\Rightarrow E_{\text{hybrid}} - E_{\text{Most stable resonating structure}}$

Previous Year's Question

The chemical elements are arranged int he order of increasing electronegativites in the sequence **[AIPMT-2010]**

(1) P, Si, Se, Br, N

(2) Si, Se, P, Br, N

(3) Si, P, Se, Br, N

(4) Se, P, Si, Br, N

(II) Mullikan scale

$$EN \Rightarrow \frac{IP + EA}{2} \text{ ev / atom}$$

Relationship between X_P and X_M

$$\boxed{X_P = \frac{X_M}{2.8}} \quad \text{or} \quad \boxed{X_P = \frac{IP + EA}{5.6}} \text{ ev/atom}$$

Or $\boxed{X_P = \frac{IP + EA}{540}}$ KJ/mol

1 Kcal = 4.2 KJ

Applications

(1) Bond polarity - $\propto \Delta EN$ **Ex :** H – F > H – H

(2) % ionic character $\propto \Delta EN$

Accrording to Henry-Smith equation

% ionic character $= 16|EN| + 3.5|EN|^2$

Ex: CsF is having highest $\Delta EN = 3.3$

% ionic character = 16 (3.3) + 3.5 $(3.3)^2$ = 91 %

Ionic character can never be 100 % since polarisation exists

Covalent character can never be 100 % since Vander Wall forces exists.

(3) Bond length (Inter nuclear distance)

$d_A - d_B = r_A + r_B - 0.09|\Delta EN|$

(Schoemaker & Stevenson formula)

Ex: (1) $NH_3 > SbH_3 > AsH_3 > PH_3$ (Bond polarity)

(2) $H_2O > H_2S > H_2Se > H_2Te$ (Bond polarity)

(3) HF > HCl > HBr > HI (Ionic character)

(4) NaCl < MgS < AlP (Covalent character)

(5) B < P < S < N < O < F (Non metallic character)

Previous Year's Question

Which element has the lowest electronegativity

[AIPMT]

(1) Li (2) F
(3) Fe (4) Cl

Rack your Brain

The bond length decreases with multiplicity of bnod. Why?

Concept Ladder

If the EN difference of a covalently bonded atom ($\Delta\chi$) increases, the bond energy of the covalent bond also increases.

Previous Year's Question

Which of the following order is wrong?

[AIPMT]

(1) $NH_3 < PH_3 < AsH_3$ – acidic
(2) Li < Be < B < C –1[st] IP
(3) $Al_2O_3 < MgO < Na_2O < K_2O$ – basic
(4) $Li^+ < Na^+ < K^+ < Cs^+$ – ionic radius

Acidic/Basic Nature :

(1) Lewis concept :

AA : Acid–acceptor of electron pair.sss

BD : Base–donor of electron pair.

Lewis Base :

- Anionic species.

  Ex : $NH_2^{\ominus}$, $OH^{\ominus}$, $F^{\ominus}$.

- Lone pair containing species.

  Ex : 2.303 RT

Lewis Acid

Vacant orbital containing species :

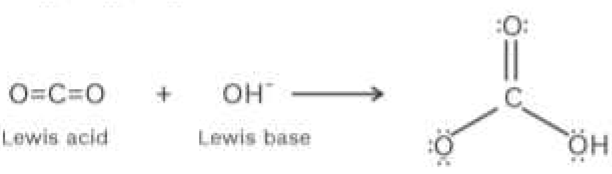
Ex : $FeCl_3$, $MnCl_2$, $MnCl_2$, $AlCl_3$, SiF_4, etc.

- Contraction of octat/hypovalent/electron deficient species.

Ex BCl_3, $AlCl_3$, $BeCl_2$ etc.

- Central atom bonded by multiple bond.

Ex CO_2, SO_2, SO_3 etc.



Cationic Species :

Ex Li^+, Be^{++}, H^+, etc.

