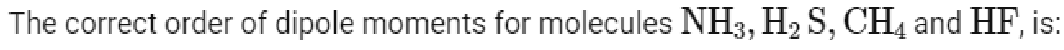
3 Chemical Bonding and Molecular Structure

Question:


The correct order of dipole moments for molecules NH_3, H_2S, CH_4 and HF, is:

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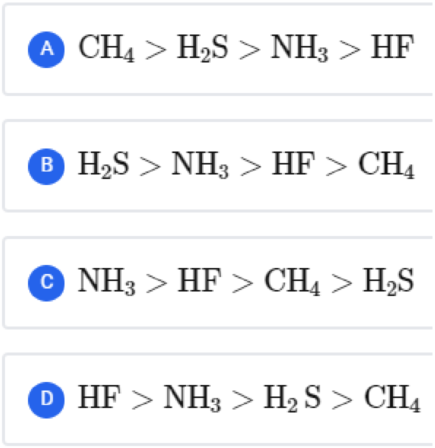

Ⓐ $CH_4 > H_2S > NH_3 > HF$

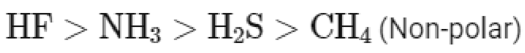
Ⓑ $H_2S > NH_3 > HF > CH_4$

Ⓒ $NH_3 > HF > CH_4 > H_2S$

Ⓓ $HF > NH_3 > H_2S > CH_4$

Answer: D

Explanation


$HF > NH_3 > H_2S > CH_4$ (Non-polar)

Question: Which one of the following represents all isoelectronic species?

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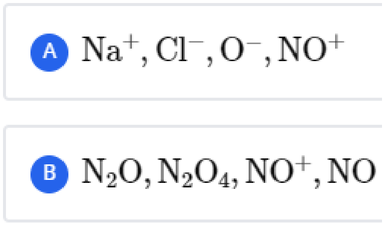
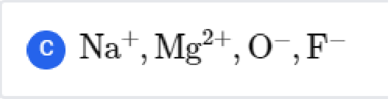

Ⓐ Na^+, Cl^-, O^-, NO^+

Ⓑ N_2O, N_2O_4, NO^+, NO


C Na^+, Mg^{2+}, O^-, F^-


D Ca^{2+}, Ar, K^+, Cl^-

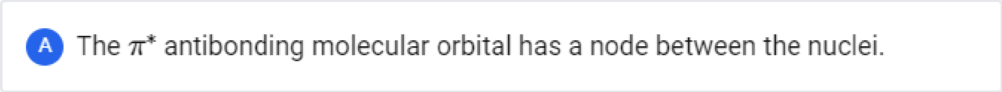
Answer: D

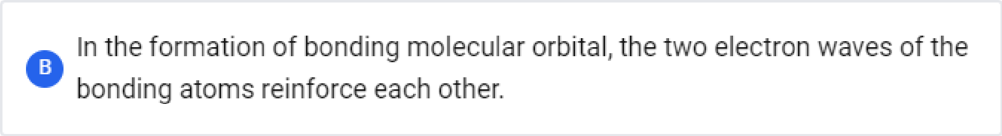
Explanation

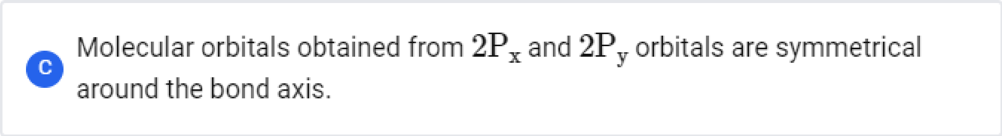
Total numbers electrons are same

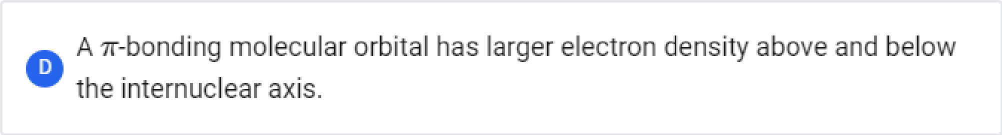
$Ca^{+2}, Ar, K^+, Cl^- \rightarrow 20$ electrons

Question: Which one of the following statements is incorrect related to Molecular Orbital Theory?


A The π^* antibonding molecular orbital has a node between the nuclei.


B In the formation of bonding molecular orbital, the two electron waves of the bonding atoms reinforce each other.


C Molecular orbitals obtained from $2P_x$ and $2P_y$ orbitals are symmetrical around the bond axis.

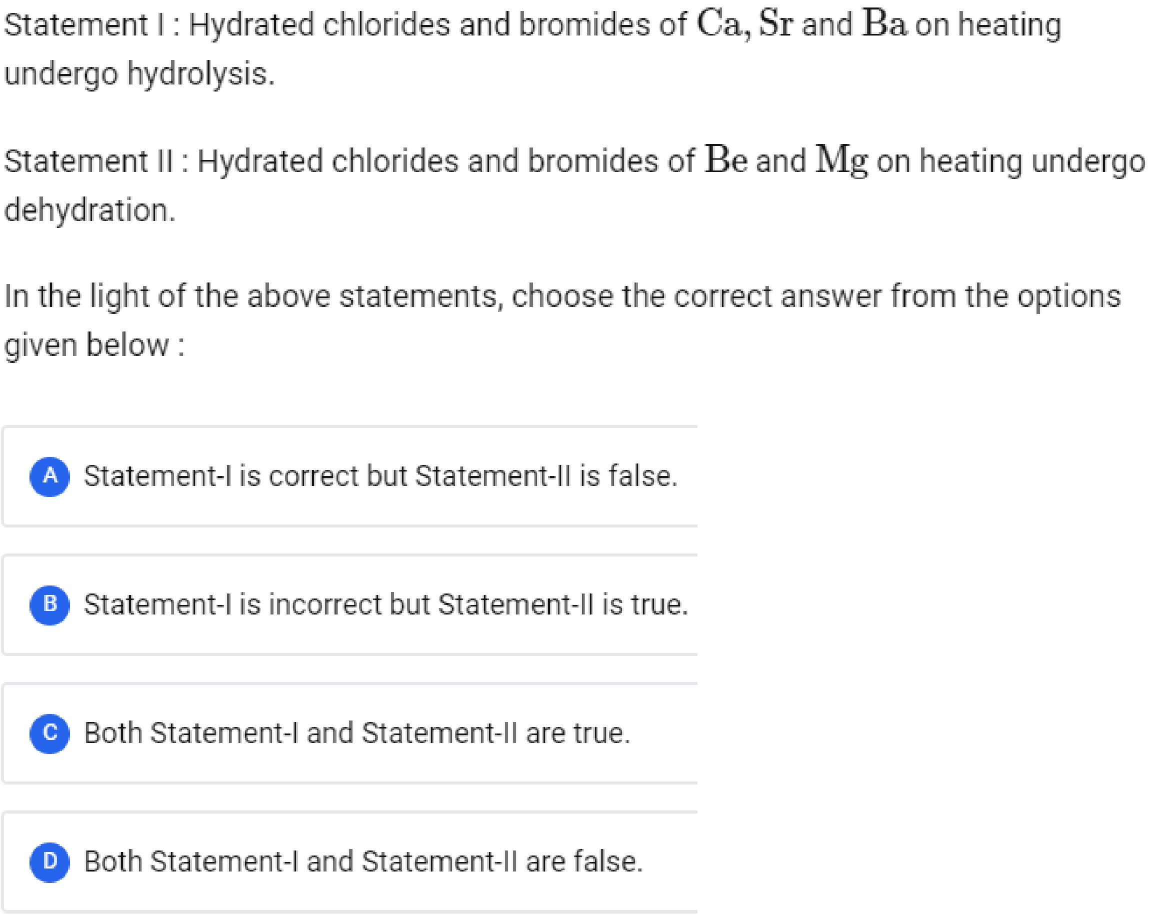

D A π-bonding molecular orbital has larger electron density above and below the internuclear axis.

Answer: C

Explanation

In the formation of BMO, the two electron waves of the bonding atoms reinforce each other due to constructive interference. Molecular orbitals obtained from $2P_x$ and $2P_y$ orbitals are 'unsymmetrical' around bond axis.

Question: Given below are two statements:



Statement I : Hydrated chlorides and bromides of Ca, Sr and Ba on heating undergo hydrolysis.

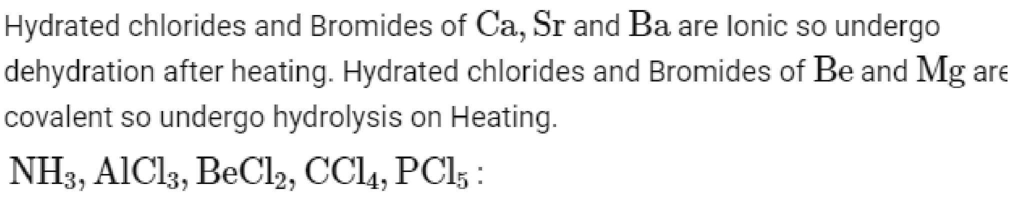
Statement II : Hydrated chlorides and bromides of Be and Mg on heating undergo dehydration.

In the light of the above statements, choose the correct answer from the options given below :

- A Statement-I is correct but Statement-II is false.
- B Statement-I is incorrect but Statement-II is true.
- C Both Statement-I and Statement-II are true.
- D Both Statement-I and Statement-II are false.

Answer: D

Explanation



Hydrated chlorides and Bromides of Ca, Sr and Ba are Ionic so undergo dehydration after heating. Hydrated chlorides and Bromides of Be and Mg are covalent so undergo hydrolysis on Heating.

$\mathrm{NH_3}, \mathrm{AlCl_3}, \mathrm{BeCl_2}, \mathrm{CCl_4}, \mathrm{PCl_5}$:

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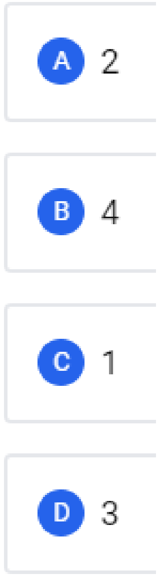


Ⓐ 2

Ⓑ 4

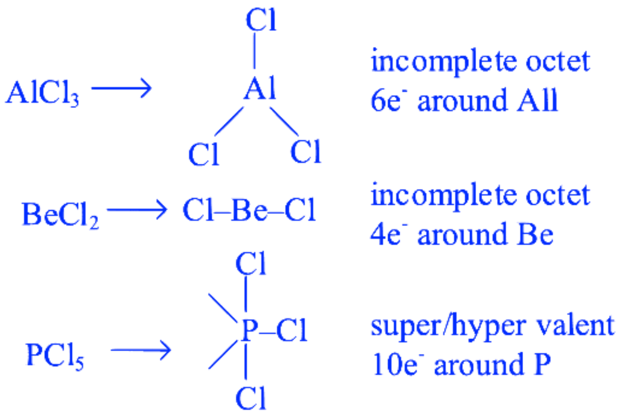
Ⓒ 1

Ⓓ 3

Answer: D

Explanation

Total number of species = 3



Question: The correct order of energies of molecular orbitals of N2 molecule, is

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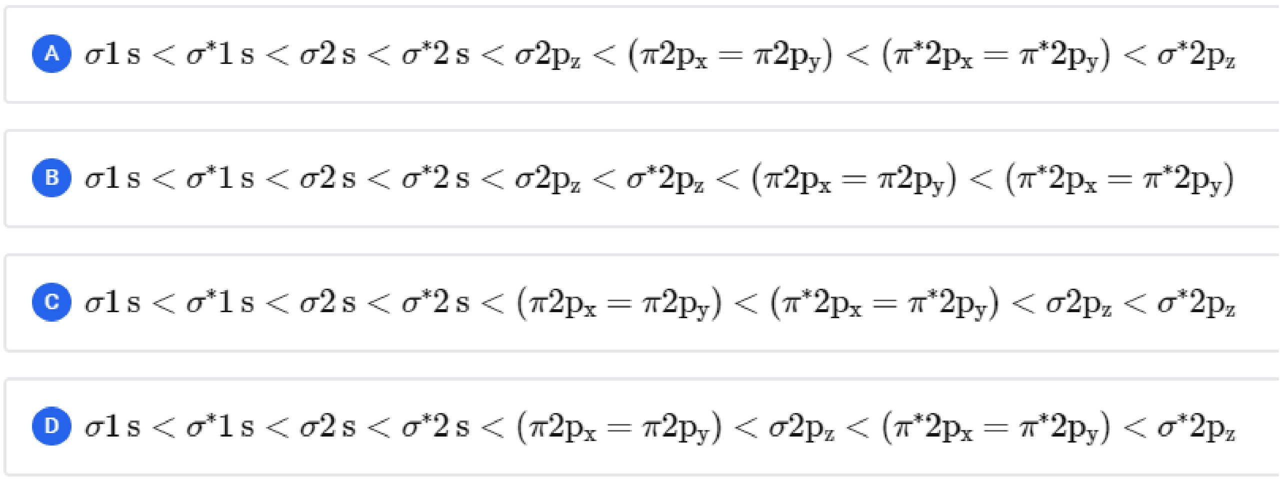


A $\sigma 1s < \sigma^*1s < \sigma 2s < \sigma^*2s < \sigma 2p_z < (\pi 2p_x = \pi 2p_y) < (\pi^*2p_x = \pi^*2p_y) < \sigma^*2p_z$

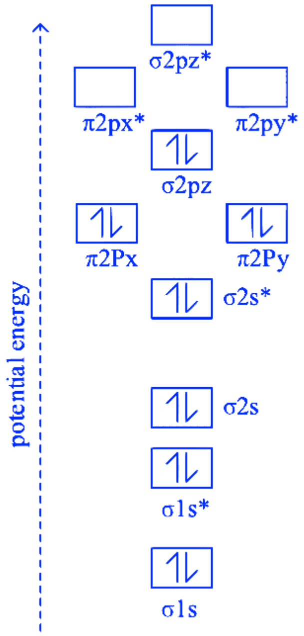
B $\sigma 1s < \sigma^*1s < \sigma 2s < \sigma^*2s < \sigma 2p_z < \sigma^*2p_z < (\pi 2p_x = \pi 2p_y) < (\pi^*2p_x = \pi^*2p_y)$

C $\sigma 1s < \sigma^*1s < \sigma 2s < \sigma^*2s < (\pi 2p_x = \pi 2p_y) < (\pi^*2p_x = \pi^*2p_y) < \sigma 2p_z < \sigma^*2p_z$

D $\sigma 1s < \sigma^*1s < \sigma 2s < \sigma^*2s < (\pi 2p_x = \pi 2p_y) < \sigma 2p_z < (\pi^*2p_x = \pi^*2p_y) < \sigma^*2p_z$

Answer: D

Molecular orbital (energy) diagram / sequence of N_2



Question: Taking stability as the factor, which one of the following represents correct relationship?

