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Chemical Bonding and Molecular Structure — JEE (Main) Pattern Topic Test

FREE SAMPLE TEST · CHEMISTRY · PATTERN OF JEE (MAIN)

DURATION	MAXIMUM MARKS	QUESTIONS	NAME / ROLL NO.
60 minutes	100	25 (20 + 5)	

GENERAL INSTRUCTIONS

1. This question paper has two sections, A and B. All 25 questions are compulsory.
2. Section A has TWENTY (20) multiple-choice questions. Each has FOUR options, (1), (2), (3) and (4), of which ONLY ONE is correct.
3. Section B has FIVE (05) questions whose answer is a numerical value. Enter the value rounded off to the nearest integer.
4. Marking scheme for both sections: +4 for a correct answer, −1 for an incorrect answer, 0 if the question is not attempted.
5. Use of a calculator, log tables or any other aid is not allowed.
6. The answer key and worked solutions are at the end of this booklet. Attempt the paper in 60 minutes before you look at them.

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Topics covered: Ionic and covalent bonds · Lattice enthalpy · Fajans' rules · Dipole moment · VSEPR theory · Hybridisation · Resonance · Sigma and pi bonds · Molecular orbital theory · Hydrogen bonding

SECTION A (Q1–20) · Multiple choice · +4 / 0 / −1

Each question has FOUR options. ONLY ONE of them is correct.

1. The shape of the ClF_3 molecule is

(1) trigonal planar

(2) trigonal pyramidal

(3) T-shaped

(4) see-saw

2. Which pair of species has the same shape?

(1) SF_4 and XeF_4

(2) NH_3 and BF_3

(3) BrF_5 and PCl_5

(4) ICl_4^- and XeF_4

3. The hybridisation of xenon and the shape of the molecule XeO_3 are

(1) sp^3 and trigonal pyramidal

(2) sp^2 and trigonal planar

(3) sp^3 and tetrahedral

(4) sp^3d and T-shaped

4. The correct order of increasing O–O bond length in O_2^{2-}, O_2^-, O_2 and O_2^+ is

(1) $O_2^{2-} < O_2^- < O_2 < O_2^+$

(2) $O_2 < O_2^+ < O_2^- < O_2^{2-}$

(3) $O_2^+ < O_2 < O_2^- < O_2^{2-}$

(4) $O_2^+ < O_2^- < O_2 < O_2^{2-}$

5. According to molecular orbital theory, which pair of species has the same bond order?

(1) O_2^- and N_2^+

(2) N_2 and O_2^{2+}

(3) O_2 and N_2^-

(4) B_2 and O_2^+

6. Which of the following molecules has zero dipole moment?

(1) NF_3

(2) SF_4

(3) BF_3

(4) ClF_3

7. Which of the following has the greatest covalent character?

(1) LiF

(2) LiI

(3) NaI

(4) KI

8. Use the data (kJ/mol): enthalpy of formation of KCl(s) −437; sublimation of K 89; first ionisation enthalpy of K 419; bond dissociation enthalpy of Cl_2 242; electron gain enthalpy of Cl −349. The lattice enthalpy of KCl (for $K^+(g) + Cl^-(g) \rightarrow KCl(s)$) is

(1) −838 kJ/mol

(2) −1415 kJ/mol

(3) −596 kJ/mol

(4) −717 kJ/mol

9. In which of the following does the central atom have sp^3d^2 hybridisation?

(1) PCl_5

(2) SF_4

(3) BrF_5

(4) XeF_2

10. The average N–O bond orders in the nitrate ion and in the nitrite ion are, respectively,

(1) 4/3 and 3/2

(2) 3/2 and 4/3

(3) 1 and 2

(4) 4/3 and 4/3

11. Assertion A: o-Nitrophenol is more volatile than p-nitrophenol.
Reason R: o-Nitrophenol forms intramolecular hydrogen bonds, whereas p-nitrophenol molecules are held together by intermolecular hydrogen bonds.
In the light of the above statements, choose the correct answer from the options given below:

