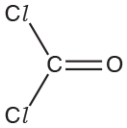
Bonding and Structure

1. Phosgene, $COCl_2$, exists as simple molecules.

The displayed formula of a phosgene molecule is shown below.



i. Draw a '*dot-and-cross*' diagram of a phosgene molecule.

Show outer electrons only.

[1]

ii. Name the shape of a phosgene molecule and explain why it has this shape.

Name of shape _____

Explanation _____

_____

_____

_____ **[3]**

2(a). Sodium sulfide, Na_2S, is an ionic compound of sodium, Na, and sulfur, S.

Draw a '*dot-and-cross*' diagram to show the bonding in sodium sulfide.

Show outer electrons only.

[2]

(b). The table below compares the properties of sodium sulfide, sodium and sulfur.

Complete the table.

		Sodium sulfide	**Sodium**	**Sulfur**
Melting point / °C		1180	98	113
Type of structure (**giant** or **simple**)				
Electrical conductivity (**good** or **poor**)	solid			
	liquid			

[3]

3. Solid barium chloride has a high melting point. Barium chloride dissolves in water to form a solution that can be used to test for sulfate ions.

i. Draw a '*dot-and-cross*' diagram to show the bonding in solid barium chloride. Show outer electrons only.

[2]

ii. A solution of barium chloride can be made in the laboratory using dilute hydrochloric acid.

Suggest a compound that can be reacted with hydrochloric acid to make barium chloride.

_____ **[1]**

4. Bromine is a reactive element. It combines with other non-metals to form covalent compounds. Phosphorus tribromide, PBr_3, and iodine monobromide, IBr, are examples of covalent compounds used in organic synthesis.

PBr_3 can be prepared by heating bromine with phosphorus, P_4.

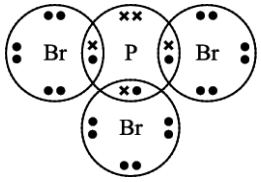
i. Write an equation for this reaction.

_____ **[1]**

ii. How many molecules are present in 1.3535 g of PBr_3?

number of molecules = ... **[3]**

iii. The '*dot-and-cross*' diagram of a molecule of PBr_3 is given below.



Name the shape of this molecule and explain why the molecule has this shape.

name: _____

explanation: _____

_____

_____

[3]

5. The hydroxyl group, –OH, is responsible for many properties of alcohols.

Methanol, CH_3OH, is soluble in water because it has polar bonds.

Pauling electronegativity values for carbon, oxygen and hydrogen are shown below.

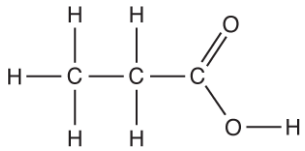
Element	Electronegativity
Carbon	2.5
Oxygen	3.5
Hydrogen	2.1

Use a labelled diagram to explain why methanol is soluble in water.

- Use displayed formulae showing one molecule of methanol and one molecule of water.
- Add partial charges δ+ and δ – to show the **two** most polar bonds in a methanol molecule and the polar bonds in a water molecule.
- Show all lone pairs.
- Label the most important intermolecular bond between the molecules.

[2]

6. The displayed formula for propanoic acid is shown below.



i. State the shape and bond angle around a carbon atom in the alkyl group of propanoic acid. Explain the shape.

Shape _____

Bond angle _____

Explanation _____

_____

_____

_____ **[2]**

ii. Suggest a value for the C–O–H bond angle in propanoic acid.

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[1]

7. Barium combines with oxygen, chlorine and nitrogen to form ionic compounds.

Barium oxide, BaO, has a giant ionic lattice structure.

i. State what is meant by the term *ionic bond*.

---

[1]

ii. Draw a '*dot-and-cross*' diagram to show the bonding in barium oxide.

Show outer electrons only.

iii. Calculate the number of barium ions in 1.50 g of barium oxide.

Give your answer in standard form and to **three** significant figures.

number of barium ions = ...

8(a). At room temperature and pressure, the first four members of the alkanes are all gases but the first four alcohols are all liquids.

Explain this difference in terms of intermolecular forces.

---

[2]

(b). The boiling points of 2-methylpropan-1-ol and butan-1-ol are shown below.

Alcohol	Boiling point / °C
2-methylpropan-1-ol	108
butan-1-ol	117

Explain why the boiling points are different.

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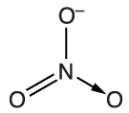
[2]

9. Nickel(II) nitrate, $Ni(NO_3)_2$, can be prepared by reacting nickel(II) oxide with dilute nitric acid.

i. Write the equation for this reaction.

[1]

ii. $Ni(NO_3)_2$ contains the NO_3^- ion. The nitrogen atom bonds to the oxygen atoms with a single covalent bond, a double covalent bond and a dative covalent bond, as shown below.



