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Chemical Bonding

Topic 1 Preliminary Concepts of Electrovalent and Covalent Bonding

Objective Questions I (Only one correct option)

1. The isoelectronic set of ions is **(2019 Main, 10 April I)**

(a) F , Li^+, Na^+ and Mg^{2+}
(b) N^3 , Li^+, Mg^{2+} and O^2
(c) Li , Na^+, O^2 and F
(d) N^3 , O^2 , F and Na^+

2. Which of the following compounds contain(s) no covalent bond(s)?

KCl, PH_3, O_2, B_2H_6, H_2SO_4 **(2018 Main)**

(a) KCl, B_2H_6, PH_3
(b) KCl, H_2SO_4
(c) KCl
(d) KCl, B_2H_6

3. The intermolecular interaction that is dependent on the inverse cube of distance between the molecules is **(2015 Main)**

(a) ion-ion interaction
(b) ion-dipole interaction
(c) London force
(d) hydrogen bond

4. The nodal plane in the -bond of ethene is located in

(a) the molecular plane **(2002, 3M)**
(b) a plane parallel to the molecular plane
(c) a plane perpendicular to the molecular plane which bisects the carbon-carbon -bond at right angle
(d) a plane perpendicular to the molecular plane which contains the carbon-carbon -bond

5. Amongst H_2O, H_2S, H_2Se and H_2Te, the one with the highest boiling point is **(2000, 1M)**

(a) H_2O because of hydrogen bonding
(b) H_2Te because of higher molecular weight
(c) H_2S because of hydrogen bonding
(d) H_2Se because of lower molecular weight

6. Arrange the following compounds in order of increasing dipole moment, toluene (I), *m*-dichlorobenzene (II), *o*-dichlorobenzene (III), *p*-dichlorobenzene (IV) **(1996, 1M)**

(a) I < IV < II < III
(b) IV < I < II < III
(c) IV < I < III < II
(d) IV < II < I < III

7. The number and type of bonds between two carbon atoms in CaC_2 are **(1996, 1M)**

(a) one sigma ( ) and one pi ( ) bonds
(b) one sigma ( ) and two pi ( ) bonds
(c) one sigma ( ) and one half pi ( ) bonds
(d) one sigma ( ) bond

8. The molecule which has zero dipole moment is **(1989, 1M)**

(a) CH_2Cl_2
(b) BF_3
(c) NF_3
(d) ClO_2

9. Element *X* is strongly electropositive and element *Y* is strongly electronegative. Both are univalent. The compound formed would be **(1980, 1M)**

(a) *X* *Y*
(b) *X* *Y*
(c) *X* *Y*
(d) *X* *Y*

10. Which of the following compound is covalent? **(1980, 1M)**

(a) H_2
(b) CaO
(c) KCl
(d) Na_2S

11. The total number of electrons that take part in forming the bonds in N_2 is **(1980, 1M)**

(a) 2
(b) 4
(c) 6
(d) 10

12. The compound which contains both ionic and covalent bonds is **(1979, 1M)**

(a) CH_4
(b) H_2
(c) KCN
(d) KCl

Objective Questions II

(One or more than one correct option)

13. Dipole moment is shown by **(1986, 1M)**

(a) 1, 4-dichlorobenzene
(b) *cis*-1, 2-dichloroethene
(c) *trans*-1, 2-dichloroethene
(d) *trans*-1, 2-dichloro-2- pentene

Numerical Value

14. Among the species given below, the total number of diamagnetic species is____

H atom, NO_2 monomer, O_2 (superoxide), dimeric sulphur in vapour phase, Mn_3O_4, $(NH_4)_2[FeCl_4]$, $(NH_4)_2[NiCl_4]$, K_2MnO_4, K_2CrO_4 **(2018 Adv.)**

Assertion and Reason

Read the following questions and answer as per the direction given below:

(a) Statement I is true; Statement II is true; Statement II is the correct explanation of Statement I

(b) Statement I is true; Statement II is true; Statement II is not the correct explanation of Statement I

(c) Statement I is correct; Statement II is incorrect

(d) Statement I is incorrect; Statement II is correct

15. **Statement I** LiCl is predominantly a covalent compound.

Statement II Electronegativity difference between Li and Cl is too small. **(1998, 2M)**

Fill in the Blank

16. There are …… bonds in a nitrogen molecule. **(1982, 1M)**

True/False

17. All molecules with polar bonds have dipole moment. **(1985, $\frac{1}{2}$ M)**

18. Linear overlapping of two atomic *p*-orbitals leads to a sigma bond. **(1983, 1M)**

Subjective Questions

19. Arrange the following ions in order of their increasing radii: Li , Mg^{2} , K , Al^{3} . **(1997, 1M)**

20. Between Na and Ag , which is stronger Lewis acid and why? **(1997, 3M)**

21. In the reaction, I + I_2 I_3, which is the Lewis acid? **(1997, 1M)**

22. Explain the difference in the nature of bonding in LiF and LiI. **(1996, 2M)**

23. The dipole moment of KCl is 3.336 10^{29} C-m which indicates that it is a highly polar molecule. The interatomic distance between K^+ and Cl in this molecule is 2.6 10^{10} m. Calculate the dipole moment of KCl molecule if there were opposite charges of one fundamental unit located at each nucleus. Calculate the percentage ionic character of KCl. **(1993, 2M)**

24. Give reasons in two or three sentences only for the following :

"Hydrogen peroxide acts as an oxidising as well as a reducing agent.'' **(1992, 1M)**

25. State four major physical properties that can be used to distinguish between covalent and ionic compounds. Mention the distinguishing features in each case. **(1978, 2M)**

Topic 2 VBT, Hybridisation and VSEPR Theory

Objective Questions I (Only one correct option)

1. The correct statements among I to III are :

I. Valence bond theory cannot explain the color exhibited by transition metal complexes.

II. Valence bond theory can predict quantitatively the magnetic properties of transition metal complexes.

III. Valence bond theory cannot distinguish ligands as weak and strong field ones. **(2019 Main, 9 April II)**

(a) II and III only

(b) I, II and III

(c) I and II only

(d) I and III only

2. The correct statement about ICl_5 and ICl_4 is **(2019 Main, 8 April II)**

(a) ICl_5 is square pyramidal and ICl_4 is tetrahedral

(b) ICl_5 is square pyramidal and ICl_4 is square planar

(c) Both are isostructural

(d) ICl_5 is trigonal bipyramidal and ICl_4 is tetrahedral

3. The ion that has sp^3d^2 hybridisation for the central atom, is **(2019 Main, 8 April II)**

(a) $[ICl_2]$ (b) $[BrF_2]$

(c) $[ICl_4]$ (d) $[IF_6]$

4. The size of the iso-electronic species Cl , Ar and Ca^{2} is affected by **(2019 Main, 8 April I)**

(a) azimuthal quantum number of valence shell

(b) electron-electron interaction in the outer orbitals

(c) principal quantum number of valence shell

(d) nuclear charge

5. In which of the following processes, the bond order has increased and paramagnetic character has changed to diamagnetic? **(2019 Main, 9 Jan II)**

(a) O_2 O_2^+ (b) N_2 N_2^+

(c) O_2 O_2^{2} (d) NO NO^+

6. Total number of lone pair of electron in I_3 ion is **(2018 Main)**

(a) 3 (b) 6

(c) 9 (d) 12

7. The group having isoelectronic species is **(2017 Main)**

(a) O^{2} , F , Na^+, Mg^{2+} (b) O , F , Na, Mg^+

(c) O^{2} , F , Na, Mg^{2+} (d) O , F , Na^+, Mg^{2+}

8. The correct statement for the molecule, CsI_3 is **(2014 Main)**

(a) it is a covalent molecule

(b) it contains Cs and I_3 ions

(c) it contains Cs^{3+} and I ions

(d) it contains Cs , I and lattice I_2 molecule

9. The species having pyramidal shape is **(2010)**

(a) SO_3 (b) BrF_3 (c) SiO_3^2 (d) OSF_2

10. Assuming that Hund's rule is violated, the bond order and magnetic nature of the diatomic molecule B_2 is **(2010)**

(a) 1 and diamagnetic (b) 0 and diamagnetic

(c) 1 and paramagnetic (d) 0 and paramagnetic

11. The species having bond order different from that in CO is

(a) NO (b) NO **(2007, 3M)**

(c) CN (d) N_2

12. Among the following, the paramagnetic compound is **(2007, 3M)**

(a) Na_2O_2 (b) O_3 (c) N_2O (d) KO_2

13. Which of the following contains maximum number of lone pairs on the central atom? **(2005, 1M)**

(a) ClO_3 (b) XeF_4 (c) SF_4 (d) I_3

14. Number of lone pair(s) in $XeOF_4$ is/are **(2004, 1M)**

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

15. Which of the following are isoelectronic and isostructural ?

NO_3^-, CO_3^{2-}, ClO_3^-, SO_3 **(2003, 1M)**

(a) NO_3^-, CO_3^2 (b) SO_3, NO_3^-

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

16. Among the following, the molecule with the highest dipole moment is **(2003, 1M)**

(a) CH_3Cl (b) CH_2Cl_2

(c) $CHCl_3$ (d) CCl_4

17. Which of the following molecular species has unpaired electron (s)? **(2002, 3M)**

(a) N_2 (b) F_2 (c) O_2^- (d) O_2^{2-}

18. Specify the coordination geometry around and hybridisation of N and B atoms in a 1 : 1 complex of BF_3 and NH_3.

(a) N : tetrahedral, sp^3 ; B: tetrahedral, sp^3 **(2002, 3M)**

(b) N : pyramidal, sp^3; B: pyramidal, sp^3

(c) N: pyramidal, sp^3; B: planar, sp^2

(d) N: pyramidal, sp^3; B: tetrahedral, sp^3

19. The correct order of hybridisation of the central atom in the following species NH_3, $[PtCl_4]^2$, PCl_5 and BCl_3 is

(a) dsp^2, dsp^3, sp^2 and sp^3 **(2001, 1M)**

(b) sp^3, dsp^2, sp^3d and sp^2

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

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

20. The common features among the species CN^-, CO and NO^+ are **(2001, 1M)**

(a) bond order three and isoelectronic

(b) bond order three and weak field ligands

(c) bond order two and acceptors

(d) isoelectronic and weak field ligands

21. The hybridisation of atomic orbitals of nitrogen in NO_2^+, NO_3 and NH_4^+ are **(2000, 1M)**

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

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

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

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

22. In the compound CH_2 CH CH_2 CH_2 C CH, the C_2 C_3 bonds is of **(1999, 2M)**

(a) sp - sp^2 (b) sp^3 - sp^3

(c) sp - sp^3 (d) sp^2 - sp^3

23. The geometry of H_2S and its dipole moment are **(1999, 2M)**

(a) angular and non-zero (b) angular and zero

(c) linear and non-zero (d) linear and zero

24. The geometry and the type of hybrid orbital present about the central atom in BF_3 is **(1998, 2M)**

(a) linear, sp (b) trigonal planar, sp^2

(c) tetrahedral, sp^3 (d) pyramidal, sp^3

25. Which one of the following compounds has sp^2- hybridisation? **(1997, 1M)**

(a) CO_2 (b) SO_2

(c) N_2O (d) CO

26. Among KO_2, AlO_2, BaO_2 and NO_2^+, unpaired electron is present in **(1997 C, 1M)**

(a) NO_2^+ and BaO_2 (b) KO_2 and AlO_2

(c) Only KO_2 (d) Only BaO_2

27. The cyanide ion CN and N_2 are isoelectronic, but in contrast to CN , N_2 is chemically inert because of **(1997 C, 1M)**

