NEET | JEE ESSENTIALS

Class XI

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Unit 2 CLASSIFICATION OF ELEMENTS AND PERIODICITY IN PROPERTIES | CHEMICAL BONDING AND MOLECULAR STRUCTURE

CLASSIFICATION OF ELEMENTS AND PERIODICITY IN PROPERTIES

Modern Periodic Law

- The physical and chemical properties of elements are periodic function of their atomic numbers.
- Periodic function is due to repetition of similar outer electronic configuration after certain regular intervals.

Features of Modern Periodic Table

- Elements are arranged in order of increasing atomic numbers.
- It has seven horizontal rows known as periods.
- There are eighteen vertical columns which are called groups or families.

Elements in Periodic Table

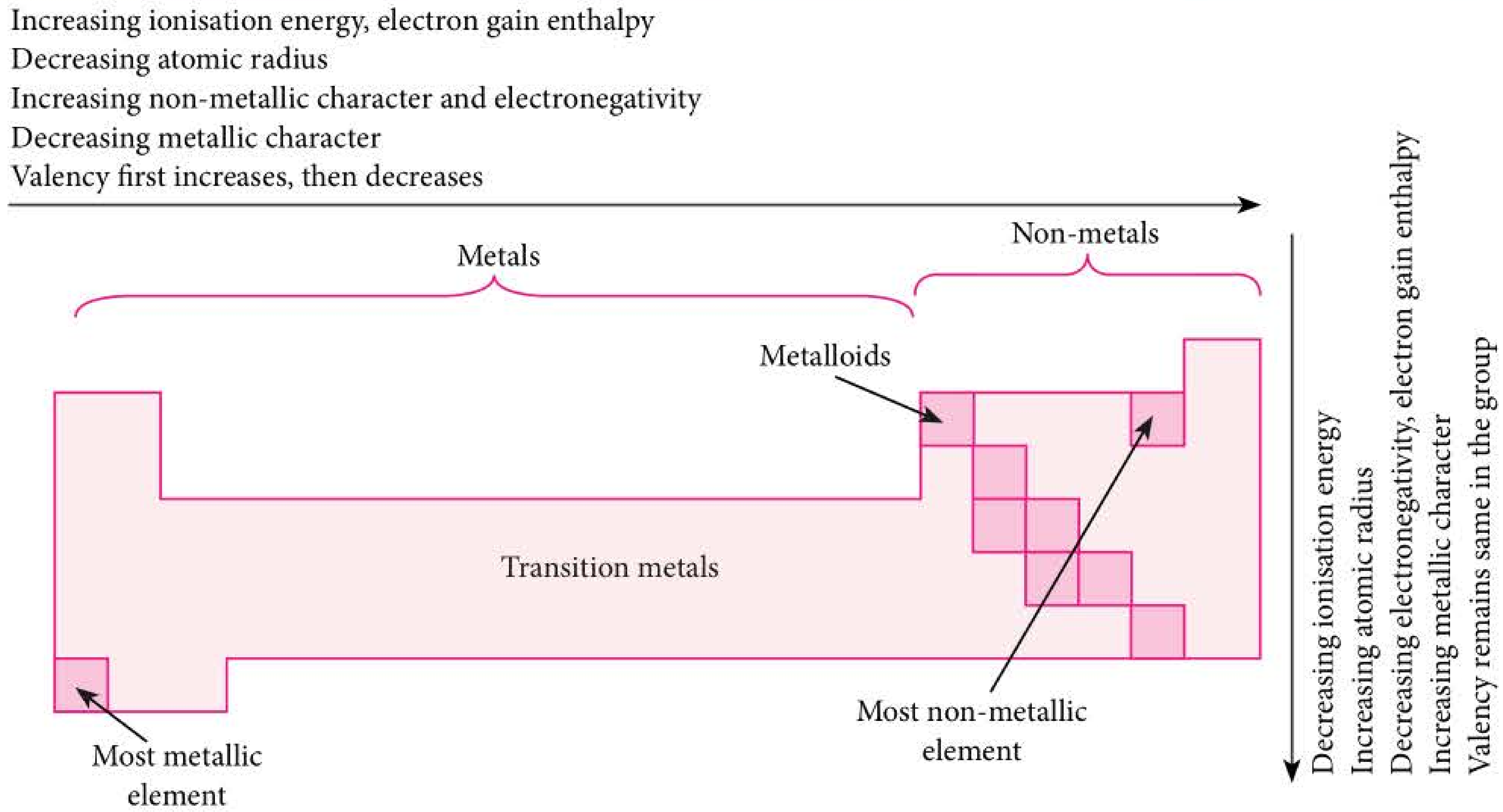
***f*-block elements**
- 4*f*-series : lanthanides
- 5*f*-series : actinides
- *E.C.* : $(n-2)f^{1-14}(n-1)d^{0-1}ns^2$
- Variable Oxidation States, most common in +3.

