PERIODIC PROPERTIES

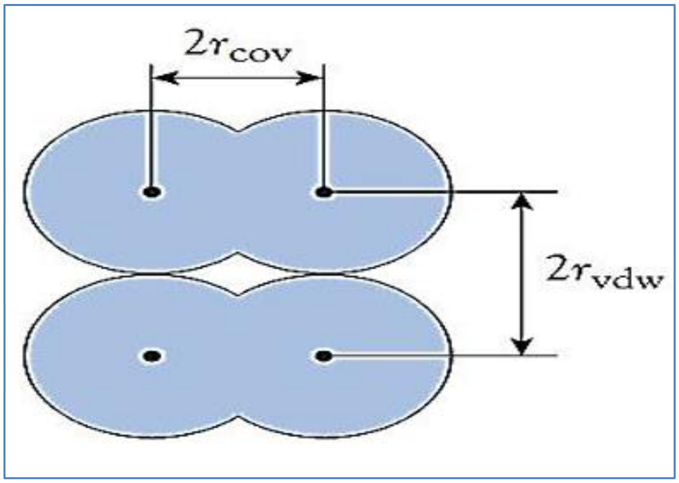
Atomic Radius : There are two common ways in which we can define atomic radius.

The covalent radius, r_{cov}, is defined as the half-distance between the nuclei of two atoms of the same element joined in a single covalent bond. The figure below represents the covalent radii (pm) of a typical group and short period.

Be 106	B 88	C 77	N 70	O 66	F 64
					Cl 99
					Br 114
					I 133

The van der Waals radius, r_{vdw}, is defined as the half-distance between the nuclei of two atoms of neighboring molecules.

The next figure shows comparison of the covalent radius, rcov, and the van der Waals radius, r_{vdw}.



In a period, left to right:

a- n (number of shells) remain constant.

b- Z increases (by one unit).

c- Z* increases (by 0.65 unit).

d- Atomic radius decreases.

In a group, top to bottom:

a- n increases.

b- Z increases.

c- No dramatic increase in Z*, almost remains constant

d- -. Atomic radius increases

Rules Slater's

$$Z^* = Z - S$$

Z*: effective nuclear charge

Z :Atomic number

S: shielding constant

1. Write the electron configuration of the atom in the following form:

(1s) (2s, 2p) (3s, 3p) (3d) (4s, 4p) (4d) (4f) (5s, 5p) (5d)

2. All electrons in orbitals of greater principal quantum number (at n+1) contribute zero.

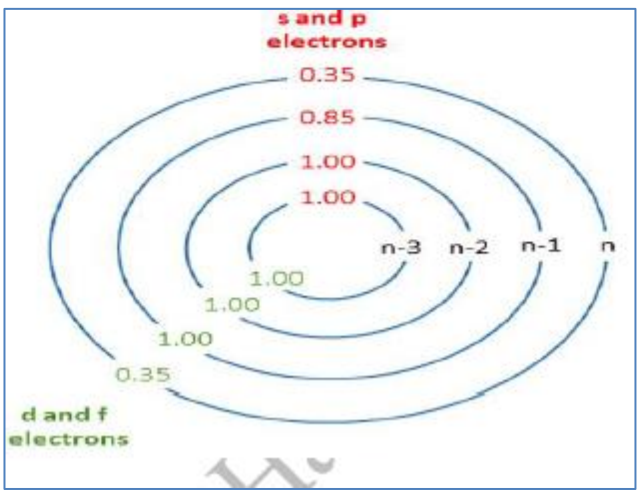
3.For **ns** or **np** valence electrons:

a. Electrons in the ***same*** **ns, np** group (same principal quantum number) contributes **(0.35)**.

b. Electrons in the (n-1) principal group contribute (0.85).

c. Electrons in the (n-2) or lower groups contribute (1.00).

4- For **nd** and **nf** valence electrons:



Example: Calculate the effective nuclear charge (Z*) of the following:

a- 2p electron in the $_8$O atom.

Ans. $_8O$: $(1S^2)$ $(2S^2$ $2P^4)$ = $(1S)^2$ $(2S$ $2P)^6$

S = (2 × 0.85) + (5 × 0.35) = 3.45

Z* = Z – S = 8 - 3.45= **4.55**

b- **3d electron in the 28Ni atom**.

Ans. $_{28}Ni$ = $(1S^2)$ $(2S^2$ $2p^6)$ $(3S^2$ $3p^6)$ $(4S^2)$ $(3d^8)$

= $(1S)^2$ $(2S2p)^8$ $(3S$ $3p)^8$ $(3d)^8$ $(4S^2)$

S = [18 ×(1)] + [7 × (0.35)] = 20.45

Z* = Z – S = 28 – 20.45 = 7.55

c- 4s electron in the $_{28}$Ni atom.

Ans. $_{28}Ni$ = $(1S^2)$ $(2S^2$ $2P^6)$ $(3S^2$ $3P^6)$ $(4S^2)$ $(3d^8)$

= $(1S2S$ $2P)^{10}$ $(3S$ $3P3d)^{16}$ $(4S)^2$

S =[10 × (1)] + [16 ×(0.85)] + [1 × (0.35)] = 23.95

Z* = Z – S = 28 – 23.95 = 4.05

d- 4f electron in the $_{73}$Ta atom.

Ans. $_{73}Ta$ = $[Xe]_{54}$ $4f^{14}$ $6S^2$ $5d^3$

= $[Xe]_{54}$ $4f^{14}$ $(6S)^2$ $(5d)^3$

S = [54 * (1)] + [13 * (0.35)] = 58.55

Z* = Z – S = 73 – 58.55 = 14.45

e- The last electron in $_{29}Cu$ atom.

Ans. $_{29}Cu = (1S^2) (2S^2\ 2P^6) (3S^2\ 3P6) (4S^1) (3d^{10})$

$= (1S2S\ 2P)^{10} (3S\ 3P3d)^{18} (4S)^1$

$S =[10 \times(1)] + [18\times (0.85)] + [0 \times (0.35)] = 25.30$

$Z^* = Z – S = 29 – 25.30 = 3.70$

It is clear from the above that in one period from left to right, the effective charge of the nucleus increases and the shielding and size decrease.

Ionization Energy (IE):- also known as the **ionization potential**, Is the energy required to remove an electron from a gaseous atom to form a gaseous cation. The losing of an electron is an **Endothermic** process (require energy).

$$X(g) + \text{energy} \rightarrow X^+(g) + e^-$$

- It became clear from studying the effective charge of the nucleus that the electrons of the outer shell are linked by the force of attraction of the protons of the positive nucleus of the atom, and therefore to overcome this attractive energy the electron must be supplied with energy.
- The first ionization energy always requires less energy than the second ionization energy. The reason is that the second valence electron suffers from a higher attractive force(Z^*) than the first valence electron.
- Ionization energy increases in the period (from left to right) due to the increase in the effective charge of the nucleus (Z^*) and decreases in the group (from top to bottom) as shown in the table below.