(a) low bond energy

(b) absence of bond polarity

(c) unsymmetrical electron distribution

(d) presence of more number of electron in bonding orbitals

28. Among the following species, identify the isostructural pairs.

NF_3, NO_3, BF_3, H_3O^+, N_3H **(1996, 1M)**

(a) $[NF_3, NO_3]$ and $[BF_3, H_3O^+]$

(b) $[NF_3, N_3H]$ and $[NO_3, BF_3]$

(c) $[NF_3, H_3O^+]$ and $[NO_3^-, BF_3]$

(d) $[NF_3, H_3O^+]$ and $[N_3H, BF_3]$

29. Which one of the following molecules is planar? **(1996, 1M)**

(a) NF_3 (b) NCl_3 (c) PH_3 (d) BF_3

30. The maximum possible number of hydrogen bonds a water molecule can form is **(1992, 1M)**

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

31. The type of hybrid orbitals used by the chlorine atom in ClO_2 is **(1992, 1M)**

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

(c) sp (d) None of these

32. The molecule which has pyramidal shape is **(1989, 1M)**

(a) PCl_3 (b) SO_3

(c) CO_3^{2-} (d) NO_3^-

33. Which of the following is paramagnetic? **(1989, 1M)**

(a) O_2^- (b) CN^-

(c) CO (d) NO^+

34. The Cl—C—Cl angle in 1, 1, 2, 2-tetrachloroethene and tetrachloromethane respectively will be about **(1988, 1M)**

(a) 120 and 109.5 (b) 90 and 109.5

(c) 109° and 90 (d) 109.5 and 120

35. The molecule that has linear structure is **(1988, 1M)**

(a) CO_2 (b) NO_2 (c) SO_2 (d) SiO_2

36. The species in which the central atom uses sp^2-hybrid orbitals in its bonding is **(1988, 1M)**

(a) PH_3 (b) NH_3 (c) CH_3^+ (d) SbH_3

37. Of the following compounds, which will have a zero dipole moment ? **(1987, 1M)**

(a) 1, 1-dichloroethylene

(b) *cis*-1, 2-dichloroethylene

(c) *trans*-1, 2-dichloroethylene

(d) None of the above

38. The hybridisation of sulphur in sulphur dioxide is **(1986, 1M)**

(a) *sp* (b) sp^3

(c) sp^2 (d) dsp^2

39. The bond between two identical non-metal atoms has a pair of electrons **(1986, 1M)**

(a) unequally shared between the two

(b) transferred fully from one atom to another

(c) with identical spins

(d) equally shared between them

40. On hybridisation of one *s* and one *p*-orbital we get

(a) two mutually perpendicular orbitals **(1984, 1M)**

(b) two orbitals at 180

(c) four orbitals directed tetrahedrally

(d) three orbitals in a plane

41. Carbon tetrachloride has no net dipole moment because of

(a) its planar structure **(1983, 1M)**

(b) its regular tetrahedral structure

(c) similar sizes of carbon and chlorine atoms

(d) similar electron affinities of carbon and chlorine

42. The ion that is isoelectronic with CO is **(1982, 1M)**

(a) CN (b) O_2

(c) O_2 (d) N_2

43. Among the following, the linear molecule is **(1982, 1M)**

(a) CO_2 (b) NO_2

(c) SO_2 (d) ClO_2

44. If a molecule MX_3 has zero dipole moment, the sigma bonding orbitals used by *M* (atomic number 21) are

(a) pure *p* (b) *sp*-hybridised **(1981, 1M)**

(c) sp^2-hybridised (d) sp^3-hybridised

Objective Questions II

(One or more than one correct option)

45. The molecules that will have dipole moment are **(1992, 1M)**

(a) 2, 2-dimethyl propane (b) *trans*-2-pentene

(c) *cis*-3-hexene (d) 2,2,3,3-tetramethyl butane

46. Which of the following have identical bond order?

(a) CN^- (b) O_2^- **(1992, 1M)**

(c) NO^+ (d) CN^+

47. The linear structure assumed by **(1991, 1M)**

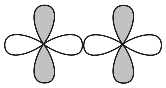
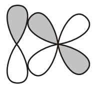
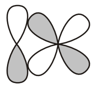
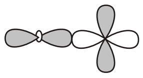
(a) $SnCl_2$ (b) CS_2 (c) NO_2^+ (d) NCO^-

48. CO_2 is isostructural with **(1986, 1M)**

(a) $HgCl_2$ (b) C_2H_2 (c) $SnCl_2$ (d) NO_2

Match the Columns

49. Match the orbital overlap figures shown in Column I with the description given in Column II and select the correct answer using the codes given below the Columns. **(2014 Adv.)**

Column I		Column II	
A.		1.	*p-d* antibonding
B.		2.	*d-d* bonding
C.		3.	*p-d* bonding
D.		4.	*d-d* antibonding

Codes

	A	B	C	D		A	B	C	D
(a)	4	3	2	1	(b)	1	2	3	4
(c)	2	3	1	4	(d)	4	1	2	3

50. Match each of the diatomic molecules in Column I with its property/properties in Column II. **(2009)**

	Column I		ColumnII
A.	B_2	p.	Paramagnetic
B.	N_2	q.	Undergoes oxidation
C.	O_2	r.	Undergoes reduction
D.	O_2	s.	Bond order 2
		t.	Mixing of '*s*' and '*p*' orbitals

Codes

	A	B	C	D
(a)	q, r, s	p, r, t, s	q, r, t	p, q, t
(b)	p, q, r, t	q, r, s, t	p, q, r, t	p, r, s, t
(c)	q, r, s, t	p, q, r	r, s, t	p, q, r, t
(d)	p, q, s, t	p, q, s	p, t	q, r, t

Fill in the Blanks

51. Among N_2O, SO_2, I_3^+ and I_3^-, the linear species are …… and …… **(1997 C, 1M)**

52. When N_2 goes to N_2, the N N bond distance … , and when O_2 goes to O_2 the O O bond distance …… **(1996, 1M)**

53. The two types of bonds present in B_2H_6 are covalent and …… **(1994, 1M)**

54. The kind of delocalisation involving sigma bond orbitals is called................ **(1994, 1M)**

55. The valence atomic orbitals on C in silver acetylide is ....hybridised. **(1990, 1M)**

56. The shape of CH_3 is …… . **(1990, 1M)**

57. …… hybrid orbitals of nitrogen atom are involved in the formation of ammonium ion. **(1982, 1M)**

58. Pair of molecules which forms strongest intermolecular hydrogen bonds is ……… . (SiH_4 and SiF_4, acetone and $CHCl_3$, formic acid and acetic acid) **(1981, 1M)**

59. The angle between two covalent bonds is maximum in …… . (CH_4, H_2O, CO_2) **(1981, 1M)**

True/False

60. The dipole moment of CH_3F is greater than that of CH_3Cl. **(1993, 1M)**

61. H_2O molecule is linear. **(1993, 1M)**

62. The presence of polar bonds in a polyatomic molecule suggests that the molecule has non-zero dipole moment. **(1990, 1M)**

63. sp^3 hybrid orbitals have equal s and p character. **(1987, 1M)**

64. In benzene, carbon uses all the three p-orbitals for hybridisation. **(1987, 1M)**

65. $SnCl_2$ is a non-linear molecule. **(1985, $\frac{1}{2}$M)**

Integer Type Questions

66. The sum of the number of lone pairs of electrons on each central atom in the following species is

$[TeBr_6]^2$, $[BrF_2]$, SNF_3 and $[XeF_3]$

(Atomic numbers : N 7, F 9, S 16, Br 35, Te 52, Xe 54) **(2017 Adv.)**

67. Among the triatomic molecules/ions $BeCl_2$, N_3, N_2O, NO_2, O_3, SCl_2, ICl_2, I_3 and XeF_2, the total number of linear molecules(s)/ion(s) where the hybridisation of the central atom does not have contribution from the d-orbital(s) is [atomic number of S = 16, Cl = 17, I = 53 and Xe 54] **(2015 adv.)**

68. A list of species having the formula XZ_4 is given below **(2014 Adv.)**

XeF_4, SF_4, SiF_4, BF_4, BrF_4, $[Cu(NH_3)_4]^2$, $[FeCl_4]^2$, $[CoCl_4]^2$ and $[PtCl_4]^2$

Defining shape on the basis of the location of X and Z atoms, the total number of species having a square planar shape is

69. The total number of lone-pair of electrons in melamine is **(2013 Adv.)**

70. Based on VSEPR theory, the number of 90° F—Br—F angles in BrF_5 is **(2010)**

Subjective Questions

71. Predict whether the following molecules are isostructural or not. Justify your answer.

(i) NMe_3 (ii) $N(SiMe_3)_3$ **(2005, 2M)**

72. On the basis of ground state electronic configuration, arrange the following molecules in increasing O—O bond length order. KO_2, O_2, $O_2[AsF_6]$ **(2004, 2M)**

73. Draw the shape of XeF_4 and OSF_4 according to VSEPR theory. Show the lone pair of electrons on the central atom. **(2004, Main, 2M)**

74. Using VSEPR theory, draw the shape of PCl_5 and BrF_5. **(2003, 2M)**

75. Draw the molecular structures of XeF_2, XeF_4 and XeO_2F_2, indicating the location of lone pair(s) of electrons. **(2000, 3M)**

76. Interpret the non-linear shape of H_2S molecule and non-planar shape of PCl_3 using valence shell electron pair repulsion (VSEPR) theory. (Atomic number : H = 1, P = 15, S = 16, Cl = 17) **(1998, 4M)**

77. Using the VSEPR theory, identify the type of hybridisation and draw the structure of OF_2. What are the oxidation states of O and F ? **(1997, 3M)**

78. Write the Lewis dot structural formula for each of the following. Give also, the formula of a neutral molecule, which has the same geometry and the same arrangement of the bonding electrons as in each of the following. An example is given below in the case of H_3O^+ and NH_3.