(1) A is true but R is false

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

(3) A is false but R is true

(4) Both A and R are true but R is NOT the correct explanation of A

12. The correct order of the bond angle (smallest first) is

(1) $H_2O < NH_3 < BF_3 < CH_4$

(2) $NH_3 < H_2O < CH_4 < BF_3$

(3) $CH_4 < NH_3 < H_2O < BF_3$

(4) $H_2O < NH_3 < CH_4 < BF_3$

13. The dipole moment of HCl is 1.03 D and its bond length is 127 pm. The percentage ionic character of the H–Cl bond is about ($1\ D = 3.33 \times 10^{-30}$ C m, $e = 1.6 \times 10^{-19}$ C)

(1) 83%

(2) 17%

(3) 21%

(4) 8.5%

14. The numbers of σ and π bonds in but-1-en-3-yne, CH_2=CH–C≡CH, are, respectively,

(1) 6 and 3

(2) 7 and 2

(3) 8 and 3

(4) 7 and 3

15. In which of the following species does the central atom carry the same number of lone pairs as the oxygen atom in H_2O?

(1) I_3^-

(2) ClF_3

(3) NH_3

(4) SF_4

16. The bond order and the magnetic behaviour of He_2^+ are

(1) 1, diamagnetic

(2) 0.5, diamagnetic

(3) 0, it does not exist

(4) 0.5, paramagnetic

17. Consider the following statements.
(A) In metallic bonding, the metal ions are held together by a sea of delocalised valence electrons.
(B) The lattice enthalpy of MgO is greater than that of NaCl.
(C) The dipole moment of NH_3 is greater than that of NF_3.
(D) A $BeCl_2$ molecule in the vapour is bent.
(E) The H–O–H bond angle in water is larger than the H–N–H bond angle in ammonia.
Choose the correct answer from the options given below:

(1) (A), (B) and (C) only

(2) (A), (C) and (D) only

(3) (B), (C) and (E) only

(4) (A), (B), (C) and (E) only

18. Which of the following species is NOT tetrahedral?

(1) NH_4^+

(2) BF_4^-

(3) XeF_4

(4) SiF_4

19. The correct order of the boiling points of the hydrogen halides is

(1) HF > HCl > HBr > HI

(2) HI > HBr > HCl > HF

(3) HF > HI > HBr > HCl

(4) HI > HF > HBr > HCl

20. Assertion A: The bond dissociation enthalpy of O_2^+ is greater than that of O_2, whereas that of N_2^+ is less than that of N_2.

Reason R: The electron removed from O_2 comes from an antibonding π^* orbital, whereas the electron removed from N_2 comes from a bonding $\sigma 2p$ orbital.

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

(1) A is true but R is false

(2) A is false but R is true

(3) Both A and R are true but R is NOT the correct explanation of A

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

SECTION B (Q21–25) · Numerical value · +4 / 0 / −1

The answer to each question is a NUMERICAL VALUE. Enter it rounded off to the nearest integer.

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21. The number of species among the following in which the central atom is sp^3d hybridised is _____.

PCl_5, SF_4, ClF_3, XeF_2, I_3^-, BrF_5, XeF_4, SF_6, ICl_4^-, IF_7

Answer: _____

22. The number of paramagnetic species among the following is _____.

O_2, O_2^+, O_2^-, O_2^{2-}, N_2, N_2^+, B_2, C_2, He_2^+, Li_2

Answer: _____

23. The total number of lone pairs of electrons on all the atoms of a $XeOF_4$ molecule is _____.

Answer: _____

24. The number of F–S–F bond angles of 90° in the SF_6 molecule is _____.

Answer: _____

25. The dipole moment of a gaseous KCl molecule is 10.3 D and its bond length is 267 pm. The percentage ionic character of the bond is _____ (to the nearest integer; 1 D = 3.33×10^{-30} C m, e = 1.6×10^{-19} C).