Lewis Basic Strength (LBS) :

$$\text{Basic} \propto \left(\frac{\text{Anionic charge}}{\text{Cationic charge}}\right)$$

$$\text{Acidic} \propto \left(\frac{\text{Cationic charge}}{\text{Anionic charge}}\right)$$

Previous Year's Question

Acidity of pentoxides in VA group **[AIPMT]**

(1) Decreases
(2) Increases
(3) Remains same
(4) None

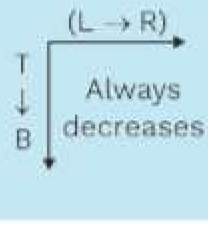
Rack your Brain

For monatomic anions of similar charge, base strength decreases with increasing size. Why?

Concept Ladder

$LBS \propto \frac{1}{EN}$ (Left to Right)

$LBS \propto \frac{1}{Size}$ (Top to Bottom)



Acidic Nature of hydrides of group 15, 16, 17 :

- Whenever conjugate base is more stable than corresponding acid is more acidic.

(Less acidic) HF $\longrightarrow$ $F^{\ominus}$(Less stable conjugate stable)

(More acidic) HI $\longrightarrow$ $I^{\ominus}$(More stable conjugate stable)

Acidic ∝ Size ; **Acidic ∝ EN**

(T → B) (T → R)

Acidic/Basic Nature of Oxides, Hydroxides, Oxyacids and metal hydride

$$\underset{\substack{\text{Metal Oxies} \\ \text{(Basic)}}}{Na_2O} + H\!-\!OH \longrightarrow \underset{\text{Hydroixde}}{2NaOH}$$

$$\underset{\substack{\text{Non-metal} \\ \text{oxide} \\ \text{(Acidic)}}}{CO_2} + HOH \longrightarrow \underset{\text{Oxyacid}}{H_2CO_3}$$

$$\underset{\substack{\text{Hydrolith} \\ \text{(Basic)}}}{CaH_2} + HOH \longrightarrow \underset{\text{Hydroxide}}{Ca(OH)_2} + 2H_2$$

$$\boxed{\text{Acidic nature} \propto \text{EN} \propto +\text{Ve O.S}}$$

$$\boxed{\text{Basic nature} \propto \frac{1}{\text{EN}} \propto \frac{1}{+\text{Ve O.S.}}}$$

Some important orders :

(1) $H_2SO_4 > H_2SeO_4 > H_2TeO_4$ (Acidic)

(2) NaOH < KOH < CsOH (Basic)

(3) $H_2SO_4 > H_2SO_4$ (Acidic)

(4) HF < HCl < HBr < HI (Acidic)

(5) $H_2O < H_2Se < H_2Se < H_2Te$ (Acidic)

(6) $NH_3 < H_2O < HF$ (Acidic)

Rack your Brain

The acidity increases as the oxidation state of N and P increases. What is the reason behind this increase in acidity?

Concept Ladder

For oxides having molecular formula M_2O_x, the following would be applicable for acidic and basic behavour. Molecules having , they are acidic and others are neutral

Previous Year's Question

Which of the following is the most basic oxide?

[AIPMT]

(1) SeO_2 (2) Al_2O_3
(3) Sb_2O_3 (4) Bi_2O_3

(7) $HOCl < HClO_2 < HClO_3 < HClO_4$ (Acidic)

(8) $N_2O < NO < N_2O_3 < N_2O_4 < N_2O_5$ (Acidic)

(9) $HClO_4 > HBrO_4 > HIO_4$ (Acidic)

(10) $MnO < MnO_2 < Mn_2O_7$ (Acidic)

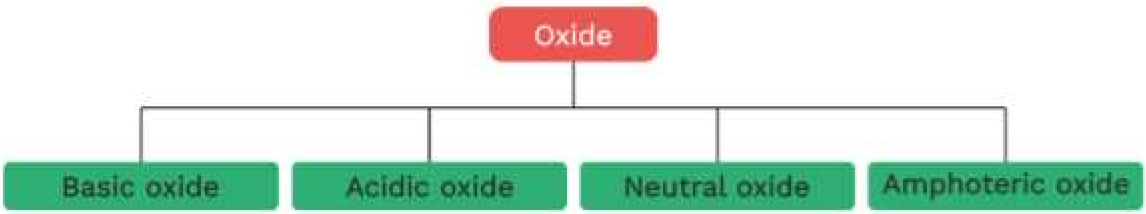
(11) $Fe(OH)_2 > Fe(OH)_3$ (Basic)

(12) $H_3PO_2 > H_3PO_3 > H_3PO_4$ (Basic)

Rack your Brain

Why CO_2 is an acidic oxide?