H	H
H O H	H N H
Lewis dot structure	Neutral molecule

(1983, 4M)

(i) O_2^2 (ii) CO_3^2 (iii) CN (iv) NCS

Topic 3 Resonance, LCAO, MOT, Other Bonding Types

Objective Questions I (Only one correct option)

1. During the change of O_2 to O_2, the incoming electron goes to the orbital. **(2019 Main, 10 April I)**

(a) $2p_x$ (b) $^*2p_x$ (c) $2p_y$ (d) $^*2p_z$

2. HF has highest boiling point among hydrogen halides, because it has **(2019 Main, 9 April II)**

(a) lowest ionic character
(b) strongest van der Waals' interactions
(c) strongest hydrogen bonding
(d) lowest dissociation enthalpy

3. Among the following species, the diamagnetic molecule is **(2019 Main, 9 April II)**

(a) CO (b) B_2 (c) NO (d) O_2

4. Among the following, the molecule expected to be stabilised by anion formation is C_2, O_2, NO, F_2. **(2019 Main, 9 April I)**

(a) C_2 (b) F_2
(c) NO (d) O_2

5. Among the following molecules/ions, C_2^2, N_2^2, O_2^2, O_2

Which one is diamagnetic and has the shortest bond length? **(2019 Main, 8 April II)**

(a) C_2^2 (b) O_2 (c) O_2^2 (d) N_2^2

6. Two pi and half sigma bonds are present in **(2019 Main, 10 Jan I)**

(a) O_2 (b) N_2 (c) N_2 (d) O_2

7. According to molecular orbital theory, which of the following is true with respect to Li_2 and Li_2? **(2019 Main, 9Jan I)**

(a) Both are unstable
(b) Li_2 is unstable and Li_2 is stable
(c) Both are stable
(d) Li_2 is stable and Li_2 is unstable

8. According to molecular orbital theory, which of the following will not be a viable molecule? **(2018 Main)**

(a) He_2^2 (b) He_2 (c) H_2 (d) H_2^2

9. Which of the following species is not paramagnetic? **(2017 Main)**

(a) NO (b) CO (c) O_2 (d) B_2

10. Assuming 2*s*-2*p* mixing is not operative, the paramagnetic species among the following is **(2014 Adv.)**

(a) Be_2 (b) B_2 (c) C_2 (d) N_2

11. Stability of the species Li_2, Li_2 and Li_2 increases in the order of **(2013 Main)**

(a) Li_2 Li_2 Li_2 (b) Li_2^- Li_2 Li_2
(c) Li_2 Li_2 Li_2 (d) Li_2 Li_2 Li_2

12. In which of the following pairs of molecules/ions both the species are not likely to exist? **(2013 Main)**

(a) H_2^+, He_2^2 (b) H_2, He_2^2 (c) H_2^2, He_2 (d) H_2, He_2^{2+}

13. Hyperconjugation involves overlap of which of the following orbitals? **(2008, 3M)**

(a) - (b) -*p* (c) *p*-*p* (d) -

14. According to *M*O theory, **(2004, 1M)**

(a) O_2^+ is paramagnetic and bond order greater than O_2
(b) O_2 is paramagnetic and bond order less than O_2
(c) O_2 is diamagnetic and bond order is less than O_2
(d) O_2 is diamagnetic and bond order is more than O_2

15. Molecular shape of SF_4, CF_4 and XeF_4 are **(2000, 1M)**

(a) the same, with 2, 0 and 1 lone pair of electrons respectively
(b) the same, with 1, 1 and 1 lone pair of electrons respectively
(c) different, with 0, 1 and 2 lone pair of electrons respectively
(d) different, with 1, 0 and 2 lone pair of electrons respectively

16. In compounds of type ECl_3, where *E* = B, P, As or Bi, the angles Cl—*E*—Cl is in order **(1999, 2M)**

(a) B > P = As = Bi (b) B > P > As > Bi
(c) B < P = As = Bi (d) B < P < As < Bi

17. The correct order of increasing C O bond length of CO, CO_3^2, CO_2 is **(1999, 2M)**

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

18. Which contains both polar and non-polar bonds? **(1997, 1M)**

(a) NH_4Cl (b) HCN (c) H_2O_2 (d) CH_4

19. Which one among the following does not have the hydrogen bond? **(1983, 1M)**

(a) Phenol (b) Liquid NH_3
(c) Water (d) HCl

Objective Question II
(One or more than one correct option)

20. According to molecular orbital theory, which of the following statements is(are) correct? **(2016 adv.)**

(a) C_2^2 is expected to be diamagnetic
(b) O_2^2 is expected to have a longer bond length than O_2
(c) N_2 and N_2 have the same bond order
(d) He_2 has the same energy as two isolated He atoms

21. Hydrogen bonding plays a central role in which of the following phenomena? **(2014 Adv.)**

(a) Ice floats in water
(b) Higher Lewis basicity of primary amines than tertiary amines in aqueous solutions
(c) Formic acid is more acidic than acetic acid
(d) Dimerisation of acetic acid in benzene

22. Which one of the following molecules is expected to exhibit diamagnetic behaviour? **(2013 Main)**

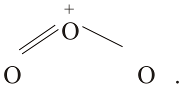
(a) C_2 (b) N_2 (c) O_2 (d) S_2

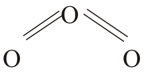
Assertion and Reason

Read the following questions and answer as per the direction given below:

(a) Statement I is correct; Statement II is correct; Statement II is the correct explanation of Statement I.
(b) Statement I is correct; Statement II is correct; Statement II is not the correct explanation of Statement I.
(c) Statement I is correct; Statement II is incorrect.
(d) Statement I is incorrect; Statement II is correct.

23. Statement I The electronic structure of O_3 is



Statement II  structure is not allowed because octet around O cannot be expanded.

(1998, 2M)

Match the Columns

24. Match the reactions in Column I with nature of the reactions/type of the products in Column II. **(2007, 6M)**

	Column I		Column II
A.	O_2 $O_2 + O_2^{2}$	1.	Redox reaction
B.	CrO_4^{2} + H^+	2.	One of the products has trigonal planar structure
C.	MnO_4 + NO_2 + H^+	3.	Dimeric bridged tetrahedral metal ion
D.	NO_3 + H_2SO_4 + Fe^{2+}	4.	Disproportionation

Codes

	A	B	C	D		A	B	C	D
(a)	2	1, 4	3	4	(b)	1, 4	3	1, 2	1
(c)	2	3	1	4	(d)	3	4	2, 3	1

Integer Questions

25. Among H_2, He_2, Li_2, Be_2, B_2, C_2, N_2, O_2 and F_2, the number of diamagnetic species is
(Atomic numbers : H 1, He 2, Li 3, Be 4, B 5, C 6, N 7, O 8, F 9) **(2017 Adv.)**

Subjective Questions

26. Write the MO electron distribution of O_2. Specify its bond order and magnetic property. **(2000, 3M)**

27. Arrange the following as stated.
"Increasing strength of hydrogen bonding (X H X)."
O, S, F, Cl, N **(1991, 1M)**

28. What effect should the following resonance of vinyl chloride have on its dipole moment? **(1987, 1M)**

$CH_2{=}CH$ Cl CH_2^- C HCl

Answers

Topic 1

1. (d) **2.** (c) **3.** (b) **4.** (a)
5. (a) **6.** (b) **7.** (b) **8.** (b)
9. (a) **10.** (a) **11.** (c) **12.** (c)
13. (b, d) **14.** (1) **15.** (c) **16.** (2)
17. F **18.** T **23.** (80.2%)

Topic 2

1. (d) **2.** (b) **3.** (c) **4.** (d)
5. (d) **6.** (c) **7.** (a) **8.** (d)
9. (d) **10.** (a) **11.** (a) **12.** (d)
13. (d) **14.** (b) **15.** (a) **16.** (a)
17. (c) **18.** (a) **19.** (b) **20.** (a)
21. (b) **22.** (d) **23.** (a) **24.** (b)
25. (b) **26.** (c) **27.** (b) **28.** (c)
29. (d) **30.** (b) **31.** (a) **32.** (a)
33. (a) **34.** (a) **35.** (a) **36.** (c)
37. (c) **38.** (c) **39.** (d) **40.** (b)
41. (b) **42.** (a) **43.** (a) **44.** (c)
45. (b, c) **46.** (a, c) **47.** (b, c, d) **48.** (a, b)
49. (c) A 2; B 3; C 1; D 4
50. (b) A p, q, r, t; B q, r, s, t; C p, q, r, t; D p, r, s, t
51. N_2O, I_3 **52.** increases, decreases
53. three centre bond-two electrons
54. hyperconjugation
55. *sp* **56.** Triangular planar **57.** sp^3
58. HCOOH and CH_3COOH **59.** CO_2 **60.** F
61. F **62.** F **63.** F **64.** F
65. T **66.** (6) **68.** (4) **69.** (6)

Topic 3

1. (b) **2.** (c) **3.** (a) **4.** (a)
5. (a) **6.** (c) **7.** (d) **8.** (d)
9. (b) **10.** (c) **11.** (b) **12.** (c)
13. (b) **14.** (a) **15.** (d) **16.** (b)
17. (a) **18.** (c) **19.** (d) **20.** (a, c)
21. (a, b, d) **22.** (a,b) **23.** (a)
24. (b) A 1, 4; B 3; C 1, 2; D 1 **25.** (6)

Hints & Solutions

Topic 1 Preliminary Concepts of Electrovalent and Covalent Bonding

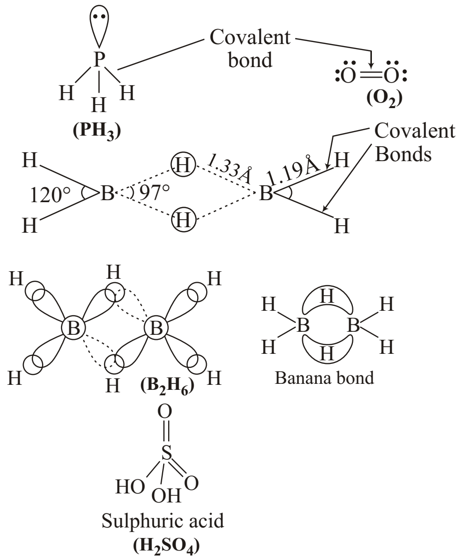
1. **Key Idea** Isoelectronic species contains same number of electrons.

The species with its atomic number and number of electrons are as follows :

Species (ions)	**At. no. (Z)**	**No. of electrons**
N^3	7	7 3 10
O^2	8	8 2 10
F	9	9 1 10
Na	11	11 1 10
Li	3	3 1 2
Mg^2	12	12 2 10

Thus, option (d) contains isoelectronic set of ions.

2. KCl is the only ionic compound. The structure of PH_3, O_2, B_2H_6 and H_2SO_4 are given below



All bond between S and O atom are covalent bonds.

