**The boiling points of the hydrides of the group 6 elements are shown below**

1. **Explain the trend in boiling points from H2S to H2Te.**
2. **Explain why the boiling point of water is higher than would be expected from the group trend.**

(i) as molecules become larger/heavier/have higher *M*r values/  
number of electrons increases; van der Waals’/London/  
dispersion forces increase

(ii) hydrogen bonding **between molecules** in H2O; this bonding is stronger  
(than van der Waals’ forces)

1. **State the shape of the electron distribution around the oxygen atom in the water molecule and state the shape of the molecule**
2. **State and explain the value of the HOH bond angle**
3. (i) tetrahedral (*accept correct 3-D diagram*)  
   bent/V-shape/angular (*accept suitable diagram*)
4. (ii) 105° (*accept 103 – 106*°)  
   lone pairs **repel** each other more than bonding pairs

**Explain why the bonds in silicon tetrachloride, SiCl4, are polar, but the molecule is not**

bonds are polar as Cl more electronegative than Si

molecule is symmetrical, hence polar effects cancel out

**The diagrams below represent the structures of iodine, sodium, and sodium iodide**

1. **i) Identify which of the structures (A, B, C) correspond to iodine, sodium, sodium oxide**

**ii) State the type of bonding in each structure**

1. **i) Sodium and sodium iodide can both conduct electricity when molten, but only sodium can conduct electricity when solid. Explain this difference in conductivity in terms of the structures of sodium and sodium iodide.**

**ii) Explain the high volatility of iodine compared to sodium and sodium iodide.**

(a) (i) A – sodium iodide, B – sodium, C – iodine (*three correct* ***[1]***)

Accept correct formulas.

(ii) A – ionic bonding  
B – metallic bonding  
C – van der Waals’ forces (and covalent bonding)

(b) (i) (for Na) (lattice of) positive ions/atoms  
 delocalized/free electrons/sea of electrons  
(for NaI) oppositely charged ions/positive and negative ions  
 free to move (only) in molten state

(ii) forces between I2 molecules are weak  
ionic/metallic bonding strong(er)

1. **Draw Lewis structures for CO2 and H2S showing all valence electrons**
2. **State the shape of each molecule and explain your answer in terms of VSEPR theory**
   1. **CO2:**
   2. **H2S**
3. **Explain and state whether each molecule is polar or non-polar.**



(ii) CO2 is linear;  
two charge centres or bonds and no lone pairs (around C);  
H2S is bent/v-shaped/angular;  
two bond pairs, two lone pairs (around S)

(iii) CO2 is non-polar, H2S is polar  
bond polarities cancel CO2 but not in H2S

**Identify the strongest type of intermolecular force in all of the compounds:**

* 1. **CH3Cl**
  2. **CH4**
  3. **CH3OH**

CH3Cl – dipole-dipole attractions  
CH4 – van der Waals’/dispersion/London forces  
CH3OH – hydrogen bond

1. **An important compound of nitrogen is ammonia NH3. The chemistry of ammonia is influenced by its polarity and its ability to form hydrogen bonds. Polarity can be explained in terms of electronegativity**
2. **Explain the term electronegativity**
3. **Draw diagram to show the hydrogen bonding between 2 molecules of NH3. The diagram should include dipoles and lone pairs of electrons**
4. **State the H-N-H bond angle in an ammonia molecule**
5. **Explain why the ammonia molecule is polar**
6. **Ammonia reacts with hydrogen ions forming ammonium ions, NH4+.**
7. **State the H–N–H bond angle in an ammonium ion.**
8. **Explain why the H–N–H bond angle of NH3 is different from the H–N–H bond angle of NH4+; referring to both species in your answer.**

(a) (i) (relative) measure of an atom’s attraction for electrons; in a bond

(ii)



*Suitable diagram indicating*  
dipoles  
lone pairs of electrons  
hydrogen bonding

(iii) 107°

Accept answer in range 107 to 109° .

(iv) molecule is asymmetrical/OWTTE

(b) (i) 109.5°

(ii) NH4+ has four bonding pairs   
(around central atom so is a regular tetrahedron);  
NH3 has three bonding pairs (of electrons) and one non-bonding pair;   
non-bonding pairs (of electrons) exert a greater repulsive force

**State the type of bonding in the compound SiCl4. Draw the Lewis structure for this compound.**

Si—Cl bonds are covalent



**Outline the principles of the valence shell electron pair repulsion (VSEPR) theory.**

find number of electron pairs/charge centres in (valence shell of) central atom;  
electron pairs/charge centres (in valence shell) of central atom repel each other;   
to positions of minimum energy/repulsion/maximum stability  
pairs forming a double or triple bond act as a single bond  
non-bonding pairs repel more than bonding pairs

1. **Use the VSEPR theory to predict and explain the shape and the bond angle of each of the molecules SCl2 and C2Cl.**
2. **Deduce whether or not each molecule is polar, giving a reason for your answer.**

(i) SCl2 two bonding pairs, two non-bonding pairs;  
angular/bent/non-linear/V-shaped  
*Both these marks can be scored from a diagram*.  
90° < angle < 107°

C2Cl2 two charge centres around each C  
linear

angle = 180°

(ii) SCl2 is polar  
C2Cl2 is non-polar  
No net dipole movement for C2Cl2 but angular SCl2 has a resultant dipole

**Draw a Lewis structure of a water molecule, name the shape of the molecule and state and explain why the bond angle is less than the bond angle in a tetrahedral molecule such as methane.**

 bent/V shaped/angular

104.5;

Accept answers in range 104 to 106.