Oxides :



Basic oxide : Metal oxide

Ex Na_2O, MgO, MnO, CrO etc.

and some d-block elements in lowest oxidation state.

Acidic oxide : Non metal oxide

Ex N_2O_5, CO_2, Mn_2O_7, CrO_3.

and some d-block elements in higher oxidation state.

Neutral oxide :

Ex CO, NO, N_2O , H_2O, OF_2.

Amphoteric oxide :

Ex SnO, SnO_2, ZnO, $Zn(OH)_2$, Al_2O_3.

- Amphoteric metals combines with NaOH to form soluble complex.
- Amphoteric metals combines with acid as well as base to release H_2 gas.
- Amphoteric metal/ oxide/ salt forms same product with acid and base.

Previous Year's Question

Among the following oxides, the one which is most basic is

[AIPMT]

(1) ZnO (2) MgO

(3) Al_2O_3 (4) N_2O_5

Previous Year's Question

The pair of amphoteric hydroxides is

[AIIMS]

(1) $Al(OH)_3$, LiOH

(2) $Be(OH)_2$, $Mg(OH)_2$

(3) $B(OH)_3$, $Be(OH)_2$

(4) $Be(OH)_2$, $Zn(OH)_2$

Q.11 Elements A, B, C, D and E have the following electronic configurations :

A : $1s^2\ 2s^2\ 2p^1$

B : $1s^2\ 2s^2\ 2p^6\ 3s^1$

C : $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^3$

D : $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^5$

E : $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 4s^2$

Which among these will belong to the same group in the periodic table ?

A.11 Out of these, elements A and B will belong to the same group of the periodic table because they have same outer electronic configuration, $ns^2\ np^1$.

Q.12 An element X with Z = 112 has been recently discovered. what is the electronic configuration of the element? To which group and period will it belong?

A.12 (a) The electronic configuration of element X is $[Rn]^{86}\ 5f^{14}\ 6d^{10}\ 7s^2$

(b) It belongs to d-block as last electron enters in d subshell.

(c) As number of electrons in (n – 1)d subshell and valence shell is equal to twelve i.e. 10 + 2. So it belongs to group 12.

(d) It belongs to period 7 of the periodic table as principal quantum number of valence shell is 7 (i.e., $7s^2$).

Q.13 Tell the relation between effective nuclear charge (Zeff), atomic number (Z) and shielding constant (σ).

A.13 $Z_{eff} = Z - \sigma$

Q.14 Pb^{4+} compounds are very good oxidising agents. Explain.

A.14 By inert pair effect, Pb^{2+} is more stable than Pb^{4+}, so Pb^{4+} compounds are very good oxidising agent.

Q.15 Arrange the following in correct order of stability :

Ga^+, In^+, Ti^+

A.15 $Ga^+ < In^+ < Ti^+$

Q.16 The atomic radii of palladium and platinum are nearly same. Why?

A.16 Atomic radii of palladium and platinum elements are nearly same because in lanthanide contraction there is poor shielding of nuclear charge by 4f-electrons.

Q.17 In the ionic compounds KF, the K^+ and F^- ions are found to have practically identical radii, about 1.34 Å each. What can you predict about the relative atomic radii of K & F?

A.17 The size of cation is smaller than its parent atom while size of anion is bigger than its parent atom. Thus, atomic radii of K will be greater than 1.34 Å while atomic radii of F will be less than 1.34 Å.

Q.18 The first ionization enthalpy of carbon is greater than that of boron, whereas the reverse is true for second ionization enthalpy. Explain.

A.18. Carbon has higher IE_1 because of smaller atomic size and greater Z_{eff}. Removal of second electron from stable $1s^2\ 2s^2$ configuration in case of B^+ requires greater energy. So, B has greater IE_2.