Answer: _____

END OF THE QUESTION PAPER

ANSWER KEY

Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8	Q9	Q10
(3)	(4)	(1)	(3)	(2)	(3)	(2)	(4)	(3)	(1)

Q11	Q12	Q13	Q14	Q15	Q16	Q17	Q18	Q19	Q20
(2)	(4)	(2)	(4)	(2)	(4)	(1)	(3)	(3)	(4)

Q21	Q22	Q23	Q24	Q25
5	6	15	12	80

WORKED SOLUTIONS

Q1. Answer (3). Cl has 7 valence electrons; 3 form bonds with F, leaving 2 lone pairs. Five electron pairs (sp^3d) take a trigonal bipyramid with the lone pairs in equatorial positions, so the atoms form a T.

Q2. Answer (4). ICl_4^- (4 bond pairs + 2 lone pairs on I: 7 + 1 − 4 = 4 electrons) and XeF_4 (4 + 2 on Xe) both have an octahedral electron arrangement with the lone pairs trans, so both are square planar. SF_4 is see-saw but XeF_4 square planar; NH_3 is pyramidal but BF_3 trigonal planar; BrF_5 is square pyramidal but PCl_5 trigonal bipyramidal.

Q3. Answer (1). Xe has 8 valence electrons; three Xe=O bonds use 6, leaving one lone pair. Three σ bonds + one lone pair = 4 electron pairs: sp^3, with the atoms in a trigonal pyramid.

Q4. Answer (3). Bond orders: O_2^+ 2.5, O_2 2, O_2^- 1.5, O_2^{2-} 1 (each added electron goes into an antibonding π* orbital). A higher bond order means a shorter bond.

Q5. Answer (2). Bond order = (bonding − antibonding electrons)/2. N_2 and O_2^{2+} both have 14 electrons: bond order 3. O_2^- 1.5 but N_2^+ 2.5; O_2 2 but N_2^- 2.5; B_2 1 but O_2^+ 2.5.

Q6. Answer (3). BF_3 is trigonal planar with three identical B–F bond dipoles at 120°, which cancel. NF_3 (pyramidal), SF_4 (see-saw) and ClF_3 (T-shaped) have lone pairs that make the shapes unsymmetrical, so their bond dipoles do not cancel.

Q7. Answer (2). Covalent character grows with the polarising power of the cation (small size, high charge) and the polarisability of the anion (large size). Li^+ is the smallest cation and I^- the largest anion, so LiI is the most covalent.

Q8. Answer (4). Born–Haber cycle: ΔfH = ΔsubH + IE + ½D(Cl_2) + Δ_egH + U. So U = −437 − 89 − 419 − 121 + 349 = −717 kJ/mol. (Using the whole of D(Cl_2) gives −838; one Cl atom is needed per formula unit.)

Q9. Answer (3). BrF_5: 5 bond pairs + 1 lone pair = 6 electron pairs, sp^3d^2 (square pyramidal). PCl_5 (5 + 0), SF_4 (4 + 1) and XeF_2 (2 + 3) each have 5 electron pairs: sp^3d.

Q10. Answer (1). Each resonance form of NO_3^- has one N=O and two N–O bonds: 4 bonds over 3 links, 4/3. NO_2^- has one N=O and one N–O: 3 bonds over 2 links, 3/2.

Q11. Answer (2). In o-nitrophenol the –OH and $–NO_2$ groups are adjacent and bond within the molecule, so molecules do not associate; in the para isomer the groups are too far apart and bond between molecules, which raises the boiling point. Both are true and R explains A (this is why o-nitrophenol can be steam distilled).

Q12. Answer (4). BF_3 is trigonal planar (120°) and CH_4 tetrahedral (109.5°). NH_3 (one lone pair, 107°) and H_2O (two lone pairs, 104.5°) are squeezed further, because lone pair–bond pair repulsion exceeds bond pair–bond pair repulsion.