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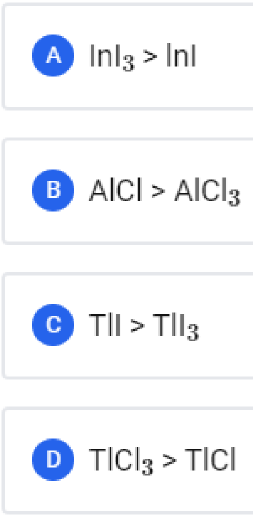


Ⓐ $InI_3 > InI$

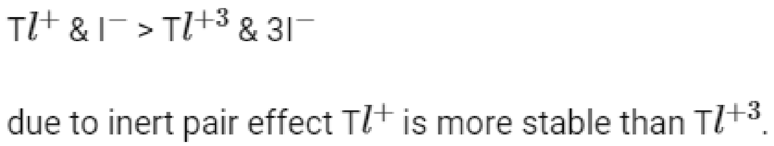
Ⓑ $AlCl > AlCl_3$

Ⓒ $TlI > TlI_3$

Ⓓ $TlCl_3 > TlCl$

Answer: C

Explanation



Tl^{+} & I^{-} > Tl^{+3} & $3I^{-}$

due to inert pair effect Tl^{+} is more stable than Tl^{+3}.

Question: Intermolecular forces are forces of attraction and repulsion between interacting particles that will include:

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A. dipole - dipole forces.

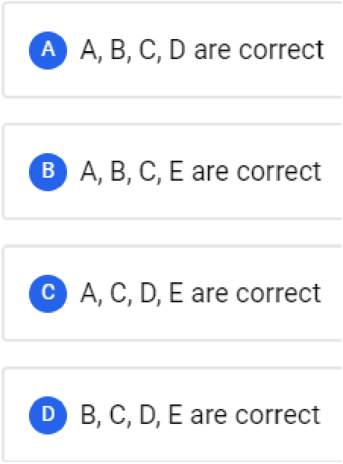
B. dipole - induced dipole forces

C. hydrogen bonding

D. covalent bonding

E. dispersion forces

Choose the most appropriate answer from the options given below:



A A, B, C, D are correct

B A, B, C, E are correct

C A, C, D, E are correct

D B, C, D, E are correct

Answer: B

Explanation

Intermolecular forces means force of attraction between two or more molecules

dipole-dipole (attraction between two or more polar molecules).

Dipole induced dipole (attraction between polar and non-polar molecules)

Hydrogen bonding (it is a special type of dipole-dipole and ion-dipole attraction)

Dispersion forces (mainly acts between non polar molecules).

Covalent bonding (acts between atom not between molecules)

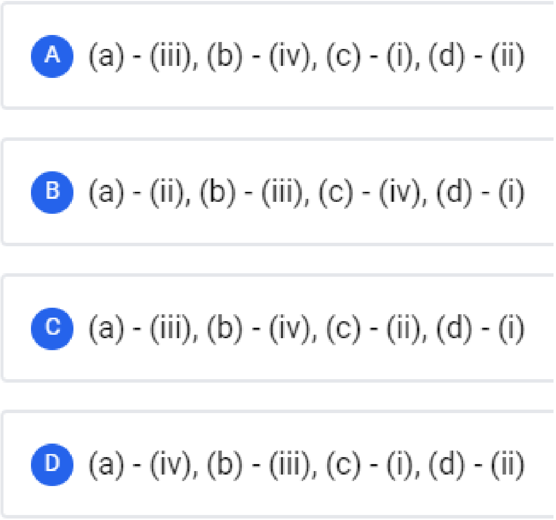
2022

MCQ (Single Correct Answer)

Q.1. Match List-I with List-II :

	List-I (Molecules)		List-II (Shape)
(a)	NH_3	(i)	Square pyramidal
(b)	ClF_3	(ii)	Trigonal bipyramidal
(c)	PCl_5	(iii)	Trigonal pyramidal
(d)	BrF_5	(iv)	T-shape

Choose the correct answer from the options given below:



A (a) - (iii), (b) - (iv), (c) - (i), (d) - (ii)

B (a) - (ii), (b) - (iii), (c) - (iv), (d) - (i)

C (a) - (iii), (b) - (iv), (c) - (ii), (d) - (i)

D (a) - (iv), (b) - (iii), (c) - (i), (d) - (ii)

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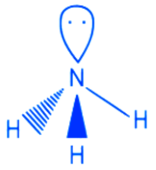
Ans. (C)

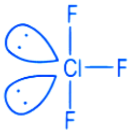
Explanation

(a) NH_3 :



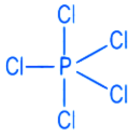
Trigonal pyramidal

(b) ClF_3 :



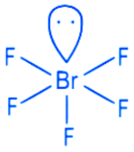
T-shape

(c) PCl_5 :



Trigonal bipyramidal

(d) BrF_5 :



Square pyramidal

(a) - (iii), (b) - (iv), (c) - (ii), (d) - (i)

Q.2. The correct order of bond angles in the following compounds/species is :

A $CO_2 < NH_3 < H_2O < \overset{+}{N}H_4$

B $H_2O < NH_3 < \overset{+}{N}H_4 < CO_2$

C $H_2O < \overset{+}{N}H_4 < NH_3 < CO_2$

D $H_2O < \overset{+}{N}H_4 = NH_3 < CO_2$

NEET 2022 Phase 2

Ans. (B)

Explanation

$CO_2 \Rightarrow sp^2$ hybridisation, bond angle = 180°

$NH_4^+ \Rightarrow sp^3$ hybridisation, bond angle = $109^\circ\ 28'$

$NH_3 \Rightarrow sp^3$ hybridisation with one lone pair on central atom, bond angle $\simeq 107^\circ$

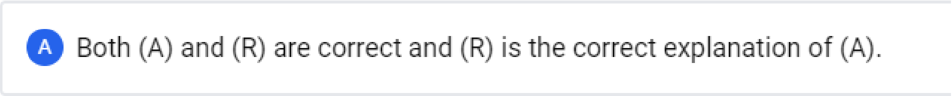
$H_2O \Rightarrow sp^3$ hybridisation with two lone pairs on central atom, bond angle $\simeq 104.5^\circ$

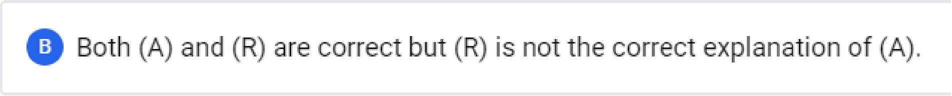
Q.3. Given below are two statements: one is labelled as Assertion (A) and the other is labelled as Reason (R)

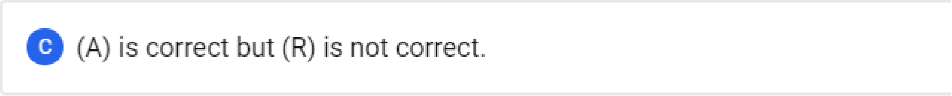
Assertion (A) : ICl is more reactive than I_2

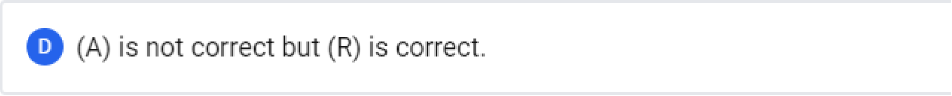
Reason (R) : I-Cl bond is weaker than I-I bond.

In the light of the above statements, choose the most appropriate answer from the options given below:


A Both (A) and (R) are correct and (R) is the correct explanation of (A).


B Both (A) and (R) are correct but (R) is not the correct explanation of (A).


C (A) is correct but (R) is not correct.


D (A) is not correct but (R) is correct.

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Ans. (A)

Explanation

In general, interhalogen compounds are more reactive than halogens (except fluorine). This is because X - X' bond in interhalogens is weaker than X - X bond in halogens excepts F - F bond. Therefore I-Cl is more reactive than I_2 because of weaker I - Cl bond then I - I bond.

Q.4. Amongst the following which one will have maximum 'lone pair - lone pair' electron repulsions?


A ClF_3


B IF_5

C SF_4

D XeF_2

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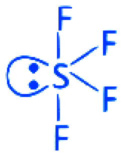
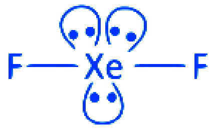
Ans. (D)

Explanation

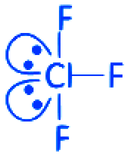
$SF_4 \rightarrow sp^3d + 1$ lone pair



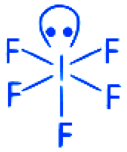
$XeF_2 \rightarrow sp^3d + 3$ lone pair



$ClF_3 \rightarrow sp^3d + 2$ lone pair



$IF_5 \rightarrow sp^3d^2 + 1$ lone pair



XeF_2 having maximum lone pairs, so, it has maximum 'lone pair-lone pair' electron repulsions.

Q.5. Which amongst the following is incorrect statement?

A The bond orders of O_2^+, O_2, O_2^- and O_2^{2-} are 2.5, 2, 1.5 and 1, respectively

B C_2 molecule has four electrons in its two degenerate π molecular orbitals

C H_2^+ ion has one electron

D O_2^+ ion is diamagnetic

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Ans. (D)

Explanation

$$\sigma 1s^2 \sigma^* 1s^2 \sigma 2s^2 \sigma^* 2s^2 \sigma 2p_z^2 \begin{array}{c} \pi 2p_x^2 \\ | \\ \pi 2p_y^2 \end{array} \quad \begin{array}{c} \pi^* 2p_x^1 \\ | \\ \pi 2p_y \end{array}$$

Due to one unpaired electron in $\pi * 2p$ molecular orbital, O_2^+ is a paramagnetic ion.

TOPIC 1

Type of Bonds, Bond Parameter and Resonance

01 The correct sequence of bond enthalpy of 'C—*X*' bond is **[NEET 2021]**

(a) $CH_3—F < CH_3—Cl < CH_3—Br < CH_3—I$

(b) $CH_3—F > CH_3—Cl > CH_3—Br > CH_3—I$

(c) $CH_3—F < CH_3—Cl > CH_3—Br > CH_3—I$

(d) $CH_3—Cl > CH_3—F > CH_3—Br > CH_3—I$

Ans. *(b)*

On moving down the group from F to I, the size of atom increases. Order of the size of halogen atoms is $I > Br > Cl > F$.

So, the bond length of C—*X* bond also increases from F to I and hence, the bond enthalpy decreases from F to I.

Correct order of bond length of C—*X* bond is

$H_3C—I > H_3C—Br > H_3C—Cl > H_3C—F$.

Correct order of bond enthalpy is

$H_3C—F > H_3C—Cl > CH_3—Br > H_3C—I$.

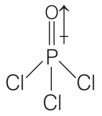
02 Which of the following molecules is non-polar in nature? **[NEET 2021]**

(a) $POCl_3$ (b) CH_2O

(c) $SbCl_5$ (d) NO_2

Ans. *(c)*

(a) **$POCl_3$** Hybridisation $= \frac{1}{2} \times 8 = 4(sp^3)$



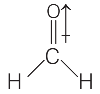
Shape = Tetrahedral

Dipole moment, $\mu \neq 0$

$POCl_3$ is polar in nature.

(b) **CH_2O** Hybridisation $= \frac{1}{2}(6) = 3(sp^2)$

Shape = Trigonal planar.

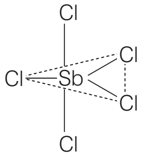


Dipole moment, $\mu \neq 0$

CH_2O is polar in nature.

(c) **$SbCl_5$** Hybridisation $= \frac{1}{2} \times 10 = 5(sp^3d)$

Shape = Trigonal bipyramidal

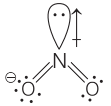


Dipole moment, $\mu = 0$

$SbCl_5$ is non-polar in nature.

(d) **NO_2** Hybridisation

$= \frac{1}{2} \times (4+2) = \frac{1}{2} \times 6 = 3(sp^2)$.



Shape = Trigonal planar

Dipole moment, $\mu \neq 0$

NO_2 is polar in nature.

03 Which of the following set of molecules will have zero dipole moment? **[NEET (Sept.) 2020]**

(a) Boron trifluoride, hydrogen fluoride, carbon dioxide, 1,3-dichlorobenzene

(b) Nitrogen trifluoride, beryllium difluoride, water, 1,3-dichlorobenzene

(c) Boron trifluoride, beryllium difluoride, carbon dioxide, 1, 4-dichlorobenzene

(d) Ammonia, beryllium difluoride, water, 1,4-dichlorobenzene

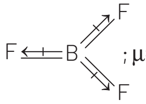
Ans. *(c)*

In option (c), for all molecules, [i, vi, iii, viii] $\mu = 0$.

The structure of all compounds are as follows :

(i) Boron trifluoride (BF_3)

$\Rightarrow$



; $\mu = 0$

(ii) Hydrogen fluoride (HF)

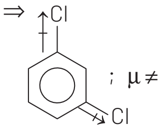
$\Rightarrow$ $H \xrightarrow{} F$; $\mu \neq 0$

(iii) Carbon dioxide (CO_2)

$\Rightarrow$ $\overset{\leftarrow}{O} = C = \vec{O}$; $\mu = 0$

(iv) 1,3-dichloro benzene

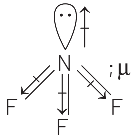
(m-$C_6H_4Cl_2$) $\Rightarrow$



; $\mu \neq 0$

(v) Nitrogen trifluoride (NF_3)

$\Rightarrow$



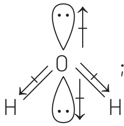
; $\mu \neq 0$

(vi) Beryllium difluoride (BeF_2)

$\Rightarrow$ $F \overset{\leftarrow}{—} Be \overset{\rightarrow}{—} F$; $\mu = 0$

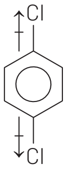
(vii) Water (H_2O)

$\Rightarrow$



; $\mu \neq 0$

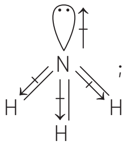
(viii) 1,4-dichloro benzene ($p = C_6H_4Cl_2$) ⇒



; $\mu = 0$

(ix) Ammonia (NH_3)

⇒



; $\mu \neq 0$

[$\because \mu$ = Dipole moment]

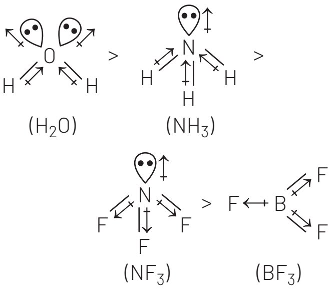
04 Which of the following is the correct order of dipole moment? **[NEET (Odisha) 2019]**

(a) $NH_3 < BF_3 < NF_3 < H_2O$
(b) $BF_3 < NF_3 < NH_3 < H_2O$
(c) $BF_3 < NH_3 < NF_3 < H_2O$
(d) $H_2O < NF_3 < NH_3 < BF_3$

Ans. ***(b)***

BF_3 has zero dipole moment as it is symmetrical in nature. H_2O has maximum dipole moment as it possess two lone pair of electrons. Between NH_3 and NF_3, NH_3 has greater dipole moment though in NH_3 and NF_3, both N possesses one lone pair of electrons.

