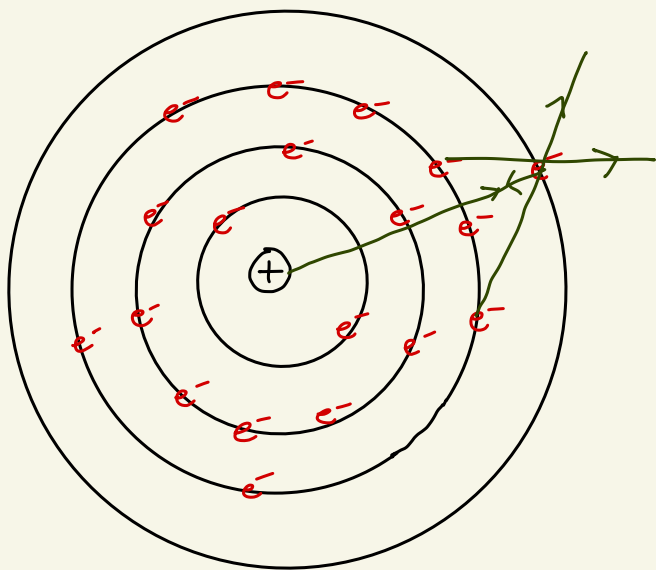# Periodic properties

SAP-4

Effective nuclear charge (Z_{eff} or Z^*) →

It is the effective force of attraction on valence shell e^- by nucleus.

__According to slater →__ $Z_{eff} = Z - \sigma$

where Z = atomic no. (nuclear charge)

σ = shielding const./screening const.

Calculation of σ according to Slater's rule →

(For s or p test e^-)

* For electrons, R.H.S. to test e^- $\sigma = 0$

* For n^{th} shell e^-, $\sigma = 0.35$ per e^-

* For $(n-1)^{th}$ shell e^-, $\sigma = 0.85$ per e^-

* For $(n-2)^{th}$, $(n-3)^{th}$, $(n-4)^{th}$ and other inner shells, $\sigma = 1$ per e^-

$_{25}Mn = 1s^2, 2s^2 2p^6, 3s^2 3p^6, 4s^2 3d^5$

$= 1s^2, 2s^2 2p^6, 3s^2 3p^6 3d^5, 4s^2$

$\sigma_{4s} = (1 \times 0.35) + (13 \times 0.85) + (10 \times 1)$

$\sigma_{3p} = (7 \times 0.35) + (8 \times 0.85) + (2 \times 1)$

$\sigma_{3s} = (1 \times 0.35) + (8 \times 0.85) + (2 \times 1)$

$\sigma_{2p} = (7 \times 0.35) + (2 \times 0.85)$

$\sigma_{2s} = (1 \times 0.35) + (2 \times 0.85)$

Ex.

$_1H = 1s^1$

$\sigma = 0 \implies Z_{eff} = 1$

⁂ Ex.

$_2He = 1s^2$

$\sigma = (1 \times 0.3) = 0.3$

$Z_{eff} = 2 - 0.3 = 1.7$

Ex.

$_3Li = 1s^2, 2s^1$

$\sigma_{2s} = (0 \times 0.35) + (2 \times 0.85) = 1.7$

$Z_{eff} = 1.3$

Ex.

$_4Be = 1s^2, 2s^2$

$$\sigma_{2s} = (1 \times 0.35) + (2 \times 0.85) = 2.05$$

$$Z_{eff} = 1.95$$

Ex. $_5B \implies Z_{eff} = 2.6$

$_6C \implies Z_{eff} = 3.25$

$_7N \implies Z_{eff} = 3.9$

$_8O \implies Z_{eff} = 4.55$

$_9F \implies Z_{eff} = 5.2$

$_{10}Ne \implies Z_{eff} = 5.85$

Note → ① <u>In 2nd and 3rd Period →</u>
Z_{eff} ↑ by 0.65 from L → R

② T → B ⟹ Z_{eff} nearly same
<u>Na, K,</u> - -
$Z_{eff} = 2.2$

③   s > p >> d >>> f
⎯⎯⎯⎯⎯→
diffused nature ↑
e^- density ↓
shielding effect ↓

37. Among the following, the energy of 2s orbital is lowest in :

(A) K   (B) Li   (C) Na   (D) H

$$E = -13.6 \frac{Z_{eff}^2}{n^2}$$
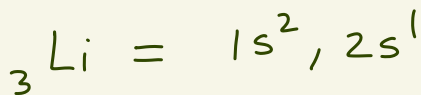
$_{19}K = (1s^2, 2s^2 2p^6, 3s^2 3p^6, 4s^1$
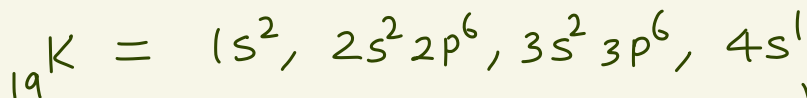
$\overline{\sigma}_{2s} = (1 \times 0.35) + (2 \times 0.85) = 2.05$