Draw the '*dot-and-cross*' diagramfor the NO_3^- ion, showing outer shell electrons only. Use a different symbol for the extra electron.

[2]

10. Compounds of calcium have many uses.

i. Identify a compound of calcium that could be used to convert a soil pH from 5.8 to 7.5.

---

[1]

ii. Calcium phosphide, Ca_3P_2, is an ionic compound used in rat poison.

Calcium phosphide can be prepared by reacting calcium metal with phosphorus, P_4.

Write the equation for the reaction of calcium with phosphorus to form calcium phosphide.

---

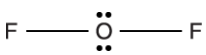
[1]

iii. Draw a '*dot-and-cross*' diagram to show the bonding in calcium phosphide, Ca_3P_2.

Show **outer** electrons only.

[2]

11. i. Fluorine is the most electronegative element.
Indicate any dipoles on the molecule of F_2O below using partial charges.



[1]

ii. Suggest the **shape** of the F_2O molecule and the F−O−F **bond angle**.

Shape .....

Bond angle .....

[1]

iii. What is the oxidation number of oxygen in F_2O?

Include the sign in your answer.

[1]

12. This question is about halogens.

Solid chlorine and solid bromine have a similar structure.

Name this structure.

[1]

13. Draw a '*dot-and-cross*' diagram to show the bonding in a nitrogen molecule.

Show **outer** electrons only.

[1]

14 This question is about the properties and reactions of butan-2-ol.

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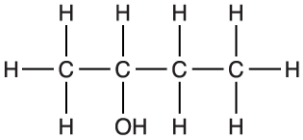


Some properties of butan-2-ol are listed in the table.

Melting point	−115 °C
Boiling point	99.5 °C

The shape around the oxygen atom in butan-2-ol is non-linear.

Predict the C−O−H bond angle and explain this shape.

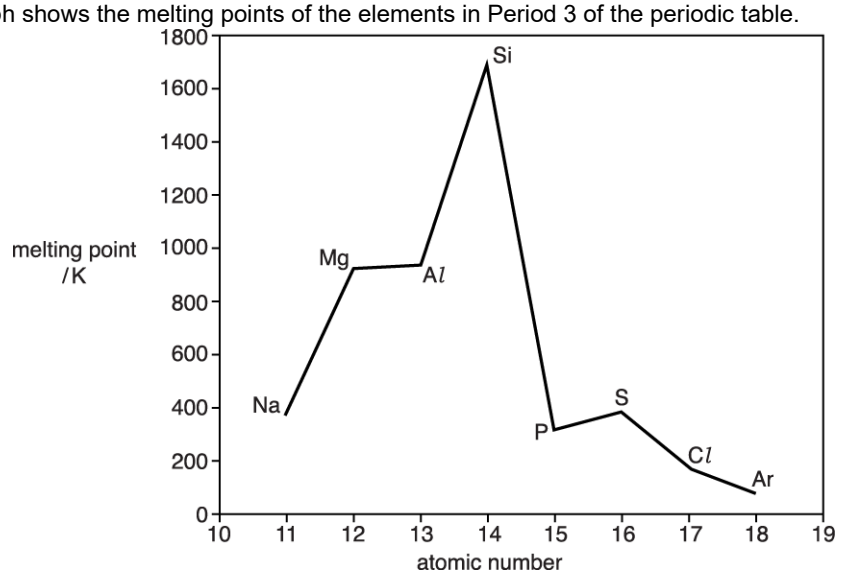
bond angle .....

explanation

.....
.....

---**[4]**

15. The graph shows the melting points of the elements in Period 3 of the periodic table.



Phosphorus and chlorine have simple molecular structures.
More information about phosphorus and chlorine is given in the table below.

Element	Molecular formula
phosphorus	P_4
chlorine	Cl_2

Explain the differences in the melting points of phosphorus and chlorine.

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[3]

16. The table shows the boiling points of ammonia, fluorine and bromine.

	Boiling point / °C
ammonia, NH_3	– 33
fluorine, F_2	– 188
bromine, Br_2	59

Explain the different boiling points of NH_3, F_2 and Br_2.

Include the names of any relevant forces and particles.

In your answer you should use appropriate technical terms, spelled correctly.

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[5]

17. Chlorine gas reacts with methane. One of the products is dichloromethane, CH_2Cl_2.

i. Chlorine is more electronegative than carbon and hydrogen, which have approximately equal electronegativity values.

Explain what is meant by the term *electronegativity*.

---**[2]**

ii. Draw a 3-D diagram of a molecule of CH_2Cl_2.

Use partial charges to indicate polar bonds.

[2]

iii. Explain why a CH_2Cl_2 molecule is polar.