***s*-block elements**
- *E.C.* : ns^{1-2}
- Belong to group-1 and group-2
- Group-1 elements form M^+ ions.
- Group-2 elements form M^{2+} ions.

***d*-block elements**
- Lies between *s*- and *p*-block elements
- *E.C.* : $(n-1)d^{1-10}ns^{0-2}$
- Group - 3 to 12
- Show variable valencies and oxidation states.

***p*-block elements**
- Group -13 to 18
- *E.C.* : ns^2np^{1-6} (excluding helium)
- Except noble gases and fluorine, all other elements show variable oxidation states.

Trends in Properties of Elements



Ionic Radius

- The effective distance from the centre of nucleus of an ion upto which it has an influence on its electron cloud is called its ionic radius.

  $d_{(a^+ - b^-)} = r_{a^+} + r_{b^-}$

  Radii of isoelectronic ions,

  $r_{\text{anion}} > r_{\text{neutral}} > r_{\text{cation}}$

  $$\text{Ionic radius} \propto \frac{1}{\text{Effective nuclear charge}}$$

Ionisation Enthalpy

- The amount of energy required to remove the most loosely bounded electrons from an isolated gaseous atom in its ground state, is called ionisation enthalpy

  $$M_{(g)} \xrightarrow{\text{Energy}} M^+_{(g)} + e^-$$

  $$\text{Ionisation energy} \propto \frac{1}{\text{Size of atom}} \propto \text{Effective nuclear charge} \propto \frac{1}{\text{Screening effect}}$$

  First ionisation energy < Second ionisation energy < Third ionisation energy

Electron Gain Enthalpy

- It is the molar enthalpy change when an neutral isolated gaseous atom in its ground state gains an electron to form the corresponding anion.

  $$X_{(g)} + e^- \longrightarrow X^-_{(g)}$$

  For elements with stable electronic configuration, electron gain enthalpy is zero or nearly zero.

Electronegativity

- The relative tendency of an atom in a molecule to attract the shared pair of electrons towards itself in a covalent bond is termed as electronegativity.

  $$E.N. \propto \frac{1}{\text{Atomic size}} \propto I.E.$$

  Flourine is most electronegative atom.
- Mulliken scale of electronegativity,

  $$\chi = \frac{1}{2}[\Delta_i H + \Delta_{eg} H]$$
- Pauling scale of electronegativity,

  $$\chi_A - \chi_B = 0.1017\sqrt{\Delta}$$

  where, $\Delta = E_{A-B} - \frac{1}{2}\sqrt{E_{A-A} + E_{B-B}}$

  here, E represents bond dissociation enthalpy (kJ mol^{-1}).

INFOSHOTS

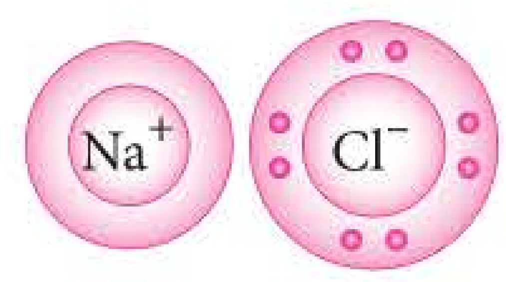
Mythological reference!

There are 15 elements named after a mythological character or reference. Thorium and vanadium are named after Norse God of war 'Thor' and Goddess of beauty 'Vanadis', respectively. Helium is named after the Sun God 'Helios', irridium after Goddess of rainbow 'Iris', and titanium after the 'Titans'.