$\left(Z_{eff}\right)_{2s} = 19 - 2.05 = 16.95$

$_{11}Na = 1s^2, 2s^2 2p^6, 3s^1$
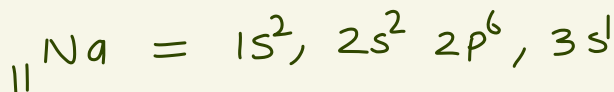
$\overline{\sigma}_{2s} = 2.05$

$Z_{eff} = 11 - 2.05 = 8.95$

$_3Li = 1s^2, 2s^1$

$\overline{\sigma}_{2s} = 0 + (2 \times 0.85) = 1.7$

$Z_{eff} = 1.3$

$_1H = 1s^1$

$\overline{\sigma}_{2s} = $ not defined $\Rightarrow Z_{eff} = $ not defined

$\Rightarrow Z_{eff} : \quad K > Na > Li > H$

$E : \quad H > Li > Na > K$

Periodic Properties →

(1) Atomic radius → The average distance of valence shell e⁻ from nucleus is called atomic radius.

It is very difficult to measure atomic radius because —

(i) Isolation of single atom is difficult.

(ii) There is no well defined boundary for the atom. (Probablity of finding the e⁻ is zero at $n = \infty$)

Types of atomic radius →

(1) **Covalent radius →** It is one half of the distance between two nuclei (inter nuclear distance) of two covalently bonded atoms in homoatomic molecule.
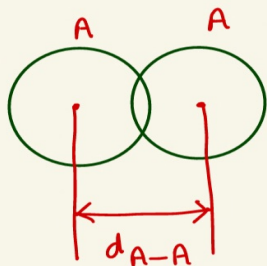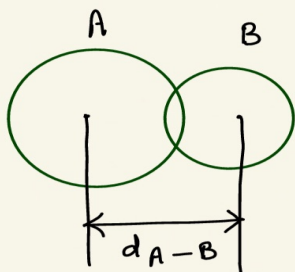

$$r_A = \frac{d_{A-A}}{2}$$

where r_A = Covalent radius of A

d_{A-A} = bond length of A — A bond.

but in case of heteroatomic molecule →

Acc. to Schomaker and stevenson equation→

$$d_{A-B} = r_A + r_B - 0.09 \, |\Delta E.N.|$$

where d_{A-B} = bond length of A−B bond

r_A = covalent radius of A

r_B = covalent radius of B

$\Delta E.N.$ = difference in electronegativity

Q. Calculate the bond length of H−F bond if H−H bond length is 0.74 A° and F−F bond length is 1.44 A° and E.N. of H and F are 2.1 and 4 respectively.
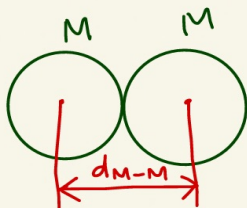
Soln→ $\quad r_H = \dfrac{d_{H-H}}{2} = \dfrac{0.74}{2} = 0.37 \, A°$

$\quad r_F = \dfrac{1.44}{2} = 0.72 \, A°$

$d_{H-F} = r_H + r_F - 0.09 \, (\Delta E.N.)$

$\quad = 0.37 + 0.72 - 0.09 \, (1.9)$

$\quad = 0.919 \, A°$

(2)   Metallic radius $\longrightarrow$ It is one half of the internuclear distance between two closest metal atoms in the metallic crystal.

$$r_M = \frac{d_{M-M}}{2}$$

where r_M = Metallic radius of M

d_{M-M} = bond length of M–M bond

✳   M.R. > C.R.

3.   Van Der Wall's Radius or Collision radius

The molecules of non metal atoms are generally gases. On cooling, the gaseous state changes to solid state.

