



Attempt all questions before checking the answer key. Show lone pairs, charges and resonance where relevant. Use qualitative MO ordering appropriate to each molecule.

A. Very short answers - 1 mark each

1. Define a covalent bond in the Lewis picture.
2. What is formal charge?
3. State the number of σ and π bonds in ethyne.
4. What is a coordinate bond? Give an example.
5. Why is the octet rule not universal?
6. Define bond order in molecular-orbital theory.

B. Short answers / practice - 2 marks each

7. Draw Lewis structures of CO_2 and NH_3 , showing lone pairs.
8. Calculate formal charges in one valid Lewis structure of ozone.
9. Why is BF_3 non-polar despite polar B-F bonds?
10. Compare σ and π bonds in overlap and rotational freedom.
11. Predict hybridisation and shape of the central atom in BeCl_2 and CH_4 .
12. Why does NH_3 have a higher boiling point than PH_3 ?
13. Find total valence electrons in NH_4^+ .
14. Is CO_2 polar? Explain using its geometry.
15. Find σ and π bond counts in ethene.
16. Predict shape of NH_4^+ .
17. Is He_2 stable according to elementary MO theory?
18. Explain why lone-pair repulsion reduces the bond angle in water.

C. Short answers - 3 marks each

19. Use VSEPR theory to explain shapes and relative bond angles of CH_4 , NH_3 and H_2O .
20. Draw resonance structures of CO_3^{2-} and explain why its C-O bonds are equivalent.
21. Explain shapes and hybridisation of PCl_5 and SF_6 , showing axial/equatorial positions where applicable.

22. Write the MO electronic configuration of O_2 , calculate bond order and explain its paramagnetism.

23. Compare bond order and stability of H_2 , H_2^+ and He_2 using MO theory.

24. Distinguish intermolecular and intramolecular hydrogen bonding with examples and an effect on physical properties.

D. Long answers - 5 marks each

25. Explain the formation of an ionic bond and factors favouring it. Use a qualitative Born-Haber cycle for NaCl to relate sublimation, ionisation, dissociation, electron gain and lattice formation.

26. Use VSEPR to predict shapes of NH_3 , H_2O , SF_4 , ClF_3 and XeF_4 . Identify bond pairs and lone pairs around the central atom in each.

27. Construct the valence MO schemes for N_2 and O_2 , showing their different orbital ordering. Find bond orders, unpaired electrons and magnetic behaviour.

28. Explain sp , sp^2 and sp^3 hybridisation with BeCl_2 , BF_3 and CH_4 . Compare geometry, bond angles and orbital overlap.

29. Discuss octet-rule failures using BF_3 , NO and PCl_5 . Explain how formal charge and resonance help select and interpret Lewis structures, using ozone as an example.

30. Compare O_2^+ , O_2 , O_2^- and O_2^{2-} using MO occupancies. Predict bond orders, relative bond lengths and numbers of unpaired electrons.

ANSWER KEY - Numerical / short answers

3) 3 σ and 2 π bonds. 8) Central O +1; singly bonded terminal O -1; double-bonded terminal O 0. 11) BeCl_2 sp, linear; CH_4 sp^3 , tetrahedral. 13) 8. 14) No; equal bond dipoles cancel in a linear molecule. 15) 5 σ and 1 π . 16) Tetrahedral. 17) No; bond order is zero. 22) Bond order 2; two unpaired electrons. 23) H_2 :1; H_2^+ :1/2; He_2 :0; He_2 not stable in the simple MO model. 26) NH_3 3BP/1LP; H_2O 2/2; SF_4 4/1; ClF_3 3/2; XeF_4 4/2. 27) N_2 : bond order 3, 0 unpaired, diamagnetic; O_2 : 2, 2 unpaired, paramagnetic. 30) Bond orders 2.5, 2, 1.5, 1; unpaired 1, 2, 1, 0; bond lengths increase in the stated order.