3. Ion-ion interaction is dependent on the square of distance, i.e.

ion-ion interaction $\frac{1}{r^2}$

Similarly, ion-dipole interaction $\frac{1}{r^3}$

London force $\frac{1}{r^6}$ and dipole-dipole interaction $\frac{1}{r^3}$

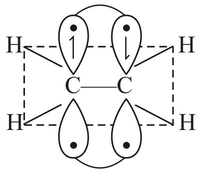
Superficially it seems as both ion-dipole interaction and hydrogen bonding vary with the inverse cube of distance between the molecules but when we look at the exact expressions of field (force) created in two situations,
it comes as

$$|E| \text{or} |F| \quad \frac{2|P|}{4 \quad r^3} \qquad \text{(In case of ion-dipole interaction)}$$

$$\text{and } F \quad \frac{2q^2r - 4q^2a}{4 \quad {}_0 r^3} \qquad \text{(In case of dipole-dipole interaction)}$$

From the above, it is clear that the ion-dipole interaction is the better answer as compared to dipole-dipole interaction, i.e. hydrogen bonding.

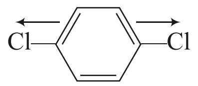
4.



Pi bond is formed by the p-orbitals whose lobes have minima in the plane of molecule, hence molecular plane is the nodal plane of pi-bond.

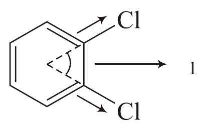
5. H-bond is the strongest intermolecular force.
All are different with 1, 0 and 2 lone pairs of electrons at central atom.

6. p-dichlorobenzene is non-polar.

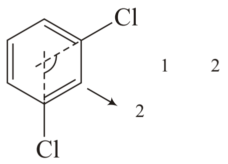


p-dichlorobenzene

The two dipole vectors cancelling each other giving zero resultant dipole moment. o-dichlorobenzene has greater dipole moment than *meta*-isomer.



(o-dichlorobenzene)
dipole vectors are at 60° angle



(m-dichlorobenzene)
dipole vectors are at 120° angle

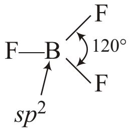
Toluene is less polar than both *ortho* and *para* dichlorobenzene. Therefore, the increasing order of dipole moment is
p-dichlorobenzene (IV) < toluene (I) < m-dichlorobenzene (II) < o-dichlorobenzene (III)

7. The carbide (C_2^2) ion has the following bonding pattern:

$$:\bar{C} \quad \bar{C}: \text{one sigma and two pi bonds.}$$

8. BF_3 has triangular planar arrangement.

Three identical vectors acting in outward direction at equal angles in a plane cancel each other giving zero resultant, hence non-polar.



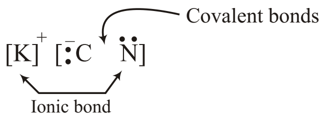
9. Strongly electropositive, univalent X will form an 1 : 1 ionic compound with strongly electronegative, univalent Y.

$$X \quad Y \qquad X \; Y$$

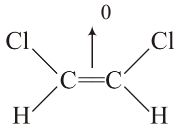
10. H_2 is a covalent, diatomic molecule with a sigma covalent bond between two hydrogen atoms.

11. N_2 has triple bond and each covalent bond is associated with one pair of electrons, therefore, six electrons are involved in forming bonds in N_2.

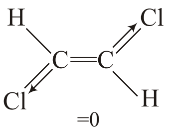
12. In KCN, the bonding between potassium ion and cyanide ion is ionic while carbon and nitrogen are covalently bonded in cyanide ion as:



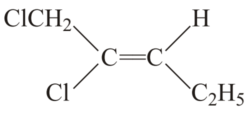
13. 1,4-dichlorobenzene is non-polar, individual dipole vectors cancel each other.



Polar



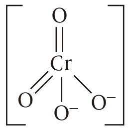
Non-polar



Polar

14. Among the given species only K_2CrO_4 is diamagnetic as central metal atom Cr in it has $[Ar]3d^0$ electronic configuration i.e., all paired electrons. The structure and oxidation state of central metal atom of this compound are as follows

Structure K^+

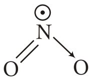


, **Oxidation state** Cr^{6+}

Rest all the compounds are **paramagnetic**. Reasons for their paramagnetism are given below

(i) H-atom have $1s^1$ electronic configuration, i.e. 1 unpaired electron.

(ii) NO_2, i.e.

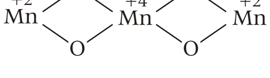


in itself is **an odd electron species.**

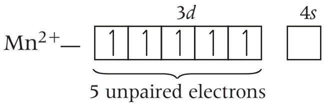
(iii) O_2 (Superoxide) has one unpaired electron in * molecular orbital.

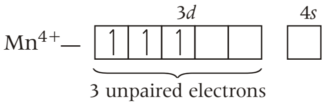
(iv) S_2 in vapour phase has O_2 like electronic configuration i.e., have 2 unpaired electrons in * molecular orbitals.

(v) Mn_3O_4 has following structure

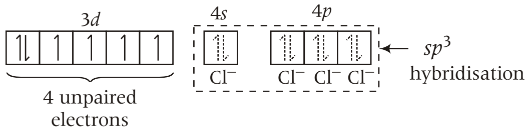


Thus, Mn is showing +2 and +4 oxidation states. The outermost electronic configuration of elemental Mn is $3d^5 4s^2$. Hence, in both the above oxidation states it has unpaired electrons as

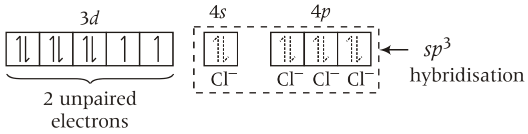




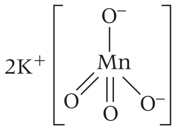
(vi) $(NH_4)_2FeCl_4$ has Fe as central metal atom with +2 oxidation state. The electronic configuration of Fe^{2+} in the complex is



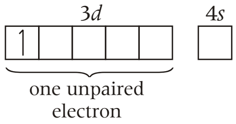
(vii) $(NH_4)_2NiCl_4$ has Ni as central metal atom with +2 oxidation state. The electronic configuration of Ni^{2+} in the complex is



(viii) In K_2MnO_4 central metal atom Mn has +6 oxidation state with following structure



Electronic configuration of Mn^{6+} is



15. Statement I is correct but Statement II is incorrect. The covalency in LiCl is due to small size of Li ion which brings about large amount of polarisation in bond.

16. These are 2 -bonds in a nitrogen molecule.

17. The resultant of individual bond dipoles may or may not be non-zero.

18. Linear overlapping of *p*-orbitals form sigma bond while sidewise overlapping of two *p*-orbitals forms a pi bond.

19. $Li^+ < Al^{3+} < Mg^{2+} < K^+$

20. Ag^+ is stronger Lewis acid because it can easily accommodate lone pair of electrons from Lewis base. On the other hand, Na^+ has noble gas configuration, cannot accept lone pair of electron, not at all a Lewis acid.

21. I_2 is Lewis acid because I coordinate its one lone pair to I_2.

22. Both LiF and LiI are expected to be ionic compounds. However , LiI is predominantly covalent because of small size of Li^+ and large size of iodide ion. A smaller cation and a larger anion introduces covalency in ionic compound.

23. Dipole moment is calculated theoretically as

$$q \quad d$$

Here, $q \quad 1.6 \quad 10^{19}$ C and $d \quad 2.6 \quad 10^{10}$ m

$$_{\text{Theo}} \quad 1.6 \quad 10^{19} \quad 2.6 \quad 10^{10} \quad 4.16 \quad 10^{29}\text{cm}$$

$$\%\ \text{ionic character} \quad \frac{_{\text{obs}}}{_{\text{Theo}}} \quad 100 \quad \frac{3.336 \quad 10^{29}}{4.16 \quad 10^{29}} \quad 100$$

$$= 80.2\%$$

24. In hydrogen peroxide (H_2O_2), oxygen is in –1 oxidation state, can be oxidised to O_2 (zero oxidation state) or can be reduced to H_2O (–2 oxidation state of oxygen).

Hence, H_2O_2 can act as both oxidising agent and reducing agent. With strong oxidising agent like $KMnO_4$, H_2O_2 acts as a reducing agent while with strong reducing agent like $H_2C_2O_4$, it acts as an oxidising agent.

25. (i) **Melting points** Ionic compounds have higher melting points than covalent compounds.

(ii) **Boiling points** Ionic compounds have higher boiling points than covalent compounds.

(iii) **Solubility** Ionic compounds have greater solubility in water than a covalent compound.

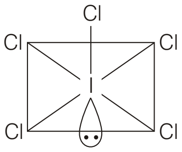
(iv) **Conductivity in aqueous solution** Ionic compounds have greater electrical conductivity in aqueous solution while covalent compounds are usually non-conducting.

Topic 2 VBT, Hybridisation and VSEPR Theory

1. Among the given statements, correct statements are I and III only. Valence bond theory (VBT) cannot explain the colour exhibited by transition metal complexes. This theory cannot distinguish ligands as weak and strong field ones.

2. For ICl_5

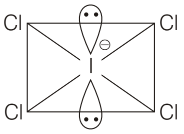
$$H \quad \frac{1}{2}(7 \quad 5 \quad 0 \quad 0) \quad 6\ (sp^3d^2)$$



sp^3d^2 hybridised
Geometry : Octahedral
Shape / Structure : Square pyramidal

For $\ddot{I}Cl_4$

$$H \quad \frac{1}{2}(7 \quad 4 \quad 0 \quad 1) \quad 6\ (sp^3d^2)$$



sp^3d^2 hybridised
Geometry : Octahedral
Shape/Structure : Square planar

So, ICl_5 and ICl_4 are isolobal but not isostructural.

3. **Key Idea** The hybridisation for a central atom in a species can be calculated using formula

$$H \quad \frac{1}{2}(V \quad M \quad C \quad A)$$

where, H No. of hybridised orbitals used by central atoms.
V No. of valence electrons of the central atom.
M No. of mono-valent atoms (bonded).
C No. of cationic (positive) charge.
A No. of anionic (negative) charge.

The hybridisation of given species are as follows :

- For $[ICl_2]$ and $[BrF_2]$

$$H \quad \frac{1}{2}(7 \quad 2 \quad 0 \quad 1) \quad 5\ (sp^3d)$$

- For $[ICl_4]$,

$$H \quad \frac{1}{2}(7 \quad 4 \quad 0 \quad 1) \quad 6\ (sp^3d^2)$$

- For $[IF_6]$,

$$H \quad \frac{1}{2}(7 \quad 6 \quad 0 \quad 1) \quad 7\ (sp^3d^3)$$

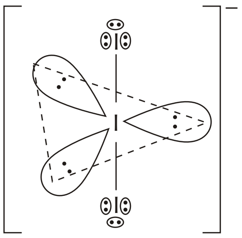
4. The radius of isoelectronic species is inversely proportional to their nuclear charge or atomic number (Z). Thus, greater the value of Z, lesser the radii of isoelectronic species.