In the solid state, the non metallic elements usually exist as aggregations of molecules are held together by van der wall forces. **One half of the distance between the nuclei of two adjacent atoms belonging to two neighbouring molecules of a compound in the solid state is called van der walls radius.**

It may also be defined as half of the inter nuclear distance of two non bonded neighbouring atoms of two adjacent molecules.
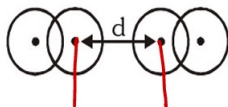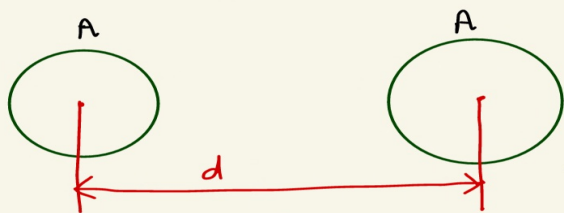

$$V.W.R. = \frac{d}{2}$$

van der Wall's radius = $\frac{1}{2}$ Internuclear distance between two successive nuclei of two covalent molecules (d)

Van der wall's radius > Metallic radius > Covalent radius

* Vander wall radius is also found in inert gases.
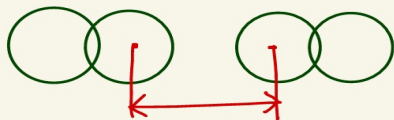
* It is half of the distance between nuclei of two isolated gaseous atoms.

A   A

$$r_A = \frac{d}{2}$$

where
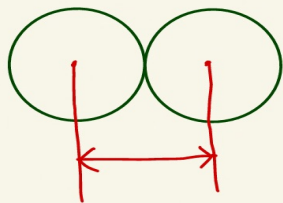$r_A = $ V.W.R. of A

$H_2(s)$

$H_2(g)$
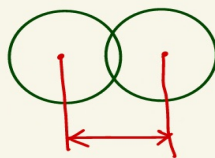
$Fe_{(s)}$

$Ar_{(g)}$
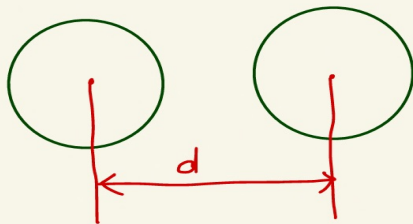
(4) Ionic radius $\longrightarrow$ Radius of ion

(i) Cationic radius $\longrightarrow$

$$Na \qquad Na^+$$
$$\xrightarrow{\hspace{3cm}}$$
$$Z_{eff} \uparrow$$
$$Size \downarrow$$

$$\text{size} \propto \frac{1}{\text{cationic charge}}$$

Ex. $Fe > Fe^{2+} > Fe^{3+}$

       $Pd > Pd^{2+} > Pd^{4+}$

(ii) **Anionic radius** $\longrightarrow$

$$
\begin{array}{cc}
Cl & Cl^{-} \\
\end{array}
$$
$$\xrightarrow{}$$
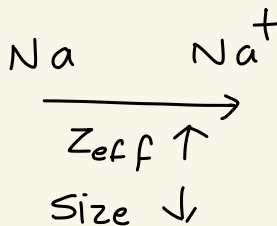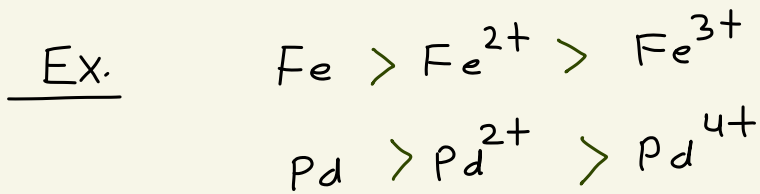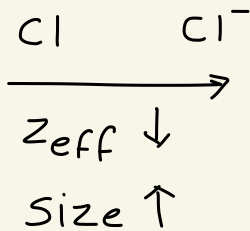
$Z_{eff} \downarrow$

Size $\uparrow$

$$\text{size} \propto \text{anionic charge}$$

Ex. $O < O^{-} < O^{2-}$

     $S < S^{2-}$
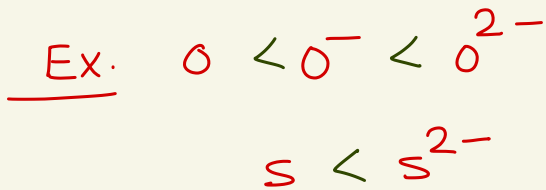
Size of isoelectronic species $\longrightarrow$

