CAMBRIDGE INTERNATIONAL AS & A LEVEL CHEMISTRY · 9701

CHEMISTRY



EXAM QUESTION PACK

3 CHEMICAL BONDING

SCORE	PERCENTAGE
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Chapter 3

Chemical bonding

3.1 Metallic bonding

112. 9701_w20_qp_11 Q: 5

Copper has a high melting point.

What is the reason for the high melting point of copper?

A strong attractive forces between copper atoms only

B strong attractive forces between copper ions and delocalised electrons

C strong attractive forces between copper ions only

D strong attractive forces between copper atoms and delocalised electrons

---

3.2 Covalent bonding and coordinate (dative covalent) bonding

113. 9701_s21_qp_12 Q: 8

Nitrogen and oxygen can react together to form nitrogen monoxide, NO.

$$N_2 + O_2 \rightarrow 2NO \qquad \Delta H = +180\,kJ\,mol^{-1}$$

What is the bond energy of the bond between the atoms in NO?

A $630\,kJ\,mol^{-1}$ **B** $810\,kJ\,mol^{-1}$ **C** $1260\,kJ\,mol^{-1}$ **D** $1620\,kJ\,mol^{-1}$

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114. 9701_s20_qp_11 Q: 3

When considering one molecule of ethene, which row describes both the hybridisation of the atomic orbitals in the carbon atoms and the overall bonding?

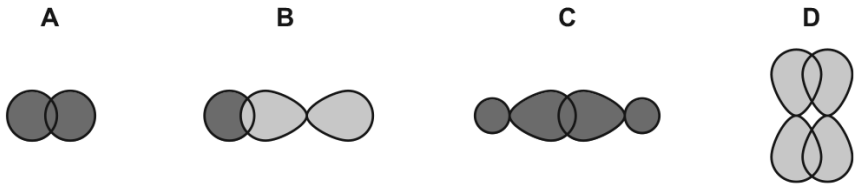
	hybridisation	bonding
A	sp^2	4 σ bonds 1 π bond
B	sp^2	5 σ bonds 1 π bond
C	sp^3	4 σ bonds 1 π bond
D	sp^3	5 σ bonds 1 π bond

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115. 9701_s19_qp_12 Q: 4

A σ bond is made between two carbon atoms in a molecule of ethene.

Which diagram shows the orbital overlap that occurs to form this bond?



---

116. 9701_m18_qp_12 Q: 6

Sodium hydroxide neutralises acid.

$$H^+ + OH^- \rightarrow H_2O$$

In a 11 000 dm^3 sample of an aqueous solution, the concentration of acid, $[H^+]$, is 1.26×10^{-3} mol dm^{-3}.

Which mass of solid sodium hydroxide neutralises the acid?

A 0.0214 g **B** 0.0504 g **C** 236 g **D** 554 g

---

117. 9701_s18_qp_13 Q: 4

Which statement describes the bond between carbon and hydrogen in an ethene molecule?

A a π bond between an s orbital and an sp^2 orbital

B a π bond between an s orbital and an sp^3 orbital

C a σ bond between an s orbital and an sp^2 orbital

D a σ bond between an s orbital and an sp^3 orbital

---

118. 9701_s16_qp_11 Q: 2

What is the correct number of bonds of each type in the Al_2Cl_6 molecule?

	covalent	co-ordinate (dative covalent)
A	6	1
B	6	2
C	7	0
D	7	1

---

119. 9701_w16_qp_12 Q: 6

When solid aluminium chloride is heated, Al_2Cl_6 is formed.

Which bonding is present in Al_2Cl_6?

A covalent and co-ordinate (dative covalent)

B covalent only

C ionic and co-ordinate (dative covalent)

D ionic only

---

120. 9701_s15_qp_11 Q: 10

The double bond between the two carbon atoms in an ethene molecule consists of one σ bond and one π bond.

Which orbitals overlap to form each of these bonds?

	σ bond	π bond
A	sp^2–sp^2	p–p
B	sp^2–sp^2	sp^2–sp^2
C	sp^3–sp^3	p–p
D	sp^3–sp^3	sp^2–sp^2

---

121. 9701_s15_qp_12 Q: 3

Phosphorus forms a compound with hydrogen called phosphine, PH_3. This compound can react with a hydrogen ion, H^+.

Which type of interaction occurs between PH_3 and H^+?

A dative covalent bond

B dipole-dipole forces

C hydrogen bond

D ionic bond

3.3 Shapes of molecules

122. 9701_m22_qp_12 Q: 25

When ammonia, NH_3, is dissolved in water, a small concentration of ammonium ions, NH_4^+, is formed.

Which row is correct?

	number of electrons in one ammonium ion	change of the H–N–H angle from ammonia to the ammonium ion
A	8	decreases
B	8	increases
C	10	decreases
D	10	increases

---

123. 9701_s21_qp_11 Q: 3

Phosphorus forms two chlorides. Phosphorus(III) chloride, PCl_3, is a covalent liquid.

Phosphorus(V) chloride is an ionic solid. One of the ions present is $[PCl_4]^+$.

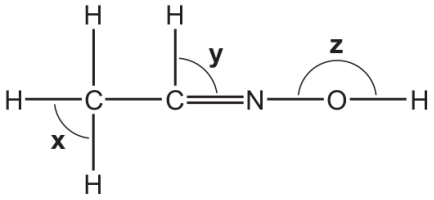
What is the shape of the PCl_3 molecule and the $[PCl_4]^+$ ion?

	PCl_3	$[PCl_4]^+$
A	pyramidal	square planar
B	pyramidal	tetrahedral
C	tetrahedral	square planar
D	trigonal planar	tetrahedral

---

124. 9701_s21_qp_13 Q: 4

Ethanal reacts with hydroxylamine, NH_2OH, to form the molecule shown.