5.

Species	Valence MOs	Bond Order $\frac{N_b \quad N_a}{2}$	Paramagnetic/ Diamagnetic Nature
NO(15e)	$[8e\ ]\ 2p_x^2 \quad 2p_y^2\ 2p_z^2$ $*2p_x^1 \quad *2p_y^0 \quad * \quad pz^0$	$\frac{6 \quad 1}{2}$ 2.5	Paramagnetic
–e			
NO (14e)	$[8e\ ]\ 2p_x^2 \quad 2p_y^2\ 2p_z^2$ $*2p_x^0 \quad *2p_y^0\ *2p_z^0$	$\frac{6 \quad 0}{2}$ 3	Diamagnetic
N_2(14e)	$[8e\ ]\ 2p_x^2 \quad 2p_y^2 \quad p_z^2$ $*2p_x^0 \quad *2p_y^0,\ 2p_z^0$	$\frac{6 \quad 0}{2}$ 3	Diamagnetic
–e			
N_2 (13e)	$[8e\ ]\ 2p_x^2 \quad 2p_y^2 \quad 2p_{z}1$ $*2p_x^0 \quad *2p_y^0\ *2pz_0$	$\frac{5 \quad 0}{2}$ 2.5	Paramagnetic
O_2(16e)	$[8e\ ]\ 2p_z^2\ 2p_x^2 \quad 2p_y^2$ $*2p_x^1 \quad *2p_y^1\ *2p_z^0$	$\frac{6 \quad 2}{2}$ 2	Paramagnetic
–e			
O_2 (15e)	$[8e\ ]\ 2p_z^2\ 2p_x^2 \quad 2p_y^2$ $*2p_x^1 \quad *2p_y^0\ *2p_z^0$	$\frac{6 \quad 1}{2}$ 2.5	Paramagnetic
+2e			
O_2^2 (18e)	$[8e\ ]\ 2p_z^2\ 2p_x^2 \quad 2p_y^2$ $*2p_x^2 \quad *2p_y^2\ *2p_z^0$	$\frac{6 \quad 4}{2}$ 1	Diamagnetic

So, only in the conversion of NO   NO$^+$, the bond order has increased (2.5   3) and paramagnetic character has changed to diamagnetic.

6. The structure of I_3 ion is



Hence, 9 is the correct answer.

7. Isoelectronic species are those which contains same number of electrons.

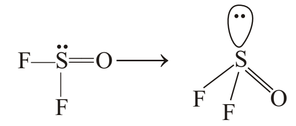
Species	Atomic number	Number of electrons
O^{2}	8	10
F	9	10
Na	11	10
Mg^{2}	12	10
O	8	9
Na	11	11
Mg	12	11

Option (a) is correct which contains isoelectronic species O^{2} , F , Na , Mg^{2} .

8. I_3 is an ion made up of I_2 and I which has linear shape.

While Cs is an alkali metal cation.

9.



S is sp^3 hybridised Pyramidal

SO_3 is planar (S is sp^2 hybridised), BrF_3 is T-shaped and SiO_3^{2} is planar (Si is sp^2 hybridised).

10. For molecules lighter than O_2, the increasing order of energies of molecular orbitals is

$$1s \;\; {}^{*}1s \;\; 2s \;\; {}^{*}2s \;\; \begin{matrix}2p_y\\ 2p_z\end{matrix} \;\; 2p_x \;\; {}^{*}2p_x \;\; \begin{matrix}{}^{*}2p_y\\ {}^{*}2p_z\end{matrix}.....$$

where, $2p_y$ and $2p_z$ are degenerate molecular orbitals, first singly occupied and then pairing starts if Hund's rule is obeyed. If Hund's rule is violated in B_2, electronic arrangement would be

$$1s^2 \;\; {}^{*}1s^2 \;\; 2s^2 \;\; {}^{*}2s^2 \;\; \begin{matrix}2p_y^2\\ 2p_z\end{matrix}...$$

No unpaired electron-diamagnetic.

$$\text{Bond order} \quad \frac{\text{bonding electrons} \quad \text{antibonding electrons}}{2}$$

$$\frac{6 \quad 4}{2} \quad 1$$

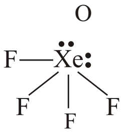
11. The bond order of CO = 3. NO^{+}, CN and N_2 are isoelectronic with CO, have the same bond order as CO. NO (16*e*) has bond order of 2.

12. O_2 in KO_2 has 17 electrons, species with odd electrons are always paramagnetic.

13. ClO_3 : O Cl O one lone pair at Cl.

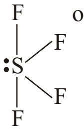
O

XeF_4 :



two lone pairs at Xe.

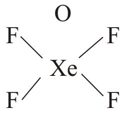
SF_4 :



one lone pair at S.

I_3 : I I I three lone pairs at central iodine.

14.



At central atom (Xe), there is one lone pair.

15. NO_3 and CO_3^{2} both have 32 electrons, central atom sp^2 hybridised, triangular planar.

16. CH_3Cl has the highest dipole moment.

17. O_2 has odd number(17) of electrons, therefore it must contain at least one unpaired electron.

F H

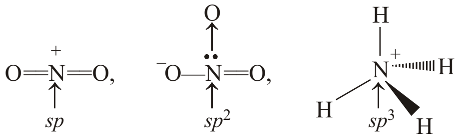
18. F B N H Both 'B' and 'N' sp^3 tetrahedral.

F H

19. NH_3 sp^3, $[PtCl_4]^2$ dsp^2, PCl_5 sp^3d, BCl_3 sp^2

20. All three have 14 electrons (iso electronic) with bond order of three.

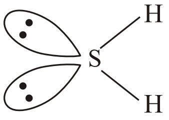
21.



22. $\overset{1}{C}H_2 = \overset{2}{C}H \quad \overset{3}{C}H_2 \quad \overset{4}{C}H_2 \quad \overset{5}{C} \quad \overset{6}{C}H$

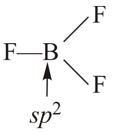
Hybridisation at C_2 sp^2 and at C_3 sp^3.

23. H_2S has sp^3 hybridised sulphur, therefore, angular in shape with non-zero dipole moment.



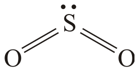
(Non-linear, polar molecule)

24.



(Trigonal planar)

25. Sulphur in SO_2 is sp^2-hybridised.



Electron pair 2 (-bonds) + 1 (lone pair) = 3

Hybridisation sp^2

Carbon in CO_2 is *sp*-hybridised, N in N_2O is *sp*-hybridised, carbon in CO is *sp*-hybridised.

26. Molecular orbital electronic configuration are

$$KO_2\ (O_2\ ):\ 1s^2\ {}^*1s^2\ \ 2s^2\ {}^*2s^2\ \ 2p_x^2 \left|\begin{array}{c|c} 2p_y^2 & {}^*2p_y^2 \\ 2p_z^2 & {}^*2p_z^1 \end{array}\right| {}^*2p_x^0$$

Has one unpaired electron in ${}^*2p$ orbital.

AlO_2 has both oxygen in O^2 state, therefore, no unpaired electron is present.

$BaO_2\ (O_2^2\ )$

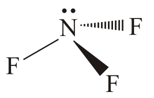
$$1s^2\ {}^*1s^2\ \ 2s^2\ {}^*2s^2\ \ 2p_x^2 \left|\begin{array}{c|c} 2p_y^2 & {}^*2p_y^2 \\ 2p_z^2 & {}^*2p_z^2 \end{array}\right| {}^*2p_x^0$$

Has no unpaired electron.

NO_2 has [O═N═O] bonding, hence no unpaired electron.

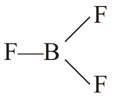
27. N_2 is a neutral, non-polar, inert molecule while CN is a highly polar, highly active ion.

28. NF_3 :



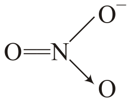
Pyramidal
(N-sp^3)

BF_3 :



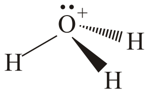
Triangular planar
(B-sp^2)

NO_3^- :



Triangular planar
(N-sp^2)

H_3O^+ :



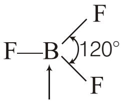
Pyramidal
(O-sp^3)

N_3H $\quad \overline{N}\quad N\quad N\quad H$

Central nitrogen is *sp*-hybridised

Therefore, NF_3, H_3O and BF_3, NO_3 pairs have same shape.

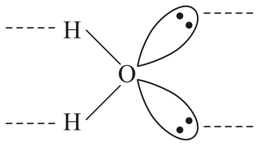
29. BF_3 has triangular planar arrangement.



sp^2-hybridised

There identical vectors acting in outward direction, at equal angles in a plane, cancel each other giving zero resultant, hence non-polar.

30. A water molecule can form at the most four H-bonds.



Four sites of H-bonding

31. O Cl═O

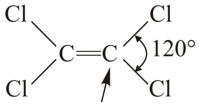
electron pairs at Cl = 2 (-bonds) + 2 (lone-pairs) = 4

Hybridisation at Cl = sp^3

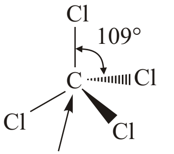
32. PCl_3 has sp^3-hybridised phosphorus, with one lone pair. Therefore, molecule has pyramidal shape like ammonia.

33. O_2 has odd number of electrons, hence it is paramagnetic.

34.



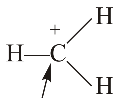
sp^2-hybridised



sp^3-hybridised

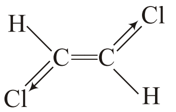
35. CO_2 is linear because carbon is *sp*-hybridised.

36. In CH_3^+, there are only three electron pairs around carbon atom giving sp^2-hybridisation state.



sp^2-hybridised

37. Dipole vectors in *trans*-1, 2-dichloroethylene are at 180° and directed in opposite direction, cancelling each other.



dipole moment = 0

38. In SO_2, the Lewis-dot structure is

O═ S ═O

Electron pairs at S 2 (-bonds) + 1 (lone-pair) 3
sp^2 hybridised.

NOTE

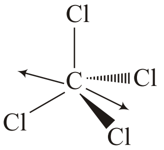
-bonded electrons are not present in hybrid orbitals, therefore not counted in electron pairs. Rather bonds are formed by lateral overlapping of pure *p*-orbitals.

39. Bonds between identical non-metal is purely covalent due to same electronegativities of the bonded atoms. Hence, the bonded atoms have equal holds on the shared pair of electrons.