This is beacuse in case of NF_3, the net N—H bond dipole is in the same direction as the direction of dipole of lone pair. But in case of NF_3, the direction of net dipole moment of three —N—F bonds is opposite to that of the dipole moment of the lone pair. Thus, the correct of dipole moment is



05 Which one of the following pairs of species have the same bond order? **[NEET 2017]**

(a) CO, NO
(b) O_2, NO^+
(c) CN^-, CO
(d) N_2, O_2^-

Ans. ***(c)***

Key concept *The species that have same number of electrons have same bond order.*

Species	Number of electrons
CO	6 + 8 = 14
NO	7 + 8 = 15
O_2	8 + 8 = 16
NO^+	7 + 8 − 1 = 14
CN^-	6 + 7 + 1 = 14
O_2^-	8 + 8 + 1 = 17

Thus, both CN^- and CO have equal number of electrons. So, their bond order will be same.

06 Predict the correct order among the following. **[NEET 2016, Phase I]**

(a) lone pair-lone pair > bond pair-bond pair > lone pair-bond pair
(b) bond pair-bond pair > lone pair-bond pair > lone pair-lone pair
(c) lone pair-bond pair > bond pair-bond pair > lone pair-lone pair
(d) lone pair-lone pair > lone pair-bond pair > bond pair-bond pair

Ans. ***(d)***

According to the postulate of VSEPR theory, a lone pair occupies more space than a bonding pair, since it lies closer to the central atom. This means that the repulsion between the different electron pairs follow the order.

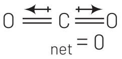
$$lp-lp > lp-bp > bp-bp$$

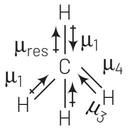
07 Which of the following molecules has the maximum dipole moment? **[CBSE AIPMT 2014]**

(a) CO_2
(b) CH_4
(c) NH_3
(d) NF_3

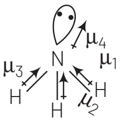
Ans. ***(d)***

CO_2 and CH_4 have zero dipole moment as these are symmetrical in nature. Between NH_3 and NF_3, NF_3 has greater dipole moment though in NH_3 and NF_3 both, N possesses one lone pair of electrons.



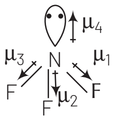


$$\because \mu_{res} = \mu_1 + \mu_2 + \mu_3 = -\mu_4$$
$$\text{and } \mu_{net} = \mu_{res} + \mu_4$$
$$\therefore \mu_{net} = \mu_1 + \mu_2 + \mu_3 + \mu_4$$
$$= -\mu_4 + \mu_4 = 0$$
$$_{net} = 0$$



Resultant of
3N—H
bond lie in the same direction as μ_4

Hence, $\mu_{net} = \mu_{res} + \mu_4$



Resultant of
3N—F
bond lie opposite to μ_4

This is because in case of NH_3, the net N—H bond dipole is in the same direction as the direction of dipole of lone pair but in case of NF_3, the direction of net bond dipole of three —N—F bonds is opposite than that of the dipole of the then lone pair.

08 Which one of the following molecules contain no π-bond? **[NEET 2013]**

(a) CO_2
(b) H_2O
(c) SO_2
(d) NO_2

Ans. ***(b)***

All the molecules have O-atom with lone pairs, but in H_2O the H-atom has no vacant orbital for π-bonding. That's why it does not have any π-bond.

In all other given molecules, the central atom because of the presence of vacant orbitals is capable to form π-bonds.

09 Which of the following is least likely to behave as Lewis base? **[CBSE AIPMT 2011]**

(a) NH_3
(b) BF_3
(c) OH^-
(d) H_2O

Ans. ***(b)***

BF_3 is an electron deficient species, thus behaves like a Lewis acid.

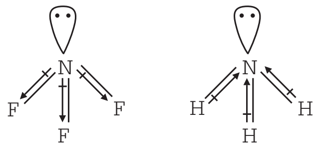
$$\because \text{Bond order} = \frac{N_b - N_a}{2}$$

10 The electronegativity difference between N and F is greater than that between N and H yet the dipole moment of NH_3 (1.5 D) is larger than that of NF_3 (0.2 D). This is because **[CBSE AIPMT 2006]**

(a) in NH_3 as well as in NF_3, the atomic dipole and bond dipole are in the same direction
(b) in NH_3, the atomic dipole and bond dipole are in the same direction whereas in NF_3 these are in opposite directions
(c) in NH_3 as well as NF_3, the atomic dipole and bond dipole are in opposite directions

(d) in NH_3 the atomic dipole and bond dipole are in the opposite directions whereas in NF_3 these are in the same directions

Ans. ***(b)***



$\mu = 0.24$ D $\mu = 1.47$ D

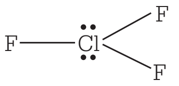
F is more electronegative than N, therefore direction of bond is from N to F whereas N is more electronegative than H, the direction of the bond is from H to N. Thus whereas resultant moment of N-H bonds adds up to the bond moment of lone pair, that of 3N-F bonds partly cancel the resultant moment of lone pair. Hence, the net dipole moment of NF_3 is less than that of NH_3.

11 In which of the following molecules are all the bonds not equal? **[CBSE AIPMT 2006]**

(a) ClF_3 (b) BF_3
(c) AlF_3 (d) NF_3

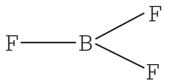
Ans. ***(a)***

In ClF_3 all bonds are not equal due to its trigonal-bipyramidal (sp^3d hybridisation) geometry

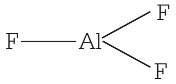


Trigonal bipyramidal geometry

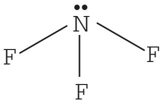
BF_3 and AlF_3 show trigonal symmetric structure due to sp^2 hybridisation.



and



NF_3 shows pyramidal geometry due to sp^3 hybridisation.

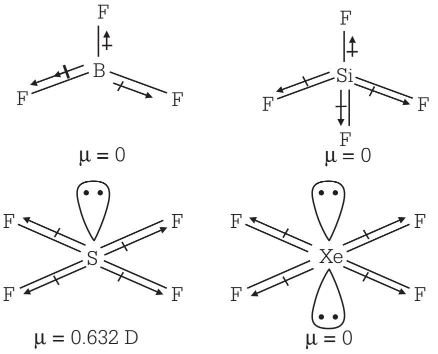


3*bp* + 1*lp*

12 Which of the following would have a permanent dipole moment? **[CBSE AIPMT 2005]**

(a) BF_3 (b) SiF_4
(c) SF_4 (d) XeF_4

Ans. ***(c)***



(Permanent dipole moment)

$\because$ SF_4 have $\mu > 0$

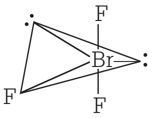
$\therefore$ It has permanent dipole moment.

13 In BrF_3 molecule, the lone pairs occupy equatorial positions to minimise **[CBSE AIPMT 2004]**

(a) lone pair-bond pair repulsion
(b) bond pair-bond pair repulsion
(c) lone pair-lone pair repulsion and lone pair-bond pair repulsion
(d) lone pair-lone pair repulsion

Ans. ***(d)***

In BrF_3 molecule, Br is sp^3d hybridised, but its geometry is T-shaped due to distortion of geometry from trigonal bipyramidal to T-shaped by the involvement of lone pair-lone pair repulsion.



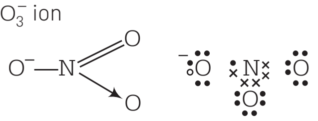
Here, *lp* – *lp* repulsion = 0
lp – *bp* repulsion = 4
bp – *bp* repulsion = 2

14 In NO_3^- ion number of bond pair and lone pair of electrons on nitrogen atom are **[CBSE AIPMT 2002]**

(a) 2, 2 (b) 3, 1 (c) 1, 3 (d) 4, 0

Ans. ***(d)***

In NO_3^- ion



Nitrogen has four bond pair and zero lone pair of electrons, due to the presence of one coordination bond.

15 In which of the following, bond angle is maximum? **[CBSE AIPMT 2001]**

(a) NH_3 (b) NH_4^+ (c) PCl_3 (d) SCl_2

Ans. ***(b)***

In NH_4^+ bond angle is maximum (nearer 109°) due to its tetrahedral geometry.

16 In PO_4^{3-} ion, the formal charge on each oxygen atom and P—O bond order respectively are **[CBSE AIPMT 1998]**

(a) – 0.75, 0.6 (b) – 0.75, 1.0
(c) – 0.75, 1.25 (d) – 3, 1.25

Ans. ***(c)***

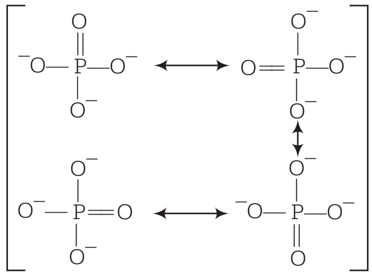
P—O bond order

$$= \frac{\text{Total Number of bonds in all possible direction between two atoms}}{\text{Total number of resonating structures}}$$

$$= \frac{2+1+1+1}{4} = \frac{5}{4} = 1.25$$

$\therefore$ Bond order = 1.25

Resonating structures are



Total charge on PO_4^{3-} ion is –3

$$= \frac{\text{Total charge}}{\text{Total entity of O-atom}}$$

So, the average formal charge on each O-atom is $= -\frac{3}{4} = -0.75$

17 Which one is not paramagnetic among the following? [at. no. of Be = 4, Ne = 10, As = 33, Cl = 17] **[CBSE AIPMT 1998]**

(a) Cl^- (b) Be
(c) Ne^{2+} (d) As^+

Ans. ***(a)***

Paramagnetic character is based upon presence of unpaired electron.

$${}_{17}Cl^- = 1s^2, 2s^2 2p^6, 3s^2 3p_x^2 3p_y^2 3p_z^2$$

In Cl^- no unpaired electron, so it is in nature diamagnetic.

$${}_4Be = 1s^2, 2s^1 2p_x^1$$

$${}_{10}Ne^{2+} = 1s^2, 2s^2 2p_x^2 2p_y^1 2p_z^1$$

$${}_{33}As^+ = 1s^2, 2s^2 2p^6, 3s^2 3p^6 3d^{10}, 4s^2 4p_x^1 4p_y^1 4p_z^0$$

While all others have unpaired electron, so they are paramagnetic in nature.

18 The molecule which does not exhibit dipole moment is **[CBSE AIPMT 1997]**

(a) NH_3
(b) $CHCl_3$
(c) H_2O
(d) CCl_4

Ans. ***(d)***

CCl_4 does not show dipole moment because it has tetrahedral symmetrical structure.

19 For two ionic solids CaO and KI, identify the wrong statement among the following. **[CBSE AIPMT 1997]**

(a) Lattice energy of CaO is much larger than that of KI
(b) KI is soluble in benzene
(c) KI has lower melting point
(d) CaO has higher melting point

Ans. ***(b)***

KI is ionic compound, so it is not soluble in non-polar solvent (i.e. dipole moment (μ) for benzene $= 0$).

20 Which one of the following has the highest dipole moment? **[CBSE AIPMT 1997]**

(a) AsH_3
(b) SbH_3
(c) PH_3
(d) NH_3

Ans. ***(d)***

In the given molecules nitrogen has greater electronegativity. So, it has greater dipole moment and correct order of dipole moment is

$$NH_3 > PH_3 > AsH_3 > SbH_3$$

21 The BCl_3 is a planar molecule whereas NCl_3 is pyramidal because **[CBSE AIPMT 1995]**

(a) B — Cl bond is more polar than N — Cl bond
(b) N — Cl bond is more covalent than B — Cl bond
(c) nitrogen atom is smaller than boron atom
(d) BCl_3 has no lone pair but NCl_3 has a lone pair of electrons

Ans. ***(d)***

BCl_3 have sp^2 hybridisation and no lone pair of electron on central atom but NCl_3 have sp^3 hybridisation and also contains one lone pair of electron on nitrogen, so BCl_3 is planar.

22 The weakest among the following types of bond is **[CBSE AIPMT 1994]**

(a) ionic
(b) covalent
(c) metallic
(d) H-bond

Ans. ***(d)***

H-bond is weakest bond because its bond dissociation energy is very low as compared to other given bonds (10 kJ mol^{-1}).

23 Which of the following pairs will form the most stable ionic bond? **[CBSE AIPMT 1994]**

(a) Na and Cl
(b) Mg and F
(c) Li and F
(d) Na and F

Ans. ***(b)***

The ionic bond between Mg and F is most stable because in these the electrostatic force of attraction is maximum. As Mg has high electropositive character and F has high electronegative character among all other options that are given in question.

24 Which of the following statements is not correct? **[CBSE AIPMT 1993, 1990]**

(a) Double bond is shorter than a single bond
(b) Sigma bond is weaker than a π-bond
(c) Double bond is stronger than a single bond
(d) Covalent bond is stronger than hydrogen bond

Ans. ***(b)***

Sigma bond is always stronger than π-bond because the extent of overlapping is maximum in sigma bond formation.

25 Which one of the following is the correct order of interactions? **[CBSE AIPMT 1993]**

(a) Covalent < hydrogen bonding < van der Waals' < dipole-dipole
(b) van der Waals' < hydrogen bonding < dipole-dipole < covalent
(c) van der Waals' < dipole-dipole < hydrogen bonding < covalent
(d) Dipole-dipole < van der Waals' < hydrogen bonding < covalent

Ans. ***(b)***

The van der Waals' forces are weakest forces and covalent bond is strongest, so the order of interactions is van der Waals' < H-bonding < dipole-dipole < covalent.