Q.19 Among the elements B, Al, C and Si,

(i) Which element has the highest first ionization enthalpy?

(ii) Which element has the most metallic character?

Justify your answer in each case.

A.19 (i) C (ii) Al

Q.20 Among alkali metals, which element do you expect to be least electronegative?

A.20 Cesium (Cs).

Q.21 Which important property did Mendeleev use to classify the elements in his periodic table?

A.21 Mendeleev used the atomic masses of the element in classifying the elements in his periodic table. According to Mendeleev's law, the elements are arranged such that their properties are a periodic function of their atomic masses.

Q.22 What is the basis of classification of elements in the long form of the periodic table?

A.22 The elements are arranged such that their physical and chemical properties are a periodic function of their atomic numbers.

Q.23 Which two elements of the following belong to the same period. Al, Si, Ba and O.

A.23 Al and Si.

Q.24 What are horizontal rows and vertical columns of the periodic table called?

A.24. Horizontal rows are called periods while vertical columns are called groups.

Q.25. Give four examples of species which are isoelectronic with Ca^{2+}.

A.25. Ar, K^+, Cl^-, S^{2-} or P^{3-} are isoelectronic with Ca^{2+} since all have 18 electrons.

Q.26 Which among the following are transition and which are inner transition elements? Sg, Bk, Er, Fm, Fe, Pb, Cr, Ca, Ar, Zr, Ce

A.26. Transition elements : Sg, Fe, Cr, Ze

Inner transition elements : Bk, Er, Fm, Ce

Q.27. Why are electron gain enthalpies of Be and Mg positive?

A.27 They have fully filled s-orbitals and hence have no tendency to accept an additional electron. consequently, energy has to be supplied if an extra electron has to be added to the much higher energy p-orbitals of the valence shell. That is why electron gain enthalpies of Be and Mg are positive.

Q.28 What are the atomic numbers of elements which constitute f-block (lanthanoids and actinoids)?

A.28 Lanthanoids = 58 to 71, Actinoids = 90 to 103.

Q.29 Lanthanoids and actinoids are placed in separate rows at the bottom of the periodic table. Explain the reason for this arrangement.

A.29 These have been placed separately at the bottom of the periodic table for convenience. If they are placed within the body of the periodic table in series order of increasing atomic numbers, the periodic table will become extremely long and cumbersome.

Q.30 Explain why chlorine can be converted into chloride ion more easily as compared to fluoride ion from fluorine.

A.30 since electron gain enthalpy of Cl is more negative than that of F, therefore, more energy is released when $Cl \longrightarrow Cl^-$ than when $F \longrightarrow F^-$

Chapter Summary

1. **Modern periodic table (long form of the periodic table)**
   - Elements are arranged in order of their increasing atomic number.
   - It consists of 18 group and 7 period.
   - First period contain only two element. It is the shortest period of Periodic table.
   - 6^{th} and 7^{th} period contains 32 elements. It is the longest period of the periodic table.
2. **Modern periodic table is divided into four blocks viz. s, p, d and f.**

   (i) **s-Block elements :**
   - These elements contain 1 or 2 electrons in the s-orbital of their respective outermost shells.
   - Outer shell electronic configuration being ns1-2. Where n = 1 to 7.
   - It include elements of group 1 and group 2.
   - Group 1 is known as alkali metals included hydrogen and group 2 is known as alkali earth metals.
   - There are 14 elements s-block elements.

   (ii) **p-Block elements :**
   - These elements contain 1-6 electrons in the p-orbitals of their respective outermost shells.
   - Outer shell electronic configuration being $ns^2\ np^{1-6}$ where n = 2 to 7.
   - It include elements of groups 13, 14, 15, 16, 17 & 18 excluding helium.
   - There are 36 elements in p-block.

   (iii) **d-Block elements :**
   - d-block elements are also called transition elements.
   - It contains 1 to 10 electrons in their d-orbitals of their respective penultimate shells.
   - Outer shell electronic configuration $(n-1)d^{1-10}\ ns^{0-2}$ where n = 4 to 7.
   - It include elements of groups 3, 4, 5, 6, 7, 8, 9, 10, 11 & 12.
   - It is further divided into four series :
     3d-series (first transition series)
     4d-series (second transition series)
     5d-series (third transition series)
     6d-series (fourth transition series)
   - There are 40 elements in d-block.