40. Hybridisation of one '*s*' and one '*p*' orbitals gives two *sp* hybrid orbitals oriented linearly at 180°.

$s \quad p \qquad 2sp$ hybrid orbitals

41. CCl_4 has a regular tetrahedral shape.



Net dipole = 0

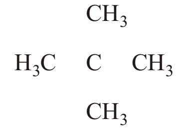
42. CO has a total of 14 electrons and CN also has 14 electrons.

$$\mathrm{C}\,(6e\ \ ) + \mathrm{N}\,(7e\ \ ) + e \qquad\qquad \mathrm{CN}\ \ (14e\ \ )$$

43. CO_2 is a linear molecule because of *sp*-hybridisation around carbon atom.

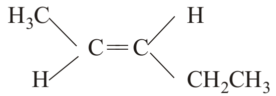
44. For non-polar MX_3, it must have triangular planar arrangement, i.e. there should be sp^2-hybridisation around M.

45.

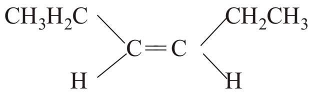


$$\begin{matrix} & CH_3 & \\ H_3C & C & CH_3 \\ & CH_3 & \end{matrix}$$

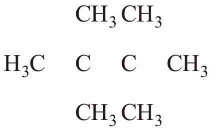
Symmetric, non-polar



Polar



Polar

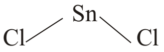


$$\begin{matrix} & CH_3 & CH_3 & \\ H_3C & C & C & CH_3 \\ & CH_3 & CH_3 & \end{matrix}$$

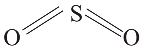
Symmetric, non-polar

46. CN and NO^+ are isoelectronic, have the same bond order of 3.

47. S═C═S (Linear) O═N═O (Linear) O C N (Linear)



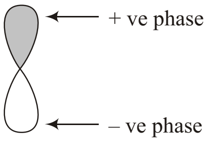
Bent



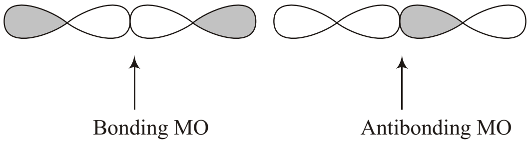
Bent

48. CO_2, $HgCl_2$, C_2H_2 are all linear.

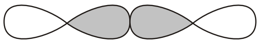
49. **PLAN** This problem includes basic concept of bonding. It can be solved by using the concept of molecular orbital theory.



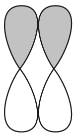
Any orbital has two phase +ve and –ve. In the following diagram, +ve phase is shown by darkening the lobes and –ve by without darkening the lobes.



When two same phase overlap with each other, it forms bonding molecular orbital otherwise antibonding.



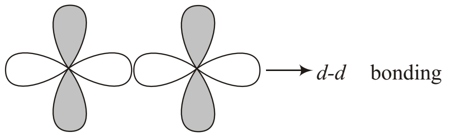
-bond



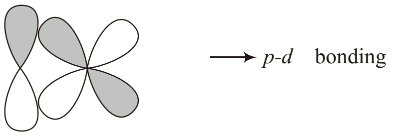
-bond

On the basis of above two concepts, correct matching can be done as shown below:

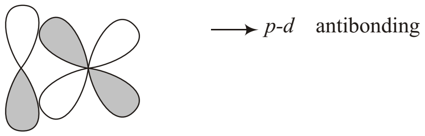
A.



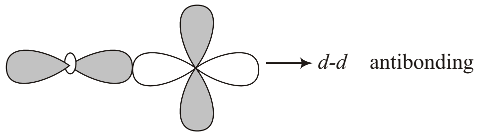
B.



C.



D.



A 2, B 3, C 1, D 4

Hence, (c) is the correct option.

50. (A) $B_2:\ 1s^2\ {}^*1s^2\ \ 2s^2\ {}^*2s^2 \left|\begin{matrix}2p_y^1\\ 2p_z^1\end{matrix}\right|$ paramagnetic.

Bond order $\dfrac{6\quad 4}{2}\quad 1$

Bond is formed by mixing of *s* and *p* orbitals.

B_2 undergoes both oxidation and reduction as

$$B_2 + O_2 \quad \overset{\text{Heat}}{} \quad B_2O_3 \quad \text{(Oxidation)}$$
$$B_2 + H_2 \qquad\qquad B_2H_6 \quad \text{(Reduction)}$$

(B) $N_2:\ 1s^2\ {}^*1s^2\ \ 2s^2\ {}^*2s^2\ \ 2p_x^2 \left|\begin{matrix}2p_y^2\\ 2p_z^2\end{matrix}\right|$ diamagnetic.

Bond order $\dfrac{10\quad 4}{2}\quad 3\quad 2$

N_2 undergoes both oxidation and reduction as

$$N_2 + O_2 \qquad\qquad NO$$
$$N_2 + 3H_2 \quad \overset{\text{Catalyst}}{} \quad NH_3$$

In N_2, bonds are formed by mixing of *s* and *p* orbitals.

(C) $O_2\ :\ 1s^2\ {}^*1s^2\ \ 2s^2\ {}^*2s^2\ \ 2p_x^2 \left|\begin{matrix}2p_y^2\\ 2p_z^2\end{matrix}\right| \begin{matrix}{}^*2p_y^2\\ {}^*2p_z^1\end{matrix} \left|\ {}^*2p_x^0\right.$

Paramagnetic with bond order 1.5. O_2 undergoes both oxidation and reduction and bond involves mixing of *s* and *p*-orbitals.

(D) $O_2:\ 1s^2\ {}^*1s^2\ \ 2s^2\ {}^*2s^2\ \ 2p_x^2 \left|\begin{matrix}2p_y^2\\ 2p_z^2\end{matrix}\right| \begin{matrix}{}^*2p_y^1\\ {}^*2p_z^1\end{matrix} \left|\ {}^*2p_x^0\right.$

Paramagnetic with bond order 2.

O_2 undergoes reduction and the bond involves mixing of *s* and *p*-orbitals.

51. N_2O and I_3 are linear species.

52. Bond order in N_2 is 3 while same in N_2^+ is 2.5, hence bond distance increases as N_2 goes to N_2^+.
Bond order in O_2 is 2 while same in O_2^+ is 2.5, hence bond distance decreases as O_2 goes to O_2^+.

53. Three centred-2 electrons.

54. Hyperconjugation involves delocalisation of   -electrons.

55. *sp*-hybridised.

56. Triangular planar. Carbon in CH_3^+ is sp^2 hybridised.

57. sp^3-hybrid orbital holding the lone pair is involved in formation of ammonium ion.

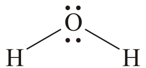
58. H $\overset{O}{C}$ OH and CH_3 $\overset{O}{C}$ OH . Both are capable of forming H-bonds.

59. CO_2, it is 180°.

60. Dipole moment ( )   *q.d*

Since electronegativity of F and Cl are very close, it is the internuclear distance (*d*) that decides dipole moment here. Hence, C   Cl bond has greater dipole moment the C-F bond.

61. H_2O is V-shaped molecule.



V-shaped

62. False

63. In sp^3-hybrid orbital, there is 25 % *s*-character and 75 % *p*-character.

64. Carbon in benzene is sp^2-hybridised, i.e. uses only two of its *p*-orbitals in hybridisation.

65. Sn in $SnCl_2$ has sp^2-hybridisation.

66.

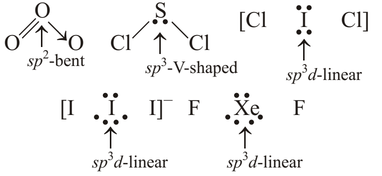
S.N.	Species	No. of -bonds with central atom	No. of L.P at central atom
(i)	In $[TeBr_6]^2$	6	1
(ii)	In $[BrF_2]$	2	2
(iii)	In SNF_3	4	0
(iv)	In $[XeF_3]$	3	3

67. Cl $\underset{sp}{Be}$ Cl N $\underset{sp}{N}$ N^-

N $\underset{sp}{N}$ O O $\underset{sp}{N}$ O

All the above mentioned molecules/ions have *sp*-hybridised central atom and no one pair at central atom, hence linear also.

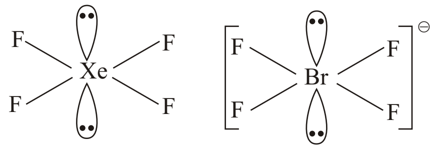
Others are :

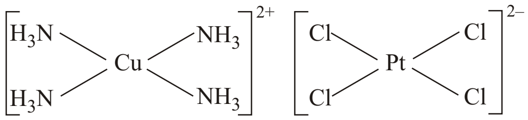


[Although ICl_2^-, I_3^- and XeF_2 all also are linear but in them *d*-orbital contribute in hybridisation.]

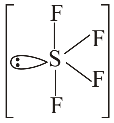
68. **PLAN** This problem includes concept of hybridisation using VBT, VSEPR theory, etc.,

XeF_4, BrF_4 ,$[Cu(NH_3)_4]^2$,$[PtCl_4]^2$ are square planar as shown below:

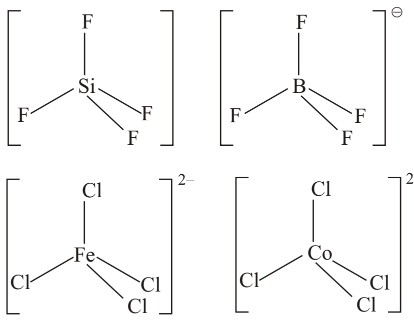




SF_4 (*See-saw*) as shown below:

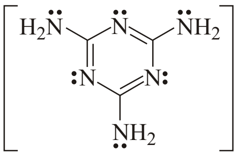


SiF_4, BF_4 , $[FeCl_4]^2$, $[CoCl_4]^2$ are tetrahedral as shown below:



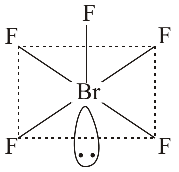
Hence, correct integer is 4.

69. **PLAN** Melamine is a heterocyclic compound.



Each nitrogen atom has one pair of lone pair. Thus, in all six lone pairs.

70.

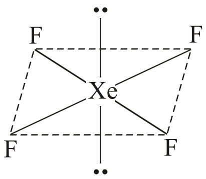


Lone pair would push the Br—F bond pairs in upward direction and all Br—F bond angles will contract.

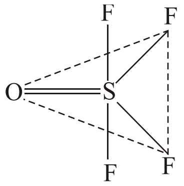
71. No, (i) NMe_3 is pyramidal while (ii) $N(SiMe_3)_3$ is planar. In the latter case, *p* -*d* back bonding between N and Si makes N sp^2-hybridised.

72. Bond order : O_2 1.5, O_2 = 2, O_2^+ = 2.5
Bond length : $O_2^+ < O_2 < O_2$

73.

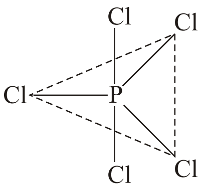


Square planar

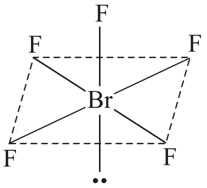


Trigonal bipyramidal

74.