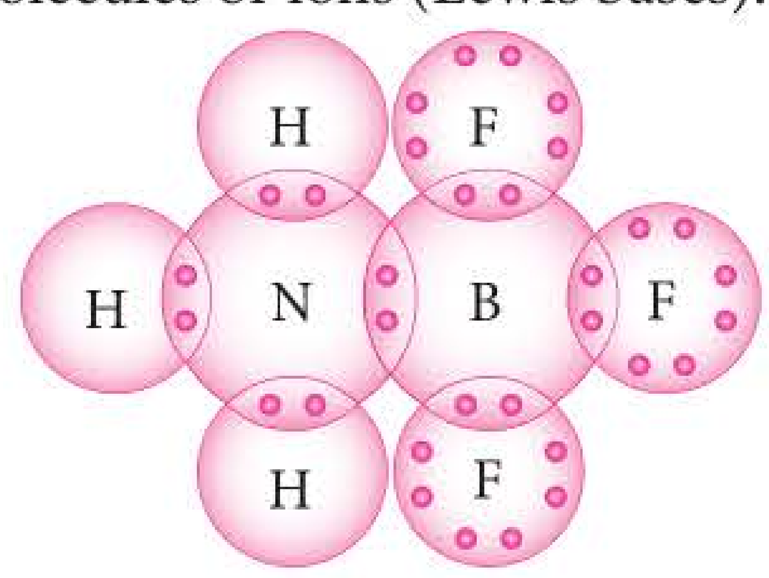
Types of Bonds

Bonds

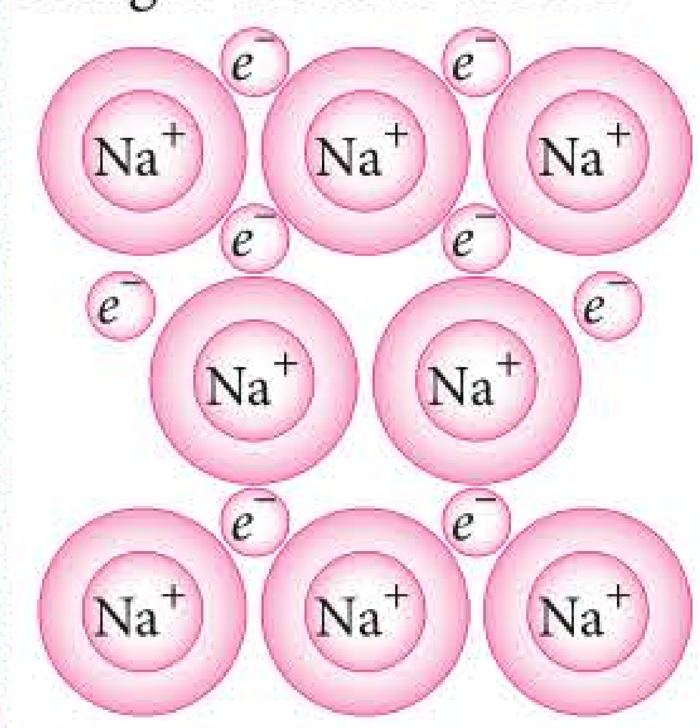
Ionic bond
Electrostatic attraction between a cation (metal) and an anion (non-metal).



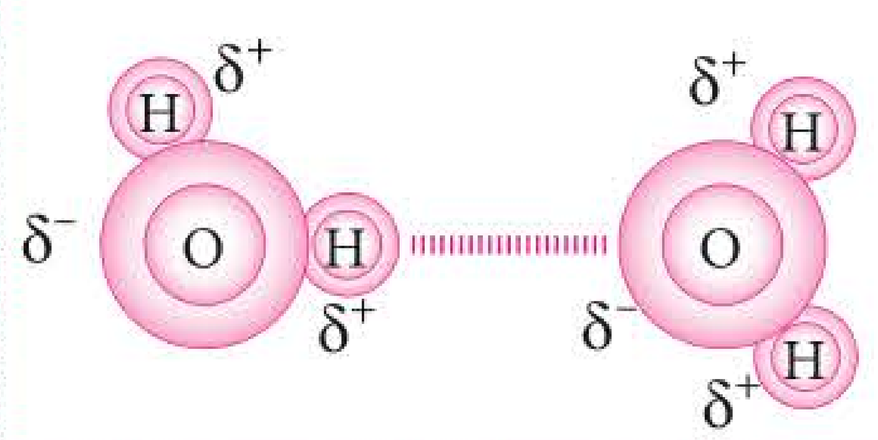
Coordinate bond
Coordinate bonds are formed between electron deficient molecules or ions (Lewis acids) and electron rich molecules or ions (Lewis bases).