What is the order of **increasing** bond angle in this structure from smallest to largest?

A **z**, **x**, **y** **B** **y**, **z**, **x** **C** **x**, **z**, **y** **D** **z**, **y**, **x**

---

125. 9701_w21_qp_12 Q: 5

Atom X is the central atom in a molecule.

In this molecule, atom X has four pairs of valence electrons in its outer shell.

The four pairs of valence electrons include at least one bond pair and at least one lone pair.

What could be a possible shape for the molecule?

A linear

B non-linear

C trigonal bipyramidal

D trigonal planar

---

126. 9701_m20_qp_12 Q: 3

Which molecule does **not** have any 90° or 180° bond angles?

A C_2H_6 **B** CO_2 **C** PF_5 **D** SF_6

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127. 9701_m20_qp_12 Q: 8

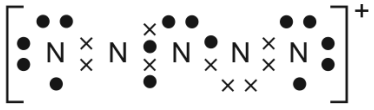
A stable ion N_5^+ has been produced by research chemists.

Which structure is most likely to show the electron arrangement of this ion?

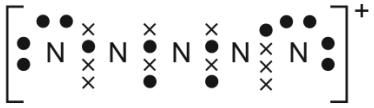
A



B



C



D



---

128. 9701_s20_qp_13 Q: 2

Which molecule contains six bonding electrons?

A NCl_3 **B** H_2S **C** C_2H_4 **D** SF_6

---

129. 9701_s20_qp_13 Q: 9

At 200 °C aluminium chloride is a gas with M_r = 267.

What is the number of covalent bonds, dative covalent bonds and lone pairs of electrons in one molecule of aluminium chloride at 200 °C?

	covalent bonds	dative covalent bonds	lone pairs
A	6	2	0
B	6	2	16
C	6	2	18
D	3	0	9

---

130. 9701_m19_qp_12 Q: 4

The eight species that follow all have covalent bonds.

In which pair do the species have different shapes from each other?

A $BeCl_2$ and CO_2

B CH_4 and NH_4^+

C NH_3 and BF_3

D SCl_2 and H_2O

---

131. 9701_s19_qp_11 Q: 5

In which species is there a lone pair of electrons?

A CH_3 **B** CH_3^+ **C** CH_3^- **D** CH_4

---

132. 9701_w19_qp_11 Q: 3

Which molecule or ion contains the smallest bond angle?

A C_2H_4 **B** CH_3COCH_3 **C** NH_4^+ **D** NH_3

---

133. 9701_m18_qp_12 Q: 5

Which mass of solid residue is obtained from the thermal decomposition of 4.10 g of anhydrous calcium nitrate?

A 0.70 g **B** 1.00 g **C** 1.40 g **D** 2.25 g

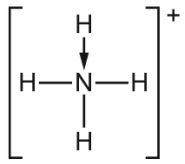
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134. 9701_s18_qp_12 Q: 18

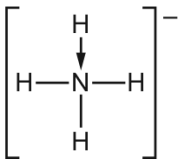
The dative covalent bond can be represented by an arrow, →. The arrow points towards the atom receiving the lone pair.

Which diagram of an ammonium ion is correct?

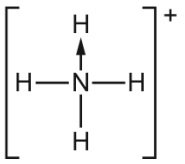
A



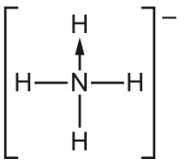
B



C



D



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135. 9701_w18_qp_12 Q: 4

In which set do all the molecules have all their atoms arranged in one plane?

A $AlCl_3$, BF_3, PH_3

B $AlCl_3$, CO_2, NH_3

C BF_3, C_2H_4, C_3H_6

D C_2H_4, CO_2, H_2O

---

136. 9701_w17_qp_11 Q: 3

In which structure are three atoms bonded together in a straight line?

A poly(ethene), $-(CH_2CH_2)_n-$

B propane, C_3H_8

C silicon tetrachloride, $SiCl_4$

D sulfur hexafluoride, SF_6

---

137. 9701_w17_qp_12 Q: 4

Ethane burns in oxygen to produce carbon dioxide and water vapour.

Which bond angles are present in the molecules of ethane and its combustion products?

	ethane	combustion products
A	90°	104.5° and 180°
B	90°	109.5° and 120°
C	109.5°	104.5° and 180°
D	109.5°	109.5° and 180°

---

138. 9701_m16_qp_12 Q: 6

Which series shows molecules in order of increasing bond angle?

A $CH_4 \rightarrow BF_3 \rightarrow NH_3$

B $H_2O \rightarrow CO_2 \rightarrow BF_3$

C $NH_3 \rightarrow CH_4 \rightarrow CO_2$

D $NH_3 \rightarrow CH_4 \rightarrow H_2O$

---

139. 9701_m16_qp_12 Q: 15

Which row of the table is correct?

	shape		bonds present	
	ammonia molecule	ammonium ion	ammonia molecule	ammonium ion
A	pyramidal	regular tetrahedral	σ	σ
B	pyramidal	regular tetrahedral	σ	π
C	regular tetrahedral	pyramidal	σ	σ
D	regular tetrahedral	pyramidal	π	σ

---

140. 9701_s16_qp_11 Q: 5

Dicarbon monoxide, C_2O, is found in dust clouds in space. The structure of this molecule is C=C=O. The molecule contains no unpaired electrons.

How many lone pairs of electrons are present in a molecule of C_2O?

A 1 **B** 2 **C** 3 **D** 4

---

141. 9701_s16_qp_12 Q: 5

Each of the four species in this question are isolated and gaseous.

Which species is **not** planar?