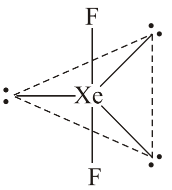


Trigonal bipyramidal
(P is sp^3d-hybridised)

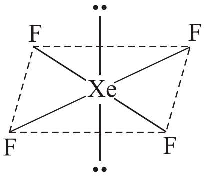


Square pyramidal
(Br is sp^3d^2-hybridised)

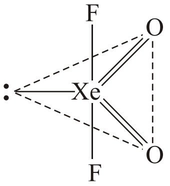
75.



Linear



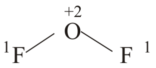
Square planar



See-saw shaped

76. In H_2S, S is sp^3-hybridised with two lone pairs of electrons on it giving V-shaped (water like) shape. In PCl_3, P is sp^3-hybridised with one lone pair of electrons on it. Therefore, PCl_3 is pyramidal in shape.

77. F O F



V-shaped

Electron pair P 2 2 4
Hybridisation sp^3

78. (i) O_2^{2} : O O ^{2} and Cl Cl (Cl_2)

O ^{2}

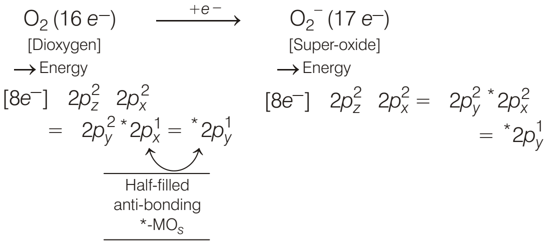
(ii) CO_3^{2} : C and F B F (BF_3)
O O F

(iii) CN : C N and C O (CO)

(iv) NCS : S C N and Cl C N (ClCN)

Topic 3 Resonance, LCAO, MOT, Other Bonding Types

1. The change of O_2 to O_2 can be as follows:



So, in the formation of O_2 from O_2, the 17th electron goes to the $^*2p_x$ or $^*2p_y$ molecular orbital (anti-bonding) which is half-filled in O_2.

2. HF has highest boiling point among hydrogen halides because it has strongest hydrogen bonding. Here, the hydrogen bond exists between hydrogen of one molecule and fluorine atom of another molecule as shown below.

$$\ldots\overset{+}{H}\quad F\ldots\overset{+}{H}\quad F\ldots H\quad F$$

In this molecule, hydrogen bond behaves like a bridge between two atoms that holds one atom by covalent bond and the other by hydrogen bond.

3. **Key Idea** Magnetic nature can be detected by molecular orbital theory. Presence of unpaired electrons means paramagnetic and absence of unpaired electrons means diamagnetic in nature.

Among the given options, CO is a diamagnetic molecule. It can be proved by molecular orbital (MO) theory. The electronic configuration of given diatomic molecules are given below.

- CO (Number of electrons 14)

Electronic configuration $1s^2$, $^*1s^2$, $2s^2$, $^*2s^2$, p_z^2, $2p_x^2$ $2p_y^2$

Since, there is no unpaired electron in the CO molecule, so it is diamagnetic.

- NO (Number of electrons 15)

Electronic configuration $1s^2$, $^*1s^2$, $2s^2$, $^*2s^2$, $2p_z^2$, $2p_x^2$ $2p_y^2$, $^*2p_x^1$ $^*2p_y^0$

Since, NO has one unpaired electron in $^*2p_x^1$ orbital, so it is paramagnetic.

- B_2 (Number of electrons 10)

Electronic configuration $1s^2$, $^*1s^2$, $2s^2$, $^*2s^2$, $2p_x^1$ p_y^1

Since, two unpaired electrons are present in $2p_x^1$ and $2p_y^1$ orbital. So, it is paramagnetic.

- O_2 (Number of electrons 16)

Electronic configuration $1s^2$, $^*1s^2$, $2s^2$, $^*2s^2$, $2pz^2$, $2p_x^2$ $2p_y^2$, $^*2p_x^1$ $^*2p_y^1$

Since, two unpaired electrons are present in $^*2p_x^1$ and $^*2p_y^1$ orbital. So, it is also paramagnetic.

4. C_2 will be stabilised after forming anion. The electronic configuration of carbon is $1s^2\ 2s^2\ 2p^2$. There are twelve electrons in C_2. After forming anion (i.e. C_2^-), the electronic configuration is

- $C_2 : (\ 1s)^2(\ ^*1s)^2(\ 2s)^2(\ *2s)^2(\ 2p_x^2\quad 2p_y^2)(\quad p_z^1)$ or $KK(\ 2s)^2(\ ^*2s)^2(\ 2p_x^2\quad 2p_y^2).\ 2p_z^1$

Bond order $\frac{1}{2}(N_b\quad N_a)\quad \frac{1}{2}(9\quad 4)\quad 2.5$

For other options such as F_2 , O_2, NO , the electronic configurations are as follows :

$F_2\ :(\ 1s)^2(\ ^*1s)^2(\ 2s)^2(\ ^*2s)^2(\ 2p_z)^2(\ 2p_x^2\quad 2p_y^2)(\ ^*2p_x^2\quad ^*2p_y^2)(\ ^*2p_z^1)$

Bond order $1/2(N_b\quad N_a)\quad 1/2(10\quad 9)\quad 0.5$

- $O_2 :(\ 1s)^2(\ ^*1s)^2(\ 2s)^2(\ ^*2s)^2(\ 2p_z)^2(\ 2p_x^2\quad 2p_y^2)(\ ^*2p_x^2\quad ^*2p_y^1)$

Bond order $\frac{1}{2}(N_b\quad N_a)\quad \frac{1}{2}(10\quad 7)\quad 1.5$

- $NO :(\ 1s)^2(\ ^*1s)^2(\ 2s)^2(\ *2s)^2(\ 2p_z)^2(\ 2p_x^2\quad 2p_y^2)(\ ^*\ 2p_x^1\quad ^*2p_y^1)$

Bond order $\frac{1}{2}(N_b\quad N_a)\quad \frac{1}{2}(10\quad 6)\quad 2$

The value of bond order of C_2 is highest among the given options. Bond order between two atoms in a molecule may be taken as an approximate measure of the bond length.
The bond length decreases as bond order increases. As a result, stability of a molecule increases.

5.

Species	**MO energy order**	**Bond order** (BO)	***n*, number of unpaired *e***	**Magnetic character**
$C_2^2\ (14e\ )$	$[8\bar{e}]\ 2p_x^2\quad 2p_y^2\ 2p_z^2$	$\frac{6\quad 0}{2}\quad 3$	0	Diamagnetic
$O_2(16e\ )$	$[8\bar{e}]\ 2p_z^2\ 2p_x^2\quad 2p_y^2\ ^*2p_x^1\quad ^*2p_y^1$	$\frac{6\quad 2}{2}\quad 2$	2	Paramagnetic
$O_2^2\ (18e\ )$	$[8\bar{e}]\ 2p_z^2\ 2p_x^2\quad 2p_y^2\ ^*2p_x^2\quad ^*2p_y^2$	$\frac{6\quad 4}{2}\quad 1$	0	Diamagnetic
$N_2^2\ (16e\ )$	$[8\bar{e}]\ 2p_x^2\quad 2p_y^2\ 2p_z^2\ ^*2p_x^1\quad ^*2p_y^1$	$\frac{6\quad 2}{2}\quad 2$	2	Paramagnetic

Bond length $\quad\frac{1}{\text{BO (Bond order)}}$. So order of bond length $\underset{(BO\quad 3)}{C_2^2}\quad \underset{(BO\quad 2)}{O_2}\quad N_2^2\quad \underset{(BO\quad 1)}{O_2^2}$

The diamagnetic species with shortest bond length is C_2^2 (option-a).

6. The energy order of MOs of the given species are as follows:

$O_2(16e\ \text{'s})\quad 1s^2,\ ^*1s^2,\ 2s^2,\ ^*2s^2,\ 2p_z^2,$
$2p_x^2\quad 2p_y^2,\ ^*2p_x^1\quad ^*2p_y^1,$
$O_2\ (15e\ \text{'s})\quad 1s^2,\ ^*1s^2,\ 2s^2,\ ^*2s^2,\ 2p_z^2,$
$2p_x^2\quad 2p_y^2,\ ^*2p_x^1\quad ^*2p_y^0$
$N_2(14e\ \text{'s})\quad 1s^2\ ^*1s^2,\ 2s^2,\ ^*2s^2$
$2p_x^2\quad 2p_y^2,\ 2p_z^2$
$N_2\ (13e\ \text{'s})\quad 1s^2\ ^*1s^2\quad s^2\ ^*2s^2$
$2p_x^2\quad 2p_z^2\ 2p_z^1$

Thus, in case of N_2, two -bonds and half -bond are present in the bonding MOs.

7. Considering molecular orbital theory (MOT) :

The electronic configuration of $Li_2\ (Z\quad 5)\quad 1s^2,\ ^*1s^2,\ 2s^1$

Bond order (BO) $\frac{N_b\quad N_a}{2}\quad \frac{3\quad 2}{2}\quad \frac{1}{2}$

The electronic configuration of $Li_2(Z\quad 7)\quad 1s^2,\ ^*1s^2,\quad s^2,\quad s^1$

Bond order (BO) $\frac{N_b\quad N_a}{2}\quad \frac{4\quad 3}{2}\quad \frac{1}{2}$

For the species having the same value of BO, the specie having lesser number of antibonding electrons $[N_a]$ will be more stable.

Here, N_a of Li_2^+ (2) $\quad N_a$ of Li_2 (3). So, their order of stability will be $Li_2 \quad Li_2$.

8. **Key Idea** *According to M.O.T, the viability of any molecule can be judged through the calculation of bond order.*

Electronic	Configuration	Bond order
He_2	$1s^2 \quad \overset{*}{1s^1}$	$\frac{2 \quad 1}{2} \quad 0.5$
H_2	$1s^2 \quad \overset{*}{1s^1}$	$\frac{2 \quad 1}{2} \quad 0.5$
H_2^2	$1s^2 \quad \overset{*}{1s^2}$	$\frac{2 \quad 2}{2} \quad 0$
He_2^2	$1s^2$	$\frac{2 \quad 0}{2} \quad 1$

The molecule having zero bond order will not be viable hence, H_2^2 (option d) is the correct answer.

9. To identify the magnetic nature we need to check the molecular orbital configuration. If all orbitals are fully occupied, species is diamagnetic while when one or more molecular orbitals is/are singly occupied, species is paramagnetic.

(a) NO (7 $\quad$ 8 $\quad$ 15) $\quad 1s^2, {}^*1s^2, 2s^2, {}^*2s^2,$

$2p_x^2 \quad 2p_y^2, 2p_z^2, {}^*2p_x^1 \quad {}^*2p_y^0$

One unpaired electron is present. Hence, it is paramagnetic.