Metallic bond
Attraction between mobile electrons and positively charged metallic atoms.



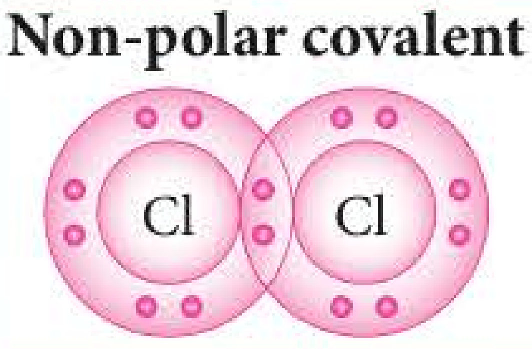
Hydrogen bond
Bond between H-atom and electronegative elements (like N, O, F)



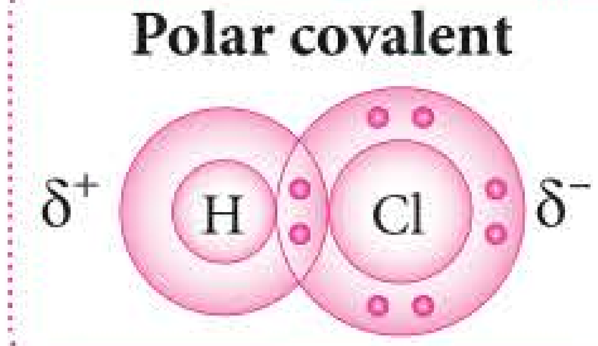
- **Intermolecular** *e.g.*, HF, H_2O
- **Intramolecular** *e.g.*, *o*-Nitrophenol

Covalent bond
Bond between non-metal atoms due to sharing of electron pairs.

Non-polar covalent



Polar covalent



- **Formal charge on an atom** = Total number of valence electrons in an atom – Total number of lone pairs of electrons – $\frac{1}{2}$ (Total number of shared electrons).

VSEPR Theory

- It states that bonded atoms in a molecule adopt that particular arrangement in space, in which electron pairs surrounding the central atom repel one another and go far apart so, there are no further repulsions.
- The magnitude of repulsion is : $lp - lp > lp - bp > bp - bp$
- Shape of the molecule is determined by this theory.

Geometry Based on VSEPR Theory

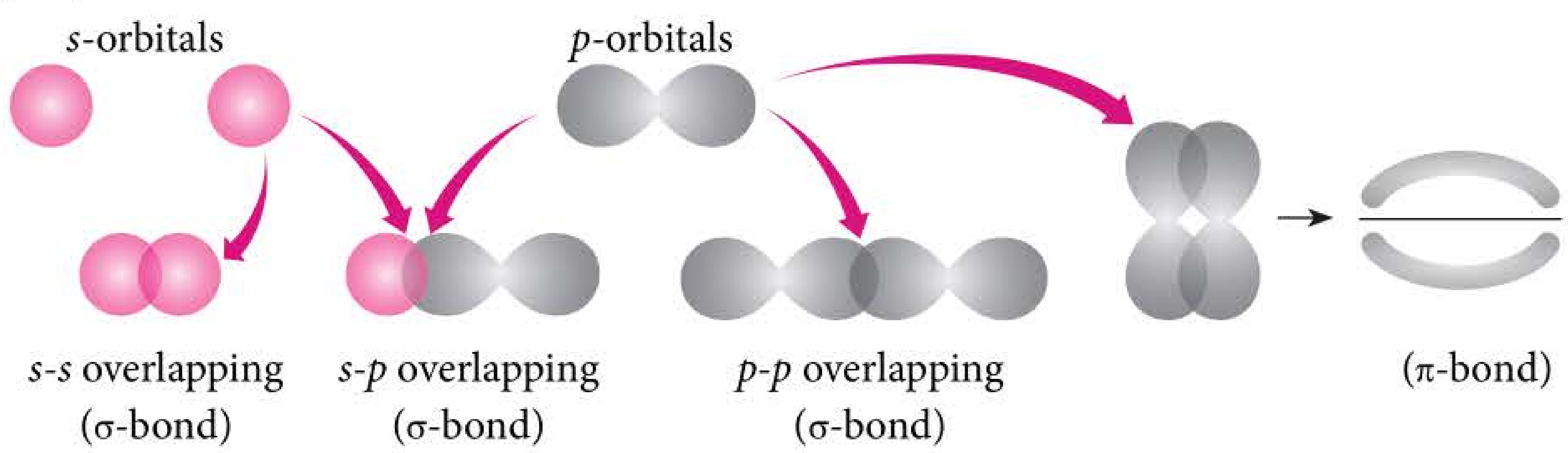
Total number of electron pairs	Molecular formula	Geometry	Bond angle	Example
2	AX_2	Linear	180°	$BeCl_2$
3	AX_3 AX_2E	Trianglar planar Bent (V-shape)	120° 119°	BF_3 SO_2