26 Among the following which compound will show the highest lattice energy? **[CBSE AIPMT 1993]**

(a) KF
(b) NaF
(c) CsF
(d) RbF

Ans. ***(b)***

NaF has high lattice energy because Na^+ is smallest in size and lattice energy increases as the size of cation decreases. (In the given question anion is common in all compound)

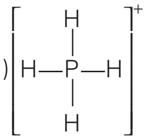
27 Strongest hydrogen bonding is shown by **[CBSE AIPMT 1992]**

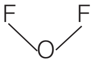
(a) H_2O
(b) NH_3
(c) HF
(d) H_2S

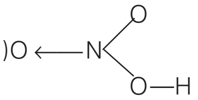
Ans. ***(c)***

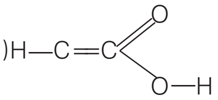
HF have strongest hydrogen bond because the electronegativity of F-atom is high and produce strong electrostatic force of attraction.

28 Which one of the following formulae does not correctly represent the bonding capacities of the atoms involved? **[CBSE AIPMT 1991]**

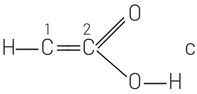
(a) 

(b) 

(c) 

(d) 

Ans. ***(d)***

In  carbon number 2 have five valency which is not possible, so it does not correctly represent the bonding capacities of C atom.

29 Among LiCl, $BeCl_2$, BCl_3 and CCl_4, the covalent bond character follows the order **[CBSE AIPMT 1990]**

(a) $LiCl < BeCl_2 > BCl_3 > CCl_4$
(b) $LiCl < BeCl_2 < BCl_3 > CCl_4$
(c) $LiCl < BeCl_2 < BCl_3 < CCl_4$
(d) $LiCl > BeCl_2 > BCl_3 > CCl_4$

Ans. ***(c)***

The electronegativity increases from left to right in any period, so the electronegativity follows the order

$$Li < Be < B < C$$

and hence, the covalent character of chlorides of these elements increase from Li to C because size of cation left to right decreases and according to Fajans' rule covalent character increases.

30 H_2O has a net dipole moment while BeF_2 has zero dipole moment because **[CBSE AIPMT 1989]**

(a) H_2O molecule is linear while BeF_2 is bent
(b) BeF_2 molecule is linear while H_2O is bent
(c) fluorine has more electronegativity than oxygen
(d) beryllium has more electronegativity than oxygen

Ans. *(b)*

H_2O have bent structure in which the two O—H bonds are oriented at an angle of 104.5°, so water have a net dipole moment whereas BeF_2 have linear geometry, so the dipole moment of one bond is cancelled by another bond, so it have zero dipole moment.

TOPIC 2

Hybridisation and VSEPR Theory

31 Match List-I with List-II.

	List-I		List-II
A.	PCl_5	I.	Square pyramidal
B.	SF_6	II.	Trigonal planar
C.	BrF_5	III.	Octahedral
D.	BF_3	IV.	Trigonal bipyramidal

Choose the correct answer from the options given below **[NEET 2021]**

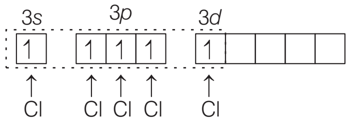
	A	B	C	D
(a)	IV	III	I	II
(b)	II	III	IV	I
(c)	III	I	IV	II
(d)	IV	III	II	I

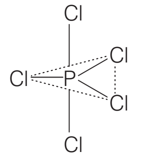
Ans. *(a)*

(A) $\mathbf{PCl_5}$

P (Ground state) $= 3s^2 3p^3$

P* (excited state)





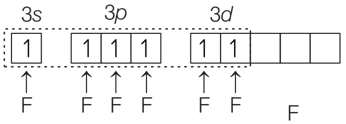
Hybridisation of P $\rightarrow sp^3d$

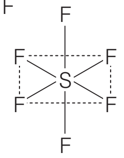
Structure of $PCl_5 \rightarrow$ Trigonal bipyramidal

(B) $\mathbf{SF_6}$

S (Ground state) $= 3s^2 3p^4$

S* (excited state)





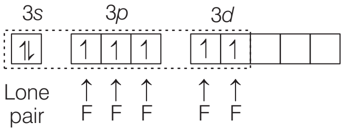
Hybridisation of S $\rightarrow sp^3d^2$

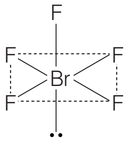
Structure of $SF_6 \rightarrow$ Octahedral

(C) $\mathbf{BrF_5}$

Br (Ground state) $= 3s^2 3p^5$

Br* (excited state)





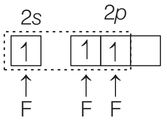
Hybridisation of Br $\rightarrow sp^3d^2$

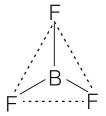
Structure of $BrF_5 \rightarrow$ Square pyramidal

(D) $\mathbf{BF_3}$

B (Ground state) $= 2s^2 2p^1$

B* (excited state)





Hybridisation of B $\rightarrow sp^2$

Structure of $BF_3 \rightarrow$ Trigonal planar

∴ Correct match is

(A)-(IV); (B)-(III); (C)-(I); (D)-(II)

32 BF_3 is planar and electron deficient compound. Hybridisation and number of electrons around the central atom, respectively are **[NEET 2021]**

(a) sp^3 and 4
(b) sp^3 and 6
(c) sp^2 and 6
(d) sp^2 and 8

Ans. *(c)*

Hybridisation of a central atom can be calculate by using the formula :

$$\text{Hybridisation} = \frac{1}{2}[\text{number of valence electrons} + \text{Number of side atoms} - \text{Positive charge} + \text{Negative charge}]$$

Electronic configuration of B

$$= 1s^2, 2s^2, 2p^1$$

Number of valence electrons in B = 3 electrons in last shell, $n = 2$

Number of side atoms in BF_3 = 3F-atoms.

So, hybridisation $= \frac{1}{2}(3+3) = \frac{1}{2} \times 6 = 3.$

Hybridisation of B in BF_3 is sp^2.

Number of electrons around central atom, B in BF_3 is equal to the number of electrons in three sigma bonds (B—F) i.e.

$= 3$ B—F bonds × 2 electrons in one σ-bond.

$= 6$ electrons

33 Match the coordination number and type of hybridisation with distribution of hybrid orbitals in space based on valence bond theory. **[NEET (Oct.) 2020]**

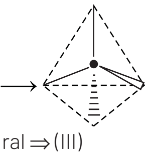
	Coordination number and type of hybridisation		**Distribution of hybrid orbitals in space**
A.	4, sp^3	I.	trigonal bipyramidal
B.	4, dsp^2	II.	octahedral
C.	5, sp^3d	III.	tetrahedral
D.	6, d^2sp^3	IV.	square planar

Select the correct option.

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

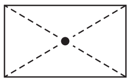
Ans. *(b)*

(A) CN=4, $sp^3 \longrightarrow$



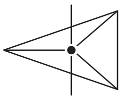
or tetrahedral ⇒ (III)

(B) CN=4, $dsp^2 \longrightarrow$



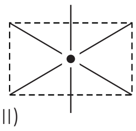
or square planar ⇒ (IV)

(C) CN=5, $sp^3d \longrightarrow$



or trigonal bipyramidal ⇒ (I)

(D) CN=6, $d^2sp^3 \longrightarrow$



or octahedral ⇒ (II)

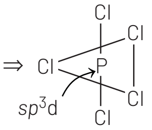
Hence, option (b) is correct.

34 Identify the wrongly matched pair. **[NEET (Oct.) 2020]**

	Molecule	**Shape of geometry of molecule**
(a)	PCl_5	Trigonal planar
(b)	SF_6	Octahedral
(c)	$BeCl_2$	Linear
(d)	NH_3	Trigonal pyramidal

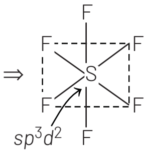
Ans. ***(a)***

(A) PCl_5 ⇒



⇒ Geometry = shape = trigonal bipyramidal [Not trigonal planar]

(B) SF_6 ⇒

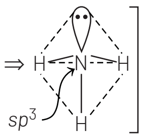


⇒ Geometry = shape = octahedral

(C) $BeCl_2 \Rightarrow Cl-\overset{sp}{Be}-Cl$

⇒ Geometry = shape = linear

(D) :NH_3 ⇒



⇒ electron geometry = tetrahedral

⇒ Shape = trigonal pyramidal

Hence, option (a) is wrongly matched pair.

35 Match the xenon compounds in Column I with its structure in Column II and assign the correct code : **[NEET (National) 2019]**

	Column I		**Column II**
A.	XeF_4	(i)	Pyramidal
B.	XeF_6	(ii)	Square planar
C.	$XeOF_4$	(iii)	Distorted octahedral
D.	XeO_3	(iv)	Square pyramidal

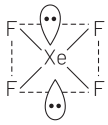
Codes

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

Ans. ***(a)***

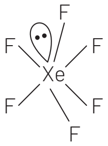
The given xenon compounds with its structures are as follows:

(A) XeF_4 —



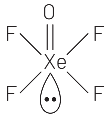
(Square planar)

(B) XeF_6 —



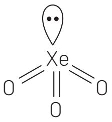
(Distorted octahedral)

(C) $XeOF_4$ —



(Square pyramidal)

(D) XeO_3 —



(Pyramidal)

Hence, the correct match is

(A)→(ii), (B)→(iii), (C)→(iv), (D)→(i)

36 Predict the correct order among the following. **[NEET 2016, Phase I]**

(a) lone pair-lone pair > bond pair-bond pair > lone pair-bond pair

(b) bond pair-bond pair > lone pair-bond pair > lone pair-lone pair

(c) lone pair-bond pair > bond pair-bond pair > lone pair-lone pair

(d) lone pair-lone pair > lone pair-bond pair > bond pair-bond pair

Ans. ***(d)***

According to the postulate of VSEPR theory, a lone pair occupies more space than a bonding pair, since it lies closer to the central atom. This means that the repulsion between the different electron pairs follow the order.

$$lp-lp > lp-bp > bp-bp$$

37 Consider the molecules CH_4, NH_3 and H_2O. Which of the given statements is false? **[NEET 2016, Phase I]**

(a) The H—O—H bond angle in H_2O is larger than the H—C—H bond angle in CH_4

(b) The H—O—H bond angle in H_2O is smaller than the H—N—H bond angle in NH_3

(c) The H—C—H bond angle in CH_4 is larger than the H—N—H bond angle in NH_3

(d) The H—C—H bond angle in CH_4, the H—N—H bond angle in NH_3 and the H—O—H bond angle in H_2O are all greater than 90°

Ans. ***(a)***

As the number of lone pair of electrons on central element increases, repulsion between those lone pair of electrons increases and therefore, bond angle decreases.

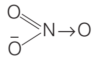
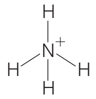
Molecules	**Bond angle**
CH_4 (no lone pair of electrons)	109.5°
NH_3 (one lone pair of electrons)	107.5°
H_2O (two lone pair of electrons)	104.45°

38 The hybridisations of atomic orbitals of nitrogen in NO_2^+, NO_3^- and NH_4^+ respectively are **[NEET 2016, Phase II]**

(a) sp, sp^3 and sp^2 (b) sp^2, sp^3 and sp

(c) sp, sp^2 and sp^3 (d) sp^2, sp and sp^3

Ans. ***(c)***

Ion	**Structure**	**Hybridisation**
NO_2^+	$O=\overset{\oplus}{N}=O$	sp
NO_3^-		sp^2
NH_4^+		sp^3

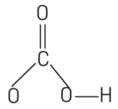
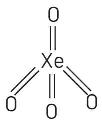
Thus, option (c) is correct.

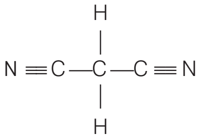
39 Which of the following species contains equal number of σ and π-bonds? **[CBSE AIPMT 2015]**

(a) HCO_3^- (b) XeO_4

(c) $(CN)_2$ (d) $CH_2(CN)_2$

Ans. ***(b)***

Structure		**σ and π bonds**
(a)		σ bond-4 π bond-1
(b)		σ bond-4 π bond-4

	Structure	σ and π bonds
(c)	$N \equiv C — C \equiv N$	σ bond-3 π bond-4
(d)	 $N \equiv C — \overset{H}{\underset{H}{C}} — C \equiv N$	σ bond-6 π bond-4

40 Which of the following pairs of ions are isoelectronic and isostructural? **[CBSE AIPMT 2015]**

(a) CO_3^{2-}, SO_3^{2-} (b) ClO_3^-, CO_3^{2-}
(c) SO_3^{2-}, NO_3^- (d) ClO_3^-, SO_3^{2-}

Ans. *(d)*

ClO_3^-, ≡ SO_3^{2-}

Number of electrons

$CO_3^{2-} = 6 + 2 + 24 = 32$
$SO_3^{2-} = 16 + 2 + 24 = 42$
$ClO_3^- = 4 + 24 + 1 = 42$
$CO_3^{2-} = 6 + 24 + 2 = 32$
$NO_3^- = 7 + 2 + 24 = 33$

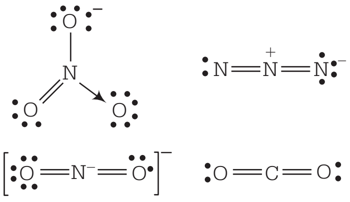
Hence, ClO_3^- and SO_3^{2-} are isoelectronic and are pyramidal in shape.

41 Which one of the following species has plane triangular shape? **[CBSE AIPMT 2014]**

(a) N_3 (b) NO_3^-
(c) NO_2^- (d) CO_2

Ans. *(b)*

Species with sp^2 hybridisation are planar triangular in shape. Among the given species NO_3^- is sp^2 hybridised with no lone pair of electrons on central atom, N. Whereas, N_3, NO_2^- and CO_2 are *sp* hybridised with a linear shape.



42 Which of the following is a polar molecule? **[NEET 2013]**

(a) BF_3 (b) SF_4 (c) SiF_4 (d) XeF_4

Ans. *(b)*

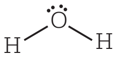
Symmetrical molecules are generally non-polar although they have polar bonds. This is because bond dipole of one bond is cancelled by that of the other. BF_3, SiF_4 and XeF_4 being symmetrical as non-polar. SF_4 is unsymmetrical because of the presence of a lone pair of electrons. Due to which it is a polar molecule.