---**[1]**

18(a). Solid aluminium fluoride has a giant ionic lattice structure.

i. Describe what is meant by the term *ionic lattice*, in terms of the type and arrangement of particles present.

---**[2]**

ii. Draw a '*dot-and-cross*' diagram for aluminium fluoride.

Show outer electrons only.

[2]

(b). Solid boron tribromide has a simple molecular lattice structure. The atoms are held together by covalent bonds.

i. What is meant by the term *covalent bond*?

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[1]

ii. Draw a '*dot-and-cross*' diagram to show the bonding in a boron tribromide molecule.

Show outer electrons only.

[1]

19 A chemist carries out reactions of barium and barium nitride, Ba_3N_2.

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Reaction 1 Barium is reacted with water.
Reaction 2 Barium nitride is reacted with water, forming an alkaline solution and an alkaline gas.
Reaction 3 Barium is reacted with an excess of oxygen at 500°C, forming barium peroxide, BaO_2.

i. Write equations for **Reaction 1** and **Reaction 2**.

Ignore state symbols.

Reaction 1:

……
……

Reaction 2:

……
……

[3]

ii. Predict the structure and bonding of Ba_3N_2.

---

[1]

iii. BaO_2 formed in **Reaction 3** contains barium and peroxide ions.
The peroxide ion has the structure $[O-O]^{2-}$.

Suggest a '*dot-and-cross*' diagram for BaO_2.

Show outer shell electrons only.

[1]

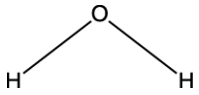
20(a). Oxides can have different types of bonding.

H_2O has hydrogen bonding.

i. Complete the diagram below to show hydrogen bonding between the H_2O molecule shown and **one** other H_2O molecule.

Include relevant dipoles and lone pairs.

Label the hydrogen bond.



[2]

ii. State and explain **two** anomalous properties of ice caused by hydrogen bonding.

1

2

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[4]

(b). Draw a '*dot-and-cross*' diagram to show the bonding in CO_2.

Show outer electrons only.

[1]

21 Antimony chloride, $SbCl_3$, exists as simple covalent molecules.

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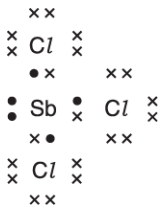
A '*dot-and-cross*' diagram of $SbCl_3$ is shown below.



i. Predict the shape of a molecule of $SbCl_3$.

Explain your answer.

name of shape:

……

……

explanation:

……

……

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[3]

ii. $SbCl_3$ molecules are polar.

Explain why.

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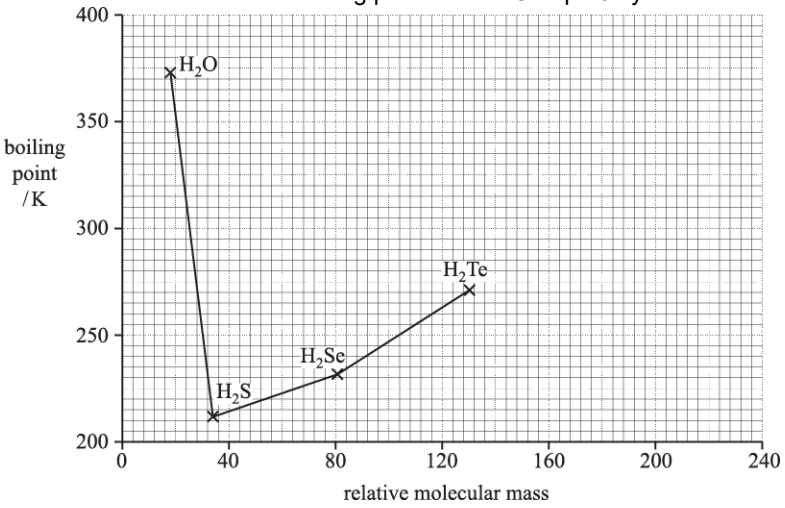
[2]

22(a). The graph below shows the variation in boiling points of the Group 16 hydrides.



i. The variation in boiling point can be explained by intermolecular bonding.
Explain why H_2S has a lower boiling point than H_2O and H_2Se.

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[4]

ii. Polonium, Po, is at the bottom of Group 16. Its hydride has the formula H_2Po.
Estimate from the graph the boiling point of H_2Po.
The relative molecular mass of H_2Po is 211.

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[1]

(b). The compounds SO_2 and MgO both contain oxygen.

The table below shows the melting point of both compounds:

Compound	Melting point / K
SO_2	200
MgO	3125

Predict the type of structure and bonding of SO_2 and MgO and explain the difference in their melting points.

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[4]

23. Carbon monoxide contains a triple bond, and includes a dative covalent bond.

Construct a '*dot-and-cross*' diagram to show the outer electron pairs in a molecule of carbon monoxide.

[2]

END OF QUESTION PAPER