

Answers to exam-style questions

Topic 4

- 1 C
- 2 B
- 3 A
- 4 D
- 5 A
- 6 C
- 7 A
- 8 B
- 9 D
- 10 B
- 11 B
- 12 D
- 13 a Pairs of electrons in the outer shell of the central atom repel each other; they take up positions in space to be as far away from each other as possible in order to minimise this repulsion. Pairs of electrons may be bonding pairs and lone pairs; lone pairs cause greater repulsion than bonding pairs of electrons. [4]
- b i The Lewis structure for PCl_3 is:



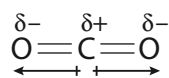
There are four pairs of electrons around the central atom. The basic shape (distribution of electron pairs) is tetrahedral; because one of the pairs of electrons is a lone pair, the actual shape of the molecule is trigonal pyramidal. The bond angle will be slightly less than that in a tetrahedron (109.5°), so predictions in the range $100\text{--}108^\circ$ will generally be accepted.

- ii The Lewis structure for CO_2 is:

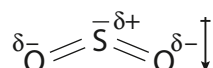


The four electrons in each double bond are constrained to be in the same region of space, so there are two electron domains around the C. The shape is linear and the bond angle is 180° . [4]

- c CO_2 is a linear molecule and so, although each individual $\text{C}=\text{O}$ bond is polar, the dipoles cancel out.



Because there is a lone pair of electrons on the S in SO_2 , the molecule is bent and the dipoles do not cancel out – one end of the molecule is δ^+ and the other is δ^- . [3]

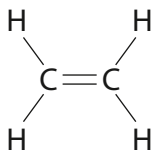


- d $\text{C}\equiv\text{O}$
 CO has a triple bond between the C and the O, whereas CO_2 has double bonds between the C and O atoms; the C–O bond in CO is shorter than that in CO_2 ; there are six electrons between the atoms in a triple bond but only four electrons between the atoms in a double bond; with more electrons between the atoms, there is greater attraction between the nuclei and the bonding electrons. [3]
- 14 a Sodium oxide has a giant ionic structure in which the ions are held in a lattice structure by strong electrostatic forces of attraction between positive ions and negative ions. Because the electrostatic attractions between the oppositely charged ions are strong, a lot of energy is required to overcome them, and the melting point is high. Na_2O does not conduct electricity when solid, because the ions are held tightly in the lattice structure. When molten, the Na^+ and O^{2-} ions are free to move, and so the liquid conducts electricity. [4]
- b Sodium and magnesium have metallic bonding, which is the electrostatic attraction between positively charged ions and delocalised electrons. Mg^{2+} has a higher positive charge than Na^+ , so there is a stronger attraction for the delocalised electrons. Mg^{2+} is smaller than Na^+ , so the nucleus of the ion is closer to the delocalised electrons and the attraction is stronger. In Mg there are more delocalised electrons per atom, and therefore more attractions holding the lattice together. [3]
- c These are all covalent molecular substances. The strength of London forces increases with relative molecular mass. AsH_3 has a higher relative

molecular mass than PH_3 , so the London forces are stronger between AsH_3 molecules, and the boiling point is higher. Although NH_3 has the lowest relative molecular mass, it has an H atom joined directly to an N atom, and therefore there will be hydrogen bonding between the molecules. Hydrogen bonding is a stronger intermolecular force than London forces, and therefore the intermolecular forces between NH_3 molecules are stronger than those between PH_3 molecules. [3]

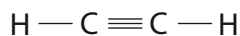
- d Silicon dioxide has a giant covalent structure, but carbon dioxide is covalent molecular. When silicon dioxide is melted, strong covalent bonds between the atoms must be broken. This requires a lot of energy, so SiO_2 has a high melting point. When carbon dioxide is melted, only the weak London forces between molecules must be overcome. This requires relatively little energy, and CO_2 has a lower melting point. [3]

- 15 a Hybridisation is the mixing of atomic orbitals to form a new set of orbitals that are better arranged in space for bonding. The number of hybrid orbitals formed is the same as the initial number of atomic orbitals. [2]
- b There are three electron domains around each C in C_2H_4 :



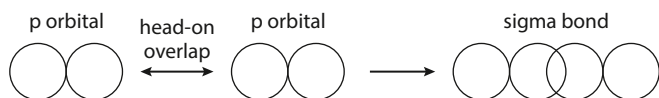
The electron domains are arranged in a trigonal planar array around each C. The type of hybridisation that gives a trigonal planar array of orbitals is sp^2 . Therefore the C atoms in C_2H_4 are sp^2 hybridised.