43 Which of the following species contains three bond pairs and one lone pair around the central atom? **[NEET 2013]**

(a) H_2O (b) BF_3 (c) NH_2^- (d) PCl_3

Ans. *(d)*

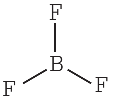
(a) $H_2O \Rightarrow$



(2 *bp* + 2 *lp*)

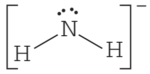
[*bp* = bond pair and *lp* = lone pair]

(b) $BF_3 \Rightarrow$



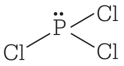
(3 *bp* + 0 *lp*)

(c) $NH_2^- \Rightarrow$



(2*bp* + 2*lp*)

(d) $PCl_3 \Rightarrow$



(3 *bp* + 1 *lp*)

Thus, in PCl_3, the central P-atom is surrounded by three bond pairs and one lone pair.

44 Considering the state of hybridisation of carbon atoms, find out the molecule among the following which is linear? **[CBSE AIPMT 2011]**

(a) $CH_3—C \equiv C—CH_3$
(b) $CH_2 = CH—CH_2—C \equiv CH$
(c) $CH_3— CH_2— CH_2— CH_3$
(d) $CH_3— CH = CH— CH_3$

Ans. *(a)*

$H_3\overset{4}{C}—\overset{3}{C} \equiv \overset{2}{C}—\overset{1}{C}H_3$ is linear because C_2 and C_3 are *sp* hybridised carbon atom.

45 Which of the two ions from the list given below, have the geometry that is explained by the same hybridisation of orbitals,

NO_2^-, NO_3^-, NH_2^-, NH_4^+, SCN^-? **[CBSE AIPMT 2011]**

(a) NH_4^+ and NO_3^- (b) SCN^- and NH_2^-
(c) NO_2^- and NH_2^- (d) NO_2^- and NO_3^-

Ans. *(d)*

$NO_2^- \longrightarrow sp^2$
$NO_3^- \longrightarrow sp^2$
$NH_2^+ \longrightarrow sp^3$
$NH_4^- \longrightarrow sp^3$
$SCN^+ \longrightarrow sp$

NO_2^- and NO_3^- both have the same hybridisation, i.e. sp^2.

46 In which of the following pairs of molecules/ions, the central atoms have sp^2 hybridisation? **[CBSE AIPMT 2010]**

(a) NO_2^- and NH_3
(b) BF_3 and NO_2^-
(c) NH_2^- and H_2O
(d) BF_3 and NH_2^-

Ans. *(b)*

Key Idea *For sp^2 hybridisation, there must be 3σ-bonds or 2σ-bonds along with a lone pair of electrons.*

(i) $NO_2^- \Rightarrow 2\sigma + 1\,lp = 3$, i.e. sp^2 hybridisation
(ii) $NH_3 \Rightarrow 3\sigma + 1\,lp = 4$, i.e. sp^3 hybridisation
iii) $BF_3 \Rightarrow 3\sigma + 0\,lp = 3$, i.e. sp^2 hybridisation
(iv) $NH_2^- \Rightarrow 2\sigma + 2\,lp = 4$, i.e. sp^3 hybridisation
(v) $H_2O \Rightarrow 2\sigma + 2\,lp = 4$, i.e. sp^3 hybridisation

Thus, among the given pairs, only BF_3 and NO_2^- have sp^2 hybridisation.

47 In which one of the following species the central atom has the type of hybridisation which is not the same as that present in the other three? **[CBSE AIPMT 2010]**

(a) SF_4 (b) I_3^-
(c) $SbCl_5^{2-}$ (d) PCl_5

Ans. *(c)*

Key Idea Molecules having same hybridisation have same number of hybrid orbitals,

$$H = \frac{1}{2}[V + X - C + A]$$

where,

V = number of valence electrons of central atom
X = number of monovalent atoms
C = charge on cation
A = charge on anion

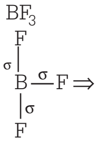
$SbCl_5^{2-} = sp^3d^2$, $PCl_5 = sp^3d$
$SF_4 = sp^3d$, $I_3^- = sp^3d$

48 In which of the following molecules/ions BF_3, NO_2^-, NH_2^- and H_2O, the central atom is sp^2 hybridised? **[CBSE AIPMT 2009]**

(a) NO_2^- and NH_2^- (b) NH_2^- and H_2O
(c) NO_2^- and H_2O (d) BF_3 and NO_2^-

Ans. *(d)*

BF_3



$\Rightarrow 3\sigma$-bonds, i.e. sp^2 hybridisation

Planar structure

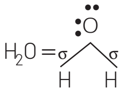
NO_2^-

$O{=}\ddot{N}{:}^{\ominus}{=}O \Rightarrow 2\sigma$-bonds +1 lone pair of electrons, i.e. sp^2 hybridisation

NH_2^-

$H\overset{\sigma}{-}\ddot{N}\overset{\sigma}{-}H \Rightarrow 2\sigma$-bonds +2 lone pairs, i.e. sp^3 hybridisation

$H_2O =$



$\Rightarrow 2\sigma$-bonds +2 lone pairs, i.e. sp^3 hybridisation, Thus, in BF_3 and NO_2^-, central atom is sp^2 hybridised, while NH_2, NH_3 and H_2O are sp^3 hybridised.

49 The angular shape of ozone molecule (O_3) consists of **[CBSE AIPMT 2008]**

(a) 1 sigma and 2 pi-bonds
(b) 2 sigma and 2 pi-bonds
(c) 1 sigma and 1 pi-bonds
(d) 2 sigma and 1 pi-bonds

Ans. *(d)*

In case of single bond, there is only one σ-bond, in case of double bond, there is one σ and one π-bonds while in case of triple bond, there is one σ and two π-bonds. Thus, angular shape of ozone (O_3) contains 2σ and 1π-bonds as shown below

• •

2 sigma and one π-bonds.

50 In which of the following pairs, the two species are isostructural? **[CBSE AIPMT 2007]**

(a) SF_4 and XeF_4
(b) SO_3^{2-} and NO_3^-
(c) BF_3 and NF_3
(d) BrO_3^- and XeO_3

Ans. *(d)*

(a) SF_4 = irregular tetrahedral (sp^3d, one lone pair)
XeF_4 = square planar (sp^3d^2, two lone pairs)
(b) SO_3^{2-} = pyramidal (sp^3, one lone pair)
NO_3^- = trigonal planar (sp^2)
(c) BF_3 = trigonal planar (sp^2)
NF_3 = pyramidal (sp^3)
(d) BrO_3^- = pyramidal (sp^3, one lone pair)
XeO_3 = pyramidal (sp^3, one lone pair)

51 Which of the following species has a linear shape? **[CBSE AIPMT 2006]**

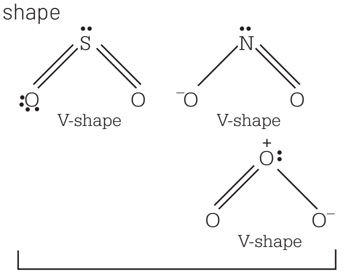
(a) NO_2^- (b) SO_2
(c) NO_2^+ (d) O_3

Ans. *(c)*

$\overset{+}{N}O_2$ has linear shape due to sp hybridisation of N in $\overset{+}{N}O_2$

$$O{=}\overset{+}{N}{=}O$$

While SO_2, NO_2^- and O_3 have angular shape



Angular shape (due to sp^2 hybridisation of central atom or ion)

52 Which of the following is not a correct statement? **[CBSE AIPMT 2006]**

(a) The electron deficient molecules can act as Lewis acids
(b) The canonical structures have no real existence
(c) Every AB_5 molecule does infact have square pyramid structure
(d) Multiple bonds are always shorter than corresponding single bond

Ans. *(c)*

Generally, AB_5 molecules have trigonal bipyramidal structure due to sp^3d hybridisation but in some cases due to presence of lone pair of electrons, its geometry becomes distorted.

53 Which of the following is not isostructural with $SiCl_4$? **[CBSE AIPMT 2006]**

(a) SCl_4 (b) SO_4^{2-}
(c) PO_4^{3-} (d) NH_4^+

Ans. *(a)*

SCl_4 is not isostructural with $SiCl_4$ because it shows square planar structure due to involvement of repulsion between lone pair and bond pair of electrons.

SO_4^{2-} shows tetrahedral structure due to sp^3 hybridisation.

PO_4^{3-} shows tetrahedral structure due to sp^3 hybridisation.

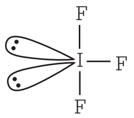
NH_4^+ shows tetrahedral structure due to sp^3 hybridisation.

54 Which of the following molecules has trigonal planar geometry? **[CBSE AIPMT 2005]**

(a) IF_3 (b) PCl_3
(c) NH_3 (d) BF_3

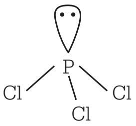
Ans. *(d)*

IF_3 has bent-T geometry



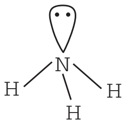
$2lp + 3\,bp = sp^3d$ hybridisation

PCl_3 has pyramidal geometry



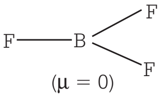
$1lp + 3\,bp = sp^3$ hybridisation

NH_3 has trigonal pyramidal geometry



$1lp + 3bp = sp^3$ hybridisation

BF_3 has trigonal planar geometry



$(\mu = 0)$

$3bp$ only $= sp^2$ (hydridisation)

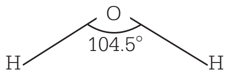
55 H_2O is dipolar, whereas BeF_2 is not. It is because **[CBSE AIPMT 2004]**

(a) the electronegativity of F is greater than that of O
(b) H_2O involves hydrogen bonding whereas BeF_2 is a discrete molecule
(c) H_2O is linear and BeF_2 is angular
(d) H_2O is angular and BeF_2 is linear

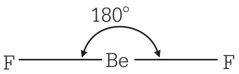
Ans. *(d)*

The structure of H_2O is angular or V-shape and has sp^3-hybridisation and

104.5° bond angle. Thus, its dipole moment is positive or more than zero.



But in BeF_2, structure is linear due to *sp* hybridisation ($\mu = 0$)



Thus, due to $\mu > 0$, H_2O is dipolar and due to $\mu = 0$, BeF_2 is non-polar.

56 In an octahedral structure, the pair of *d* orbitals involved in d^2sp^3-hybridisation is **[CBSE AIPMT 2004]**

(a) $d_{x^2-y^2}, d_{z^2}$ (b) $d_{xz}, d_{x^2-y^2}$

(c) d_{z^2}, d_{xz} (d) d_{xy}, d_{yz}

Ans. ***(a)***

In the formation of d^2sp^3 hybrid orbitals, two $(n-1)$ *d*-orbitals of e_g set, i.e. $(n-1)d_{z^2}$ and $(n-1)d_{x^2-y^2}$ orbitals, one *ns* and three *np* (np_x, np_y and np_z.) orbitals combine together.

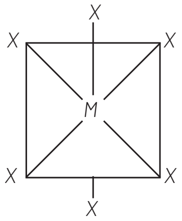
57 In a regular octahedral molecule, MX_6 the number of $X—M—X$ bonds at 180° is **[CBSE AIPMT 2004]**

(a) 3 (b) 2

(c) 6 (d) 4

Ans. ***(a)***

In octahedral structure MX_6, the six hybrid orbitals (sp^3d^2) are directed towards the cornes of a regular octahedral with an angle of 90°. According to following structure of MX_6, the number of $X—M—X$ bonds at 180° must be three.



58 Among the following, the pair in which the two species are not isostructural, is **[CBSE AIPMT 2004]**

(a) SiF_4 and SF_4 (b) IO_3^- and XeO_3

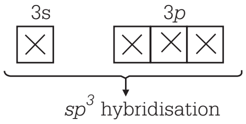
(c) BH_4^- and NH_4^+ (d) PF_6^- and SF_6

Ans. ***(a)***

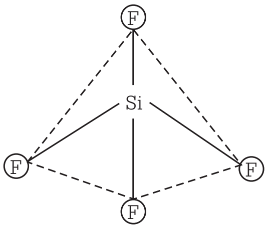
SiF_4 and SF_4 are not isostructural because SiF_4 is tetrahedral due to sp^3 hybridisation of Si.

$_{14}Si = 1s^2, 2s^2, 2p^6, 3s^2 3p^2$ (in ground state)

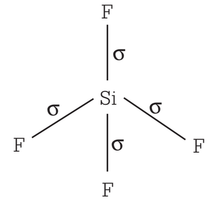
$_{14}Si = 1s^2, 2s^2 2p^6, 3s^1 3p^3$ (in excited state)



Hence, four equivalent sp^3 hybrid orbitals are obtained and they are overlapped by four *p*-orbitals of four fluorine atoms on their axis. Thus, it shows following structure :



or



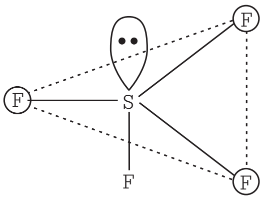
While SF_4 is not tetrahedral but it is arranged in trigonal bipyramidal geometry (has see saw shape) because in it S is sp^3d hybrid.

$$_{16}S = 1s^2, 2s^2 2p^6, 3s^2 3p_x^2 3p_y^1 3p_z^1$$

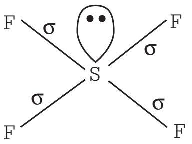
(in ground state)

$$= 1s^2, 2s^2 2p^6, \underbrace{3s^2 3p_x^1\ 3p_y^1\ 3p_z^1\ 3d_{xy}^1}_{sp^3d\text{ hybridisation}}$$

(in first excitation state)



or



Hence, five sp^3d hybrid orbitals are obtained. One orbital is already paired and rest four are overlapped with four *p*-orbitals of four fluorine atoms on their axis in trigonal bipyramidal form.

This structure is distorted from trigonal bipyramidal to tetrahedral due to involvement of repulsion between lone pair and bond pair.

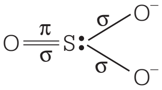
59 Which of the following has $p\pi$ - $d\pi$ bonding? **[CBSE AIPMT 2002]**

(a) NO_3^- (b) SO_3^{2-}

(c) BO_3^{3-} (d) CO_3^{2-}

Ans. ***(b)***

In SO_3^{2-}, S is sp^3 hybridised, so



$$\underset{\text{(Sulphur atom in excited state)}}{_{16}S} = 1s^2, 2s^2 2p^6, \underbrace{3s^2 3p_x^1\ 3p_y^1 3p_z^1}_{sp^3\text{hybridisation}}$$

$3d_{xy}^1$
Unhybridised

In 'S' the three *p*-orbitals forms σ-bonds with three oxygen atoms and unhybridised *d*-orbital is involved in π-bond formation.

$$O_8 = 1s^2, 2s^2 2p_x^2\ 2p_y^1 2p_z^1$$

In oxygen two unpaired *p*-orbitals are present, one is involved in σ-bond formation while other is used in π-bond formation.