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

| $e^{-} =$ | 10 | 10 | 10 | 10 | 10 | 10 | 10 |
| $Z =$ | 7 | 8 | 9 | 10 | 11 | 12 | 13 |

$$\xrightarrow{}$$

$Z_{eff} \uparrow \Rightarrow$ size $\downarrow$
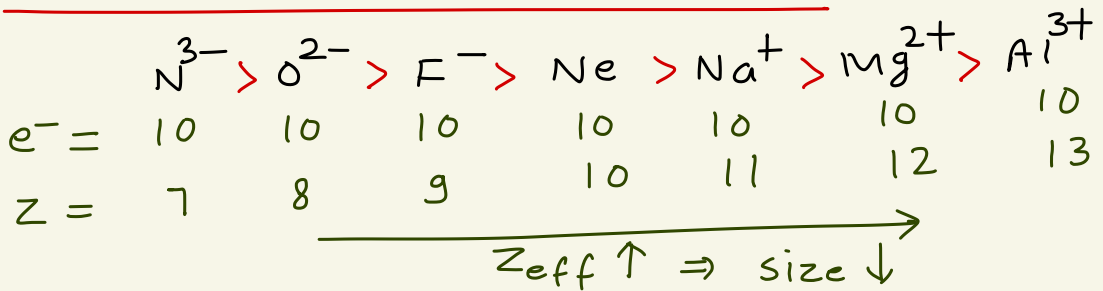
Factors affecting atomic radius →

$$r \propto \dfrac{n^2}{Z_{eff}}$$

(i) $\quad r \propto \dfrac{1}{Z_{eff}}$ $\qquad$ (ii) $\quad r \propto$ no. of shells

(iii) $\quad r \propto$ shielding effect

(iv) $\quad r \propto$ −ve charge

(v) $\quad r \propto \dfrac{1}{+ve \ charge}$

In a Period →

For s & P−block elements ⇒ L→R ⇒ Z_{eff} ↑

$$\Rightarrow A.R. \downarrow$$

$$Li > Be > B > C > N > O > F <\!< Ne$$

$$\downarrow$$
Vander waal radius

$$\Rightarrow \quad Ne > Li > Be > B > C > N > O > F$$

$$Ar > Na > Mg > Al > Si > P > S > Cl$$

For d−block elements →

$\uparrow$ A R.

Sc $Z_{eff} >\!> S.E.$

cr $Z_{eff} = S.E.$ Ni

Zn $Z_{eff} <\!< S.E.$

Atomic no. →

Group Period	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
1	H • ~0.30																H • ~0.30	He • 1.20*
2	Li • 1.23	Be • 0.89											B • 0.80	C • 0.77	N • 0.75	O • 0.73	F • 0.72	Ne • 1.60*
3	Na • 1.57	Mg • 1.36											Al • 1.25	Si • 1.17	P • 1.10	S • 1.04	Cl • 0.99	Ar • 1.91*
4	K • 2.03	Ca • 1.74	Sc • 1.44	Ti • 1.32	V • 1.22	Cr • 1.17	Mn • 1.17	Fe • 1.17	Co • 1.16	Ni • 1.15	Cu • 1.17	Zn • 1.25	Ga • 1.25	Ge • 1.22	As • 1.21	Se • 1.14	Br • 1.14	Kr • 2.00*
5	Rb • 2.16	Sr • 1.91	Y • 1.62	Zr • 1.45	Nb • 1.34	Mo • 1.29	Tc –	Ru • 1.24	Rh • 1.25	Pd • 1.28	Ag • 1.34	Cd • 1.41	In • 1.50	Sn • 1.40	Sb • 1.41	Te • 1.37	I • 1.33	Xe • 2.20*
6	Cs • 2.35	Ba • 1.98	La • 1.69	Hf • 1.44	Ta • 1.34	W • 1.30	Re • 1.28	Os • 1.26	Ir • 1.26	Pt • 1.29	Au • 1.34	Hg • 1.44	Tl • 1.55	Pb • 1.46	Bi • 1.52	Po	At	Rn
7	Fr	Ra	Ac															

Covalent radius of the elements (In Å)

<u>In a group</u> $\longrightarrow$ T $\longrightarrow$ B $\Rightarrow$ no. of shells ↑

$\Rightarrow$ size ↑

H < Li < Na < K < Rb < Cs

Be < Mg < Ca < Sr < Ba

C < Si < Ge < Sn < Pb

N < P < As < Sb < Bi

O < S < Se < Te < Po

F < Cl < Br < I < At

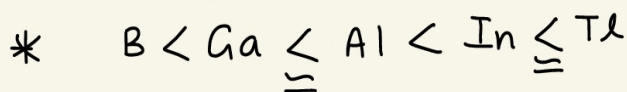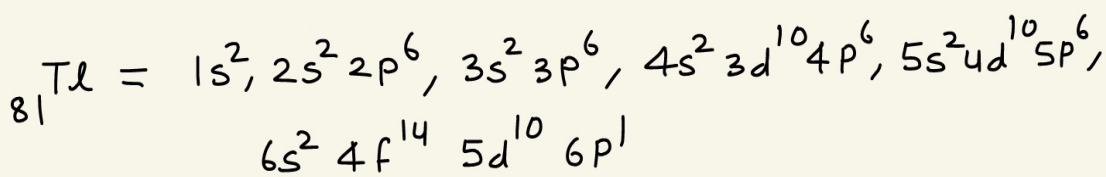He < Ne < Ar < Kr < Xe < Rn