There are two electron domains around each C in C_2H_2 :



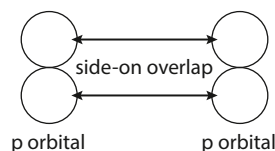
The electron domains are arranged in a linear array around each C. The type of hybridisation that gives a linear arrangement of orbitals is sp . Therefore, the C atoms in C_2H_2 are sp hybridised. [2]

- c A sigma bond is a head-on overlap of atomic orbitals that results in the electron density lying along the internuclear axis:



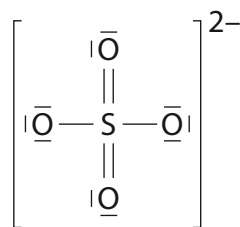
There is one sigma bond between the two C atoms in ethene and ethyne, and there are sigma bonds between the C and H atoms in ethene and ethyne.

A pi bond is a side-on overlap between two p orbitals. This results in the electron density in the pi bond lying above and below the internuclear axis:



The double bond in ethene is made up of a sigma bond and a pi bond. The triple bond in ethyne is made up of one sigma bond and two pi bonds. [4]

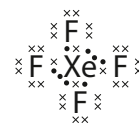
- 16 a i The Lewis structure of the SO_4^{2-} ion is:



The concept of formal charge could be used to decide between alternative Lewis structures - that with all single bonds has higher formal charges, therefore the structure shown is preferred.

There are four electron domains around the S, and therefore the shape is tetrahedral. The bond angle is 109.5° , although two of the bonds in the Lewis structure are shown as double bonds and may be expected to repel single bonds more strongly, the structure is delocalised and all bonds are equivalent.

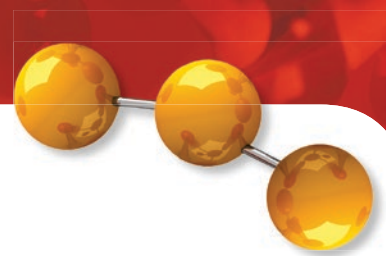
- ii The Lewis structure of XeF_4 is:



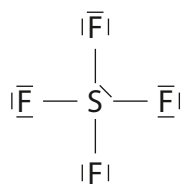
There are six electron domains around the Xe, and therefore the distribution of these electron pairs is octahedral. The two lone pairs go opposite each other, and the shape of the molecule is square planar.



The bond angles are the same as in an octahedron: i.e. 90° .



iii The Lewis structure for SF₄ is:



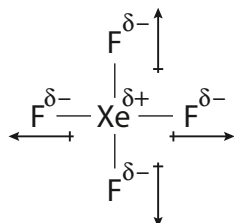
There are five electron domains around the S atom. The basic shape (arrangement of electron pairs) is trigonal bipyramidal. The lone pair in a trigonal bipyramid always goes around the middle, so the actual shape is 'see-saw' shaped:



The bond angles in a trigonal bipyramid are 90° and 120°. The lone pair causes these bond angles to close up slightly, and so we can predict bond angles of about 88° and 118°.

[6]

b XeF₄ is non-polar because, although each individual bond is polar, the square planar shape means that the dipoles cancel:



[2]

c SO₂ has two double bonds between the S and the O atoms, but SO₄²⁻ has a delocalised structure in which the π components of the double bonds are shared equally between all four sulfur-oxygen bonds. The bond order in SO₂ is 2, but that in SO₄²⁻ is 1.5. The sulfur-oxygen bond length in SO₂ would be expected to be shorter than that in SO₄²⁻.

[2]