Q13. Answer (2). A fully ionic bond would have μ = e × d = $1.6 \times 10^{-19} \times 1.27 \times 10^{-10} = 2.03 \times 10^{-29}$ C m = 6.1 D. Ionic character = 1.03/6.1 ≈ 17%.

Q14. Answer (4). σ: four C–H bonds and three C–C links = 7. π: one in C=C and two in C≡C = 3.

Q15. Answer (2). O in H_2O: (6 − 2)/2 = 2 lone pairs. ClF_3: (7 − 3)/2 = 2. I_3^-: (7 + 1 − 2)/2 = 3. NH_3: (5 − 3)/2 = 1. SF_4: (6 − 4)/2 = 1.

Q16. Answer (4). He_2^+ has 3 electrons: $(\sigma 1s)^2(\sigma^* 1s)^1$. Bond order = (2 − 1)/2 = 0.5, so it can exist, and the unpaired σ* electron makes it paramagnetic.

Q17. Answer (1). (A) is the electron-sea model. (B) Mg^{2+} and O^{2-} carry twice the charges of Na^+ and Cl^- and are smaller, so the lattice enthalpy is much larger. (C) In NH_3 the lone-pair moment adds to the N–H bond moments; in NF_3 it opposes the N–F moments. (D) is false: Be has 2 bond pairs and no lone pair, so $BeCl_2$ is linear. (E) is false: 104.5° < 107°.

Q18. Answer (3). NH_4^+, BF_4^- and SiF_4 each have four bond pairs and no lone pair on the central atom: tetrahedral. XeF_4 has four bond pairs and two lone pairs (octahedral arrangement), so it is square planar.

Q19. Answer (3). HF boils highest (293 K) because of strong intermolecular hydrogen bonding. For the rest, van der Waals forces grow with molecular size: HI (238 K) > HBr (206 K) > HCl (188 K).

Q20. Answer (4). O_2 (bond order 2) → O_2^+ (2.5): losing an antibonding electron strengthens the bond. N_2 (3) → N_2^+ (2.5): losing a bonding electron weakens it. Both are true and R explains A.

Q21. Answer 5. Five electron pairs (sp^3d): PCl_5 (5 + 0), SF_4 (4 + 1), ClF_3 (3 + 2), XeF_2 (2 + 3), I_3^- (2 + 3). BrF_5, XeF_4, SF_6 and ICl_4^- have six pairs (sp^3d^2) and IF_7 seven (sp^3d^3).

Q22. Answer 6. Unpaired electrons: O_2 2, O_2^+ 1, O_2^- 1, O_2^{2-} 0, N_2 0, N_2^+ 1, B_2 2, C_2 0, He_2^+ 1, Li_2 0. Six are paramagnetic.

Q23. Answer 15. Xe (8 valence electrons) forms one Xe=O and four Xe–F bonds, using 6, and keeps one lone pair (square pyramidal molecule). The O keeps 2 lone pairs and each F keeps 3: 1 + 2 + 4 × 3 = 15.

Q24. Answer 12. SF_6 is octahedral. Each of the 6 F atoms is at 90° to 4 others (and at 180° to 1): 6 × 4/2 = 12 angles of 90°.

Q25. Answer 80. For a full charge separation, $\mu = 1.6 \times 10^{-19} \times 2.67 \times 10^{-10} = 4.27 \times 10^{-29}$ C m = 12.8 D. Ionic character = 10.3/12.8 ≈ 80%.

All questions are original and © Master Testing Agency. Free to download and use for personal practice; not for resale. Every answer in this paper was checked independently by computer: shapes, hybridisation and lone pairs from VSEPR electron counting, bond orders and magnetism by filling molecular orbitals, dipole cancellation and bond angles from vector sums over the ideal geometries, and the Born–Haber cycle and ionic character recomputed from the data given.