A BF_3 **B** CH_3^+ **C** C_2H_4 **D** NH_3

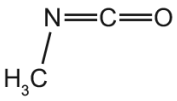
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142. 9701_s16_qp_13 Q: 7

Methyl isocyanate, CH_3NCO, is a toxic liquid which is used in the manufacture of some pesticides.

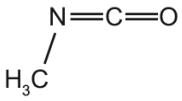
What is the approximate angle between the bonds formed by the N atom in a molecule of methyl isocyanate?

A



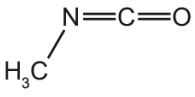
104°

B



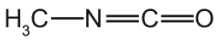
109°

C



120°

D



180°

---

143. 9701_w16_qp_12 Q: 7

In which hydride is the H–X–H bond angle the smallest?

A BH_3 **B** CH_4 **C** C_2H_6 **D** NH_3

---

144. 9701_s15_qp_13 Q: 4

Which pair has species with different shapes?

A $BeCl_2$ and CO_2

B CH_4 and NH_4^+

C NH_3 and BF_3

D SCl_2 and H_2O

3.4 Intermolecular forces, electronegativity and bond properties

145. 9701_m22_qp_12 Q: 4

For which molecule is the dipole moment zero?

A CH_3Cl **B** CH_2Cl_2 **C** $CHCl_3$ **D** CCl_4

---

146. 9701_m21_qp_12 Q: 5

In which substance are the only intermolecular forces temporary dipole-induced dipole attractions?

A hydrogen chloride

B methanol

C octane

D water

---

147. 9701_s21_qp_13 Q: 5

Descriptions of the bonding in three substances are given.

substance 1	strong covalent bonds between atoms, permanent dipole-dipole attractions between molecules
substance 2	strong covalent bonds between atoms, weak forces between molecules
substance 3	strong covalent bonds between atoms, hydrogen bonding between molecules

Which compounds could be substances 1, 2 and 3?

	substance 1	substance 2	substance 3
A	CH_3OH	Al_2Cl_6	CH_2Cl_2
B	Al_2Cl_6	CH_2Cl_2	CH_4
C	CH_2Cl_2	CH_4	CH_3OH
D	CH_4	CH_3OH	H_2O

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148. 9701_w21_qp_11 Q: 5

Which type of interaction exists between water molecules and metal cations in aqueous solution?

A dipole-dipole interactions

B hydrogen bonds

C ion-dipole interactions

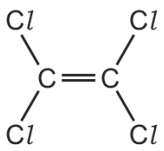
D ionic bonds

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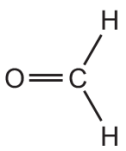
149. 9701_w21_qp_12 Q: 6

Which molecule has the largest overall dipole?

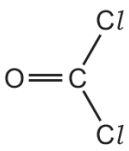
A



B



C



D



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150. 9701_w21_qp_12 Q: 7

The strength of hydrogen bonding increases as the electronegativity of the element bonded to hydrogen increases.

Some information for a range of hydrides is given.

hydride	boiling point / K
PH_3	185
HCl	188
HF	293
H_2O	373

Which statement and reason about these hydrides is correct?

A The boiling point of PH_3 is much lower than the boiling point of H_2O because PH_3 does not form hydrogen bonds or instantaneous dipole-induced dipole forces between its molecules.

B The boiling point of HF is higher than the boiling point of HCl because the bond energy of H–F is greater than the bond energy of H–Cl.

C The boiling point of H_2O is higher than the boiling point of HF because each hydrogen bond between the H_2O molecules is stronger than each hydrogen bond between HF molecules.

D The boiling points of PH_3 and HCl are similar because the molecules of PH_3 and HCl have the same number of electrons and similar intermolecular forces.

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151. 9701_w21_qp_13 Q: 5

Which type of interaction exists between water molecules and metal cations in aqueous solution?

A dipole-dipole interactions

B hydrogen bonds

C ion-dipole interactions

D ionic bonds

---

152. 9701_s20_qp_12 Q: 8

In which change are **only** temporary dipole-induced dipole forces overcome?

A $C_2H_5OH(l) \rightarrow C_2H_5OH(g)$

B $H_2O(s) \rightarrow H_2O(l)$

C $O_2(s) \rightarrow O_2(l)$

D $C_4H_{10}(l) \rightarrow C_4H_{10}(s)$

---

153. 9701_w20_qp_11 Q: 4

In which of the following, when in liquid form, are there only intermolecular forces based on temporary dipoles between the particles?

A bromine

B ethanol

C hydrogen chloride

D water

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154. 9701_s18_qp_11 Q: 5

Which molecule has no overall dipole?

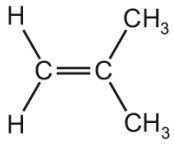
A CH_3Cl **B** CH_2Cl_2 **C** $CHCl_3$ **D** CCl_4

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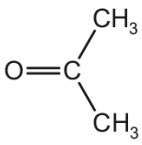
155. 9701_s17_qp_11 Q: 5

Which molecule has the largest overall dipole?

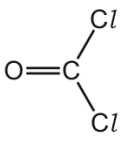
A



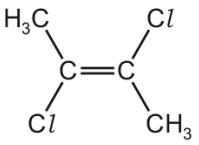
B



C



D



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156. 9701_s17_qp_12 Q: 4

Which organic compound has the highest boiling point?