(iv) **f-block elements**

- f-block elements are also called innertransition elements
- It contains 1-14 electrons in the f-orbitals of their anti-penultimate shells.
- Outer shell electronic configuration being : (n-2)f1-14 (n-1)d0-1 ns2, where n = 6 to 7.
- It is divided into two series of f-block elements each containing 14 elements.
  4f-series (Lanthanoids)
  5f-series (Actinoids)
- There are 28 elements in f-block.

3. **Size of atoms**

It is expressed in terms of following parameters.

(i) Atomic radius is the distance between the centre of the nucleus to the outermost shell containing electrons.

(ii) Covalent radius is one-half the distance between the nuclei of two covalently bonded atoms of the same element in a molecule.

(iii) van der Waals radius is one-half the distance between the nuclei of two adjacent identical atoms belonging to two neighbouring molecules of an element. The atomic radii of noble gases or inert gases are van der waals radii.

(iv) Metallic radius is one-half the internuclear distance between the two adjacent metal ions in the metallic lattice.

Van der Walls radius > metallic radius > covalent radius.

4. **Atomic and ionic size.**

(i) In a group, atomic and ionic radii increase from top to bottom due to increase in the number of shells and the corresponding increase in the screening effect of the inner electrons.

(ii) The radius of a cation is always smaller than its parent atom while the radius of an anion is always larger than its parent atom.

(iii) The radius of a cation is always smaller than its parent atom while the radius of an anion is always larger than its parent atom.

(iv) Isoelectronic species are neutral or ionic species which have the same number of electrons but different nuclear charges. The ionic radii of isoelectronic ions increase with the decrease in the magnitude of the nuclear charge,

e.g., $Al^{3+} < Mg^{2+} < Na^{+} < Ne < F^{-} < O^{2-} < N^{3-}$

5. **Electron gain enthalpy**

(i) Electron gain enthalpy of an element is the energy released when a neutral isolated gaseous atom accepts an extra electron to form the gaseous anion. It is denoted by $\Delta_{eg}H$.

(ii) The $\Delta_{eg}H_1$ for most of the elements is negative while their $\Delta_{eg}H_2$ is always positive.

(iii) $\Delta_{eg}H_1$ becomes more negative from left to right in a period and less negative from top to bottom in a group.

(iv) The overall negative $\Delta_{eg}H$ for halogens; Cl > F > Br > I
for chalogens; S > Se > Te > Po > O.

6. Ionization enthalpy.

The minimum amount of energy required to remove the most loosely bound electron
from an isolated gaseous atom to convert into gaseous cation is called ionization enthalpy. It is represented by $\Delta_i H$ and units are electron volts (eV) per atom or kcal mol-1.

(i) The successive ionization enthalpies follow the sequence : $\Delta_i H_3 > \Delta_i H_2 > \Delta_i H_1$.

(ii) The $\Delta_i H$ decreases from top to bottom in a group due to increase in atomic size and screening effect.

(ii) $\Delta_i H$ increases from left to right in a period due to a corresponding increase in the nuclear charge.

7. Electronegativity (EN)

Electronegativity of an element is the tendency of its atom to attract the shared pair of electrons towards itself in a covalent bond.

(i) The electronegativity of an atom decreases regularly down a group from top to bottom but increases along a period from left to right.

(ii) On the Pauling scale electronegativity of F is the maximum (4) Cs or Fr is the lowest (0.7).

(iii) Pauling and Mulliken scales are related by the expression, Pauling scale = Mulliken scale/2.8.

8. Some elements of the second period show diagonal relationship with elements of third

Period and hence exhibit some similar properties. For example, in some properties, Li
resembles Mg, Be resembles Al and B resembles Si.