Thus in SO_3^{2-}, *p* and *d*-orbitals are involved for $p\pi$-$d\pi$ bonding.

60 Which of the following two are isostructural? **[CBSE AIPMT 2001]**

(a) XeF_2, and IF_2^- (b) NH_3, and BF_3

(c) CO_3^{2-}, and SO_3^{2-} (d) PCl_5, and ICl_5

Ans. ***(a)***

Compounds having same structure and same hybridisation are known as **isostructural species**. e.g.

XeF_2 and IF_2^- are sp^3d hybridised and both have linear shape.

$F—I^-—F$ $F—Xe—F$

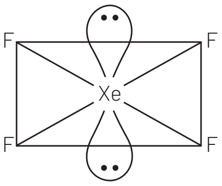
61 Which one of the following is planar? **[CBSE AIPMT 2000]**

(a) XeF_4 (b) XeO_4

(c) XeO_3F (d) XeO_3F_2

Ans. ***(a)***

Structure of XeF_4 is as follows



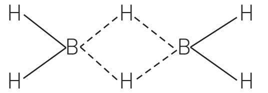
It involves sp^3d^2 hybridisation in Xe-atom. The molecules has square planar structure. Xe and four F-atoms are coplanar. The lone pairs are present on axial positions, minimise electron pair repulsion.

62 The type of hybridisation of boron in diborane is **[CBSE AIPMT 1999]**

(a) sp hybridisation
(b) sp^2 hybridisation
(c) sp^3 hybridisation
(d) sp^3d^2 hybridisation

Ans. ***(c)***

Each boron atom in diborane (B_2H_6) is sp^3 hybridised. In the structure of diborane four H-atoms, two on the left and two on the right, known as terminal hydrogens, are in different environments from the other two hydrogen atoms which are known as bridging atoms. The two boron atoms and the four terminal hydrogen atoms lie in the same plane while the two boron atoms and the two bridging hydrogen atoms, one above and the other below, lie in a plane perpendicular to this plane.



Structure of diborane molecule

63 AsF_5 molecule is trigonal bipyramidal. The hybrid orbitals used by As-atoms for bonding are **[CBSE AIPMT 1997]**

(a) $d_{x^2-y^2}, d_{z^2}, s, p_x, p_y$
(b) d_{xy}, s, p_x, p_y, p_z
(c) s, p_x, p_y, p_z, d_{xy}
(d) $d_{x^2-y^2}, s, p_x, p_y, p_z$

Ans. ***(c)***

$$As = 1s^2, 2s^2, 2p^6, \underbrace{3s^1 3p_x^1\ 3p_y^1\ 3p_z^1\ 3d^1}_{sp^3d \text{ hybridisation}}$$

Due to this hybridisation, geometry of the AsF_5 molecule is trigonal bipyramidal and the hybrid orbitals used by As-atom are s, p_x, p_y, p_z and d_{xy}.

64 Which of the following does not have a tetrahedral structure? **[CBSE AIPMT 1994]**

(a) BH_4^- (b) BH_3 (c) NH_4^+ (d) H_2O

Ans. ***(b)***

BH_3 have sp^2 hybridisation, so it have trigonal planar structure, not tetrahedral structure.

65 Among the following orbital bonds, the angle is minimum between **[CBSE AIPMT 1994]**

(a) sp^3 bonds
(b) p_x and p_y-orbitals
(c) H — O — H in water
(d) sp bonds

Ans. ***(b)***

When p_x and p_y form bond, then the bond angle is minimum and it is only 90°.

NOTE

Bond angle in sp^3 bonds, $H-O-H$ in water and in sp bonds are 109°28, 180° and 180° respectively.

66 When the hybridisation state of carbon atom changes from sp^3 to sp^2 and finally to sp, the angle between the hybridised orbitals **[CBSE AIPMT 1993]**

(a) decreases gradually
(b) decreases considerably
(c) is not affected
(d) increases progressively

Ans. ***(d)***

In sp^3 hybridisation bond angle is 109°28′.
In sp^2 hybridisation bond angle is 120°.
In sp hybridisation bond angle is 180°.

67 Which structure is linear? **[CBSE AIPMT 1992]**

(a) SO_2 (b) CO_2
(c) CO_3^{2-} (d) SO_4^{2-}

Ans. ***(b)***

Out of $SO_2, CO_3^{2-}, SO_4^{2-}$ and CO_2, CO_2 have sp hybridisation, thus have linear geometry.

68 An sp^3 hybrid orbital contains **[CBSE AIPMT 1991]**

(a) $\frac{1}{4}$ s-character
(b) $\frac{1}{2}$ s-character
(c) $\frac{1}{3}$ s-character
(d) $\frac{2}{3}$ s-character

Ans. ***(a)***

In sp^3 hybrid orbital one part, out of four orbital is s-orbital, so it have 25% or $\frac{1}{4}$ s-character.

69 In which one of the following molecules, the central atom said to adopt sp^2 hybridisation? **[CBSE AIPMT 1989]**

(a) BeF_2 (b) BF_3
(c) C_2H_2 (d) NH_3

Ans. ***(b)***

BeF_2 — sp hybridisation
BF_3 — sp^2 hybridisation
C_2H_2 — sp hybridisation
NH_3 — sp^3 hybridisation

70 Which of the following molecule does not have a linear arrangement of atoms? **[CBSE AIPMT 1989]**

(a) H_2S (b) C_2H_2
(c) BeH_2 (d) CO_2

Ans. ***(a)***

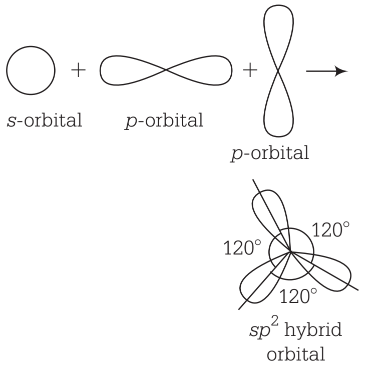
H_2S have sp^3 hybridisation while remaining all have sp hybridisation, so H_2S have bent structure and other have linear geometry.

71 Equilateral shape has **[CBSE AIPMT 1988]**

(a) sp hybridisation
(b) sp^2 hybridisation
(c) sp^3 hybridisation
(d) dsp^2 hybridisation

Ans. ***(a)***

Equilateral or triangular planar geometry is formed by sp^2 hybridisation.

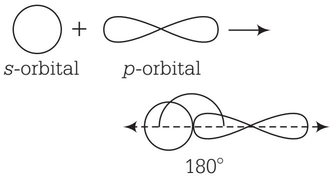


72 The angle between the overlapping of one s-orbital and one p-orbital is **[CBSE AIPMT 1988]**

(a) 180° (b) 120°
(c) 109°28′ (d) 120° 60′

Ans. ***(a)***

When s-orbital and p-orbital overlap each other, then the bond angle formed is 180° as given below



TOPIC 3

Molecular Orbital Theory, Hydrogen and Metallic Bonding

73 Identify a molecule which does not exist. **[NEET (Sep.) 2020]**

(a) Li_2 (b) C_2 (c) O_2 (d) He_2

Ans. ***(d)***

If bond order of a molecules becomes zero, the molecule will not exist.

Bond order

$$= \frac{\text{Number of bonding electrons} - \text{Number of antibonding electrons}}{2}$$

$$= \frac{N_b - N_a}{2}$$

$$Li_2(6e^-) \Rightarrow \sigma^2_{1s}\ \sigma^{*2}_{1s}\ \sigma^2_{2s};\ BO = \frac{4-2}{2} = 1$$

$$C_2\,(12e^-) \Rightarrow \sigma^2_{1s}\ \sigma^{*2}_{1s}\ \sigma^2_{2s}\ \sigma^{*2}_{2s}\ \pi_{2p_x} = \pi^2_{2p_y};\quad BO = \frac{8-4}{2} = 2$$

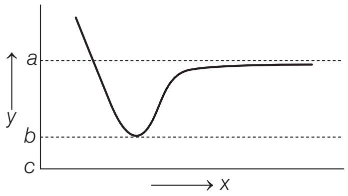
$$O_2\,(16e^-) \Rightarrow \sigma^2_{1s}\ \sigma^{*2}_{1s}\ \sigma^2_{2s}\ \sigma^{*2}_{2s}\ \sigma^2_{2p_z}\ \pi^2_{2p_x} = \pi^2_{2p_y}\ \pi^{*1}_{2p_x} = \pi^{*1}_{2p_y};$$

$$BO = \frac{10-6}{2} = 2$$

$$He_2(4e^-) = \sigma^2_{1s}\ \sigma^{*2}_{1s};\ BO = \frac{2-2}{2} = 0$$

So, He_2 does not exist.

74 The potential energy (y) curve for H_2 formation as a function of internuclear distance (x) of the H-atoms is shown below. **[NEET (Oct.) 2020]**

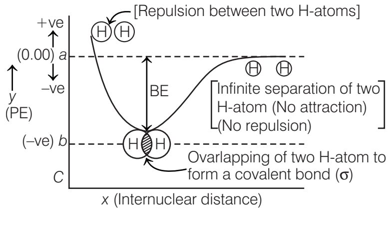


The bond energy of H_2 is

(a) $(b-a)$ (b) $\frac{(c-a)}{2}$

(c) $\frac{(b-a)}{2}$ (d) $(c-a)$

Ans. ***(a)***



From the information mentioned in the above curve, bond energy (BE) of H_2 molecule is $(b-a)$ or $|b-a|$.

75 Which of the following diatomic molecular species has only π-bonds according to molecular orbital theory? **[NEET (National) 2019]**

(a) N_2 (b) C_2

(c) Be_2 (d) O_2

Ans. ***(b)***

The molecular orbital configuration of C_2 is

$$C_2(Z=12) = \sigma 1s^2, \sigma^* 1s^2, \sigma 2s^2, \sigma^* 2s^2, \pi 2p_x^2 = \pi 2p_y^2.$$

Double bond in C_2 consists of both π-bonds because of the presence of last (valence) four electrons in two π-molecular orbitals.

The configuration of N_2, Be_2 and O_2 are as follows:

$N_2(Z=14) - \sigma 1s^2, \sigma^* 1s^2, \sigma 2s^2, \sigma^* 2s^2, \pi 2p_x^2 = \pi 2p_y^2, \sigma 2p_z^2$ (1 σ and 2 π-bonds)

$Be_2(Z=8) - \sigma 1s^2, \sigma^* 1s^2, \sigma 2s^2, \sigma^* 2s^2$ (σ bonds only)

$O_2(Z=16) - \sigma 1s^2, \sigma^* 1s^2, \sigma 2s^2, \sigma^* 2s^2, \sigma^* 2p_z^2, \pi 2p_x^2 = \pi 2p_y^2, \pi^* 2p_x^1 = \pi^* 2p_z^1$ (σ, π and 1π^* bond)

Hence, option (b) is correct.

76 Which of the following is paramagnetic? **[NEET (Odisha) 2019]**

(a) N_2 (b) H_2

(c) Li_2 (d) O_2

Ans. ***(d)***

Key Idea If all the electron in a molecule are paired, the molecule is diamagnetic and if there are unpaired electrons in a molecule, it is paramagnetic.

Molecular orbital configuration of given molecules are as follows:

(a) $N_2(Z=14) - \sigma 1s^2, \sigma^* 1s^2, \sigma 2s^2, \sigma^* 2s^2, \pi 2p_x^2 = \pi 2p_y^2, \sigma 2p_z^2$
It is a diamagnetic molecule due to absence of unpaired electron.

(b) $H_2(Z=2) - 1\sigma^2$
It is a diamagnetic molecule.

(c) $Li_2\ (Z=6) - \sigma 1s^2, \sigma^* 1s^2, \sigma 2s^2$
It is a diamagnetic molecule.

(d) $O_2(Z=16) - \sigma 1s^2, \sigma^* 1s^2, \sigma 2s^2, \sigma^* 2s^2, \sigma 2p_z^2, \pi 2p_x^2 = \pi 2p_y^2, \pi^* 2p_x^1 = \pi^* 2p_y^1$
It is a paramagnetic molecule due to presence of unpaired electrons in each orbital of degenerate levels.

Thus, option (d) is correct.

77 Consider the following species CN^+, CN^-, NO and CN

Which one of these will have the highest bond order? **[NEET 2018]**

(a) CN^+ (b) CN^-

(c) NO (d) CN

Ans. ***(b)***

The formula of bond order is given as

$$B.O. = \frac{\begin{bmatrix}\text{No. of electrons}\\ \text{in bonding}\end{bmatrix} - \begin{bmatrix}\text{No. of electrons}\\ \text{in antibonding}\end{bmatrix}}{2}$$

Energy level pattern for molecular orbitals of different molecules depends upon their central atom.

NO : Central atom is N
(Total number of electrons = 15)

$$\therefore\quad \sigma 1s^2, \sigma^* 1s^2, \sigma 2s^2, \sigma^* 2s^2, (\pi 2p_x^2 \simeq \pi 2p_y^2), \sigma 2p_z^2, (\pi 2^{*1}_{px} \approx \pi 2^{*0}_{py})$$

$$B.O. = \frac{10-5}{2} = 2.5$$

CN^- : Central atom is C
[Total number of electrons = 14]

$$\sigma 1s^2, \sigma^* 1s^2, \sigma 2s^2, \sigma^* 2s^2, (\pi 2px^2 \approx \pi 2py^2\ \sigma 2p_z^2)$$

$$B.O. = \frac{10-4}{2} = 3$$

CN : Central atom is C
[Total number of electrons = 13]

$$\sigma 1s^2, \sigma^* 1s^2, \sigma 2s^2, \sigma^* 2s^2, (\pi 2p_x^2 \approx \pi 2p_y^2), \sigma 2p_z^1$$

$$B.O = \frac{9-4}{2} = 2.5$$

CN^+ : Central atom is C
[Total number of electrons = 12]

$$\sigma 1s^2, \sigma^* 1s^2, \sigma 2s^2, \sigma^* 2s^2, (\pi 2p_x^2 \approx \pi 2p_y^2)$$

$$B.O = \frac{8-4}{2} = 2$$

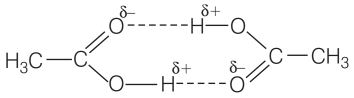
Therefore, option (b) is correct.