A $C(CH_3)_4$

B $CH_3CH_2CH_2CH_2CH_3$

C $CH_3COCH_2CH_3$

D $CH_3CH(OH)CH_2CH_3$

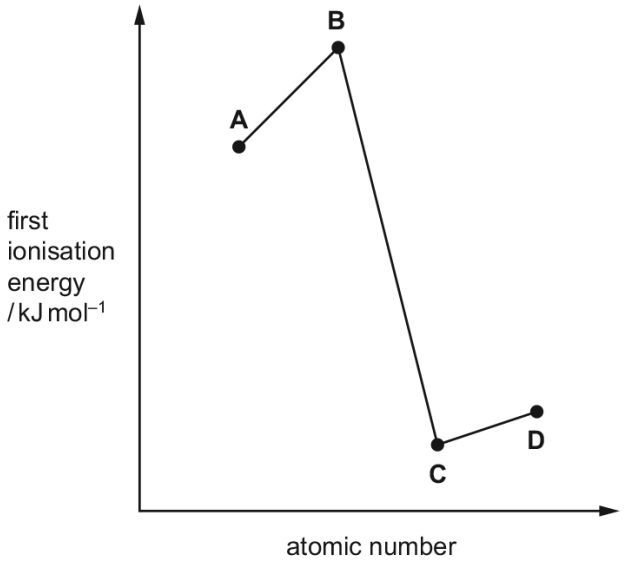
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157. 9701_w17_qp_11 Q: 2

The relative first ionisation energies of four elements with consecutive atomic numbers below 20 are shown on the graph.

One of the elements reacts with hydrogen to form a covalent compound with formula HX.

Which element could be X?



---

158. 9701_s16_qp_11 Q: 7

At room temperature and pressure, H_2O is a liquid and H_2S is a gas.

What is the reason for this difference?

A O has higher first and second ionisation energies than S.

B The covalent bond between O and H is stronger than the covalent bond between S and H.

C There is significant hydrogen bonding between H_2O molecules but not between H_2S molecules.

D The instantaneous dipole-induced dipole forces between H_2O molecules are stronger than the instantaneous dipole-induced dipole forces between H_2S molecules.

---

159. 9701_s16_qp_13 Q: 6

Carbon and silicon have the same outer electronic structure.

Why is a Si–Si bond weaker than a C–C bond?

A Silicon atoms have a larger atomic radius than carbon atoms.

B Silicon has a greater nuclear charge than carbon.

C Silicon has a smaller first ionisation energy than carbon.

D Silicon is more metallic than carbon.

---

160. 9701_w16_qp_12 Q: 13

Which element shows the greatest tendency to form covalent compounds?

A boron

B magnesium

C neon

D potassium

---

161. 9701_s15_qp_11 Q: 2

Which quantity gives the best indication of the relative strengths of the hydrogen bonds between the molecules in liquid hydrogen halides?

A bond dissociation energies

B enthalpy changes of formation

C enthalpy changes of solution

D enthalpy changes of vaporisation

---

162. 9701_s15_qp_13 Q: 6

Which statement can be explained by intermolecular hydrogen bonding?

A Ethanol has a higher boiling point than propane.

B Hydrogen chloride has a higher boiling point than silane, SiH_4.

C Hydrogen iodide forms an acidic solution when dissolved in water.

D Propanone has a higher boiling point than propane.

---

163. 9701_w15_qp_11 Q: 4

Nitrogen, N_2, and carbon monoxide, CO, both have $M_r = 28$.

The boiling point of N_2 is 77 K.

The boiling point of CO is 82 K.

What could be responsible for this difference in boiling points?

A CO molecules have a permanent dipole, the N_2 molecules are not polar.

B N_2 has σ and π bonding, CO has σ bonding only.

C N_2 has a strong N≡N bond, CO has a C=O bond.

D The CO molecule has more electrons than the N_2 molecule.

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164. 9701_w15_qp_12 Q: 1

Which type of bonding is **never** found in elements?

A covalent

B ionic

C metallic

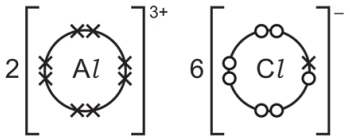
D van der Waals' forces

3.5 Dot-and-cross diagrams

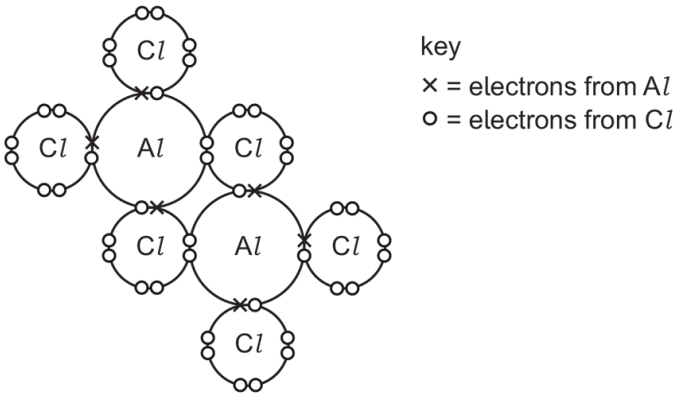
165. 9701_m22_qp_12 Q: 5

Which dot-and-cross diagram is correct for Al_2Cl_6?

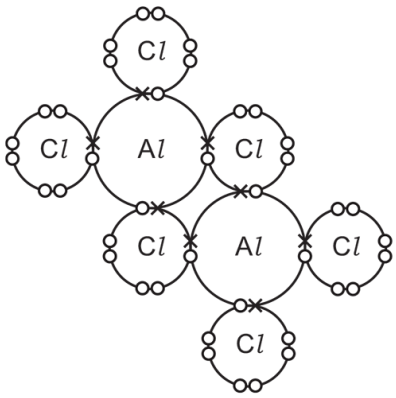
A



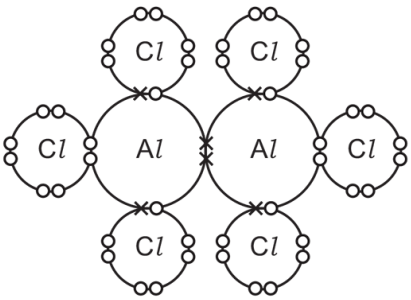
B



C



D



---

166. 9701_s21_qp_13 Q: 6

Which type of bonding is **never** found in elements?