4	AX_4 AX_3E AX_2E_2	Tetrahedral Trigonal pyramidal Bent	109°28′ 107°48′ 104°27′	CH_4, SiH_4 NH_3 H_2O
5	AX_5 AX_4E AX_3E_2 AX_2E_3	Trigonal bipyramidal Irregular tetrahedral (Sea saw) T-shaped Linear	120 and 90° 101°36′ and 86°33′ 87°40′ 180°	PCl_5 SF_4 and IF_4^+ ClF_3 I_3^-
6	AX_6 AX_5E AX_4E_2	Octahedral Square pyramidal Square planar	90° 84° 30′ 90°	SF_6 BrF_5 XeF_4
7	AX_7	Pentagonal bipyramidal	72° 90′	IF_7

Valence Bond Theory (VBT)

- The formation of covalent bond is due to pairing of electrons present in the valence shell having opposite spin.

Overlapping of Atomic Orbitals



Hybridisation

- The intermixing of atomic orbitals of same energy or slightly different energy to produce entirely new sets of orbitals of equivalent energies and identical shapes.
- The structure of any molecule can be predicted on the basis of hybridisation by using formula :

$$\text{No. of hybrid orbitals } (H) = \frac{1}{2}\left[\begin{pmatrix}\text{No. of valence}\\ \text{electrons of}\\ \text{central atom}\end{pmatrix} + \begin{pmatrix}\text{No. of}\\ \text{monovalent}\\ \text{atoms}\end{pmatrix} - \begin{pmatrix}\text{Charge}\\ \text{present}\\ \text{on the}\\ \text{cation}\end{pmatrix} + \begin{pmatrix}\text{Charge}\\ \text{present}\\ \text{on the}\\ \text{anion}\end{pmatrix}\right]$$

$$\Rightarrow \quad H = \frac{1}{2}[V + M - c + a]$$

Molecular Orbital Theory (MOT)

- Atomic orbitals of comparable energies combine to form molecular orbitals.
- The number of molecular orbitals formed is equal to the number of combining atomic orbitals.
- When two atomic orbitals combine, two molecular orbitals are formed, one with lower energy (bonding molecular orbital) another with high energy (antibonding molecular orbital).

INFOSHOTS

Chemical bonding in metal borides!

Ultrahard materials, such as TiB_2, ReB_2 and OsB_2 are being developed as potential lower cost alternatives to diamond, carbides and boron-nitride that are traditionally used for cutting, drilling and polishing tools.

Order of Energy

- For O_2 and F_2,
  $\sigma 1s < \sigma^*1s < \sigma 2s < \sigma^*2s < \sigma 2p_z < \pi 2p_x = \pi 2p_y < \pi^*2p_x = \pi^*2p_y < \sigma^*2p_z$
- For Li_2 to N_2,
  $\sigma 1s < \sigma^*1s < \sigma 2s < \sigma^*2s < \pi 2p_x = \pi 2p_y < \sigma 2p_z < \pi^*2p_x = \pi^*2p_y < \sigma^*2p_z$
- Bond order $= \frac{1}{2}(N_b - N_a)$
  $\because$ N_b = Number of electrons in bonding molecular orbitals,
  N_a = Number of electrons in antibonding molecular orbitals.
- Bond strength $\propto$ Bond order $\propto \frac{1}{\text{Bond length}}$