B < Al $\gtrsim$ Ga < In = Tl

$\downarrow$ Transition contraction (due to Poor shielding) of d–es

$\downarrow$ Lanthanoid Contraction

<u>Lanthanoid Contraction</u> $\longrightarrow$ Due to very poor
shielding effect of f-electrons, corresponding
protons inside the nucleus attract outermost
shell e^- more strongly, by which radius of
the element gets contracted. This effect is
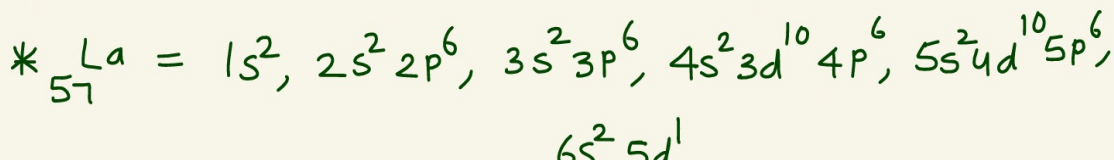called lanthanoid contraction.

$$_{81}Tl = 1s^2, 2s^2 2p^6, 3s^2 3p^6, 4s^2 3d^{10} 4p^6, 5s^2 4d^{10} 5p^6,$$
$$6s^2 4f^{14} 5d^{10} 6p^1$$

* $B < Ga \underset{=}{<} Al < In \underset{=}{<} Tl$

<u>In d-block</u> $\longrightarrow$

                                      $\nearrow$ NO f-e^-
                                 $\Rightarrow$ NO lanthanoid
                                        Contraction

3rd group $\longrightarrow$ Sc < Y < La

4	5	6	7	8	9	10	11	12
Ti	V	Cr					Cu	Zn
$\wedge$	$\wedge$	$\wedge$	$-$ $\cdot$ $--$	$--$	$---$		$\wedge$	$\wedge$
Zr	Nb	Mo		Lanthanoid			Ag	Cd
$\underset{\sim}{}$	$\underset{\sim}{}$	$\underset{\sim}{}$		Contraction			$\underset{=}{}$	$\wedge$
Hf	Ta	Tc					Au	Hg

* $_{57}La = 1s^2, 2s^2 2p^6, 3s^2 3p^6, 4s^2 3d^{10} 4p^6, 5s^2 4d^{10} 5p^6,$
$$6s^2 5d^1$$

6. The ionic radii (in Å) of N^{3-}, O^{2-} and F^- respectively are: **(2015)**

(A)   1.36, 1.40 and 1.71

(B)   1.36, 1.71 and 1.40

(C)   1.71, 1.40 and 1.36

(D)   1.71, 1.36 and 1.40

$$N^{3-} > O^{2-} > F^-$$
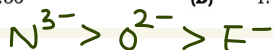
10. Atomic radii of fluorine and neon in Angstrom units are respectively given by: **(1987)**

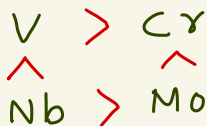(A)   0.72, 1.60   (B)   1.60, 1.60   (C)   0.72, 0.72   (D)   None of these

6. Four elements have the following radii : 117pm, 122pm, 129pm and 134pm. The elements are V, Cr, Nb and Mo. Which one has the radius of 117 pm ?

(A)   V   (B)   Cr   (C)   Nb   (D)   Mo

$$V > Cr$$
$$\land \qquad \land$$
$$Nb > Mo$$

18. Which of the following arrangements represents the correct order of increasing radius?

(A) $Mg^{2+} < K^+ < Se^{2-} < S^{2-}$

(B) $Mg^{2+} < K^+ < S^{2-} < Se^{2-}$

(C) $Se^{2-} < S^{2-} < Mg^{2+} < K^+$

(D) $Mg^{2+} < Se^{2-} < K^+ < S^{2-}$

$$K^+ < S^{2-} \qquad\qquad S^{2-} < Se^{2-}$$

Homework

DTS- 1 to 11
**Q.1-7,9,10,12,13,18,30,33,36,38-40,42,44,45,47,51,52,
54,63,71,75,78,83,85,90,92,93,95,126-128,130,132,133,
135-137**