A covalent

B ionic

C metallic

D van der Waals' forces

Chapter 3

Chemical bonding

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3.1 Ionic bonding

11. 9701_S15_qp_21 Q: 1

(a) Chemists recognise that atoms are made of three types of particle.

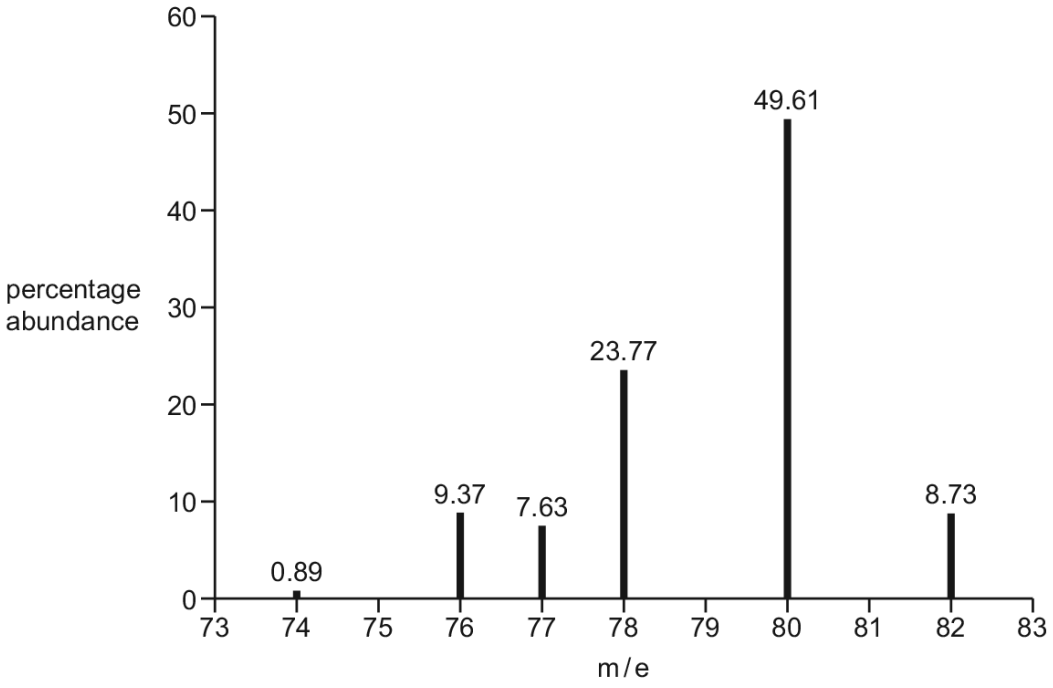
Complete the following table with their names and properties.

name of particle	relative mass	relative charge
		0
	1/1836	

[3]

(b) The relative atomic mass of an element can be determined using data from its mass spectrum.

The mass spectrum of element **X** is shown, with the percentage abundance of each isotope labelled.



(i) Define the terms *relative atomic mass* and *isotope*.

relative atomic mass .....

.....

.....

isotope .....

.....

[3]

(ii) Use the data in the mass spectrum to calculate the relative atomic mass, A_r, of **X**. Give your answer to **two** decimal places and suggest the identity of **X**.

A_r of **X** .....

identity of **X** .....
[2]

(c) The element tellurium, Te, reacts with chlorine to form a single solid product, with a relative formula mass of 270. The product contains 52.6% chlorine by mass.

(i) Calculate the molecular formula of this chloride.

molecular formula ..... [3]

(ii) This chloride melts at 224 °C and reacts vigorously with water.

State the type of bonding **and** structure present in this chloride and explain your reasoning.

.....

.....

.....

..... [2]

(iii) Suggest an equation for the reaction of this chloride with water.

..... [1]

(d) Sodium and silicon also react directly with chlorine to produce the chlorides shown.

chloride	melting point / °C	difference between the electronegativities of the elements
NaCl	801	2.2
$SiCl_4$	–69	1.3

(i) Describe what you would **see** during the reaction between sodium and chlorine.

.....

.....

..... [2]

(ii) Explain the differences between the melting points of these two chlorides in terms of their structure **and** bonding. You should refer to the difference between the electronegativities of the elements in your answer.

NaCl structure **and** bonding .....

.....

$SiCl_4$ structure **and** bonding .....

.....

explanation .....

.....

.....

.....

.....

..... [4]

[Total: 20]

3.2 Covalent and co-ordinate bonding including shapes of simple molecules

12. 9701_w17_qp_22 Q: 1

The elements sodium to sulfur react with chlorine. The melting points of some of the chlorides formed are shown.

chloride	$NaCl$	$MgCl_2$	$AlCl_3$	$SiCl_4$	PCl_3	SCl_2
melting point/K	1074	987	463	203	161	195

(a) Predict the shapes of $AlCl_3$ and PCl_3.

Draw diagrams to show the shapes, name the shapes and state the bond angles.

$AlCl_3$	PCl_3
shape	shape .....
angle	angle .....

[4]

(b) (i) Explain, in terms of structure and bonding, why the melting point of $SiCl_4$ is much lower than that of $NaCl$.

.....

.....

.....

.....

..... [3]

(ii) Explain why the melting point of $SiCl_4$ is higher than that of PCl_3.

.....

.....

..... [2]

(iii) Draw the 'dot-and-cross' diagram of a molecule of $SiCl_4$.
Show outer electrons only.

[1]

[Total: 10]

3.3 Intermolecular forces, electronegativity and bond properties

13. 9701_s17_qp_21 Q: 2

Structure and bonding can be used to explain many of the properties of substances.

(a) Copper, ice, silicon(IV) oxide, iodine and sodium chloride are all crystalline solids.