78 Which one of the following compounds shows the presence of intramolecular hydrogen bond? **[NEET 2016, Phase II]**

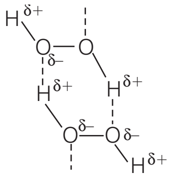
(a) H_2O_2
(b) HCN
(c) Cellulose
(d) Concentrated acetic acid

Ans. ***(c)***

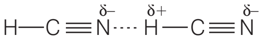
Intermolecular hydrogen bonding is present in concentrated acetic acid, H_2O_2 and HCN while cellulose has intramolecular hydrogen bonding as shown below :



Concentrated Acetic Acid

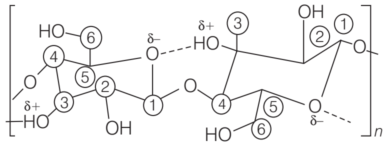


H_2O_2



$\overset{}{H—C≡}\overset{\delta-}{N}\cdots\overset{\delta+}{H}—C≡\overset{\delta-}{N}$

HCN



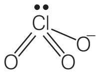
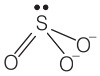
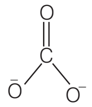
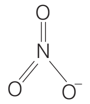
Cellulose

In above molecules, dotted lines represent hydrogen bonding.

79 Which of the following pairs of ions is isoelectronic and isostructural? **[NEET 2016, Phase II]**

(a) CO_3^{2-}, NO_3^- (b) ClO_3^-, CO_3^{2-}
(c) SO_3^{2-}, NO_3^- (d) ClO_3^-, SO_3^{2-}

Ans. *(a) and (d)*

Species	Total number of electrons	Structure	Shape
ClO_3^-	42		Pyramidal
SO_3^{2-}	42		Pyramidal
CO_3^{2-}	32		Trigonal planar
NO_3^-	32		Trigonal planar

Hence both options (a) and (d) are correct.

80 Which of the following options represents the correct bond order? **[CBSE AIPMT 2015]**

(a) $O_2^- > O_2 > O_2^+$ (b) $O_2^- < O_2 < O_2^+$
(c) $O_2^- > O_2 < O_2^+$ (d) $O_2^- < O_2 > O_2^+$

Ans. *(b)*

Bond order of O_2^-

$O_2^- = \sigma 1s^2, \overset{*}{\sigma} 1s^2, \sigma 2s^2, \overset{*}{\sigma} 2s^2$

$$\sigma 2p_z^2 (\pi 2p_x^2 = \pi 2p_y^2)(\pi^* 2p_x^1 = \pi^* 2p_y^1)$$

Bond order

$$= \frac{\text{number of electrons in BMO} - \text{number of elections ABMO}}{2}$$

$$= \frac{10-7}{2} = \frac{3}{2} = 1.5$$

$$O_2^+ = \sigma 1s^2, \overset{*}{\sigma} 1s^2, \sigma 2s^2, \overset{*}{\sigma} 2s^2 \ \sigma 2p_z^2$$

$$(\pi 2p_x^2 = \pi 2p_y^2)(\pi^* 2p_x^1 = \pi^* 2p_y^0)$$

$$BO = \frac{10-5}{2} = \frac{5}{2} = 2.5$$

$$O_2 = \sigma 1s^2 \ \overset{*}{\sigma} 1s^2, \sigma 2s^2, \overset{*}{\sigma} 2s^2 \sigma 2p_z^2$$

$$(\pi 2p_x^2 = \pi 2p_y^2)\ (\overset{*}{\pi} 2p_x^1 = \overset{*}{\pi} 2p_y^1)$$

$$BO = \frac{10-6}{2} = \frac{4}{2} = 2$$

So, the correct sequence is

$$O_2^- < O_2 < O_2^+$$

81 Which of the following is paramagnetic? **[NEET 2013]**

(a) CO (b) O_2^-
(c) CN^- (d) NO^+

Ans. *(b)*

Paramagnetic species contains unpaired electrons in their molecular orbital electronic configuration.

Molecular orbital configuration of the given species is as

$$CO\ (6+8=14)$$

$$= \sigma 1s^2, \overset{*}{\sigma} 1s^2, \sigma 2s^2, \overset{*}{\sigma} 2s^2, \pi 2p_x^2 \approx \pi 2p_y^2, \sigma 2p_z^2$$

(All the electrons are paired so, it is diamagnetic).

$$O_2^-\ (8+8+1=17)$$

$$= \sigma 1s^2, \overset{*}{\sigma} 1s^2, \sigma 2s^2, \overset{*}{\sigma} 2s^2, \sigma 2p_z^2, \pi 2p_x^2 \approx \pi 2p_y^2, \ \overset{*}{\pi} 2p_x^2 \approx \overset{*}{\pi} 2p_y^1$$

(It contains one unpaired electron so, it is paramagnetic.)

CN^- $(6+7+1=14)$ = same as CO

NO^+ $(7+8-1=14)$ = same as CO

Thus, among the given species only O_2^- is paramagnetic.

82 Bond order of 1.5 is shown by **[NEET 2013]**

(a) O_2^+ (b) O_2^-
(c) O_2^{2-} (d) O_2

Ans. *(b)*

Molecular orbital configuration of O_2^+ $(8+8-1=15)$

$$= \sigma 1s^2, \overset{*}{\sigma} 1s^2, \sigma 2s^2, \overset{*}{\sigma} 2s^2, \sigma 2p_z^2,$$

$$\pi 2p_x^2 \approx \pi 2p_y^2, \overset{*}{\pi} 2p_x^1 \approx \overset{*}{\pi} 2p_y^0$$

$$\text{Bond order (BO)} = \frac{N_b - N_a}{2}$$

(where, N_b = number of electrons in bonding molecular orbital,

N_a = number of electrons in antibonding molecular orbital)

$$\therefore \quad BO = \frac{10-5}{2} = 2.5$$

Similarly,

(b) O_2^- $(8+8+1=17)$

so, $BO = \dfrac{N_b - N_a}{2} = \dfrac{10-7}{2} = 1.5$

(c) O_2^{2-} $(8+8+2=18)$

$$BO = \frac{N_b - N_a}{2} = \frac{10-8}{2} = 1$$

(d) O_2 $(8+8=16)$

$$BO = \frac{10-6}{2} = 2$$

Thus, O_2^- shows the bond order 1.5.

83 The pair of species with the same bond order is **[NEET 2013]**

(a) O_2^{2-}, B_2 (b) O_2^+, NO^+
(c) NO, CO (d) N_2, O_2

Ans. *(a)*

According to molecular orbital theory,

O_2^{2-} $(8+8+2=18)$

$$= \sigma 1s^2, \overset{*}{\sigma} 1s^2, \sigma 2s^2, \overset{*}{\sigma} 2s^2, \sigma 2p_z^2, \pi 2p_x^2 \approx \pi 2p_y^2, \ \overset{*}{\pi} 2p_x^2 \approx \overset{*}{\pi} 2p_y^2$$

$$\text{Bond order (BO)} = \frac{N_b - N_a}{2} = \frac{10-8}{2} = 1$$

$$B_2 (5+5=10) = \sigma 1s^2, \overset{*}{\sigma} 1s^2, \sigma 2s^2, \overset{*}{\sigma} 2s^2, \pi 2p_x^1 \approx \pi 2p_y^1$$

$$BO = \frac{6-4}{2} = 1$$

Thus, O_2^{2-} and B_2 have the same bond order.

NOTE

BO of $O_2^+ = 2.5$, $NO^+ = 3$, $NO = 2.5$, $CO = 3$, $N_2 = 3$ and $O_2 = 2$

84 Which of the following has the minimum bond length? **[CBSE AIPMT 2011]**

(a) O_2^- (b) O_2^{2-}
(c) O_2 (d) O_2^+

Ans. *(d)*

Bond order of $O_2^+ = \dfrac{10-5}{2} = 2.5$

Bond order of $O_2^- = \frac{10-7}{2} = 1.5$

Bond order of $O_2^{2-} = \frac{10-8}{2} = 1$

Bond order of $O_2 = \frac{10-6}{2} = 2$

$\because$ Maximum bond order = minimum bond length.

$\therefore$ Bond length is minimum for O_2^+

85 Which one of the following species does not exist under normal conditions? **[CBSE AIPMT 2010]**

(a) Be_2^+ (b) Be_2
(c) B_2 (d) Li_2

Ans. *(b)*

Key Idea *Molecules with zero bond order, do not exist.*

According to molecular orbital theory,

(a) Be_2^+ $(4+4-1=7)$

$= \sigma 1s^2, \overset{*}{\sigma} 1s^2, \sigma 2s^2, \overset{*}{\sigma} 2s^1$

$$\text{Bond order (BO)} = \frac{4-3}{2} = 0.5$$

(b) Be_2 $(4+4=8)$

$= \sigma 1s^2, \overset{*}{\sigma} 1s^2, \sigma 2s^2, \overset{*}{\sigma} 2s^2$

$$BO = \frac{4-4}{2} = 0$$

(c) $B_2 (5+5=10)$

$= \sigma 1s^2, \overset{*}{\sigma} 1s^2, \sigma 2s^2, \overset{*}{\sigma} 2s^2, \pi 2p_x^1 \approx \pi 2p_y^1$

$$\text{Bond order (BO)} = \frac{6-4}{2} = 1$$

(d) Li_2 $(3+3=6) = \sigma 1s^2, \overset{*}{\sigma} 1s^2, \sigma 2s^2$

$$BO = \frac{4-2}{2} = 1$$

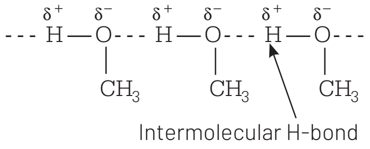
Thus, Be_2 does not exist under normal conditions.

86 What is the dominant intermolecular force on bond that must be overcome in converting liquid CH_3OH to a gas? **[CBSE AIPMT 2009]**

(a) Hydrogen bonding
(b) Dipole-dipole interaction
(c) Covalent bonds
(d) London or dispersion force

Ans. *(a)*

In between CH_3OH molecules intermolecular H-bonding exist.



Hence, it is the intermolecular H-bonding that must be overcome in converting liquid CH_3OH to gas.

87 According to molecular orbital theory which of the following lists rank the nitrogen species in terms of increasing bond order? **[CBSE AIPMT 2009]**

(a) $N_2^- < N_2 < N_2^{2-}$ (b) $N_2^{2-} < N_2^- < N_2$
(c) $N_2 < N_2^{2-} < N_2^-$ (d) $N_2^- < N_2^{2-} < N_2$

Ans. *(b)*

According to the molecular orbital theory (MOT),

$$N_2 (7+7=14) = \sigma 1s^2, \overset{*}{\sigma} 1s^2, \sigma 2s^2, \overset{*}{\sigma} 2s^2, \pi 2p_x^2 \approx 2p_y^2, \sigma 2p_z^2$$

$$\text{Bond order} = \frac{10-4}{2} = 3$$

$N_2^- (7+7+1=15)$

$= \sigma 1s^2, \overset{*}{\sigma} 1s^2, \sigma 2s^2, \overset{*}{\sigma} 2s^2, \sigma 2p_z^2, \pi 2p_x^2 \approx 2p_y^2, \overset{*}{\pi} 2p_x^1$

$$BO = \frac{10-5}{2} = 2.5$$

$N_2^{2-} (7+7+2=16)$

$= \sigma 1s^2, \overset{*}{\sigma} 1s^2, \sigma 2s^2, \overset{*}{\sigma} 2s^2, \sigma 2p_z^2, \pi 2p_x^2 \approx \pi 2p_y^2, \overset{*}{\pi} 2p_x^1 \approx \overset{*}{\pi} 2p_y^1$

$$BO = \frac{10-6}{2} = 2$$

Hence, the increasing order of bond order is,

$$N_2^{2-} < N_2^- < N_2$$

88 Four diatomic species are listed below in different sequences. Which of these presents the correct order of their increasing bond order? **[CBSE AIPMT 2008]**

(a) $O_2^- < NO < C_2^{2-} < He_2^+$
(b) $NO < C_2^{2-} < O_2^- < He_2^+$
(c) $C_2^{2-} < He_2^+ < NO < O_2^-$
(d) $He_2^+ < O_2^- < NO < C_2^{2-}$

Ans. *(d)*

The molecular orbital configuration of

$O_2^- (8+8+1=17) = \sigma 1s^2, \overset{*}{\sigma} 1s^2, \sigma 2s^2, \overset{*}{\sigma} 2s^2, \sigma 2p_x^2, \pi 2p_y^2 \approx \pi 2p_z^2, \overset{*}{\pi} 2p_y^2 \approx \overset{*}{\pi} 2p_z^1$

$$\text{Bond order (BO)} = \frac{N_b - N_a}{2} = \frac{10-7}{2} = 1.5$$

$NO (7+8=15) = \sigma 1s^2, \overset{*}{\sigma} 1s^2, \sigma 2s^2, \overset{*}{\sigma} 2s^2, \sigma 2p_x^2$

$\pi 2p_y^2 \approx \pi 2p_z^2, \overset{*}{\pi} 2p_y^1 \approx \overset{*}{\pi} 2p_z^0$

$$BO = \frac{10-5}{2} = 2.5$$

$C_2^{2-} (6+6+2=14) = \sigma 1s^2, \overset{*}{\sigma} 1s^2, \sigma 2s^2, \overset{*}{\sigma} 2s^2, \pi 2p_y^2 \approx \pi 2p_z^2, \sigma 2p_x^2$

$$BO = \frac{10-4}{2} = 3$$

$He_2^+ (2+2-1=3) = \sigma 1s^2, \overset{*}{\sigma} 1s^1$

$$BO = \frac{2-1}{2} = \frac{1}{2} = 0.5$$

Hence, order of increasing bond order is

$$He_2^+ < O_2^- < NO < C_2^{2-}$$

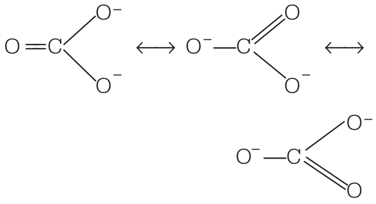
89 The correct order of C—O bond length among CO, CO_3^{2-}, CO_2 is **[CBSE AIPMT 2007]**

(a) $CO_2 < CO_3^{2-} < CO$
(b) $CO < CO_3^{2-} < CO_2$
(c) $CO_3^{2-} < CO_2 < CO$
(d) $CO < CO_2 < CO_3^{2-}$

Ans. *(d)*

A bond length is the average distance between the centres of nuclei of two bonded atoms. A multiple bond (double or triple bonds) is always shorter than the corresponding single bond.