SPEED PRACTICE

1. Anhydrous $AlCl_3$ is covalent but hydrated $AlCl_3.6H_2O$ is ionic because
(a) $AlCl_3$ dissolves in CS_2
(b) $AlCl_3$ has planar structure
(c) *I.E.* of Al is low
(d) hydration energy of Al compensates the *I.E.*

2. Atomic number 64 will have electronic configuration
(a) $[Xe]_{54}\, 6s^2\, 4f^8$ (b) $[Xe]_{54}\, 6s^2\, 4f^7\, 5d^1$
(c) $[Xe]_{54}\, 4f^{10}$ (d) $[Xe]_{54}\, 6s^2\, 4f^7\, 5p^1$

3. The correct order for bond angle in following is
(a) $NH_2^- > NH_3 > NH_4^+$
(b) $NH_4^+ > NH_2^- > NH_3$
(c) $NH_4^+ > NH_3 > NH_2^-$
(d) $NH_3 > NH_4^+ > NH_2^-$

4. Ionic radii of
(a) $Ti^{4+} < Mn^{2+}$ (b) $^{35}Cl^- < {}^{37}Cl^-$
(c) $K^+ > Cl^-$ (d) $P^{3+} > P^{5+}$

5. The species in which the N atom is in a state of *sp* hybridisation is
(a) NO_2^+ (b) NO_2^-
(c) NO_3^- (d) NO_2 **(JEE Main 2016)**

6. Consider the following statements :
1. Cs^+ is more highly hydrated than the other alkali metal ions.
2. Among the alkali metals Li, Na, K and Rb, lithium has the highest melting point.
3. Among the alkali metals only lithium forms a stable nitride by direct combination.

Out of these statements
(a) 1, 2 and 3 are correct
(b) 1 and 2 are correct
(c) 1 and 3 are correct
(d) 2 and 3 are correct.

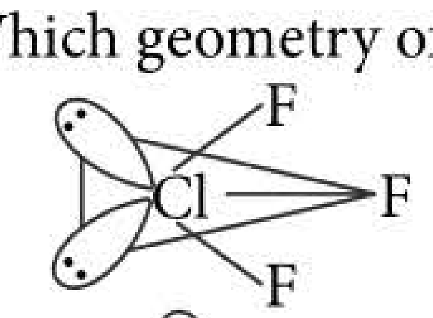
7. If climbing of water droplets is made to occur on a coated microscope slide, the slide would have to be coated in which of the following way

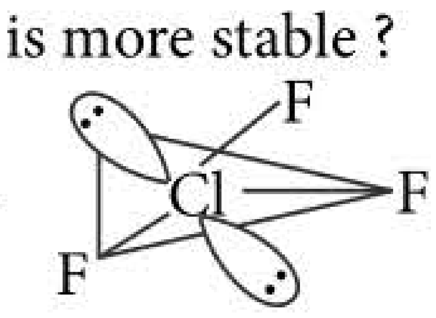
Polar	Non-Polar	Polar ↑ Non-Polar	Non-Polar ↑ Polar
P	*Q*	*R*	*S*

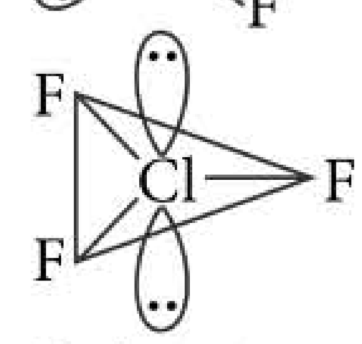
(a) *P* (b) *Q* (c) *R* (d) *S*

8. The electronic configuration of the element is $1s^2\, 2s^2\, 2p^6\, 3s^2\, 3p^3$. What is the atomic number of the element which is just below the above element in the periodic table?
(a) 33 (b) 34 (c) 31 (d) 49

9. Which geometry of ClF_3 is more stable ?

1. 

2. 

3. 

(a) Only 2, 3 (b) Only 1
(c) Only 3 (d) Only 2

10. Among the following the lowest degree of paramagnetism per mole of the compound at 298 K will be shown by