Complete the table with:
- the name of a type of bonding found in each crystalline solid,
- the type of lattice structure for each crystalline solid.

crystalline solid	type of bonding	type of lattice structure
copper		
ice		
silicon(IV) oxide		
iodine		
sodium chloride		

[5]

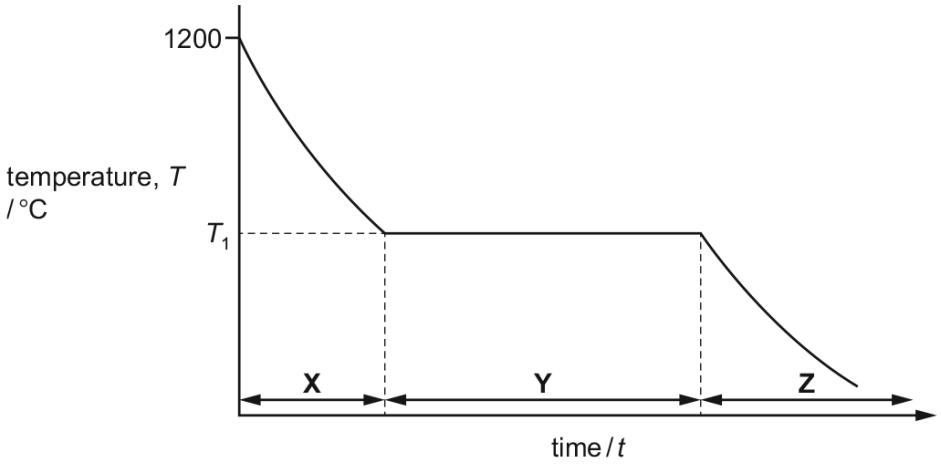
(b) (i) Name the strongest type of intermolecular force in ice.

..... [1]

(ii) Draw a fully labelled diagram of two water molecules in ice, showing the force in **(i)** and how it forms.

[3]

(c) The graph represents how the temperature of a sample of copper (melting point 1085 °C) changes as it is gradually cooled from 1200 °C.



(i) Identify the state(s) of matter present during each stage of the process shown in the graph.

X .....

Y .....

Z .....

[2]

(ii) State what is happening to the energy and movement of the particles in the copper during stage **X**.

.....

.....

..... [2]

(iii) Explain why the temperature stays constant at T_1 during stage **Y**.

.....

.....

.....

..... [2]

[Total: 15]

14. 9701_s16_qp_23 Q: 1

An experiment was carried out to determine the percentage of iron in a sample of iron wire.

(a) A 3.35 g piece of the wire was reacted with dilute sulfuric acid, in the absence of air, so that all of the iron atoms were converted to iron(II) ions. The resulting solution was made up to 250 cm^3.

(i) Write a balanced equation for the reaction between the iron in the wire and the sulfuric acid.

..... [1]

A 25.0 cm^3 sample of this solution was acidified and titrated with 0.0250 mol dm^{-3} potassium dichromate(VI). 32.0 cm^3 of the potassium dichromate(VI) solution was required for complete reaction with the iron(II) ions in the sample.

The relevant half-equations are shown.

$$Cr_2O_7^{2-} + 14H^+ + 6e^- \rightarrow 2Cr^{3+} + 7H_2O$$

$$Fe^{2+} \rightarrow Fe^{3+} + e^-$$

(ii) Use the half-equations to write an equation for the reaction between the iron(II) ions and the acidified dichromate(VI) ions.

..... [1]

(iii) Calculate the amount, in moles, of dichromate(VI) ions used in the titration.

amount = ... mol [1]

(iv) Calculate the amount, in moles, of iron(II) ions in the 25.0 cm^3 sample of solution.

amount = ... mol [1]

(v) Calculate the amount, in moles, of iron in the 3.35 g piece of wire.

amount = ... mol [1]

(vi) Calculate the mass of iron in the 3.35 g piece of wire.

mass = ... g [1]

(vii) Calculate the percentage of iron in the iron wire.

percentage = ... % [1]

(b) Some electronegativity values are shown.

element	electronegativity
aluminium	1.5
chlorine	3.0
iron	1.8

(i) Use the data to suggest the nature of the bonding in iron(III) chloride. Explain your answer.

.....

.....

..... [2]

(ii) Suggest an equation for the reaction between iron(III) chloride and water.

..... [1]

[Total: 10]

15. 9701_S15_qp_23 Q: 1

Neon is a noble gas.

(a) Complete the full electronic configuration of neon.

$1s^2$ ..... [1]

(b) **(i)** Explain what is meant by the term *first ionisation energy*.

.....

.....

..... [3]

(ii) Explain why the first ionisation energy of neon is greater than that of fluorine.

.....

..... [2]

(c) Neon has three stable isotopes.

isotope	mass number	percentage abundance
1		9.25
2	20	90.48
3	21	0.27

(i) Define the term *relative atomic mass*.

.....

..... [2]

(ii) Use the relative atomic mass of neon, 20.2, to calculate the mass number of isotope 1.

mass number = ... [2]

(d) A mixture of neon and argon has a mass of 0.275 g. The mixture was placed in a gas syringe at a temperature of 25 °C and a pressure of 100 kPa. Under these conditions the mixture was found to occupy a volume of 200 cm^3.

(i) Calculate the average M_r of the mixture.

average M_r = ... [2]

(ii) Use your answer to **(i)** to calculate the percentage of neon in the mixture.
Give your answer to **three** significant figures.

percentage of neon = ... % [1]

(e) Neon and argon can both be obtained by fractional distillation of liquid air as they have different boiling points.

Neon has a boiling point of 27.3 K. The boiling point of argon is 87.4 K.

(i) Name the force that has to be overcome in order to boil neon or argon and explain what causes it.

.....