repulsion of the two non-bonding pairs of electrons forces bond angle  
to be smaller/non-bonding pairs repel more than bonding pairs

**Predict and explain the order of the melting point for propanol, butane and propanone with reference to their intermolecular forces.**

butane < propanone < propanol

butane has van der Waals’ forces

Accept vdW, dispersion or London forces or attractions between temporary dipoles.

propanone has dipole-dipole attractions

propanol has (the stronger) H-bonding

**The elements sodium, aluminium, silicon, phosphorus and sulfur are in period 3 of the periodic table. Describe the metallic bonding present in aluminium and explain why aluminium has a higher melting point than sodium.**

delocalized electrons  
(attracted) to positive ions  
more delocalized/mobile/outer shell electrons/higher ionic charge

**Draw the Lewis structure of NCl3. Predict, giving a reason, the Cl – N – Cl bond angle in NCl3.**



All electrons must be shown.

Accept molecular structures using lines to represent bonding and lone electron pairs.

bond angle: 107109

greater repulsion between lone pair and bonding pairs

**Arrange the following in decreasing order of bond angle (largest one first), and explain your reasoning. NH2–, NH3, NH4+**

NH4+ > NH3 > NH2–

NH4+ has four bonded electron pairs (and no lone electron pairs)

NH3 has three bonded electron pairs and one electron lone pair

NH2– has two bonded electron pairs and two electron lone pairs

lone pair-lone pair > lone pair-bonded pair > bonded pair-bonded pair/  
lone pairs of electrons repel more than bonding pairs of electrons

**(i) Outline the principles of the valence shell electron pair repulsion (VSEPR) theory.**

**(ii) Use the VSEPR theory to deduce the shape of H3O+ and C2H4. For each species, draw the Lewis structure, name the shape, and state the value of the bond angle(s).**

**(iii) Predict and explain whether each species is polar.**

**(iv) Using Table 7 of the Data Booklet, predict and explain which of the bonds O-H, O-N or N-H would be most polar.**

(i) Find number of electron pairs/charge centres in (valence shell of)  
central atom  
electron pairs/charge centres (in valence shell) of central atom repel  
each other

*Any one of the following:*to positions of minimum energy/repulsion/maximum stability  
pairs forming a double or triple bond act as a single bond  
non-bonding pairs repel more than bonding pairs/ max

(ii)

|  |  |  |  |
| --- | --- | --- | --- |
| **Species** | **Lewis (electron-dot) structure** | **Shape** | **Bond angle(s)** |
| H3O+ |  | Trigonal/triangular pyramidal; | Allow values in the range 106° to 109.5°; |
| C2H4 |  | Trigonal/triangular planar; | Allow values of approximately 120°; |

(iii) H3O+: is polar and explanation either using a diagram or in words,  
involving the net dipole moment;

e.g. the three individual O-H bond dipole moments add as vectors to give a net dipole moment.

C2H4: is non-polar and explanation either using a diagram or in words,  
involving no net dipole moment

e.g. the vector sum of the individual bond dipole moments is zero.

For simple answers such as bond polarities do not cancel for H3O+ and do cancel for C2H4, Award **[1]**, only for the last two marking points.

(iv) O-H is most polar;  
O-H has greatest difference between electronegativities/calculation  
showing values of 1.4, 0.5 and 0.9 respectively

**Predict and explain which of the following compounds consist of molecules:  
NaCl, BF3, CaCl2, N2O, P4O6, FeS and CBr4.**

BF3, N2O, P4O6 and CBr4 Non-metals only/small difference in electronegativity values of the elements

**Diamond, graphite and C60 fullerene are three allotropes of carbon.**

**(i) Describe the structure of each allotrope.**

**(ii) Compare the bonding in diamond and graphite.**

(i) 3

|  |  |
| --- | --- |
| **Allotrope** | **Structure** |
| **Diamond** | 3D array/network involving tetrahedral carbons/each carbon atom joined to four others; |
| **Graphite** | layer structure involving trigonal (triangular) planar carbons/with each carbon atom joined to three others/with hexagonal (six-membered) rings of carbon atoms; |
| **C60 fullerene** | truncated icosahedrons; *Accept carbon atoms form a ‘ball’ with 32 faces, of which 12 are pentagons and 20 are hexagons, exactly like a soccer ball. Do not accept soccer ball alone*. |

(ii) Diamond: covalent bonds (only)  
Graphite: covalent bonds and the separated layers held together by  
(weak) London/van der Waals’/dispersion forces

**State two physical properties associated with metals and explain them at the atomic level.**

*Electrical conductivity:*Bonding electrons are delocalized  
Current flow occurs without displacement of atoms within the metal/  
able to flow within the metal

*Malleability:*Can be hammered into thin sheets  
atoms capable of slipping with respect to one another

**(a) Draw the Lewis structure of methanoic acid, HCOOH.**

**(b) In methanoic acid, predict the bond angle around the**

**(i) carbon atom.**

**(ii) oxygen atom bonded to the hydrogen atom.**

**(c) State and explain the relationship between the length and strength of the bonds between the carbon atom and the two oxygen atoms in methanoic acid.**

(a)



No mark without lone electron pairs.

Correct shape not necessary.  
Do not award mark if dots/crosses and bond lines are shown.  
Accept lone pairs represented as straight lines.

(b) O − C − O = 120°/H − C − O = 120°  
C − O − H = 109°/<109°

No mark for 109.5°  
Accept answer in range 100–109°

(c) length: C = O < C − O  
strength: C = O > C – O  
greater number of electrons between nuclei pull atoms together and require greater energy to break