The C-atom in CO_3^{2-} is sp^2 hybridised as shown:



The C-atom in CO_2 is sp hybridised with bond distance carbon-oxygen is 122 pm.

$$O{=}C{=}O \longleftrightarrow {}^{+}O{\equiv}C{-}\bar{O} \longleftrightarrow \bar{O}{-}C{\equiv}\overset{+}{O}$$

The C-atom in CO is sp hybridised with C—O bond distance is 110 pm.

$$:C{\equiv}O^{+}:$$

So, the correct order is

$$CO < CO_2 < CO_3^{2-}$$

90 The number of unpaired electrons in a paramagnetic diatomic molecule of an element with atomic number 16 is **[CBSE AIPMT 2006]**

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

Ans. *(a)*

Suppose the diatomic molecule is X.

Then, molecular orbital electronic configuration of

$$_{16}X = \sigma 1s^2, \overset{*}{\sigma} 1s^2, \sigma 2s^2, \overset{*}{\sigma} 2s^2, \sigma 2p_z^2, \pi 2p_x^2$$

$$\approx \pi 2p_y^2, \overset{*}{\pi} 2p_x^1 \approx \overset{*}{\pi} 2p_y^1$$

Due to presence of two unpaired electrons, it shows paramagnetic character.

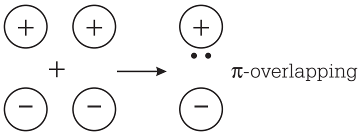
91 Main axis of a diatomic molecule is z molecular orbital, p_x and p_y overlaps to form which of the following orbitals?

[CBSE AIPMT 2001]

(a) π-molecular orbital
(b) σ-molecular orbital
(c) δ-molecular orbital
(d) No bond will form

Ans. *(a)*

For π-overlap the lobes of the atomic orbitals are perpendicular to the line joining the nuclei.



92 In $X - H - - - Y$, X and Y both are electronegative elements, then

[CBSE AIPMT 2001]

(a) electron density on X will increase and on H will decrease
(b) in both electron density will increase
(c) in both electron density will decrease
(d) on X electron density will decrease and on H increase

Ans. *(a)*

In $X - H$ ----- Y, X and Y both are electronegative elements, then electron density on X will increase and on H will decrease.

93 A compound contains atoms of three elements A, B and C. If the oxidation number of A is +2, B is +5 and that of C is −2, the possible formula of the compound is

[CBSE AIPMT 2000]

(a) $A_2(BC_3)_2$
(b) $A_3(BC_4)_2$
(c) $A_3(B_4C)_2$
(d) ABC_2

Ans. *(b)*

In $A_3(BC_4)_2$

$3 \times$ oxidation number of A

$+ 2$ [oxidation number of $B + 4 \times$ oxidatio oxidation number of C] $= 0$

$$3 \times (+2) + 2[5 + 4 \times (-2)] = 0$$

$$6 + 2[-3] = 0$$

94 Among the following group which represents the collection of isoelectronic species?

[CBSE AIPMT 2000]

(a) NO, CN^-, N_2, O_2^-
(b) NO^+, C_2^{2-}, O_2^-, CO
(c) N_2, C_2^{2-}, CO, NO
(d) CO, NO^+, CN^-, C_2^{2-}

Ans. *(d)*

Species having equal number of electrons are known as **isoelectronic species**.

Number of electrons,

$$\text{In CO} = 6 + 8 = 14$$
$$\text{In NO}^+ = 7 + 8 - 1 = 14$$
$$\text{In CN}^- = 6 + 7 + 1 = 14$$
$$\text{In C}_2^{2-} = 12 + 2 = 14$$

Hence, all have 14 electrons, so they are isoelectronic species.

95 Which one of the following is not paramagnetic? **[CBSE AIPMT 2000]**

(a) NO
(b) N_2^+
(c) CO
(d) O_2^-

Ans. *(c)*

Paramagnetic character is shown by those atoms or molecules which have unpaired electrons.

In the given compounds CO is not paramagnetic since, it does not have unpaired electrons. The configuration of CO molecule is

$$CO(14) = \sigma 1s^2, \overset{*}{\sigma} 1s^2, \sigma 2s^2, \overset{*}{\sigma} 2s^2, \sigma 2p_x^2,$$
$$\pi 2p_y^2 \approx \pi 2p_z^2$$

96 The relationship between the dissociation energy of N_2 and N_2^+ is

[CBSE AIPMT 2000]

(a) dissociation energy of N_2^+ > dissociation energy of N_2
(b) dissociation energy of N_2 = dissociation energy of N_2^+
(c) dissociation energy of N_2 > dissociation energy of N_2^+
(d) dissociation energy of N_2 can either be lower or higher than the dissociation energy of N_2^+

Ans. *(c)*

The dissociation energy will be more when the bond order will be greater and bond order ∝ dissociation energy

Molecular orbital configuration of

$$N_2(14) = \sigma 1s^2, \overset{*}{\sigma} 1s^2, \sigma 1s^2, \overset{*}{\sigma} 2s^2, \pi 2p_y{}^2$$
$$\approx \pi 2p_z{}^2, \sigma 2p_x{}^2$$

So, bond order of

$$N_2 = \frac{N_b - N_a}{2} = \frac{10 - 4}{2} = 3$$

and bond order of $N_2{}^+ = \frac{9-4}{2} = 2.5$

As the bond order of N_2 is greater than $N_2{}^+$ so, the dissociation energy of N_2 will be greater than $N_2{}^+$.

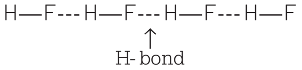
97 Which one of the following molecules will form a linear polymeric structure due to hydrogen bonding?

[CBSE AIPMT 2000]

(a) NH_3
(b) H_2O
(c) HCl
(d) HF

Ans. *(d)*

HF molecules have linear polymeric structure due to hydrogen bonding.


H—F---H—F---H—F---H—F

H-bond

98 The number of antibonding electron pairs in O_2^{2-} molecular ion on the basis of molecular orbital theory is (at. no. of O is 8)

[CBSE AIPMT 1998]

(a) 5
(b) 2
(c) 4
(d) 6

Ans. *(c)*

Total number of electrons in $O_2^{2-} = 19 + 2 = 18$

According to MOT, the configuration of O_2^{2-} is

$$\sigma 1s^2, \overset{*}{\sigma} 1s^2, \sigma 2s^2, \overset{*}{\sigma} 2s^2, \sigma 2p_x^2, \pi 2p_y^2 \approx$$
$$\pi 2p_z^2, \overset{*}{\pi} 2p_y^2 \approx \overset{*}{\pi} 2p_z^2$$

So, the number of antibonding electron pairs $= 4$

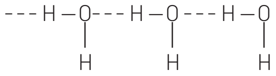
99 The high density of water compared to ice is due to

[CBSE AIPMT 1997]

(a) hydrogen bonding interactions
(b) dipole-dipole interactions
(c) dipole-induced dipole interactions
(d) induced dipole-induced dipole interactions

Ans. *(a)*

Due to polar nature, water molecules show intermolecular hydrogen bonding as


$$---H-\underset{|}{\overset{}{O}}---H-\underset{|}{O}---H-\underset{|}{O}$$
$$\quad\quad H \quad\quad H \quad\quad H$$

Hydrogen bonding

whereas the ice has open structure with large number of vacant spaces. So, density of ice is lower than water.

100 N_2 and O_2 are converted into monoanions N_2^- and O_2^- respectively. Which of the following statements is wrong? **[CBSE AIPMT 1997]**

(a) In N_2, the N—N bond weakens
(b) In O_2^-, O—O bond length increases
(c) In O_2^-, bond order decreases
(d) N_2^-, becomes diamagnetic

Ans. ***(d)***

In N_2^- total electrons $= 14 + 1 = 15$

Electronic configuration of N_2^- is

$$\sigma 1s^2, \overset{*}{\sigma} 1s^2, \sigma 2s^2, \overset{*}{\sigma} 2s^2, \sigma 2p_x^2,$$
$$\pi 2p_y^2 \approx \pi 2p_z^2, \overset{*}{\pi} 2p_y^1$$

Due to presence of one unpaired electron, it shows paramagnetic character.

101 The ion that is isoelectronic with CO is **[CBSE AIPMT 1997]**

(a) O_2^- (b) N_2^+
(c) O_2^+ (d) CN^-

Ans. ***(d)***

Isoelectronic species are having same number of electrons.

Number of electrons in $CO = 6 + 8 = 14$

Number of electrons in $O_2^- = 16 + 1 = 17$

Number of electrons in $N_2^+ = 14 - 1 = 13$

Number of electrons in $O_2^+ = 16 - 1 = 15$

Number of electrons in $CN^- = 6 + 7 + 1 = 14$

Hence, CO isoelectronic with CN^- ion.

102 The correct order of N — O bond lengths in NO, NO_2^-, NO_3^- and N_2O_4 is **[CBSE AIPMT 1996]**

(a) $N_2O_4 > NO_2^- > NO_3^- > NO$
(b) $NO > NO_3^- > N_2O_4 > NO_2^-$
(c) $NO_3^- > NO_2^- > N_2O_4 > NO$
(d) $NO > N_2O_4 > NO_2^- > NO_3^-$

Ans. ***(c)***

As the bond order increases, bond length decreases and bond order is highest for NO, i.e. 2.5 and least for NO_3^-, i.e. 1.33. So, the order of bond length is

$$\underset{1.33}{NO_3^-} > \underset{1.5}{NO_2^-} > \underset{1.5}{N_2O_4} > \underset{2.5}{NO}$$

103 The ground state electronic configuration of valence shell electrons in nitrogen molecule (N_2) is written as $KK, \sigma 2s^2, \sigma^* 2s^2, \sigma 2p_x^2, \pi 2p_y^2 \approx \pi 2p_z^2$ Bond order in nitrogen molecule is **[CBSE AIPMT 1995]**

(a) 0 (b) 1
(c) 0 (d) 3

Ans. ***(d)***

The MO configuration of N_2 is

$KK, \sigma 2s^2, {}^*\sigma 2s^2, \sigma 2p_x^2, \pi 2p_y^2 \approx \pi 2p_z^2$

Bond order of

$$N_2 = \frac{1}{2}[N_b - N_a]$$
$$= \frac{1}{2}[8 - 2]$$
$$= \frac{6}{2} = 3$$

104 The correct order of the O — O bond length in O_2, H_2O_2 and O_3 is **[CBSE AIPMT 1995]**

(a) $O_2 > O_3 > H_2O_2$ (b) $O_3 > H_2O_2 > O_2$
(c) $O_2 > H_2O_2 > O_3$ (d) $H_2O_2 > O_3 > O_2$

Ans. ***(d)***

The bond length of O—O in H_2O_2 is 147.5 pm, in O_3 is 128 pm and in O_2 it is 121 pm, so the correct order is $O_2 < O_3 < H_2O_2$.

105 Which of the following species is paramagnetic? **[CBSE AIPMT 1995]**

(a) O_2^{2-} (b) NO
(c) CO (d) CN^-

Ans. ***(b)***

The molecular orbital configuration of NO is

$$KK(\sigma 2s)^2 (\overset{*}{\sigma} 2s)^2 (\sigma 2p_x)^2 (\pi 2p_y)^2$$
$$(\pi 2p_z)^2 (\overset{*}{\pi} 2p_y)^1$$

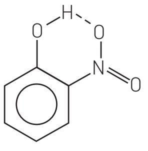
So, NO is paramagnetic because it contains one unpaired electron.

106 The boiling point of *p*-nitrophenol is higher than that of *o*-nitrophenol because **[CBSE AIPMT 1994]**

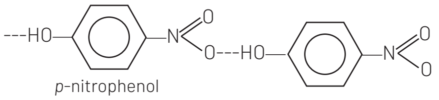
(a) NO_2 group at *p*-position behave in a different way from that at *o*-position
(b) intramolecular hydrogen bonding exists in *p*-nitrophenol
(c) there is intermolecular hydrogen bonding in *p*-nitrophenol
(d) *p*-nitrophenol has a higher molecular weight than *o*-nitrophenol

Ans. ***(c)***

The boiling point of *p*-nitrophenol is higher than that of *o*-nitrophenol because *p*-nitrophenol have intermolecular hydrogen bonding whereas *o*-nitrophenol have intramolecular H-bonding as given below



o-nitrophenol



p-nitrophenol

107 Linus Pauling received the Nobel Prize for his work on **[CBSE AIPMT 1994]**

(a) atomic structure
(b) photosynthesis
(c) chemical bonds
(d) thermodynamics

Ans. ***(c)***

Linus Pauling contributed to chemical bonding, so, he received the Nobel Prize for his work in chemical bonding.

108 Mark the incorrect statement in the following. **[CBSE AIPMT 1994]**

(a) The bond order in the species O_2, O_2^+ and O_2^- decreases as $O_2^+ > O_2 > O_2^-$
(b) The bond energy in a diatomic molecule always increases when an electron is lost
(c) Electrons in antibonding MO contribute to repulsion between two atoms
(d) With increase in bond order, bond length decreases and bond strength increases

Ans. ***(b)***

When a diatomic molecule lost electron, then its bond order may increase or decrease, so its bond energy may decrease or increase.

109 The dielectric constant of H_2O is 80. The electrostatic force of attraction between Na^+ and Cl^- will be **[CBSE AIPMT 1994]**

(a) reduced to $\frac{1}{40}$ in water than in air
(b) reduced to $\frac{1}{80}$ in water than in air
(c) will be increased to 80 in water than in air
(d) will remain unchanged

Ans. *(b)*

Water is a polar solvent and have dielectric constant 80. As NaCl is a polar compound and like dissolves like so, forces of attraction between Na^+ and Cl^- ion will reduce to $\frac{1}{80}$ in water.

110 Linear combination of two hybridised orbitals belonging to the two atoms, each having one electron leads to a

[CBSE AIPMT 1990]

(a) sigma bond
(b) double bond
(c) coordinate bond
(d) pi-bond

Ans. *(a)*

When two hybridised orbitals of two atoms undergoes linear combination, they form sigma bond.

111 Which one shows maximum hydrogen bonding?

[CBSE AIPMT 1990]

(a) H_2O (b) H_2Se
(c) H_2S (d) HF

Ans. *(d)*

Hydrogen bonding $\propto$ electronegativity

$$\propto \frac{1}{\text{Size of atom to which H is covalently bonded}}$$

Since, F is most electronegative and has smaller size, HF shows maximum strength of hydrogen bond.

112 Which of the following does not apply to metallic bond?

[CBSE AIPMT 1989]

(a) Overlapping valence orbitals
(b) Mobile valence electrons
(c) Delocalised electrons
(d) Highly directed bonds

Ans. *(d)*

Metallic bond have force of attraction on all sides between the mobile electrons and the positive kernels. Metals having free electrons as a mobile electrons. So, the metallic bond does not have directional property.