.....

..... [3]

(ii) Explain why argon has a higher boiling point than neon.

.....

.....

..... [2]

[Total: 18]

3.4 Bonding and physical properties

16. 9701_w15_qp_22 Q: 1

(a) Fill the gaps in the table for each of the given particles.

name of isotope	type of particle	charge	symbol	electron configuration
carbon-13				$1s^2 2s^2 2p^2$
		–1	$^{37}_{17}Cl^-$	
sulfur-34	atom	0		
iron-54	cation			$1s^2 2s^2 2p^6 3s^2 3p^6 3d^6$

[5]

(b) One of the factors that determines the type of bonding present between the particles of a substance is the relative electronegativities of the bonded particles.

(i) Explain the meaning of the term *electronegativity*.

.....

.....

..... [2]

(ii) Name and describe the type of bonding you would expect to find between particles with equal electronegativities.

.....

.....

..... [2]

(iii) Name and describe the type of bonding you would expect to find between particles with very different electronegativities.

.....

.....

..... [2]

(c) The boiling points of some molecules with equal numbers of electrons are given.

substance	fluorine	argon	hydrogen chloride	methanol
formula	F_2	Ar	HCl	CH_3OH
boiling point / K	85	87	188	338

(i) Explain why the boiling points of fluorine and argon are so similar.

.....

.....

..... [2]

(ii) Explain why the boiling point of hydrogen chloride is higher than that of fluorine.

.....

.....

..... [2]

(iii) Explain why methanol has the highest boiling point of all these molecules.

.....

.....

..... [2]

[Total: 17]

Q1.

(d) In the boxes below, draw diagrams to show the shapes of an ammonia molecule and an ammonium ion. Clearly show the bond angles on your diagrams.

ammonia	ammonium ion

[4]

Q2.

Hydrogen sulphide, H_2S, is a foul-smelling compound found in the gases from volcanoes. Hydrogen sulphide is covalent, melting at –85 °C and boiling at –60 °C.

(c) **(i)** Draw a 'dot-and-cross' diagram to show the structure of the H_2S molecule.

(ii) Predict the shape of the H_2S molecule.

.....

(iii) Oxygen and sulphur are both in Group VI of the Periodic Table.

Suggest why the melting and boiling points of water, H_2O, are much higher than those of H_2S.

.....

.....

..... [4]

Q3.

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2 The unsaturated hydrocarbon ethyne (acetylene), C_2H_2, is widely used in 'oxy-acetylene torches' for cutting and welding metals. In the torch, ethyne is burned in oxygen to produce a flame with a temperature of 3400 K.

(a) Ethyne is a linear molecule with a triple bond, C≡C, between the two carbon atoms.

Draw a 'dot-and-cross' diagram of an ethyne molecule.

[1]

Q4.

1 Ethene, C_2H_4, and hydrazine, N_2H_4, are hydrides of elements which are adjacent in the Periodic Table. Data about ethene and hydrazine are given in the table below.

	C_2H_4	N_2H_4
melting point/°C	–169	+2
boiling point/°C	–104	+114
solubility in water	insoluble	high
solubility in ethanol	high	high

(a) Ethene and hydrazine have a similar arrangement of atoms but differently shaped molecules.

(i) What is the H-C-H bond angle in ethene?

.....

(ii) Draw a 'dot-and-cross' diagram for hydrazine.

(iii) What is the H-N-H bond angle in hydrazine?

.....

[4]

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(b) The melting and boiling points of hydrazine are much higher than those of ethene. Suggest reasons for these differences in terms of the intermolecular forces **each** compound possesses.

.....

.....

.....

.....

.....[3]

(c) Explain, with the aid of a diagram showing lone pairs of electrons and dipoles, why hydrazine is very soluble in ethanol.

For Examiner's Use

[3]

(e) When aqueous hydrazine is reacted with HC*l*, a solid compound of formula N_2H_5Cl may be isolated. When an excess of HC*l* is used, a second solid, $N_2H_6Cl_2$, is formed.

(i) Suggest what type of reaction occurs between hydrazine and HC*l*.

.....

(ii) What feature of the hydrazine molecule enables this reaction to occur?

.....

(iii) Suggest why one molecule of hydrazine is able to react with one or two molecules of HC*l*.

.....

.....

[3]

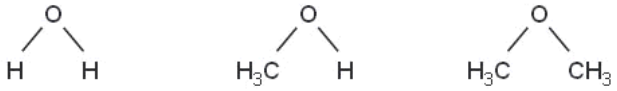
[Total: 16]

Q5.

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Examiner's Use

1 The structural formulae of water, methanol and methoxymethane, CH_3OCH_3, are given below.



(a) (i) How many lone pairs of electrons are there around the oxygen atom in methoxymethane?

.....

(ii) Suggest the size of the C–O–C bond angle in methoxymethane.

.....

[2]

The physical properties of a covalent compound, such as its melting point, boiling point, vapour pressure, or solubility, are related to the strength of attractive forces between the molecules of that compound.

These relatively weak attractive forces are called intermolecular forces. They differ in their strength and include the following.

A interactions involving permanent dipoles

B interactions involving temporary or induced dipoles

C hydrogen bonds

(b) By using the letters **A**, **B**, or **C**, state the **strongest** intermolecular force present in **each** of the following compounds.
For each compound, write the answer on the dotted line.

ethanal	CH_3CHO	.....
ethanol	CH_3CH_2OH	.....
methoxymethane	CH_3OCH_3	.....
2-methylpropane	$(CH_3)_2CHCH_3$	.....

[4]

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(c) Methanol and water are completely soluble in each other.

For Examiner Use

(i) Which intermolecular force exists between methanol molecules and water molecules that makes these two liquids soluble in each other?

.....