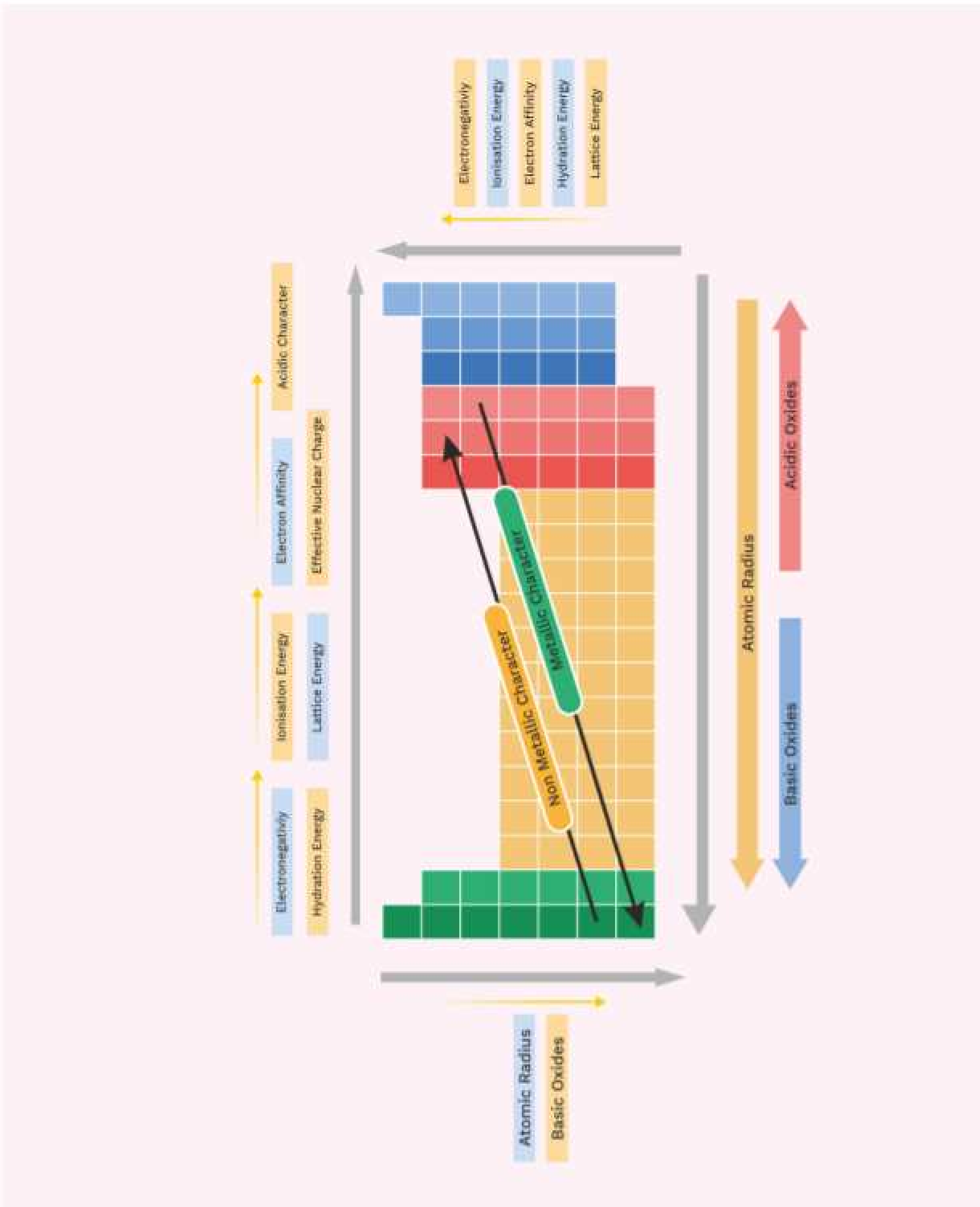
These difference arise due to :

(i) small size

(ii) large charge/ radius ratio, high electronegativity and

(iii) absence of d-orbitals among the elements of second period.

TRENDS OF PERODIC TABLE


Electronegativity
Ionisation Energy
Electron Affinity
Hydration Energy
Lattice Energy
Acidic Character
Effective Nuclear Charge
Non Metallic Character
Metallic Character
Atomic Radius
Acidic Oxides
Basic Oxides