(b) CO (6 $\quad$ 8 $\quad$ 14) $\quad 1s^2, {}^*1s^2, 2s^2, {}^*2s^2,$

$2p_x^2 \quad 2p_y^2 \quad 2p_z^2$

No unpaired electron is present. Hence, it is diamagnetic.

(c) O_2 (8 $\quad$ 8 $\quad$ 16) $\quad 1s^2, {}^*1s^2, 2s^2, {}^*2s^2, 2p_z^2,$

$2p_x^2 \quad 2p_x^2, {}^*2p_x^1 \quad {}^*2p_y^1$

Two unpaired electrons are present.
Hence, it is paramagnetic.

(d) B_2(5 $\quad$ 5) $\quad 1s^2, {}^*1s^2, 2s^2, {}^*2s^2, 2p_x^1 \quad 2p_y^1$

Two unpaired electrons are present.
Hence, it is paramagnetic.

10. **PLAN** This problem can be solved by using the concept involved in molecular orbital theory. Write the molecular orbital electronic configuration keeping in mind that there is no 2*s*-2*p* mixing, then if highest occupied molecular orbital contain unpaired electron then molecule is paramagnetic otherwise diamagnetic.

Assuming that no 2*s*-2*p* mixing takes place the molecular orbital electronic configuration can be written in the following sequence of energy levels of molecular orbitals

$$1s, \overset{*}{1s}, 2s, \overset{*}{2s}, 2p_z, 2p_x \quad 2p_y, \overset{*}{2p_x} \quad \overset{*}{2p_y}, \overset{*}{2p_z}$$

(a) $Be_2 \quad 1s^2, {}^*1s^2, 2s^2, {}^*2s^2$ (diamagnetic)

(b) $B_2 \quad 1s^2, {}^*1s^2, 2s^2, {}^*2s^2, 2p_z^2, \begin{matrix}2p_x^0\\2p_y^0\end{matrix}$ (diamagnetic)

(c) $C_2 \quad 1s^2, {}^*1s^2, 2s^2, {}^*2s^2, 2p_z^2, \begin{matrix}2p_x^1\\2p_y^1\end{matrix},$

$\begin{matrix}{}^*2p_x^0\\{}^*2p_y^0\end{matrix}, {}^*2p_z^0$ (paramagnetic)

(d) $N_2 \quad 1s^2, {}^*1s^2, 2s^2, {}^*2s^2, 2p_z^2, \begin{matrix}2p_x^2\\2p_y^2\end{matrix},$

$\begin{matrix}{}^*2p_x^0\\{}^*2p_y^0\end{matrix}, {}^*2p_z^0$ (diamagnetic)

Hence, (c) is the correct choice.

11. Li_2 (3 $\quad$ 3 $\quad$ 6) $\quad 1s^2, {}^*1s^2, 2s^2$

Bond order $\frac{N_b \quad N_a}{2} \quad \frac{4 \quad 2}{2} \quad 1$

Li_2 (3 $\quad$ 3 $\quad$ 1 $\quad$ 5) $\quad 1s^2, {}^*1s^2, 2s^1$

Bond order $\frac{3 \quad 2}{2} \quad \frac{1}{2} \quad 0.5$

Li_2 (3 $\quad$ 3 $\quad$ 1 $\quad$ 7) $\quad 1s^2, {}^*1s^2, 2s^2 \quad {}^*2s^1$

Bond order $\frac{4 \quad 3}{2} \quad \frac{1}{2} \quad 0.5$

Stability order is $Li_2 \quad Li_2 \quad Li_2$ (because Li_2 has more number of electrons in antibonding orbitals which destabilises the species).

12. Species having zero or negative bond order do not exist.

H_2^2 (1 $\quad$ 1 $\quad$ 2 $\quad$ 0) $\quad 1s^0$

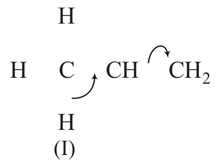
Bond order $\quad 0$

He_2 (2 $\quad$ 2 $\quad$ 4) $\quad 1s^2, {}^*1s^2$

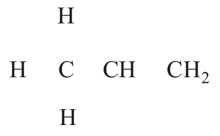
Bond order $\frac{N_b \quad N_a}{2} \quad \frac{2 \quad 2}{2} \quad 0$

So, both H_2^2 and He_2 do not exist.

13.



(I)



(II)

I and II are hyperconjugation structures of propene and involves -electrons of C—H bond and *p*-orbitals of pi bond in delocalisation.

14. O_2^+ (15*e*) : $\quad 1s^2\ {}^*1s^2 \quad 2s^2\ {}^*2s^2 \quad 2p_x^2 \left|\begin{matrix}2p_y^2\\2p_z^2\end{matrix}\right|\begin{matrix}{}^*2p_y^1\\{}^*2p_z^0\end{matrix}\right| {}^*2p_x^0$

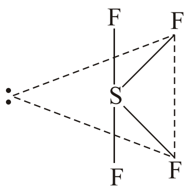
Bond order $\frac{10 \quad 5}{2} \quad$ 2.5; paramagnetic.

O_2 (16*e*) : $\quad 1s^2\ {}^*1s^2 \quad 2s^2\ {}^*2s^2 \quad 2p_x^2 \left|\begin{matrix}2p_y^2\\2p_z^2\end{matrix}\right|\begin{matrix}{}^*2p_y^1\\{}^*2p_z^1\end{matrix}\right| {}^*2p_x$

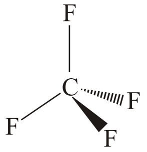
Bond order $\frac{10 \quad 6}{2} \quad 2$

Hence, (a) is the correct answer.

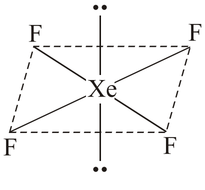
15.



See-saw shape molecule



Tetrahedral



Square planar

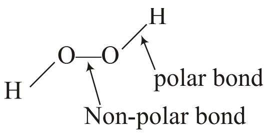
16. When E B in BCl_3, bond angle is 120°. When E P, As or Bi in ECl_3, hybridisation at E will be sp^3. Also, if central atoms are from same group, bond angle decreases down the group provided all other things are similar. Hence, the order of bond angles is $BCl_3 > PCl_3 > AsCl_3 > BiCl_3$

17. Bond length $\quad \frac{1}{\text{Bond order}}$

Bond order : $CO_2 = 2$, $CO = 3$, $CO_3^2 \quad 1 \quad \frac{1}{3} \quad \frac{4}{3}$

Therefore, order of bond length is $CO_3^2 \quad CO_2 < CO$

18. H_2O_2



19. HCl does not form hydrogen bond. For formation of hydrogen bond, atleast one hydrogen atom must be bonded to one of the three most electronegative atom O , N and F.

20.

Species	Electrons	MOEC	N_B	N_A	BO	Magnetic character
C_2^2	14	$1s^2$, $*1s^2$, $2s^2$, $*2s^2$, $2p_x^2 \quad 2p_y^2$, $2p_z^2$	10	4	3	Diamagnetic
O_2^2	14	As above according to number of electrons	10	4	3	Diamagnetic
O_2	16		10	6	2	Paramagnetic
N_2	13		9	4	2.5	Paramagnetic
N_2	15		10	5	2.5	Paramagnetic
He_2	3		2	1	0.5	Paramagnetic

Thus, (a) is correct.

(b) Bond order $O_2^2 \quad O_2$ thus,

Bond length of $O_2^{2+} \quad O_2$ thus, incorrect.

(c) N_2^+ and N_2 have same bond order thus correct.

(d) He_2 with bond order 0.5 is more stable thus, less energy than isolated He atoms. Thus, (d) is incorrect.

21. **PLAN** This problem can be solved by using concept of H-bonding and applications of H-bonding.

22. $C_2 (6 \quad 6 \quad 12) \qquad s^2, {}^* 1s^2, \; 2s^2, {}^* 2s^2, \; 2p_x^2 \quad 2p_y^2$

Since, all the electrons are paired, it is a diamagnetic species.

$N_2 \; (7 \quad 7 \quad 14) \qquad 1s^2, {}^* 1s^2, \; 2s^2,$

$${}^* 2s^2 \quad 2p_x^2 \quad 2p_y^2, \; 2p_z^2$$

It is also a diamagnetic species because of the absence of unpaired electrons.

$O_2 \; (8 \quad 8 \quad 16)$

or $\qquad S_2 \qquad 1s^2, {}^* 1s^2, \; 2s^2, \; 2s^2,$

$$2p_z^2, \; 2p_x^2 \quad 2p_y^2 \; {}^* 2p_x^1 \quad {}^* 2p_y^1$$

Due to the presence of two unpaired electrons, O_2 and S_2 both are paramagnetic molecules.

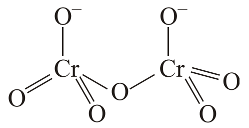
23. Statement I is correct, given structure is one of the resonance structure of ozone.

Statement II is also correct because oxygen cannot expand its octet. It is also the explanation for the given structure of ozone.

24. (A) In the reaction : $O_2 \qquad O_2 + O_2^2$

Oxygen on reactant side is in $\frac{1}{2}$ oxidation state. In product side, one of the oxygen is in zero oxidation state, i.e. oxidised while the other oxygen is in –1 oxidation state, i.e. reduced. Hence, in the above reaction, oxygen $(O^{1/2})$ is simultaneously oxidised and reduced disproportionated.

(B) In acidic medium, CrO_4^2 is converted into $Cr_2O_7^2$ which is a dimeric, bridged tetrahedral.



(C) $MnO_4 \quad NO_2 \quad H^+ \qquad Mn^{2+} + NO_3$

The above is a redox reaction and a product NO_3 has trigonal planar structure.

(D) $NO_3 \quad H_2SO_4 + Fe^{2+} \qquad Fe^+ + NO$

The above is a redox reaction.

25. H_2, Li_2, Be_2, C_2, N_2 and F_2 are diamagnetic according to molecular orbital theory.

26. $O_2 : \; 1s^2 \, {}^* 1s^2 \quad 2s^2 \, {}^* 2s^2 \quad 2p_x^2 \left| \begin{matrix} 2p_y^2 \\ 2p_z^2 \end{matrix} \right| \begin{matrix} {}^* 2p_y^1 \\ {}^* 2p_z^1 \end{matrix} \right|$

Bond order $\quad \frac{10 \quad 6}{2} \quad 2$, paramagnetic.

27. Strength of hydrogen bonding in X—H—X depends on electronegativity as well as size of X. X with higher electronegativity and smaller size forms stronger H-bond. Hence, increasing order of strength of H-bond is

$$S < Cl < N < O < F$$

28. Resonance in vinyl chloride increases polar character of the molecule.