(ii) Draw a diagram that clearly shows this intermolecular force. Your diagram should show any lone pairs or dipoles present on either molecule that you consider to be important.

[4]

(d) When equal volumes of ethoxyethane, $C_2H_5OC_2H_5$, and water are mixed, shaken, and then allowed to stand, two layers are formed.

Suggest why ethoxyethane does not fully dissolve in water. Explain your answer.

.....

.....

.....

.....[2]

[Total: 12]

Q6.

1 Copper and titanium are each used with aluminium to make alloys which are light, strong and resistant to corrosion.

Aluminium, *Al*, is in the third period of the Periodic Table; copper and titanium are both transition elements.

(a) Complete the electronic configuration of aluminium and of titanium, proton number 22.

Al	$1s^2$
Ti	$1s^2$

[1]

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Aluminium reacts with chlorine.

(b) (i) Outline how, starting from aluminium powder, this reaction could be carried out in a school or college laboratory to give a small sample of aluminium chloride. A diagram is not necessary.

.....

.....

.....

(ii) Describe what you would see during this reaction.

.....

.....

(iii) At low temperatures, aluminium chloride vapour has the formula Al_2Cl_6.
Draw a 'dot-and-cross' diagram to show the bonding in Al_2Cl_6.
Show outer electrons only.
Represent the aluminium electrons by ●.
Represent the chlorine electrons by ***x***.

[6]

Copper forms two chlorides, $CuCl$ and $CuCl_2$.

(c) When copper is reacted directly with chlorine, only $CuCl_2$ is formed.
Suggest an explanation for this observation.

.....

..... **[1]**

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Titanium also reacts with chlorine.

(d) When an excess of chlorine was reacted with 0.72 g of titanium, 2.85 g of a chloride **A** was formed.

(i) Calculate the amount, in moles, of titanium used.

(ii) Calculate the amount, in moles, of chlorine atoms that reacted.

(iii) Hence, determine the empirical formula of **A**.

(iv) Construct a balanced equation for the reaction between titanium and chlorine.

.....

[4]

(e) At room temperature, the chloride of titanium, **A**, is a liquid which does not conduct electricity.

What does this information suggest about the bonding and structure in **A**?

.....

.....

..... [2]

[Total: 14]

Q7.

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Examiner Use

1 Elements and compounds which have small molecules usually exist as gases or liquids.

(a) Chlorine, Cl_2, is a gas at room temperature whereas bromine, Br_2, is a liquid under the same conditions.

Explain these observations.

.....

.....

..... [2]

(b) The gases nitrogen, N_2, and carbon monoxide, CO, are isoelectronic, that is they have the same number of electrons in their molecules.

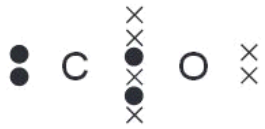
Suggest why N_2 has a lower boiling point than CO.

.....

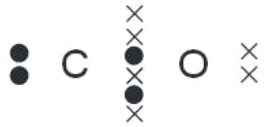
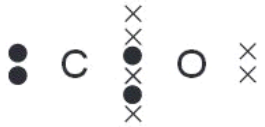
.....

..... [2]

(c) A 'dot-and-cross' diagram of a CO molecule is shown below. Only electrons from outer shells are represented.



In the table below, there are three copies of this structure.
On the structures, draw a circle round a pair of electrons that is associated with **each** of the following.

(i) a co-ordinate bond	**(ii)** a covalent bond	**(iii)** a lone pair
		

[3]

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(d) Hydrogen cyanide, HCN, is a gas which is also isoelectronic with N_2 and with CO. Each molecule contains a strong triple bond with the following bond energies.

bond	bond energy/kJmol^{-1}
−C≡N in HCN	890
N≡N	994
C≡O	1078

Although each compound contains the same number of electrons and a strong triple bond in its molecule, CO and HCN are both very reactive whereas N_2 is not.

Suggest a reason for this.

.....

..... [1]

Q8.

1 Hydrazine, N_2H_4, can be used as a rocket fuel and is stored as a liquid. It reacts exothermically with oxygen to give only gaseous products.

The enthalpy change of a reaction such as that between hydrazine and oxygen may be calculated by using standard enthalpy changes of formation.

(c) The bonding in hydrazine is similar to that in ammonia.

(i) Showing outer-shell electrons only, draw a 'dot-and-cross' diagram of an ammonia molecule.

(ii) Draw a diagram to show the three-dimensional shape of an ammonia molecule.

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(iii) Draw a diagram to show the shape of a hydrazine molecule.
Show clearly which atom is joined to which and show clearly the value of **one** bond angle.

[4]

(d) Deduce the oxidation state of nitrogen in hydrazine.

..... [1]

Q9.

(f) The boiling points of these two compounds are given below.

compound	bp/K
CH_3CH_3	184.5
CH_3F	194.7

Suggest explanations for the following.

(i) the close similarity of the boiling points of the two compounds

.....

.....

(ii) the slightly higher boiling point of CH_3F

.....

.....

[2]

Q10.

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(f) Another sulfur compound which is present in the Earth's atmosphere is carbonyl sulfide, OCS. The sequence of atoms in the molecule is oxygen-carbon-sulfur and the molecule is **not** cyclic.

(i) Draw a 'dot-and-cross' diagram of the OCS molecule.
Show outer electrons only.

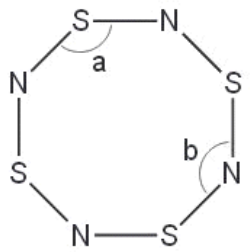
(ii) Suggest a value for the O – C – S bond angle.

.....

[2]

Q11.

(c) Sulfur forms the compound S_4N_4 with nitrogen. The structure of S_4N_4 is shown below. Assume all bonds shown are single bonds.



(i) Determine the number of lone pairs of electrons around a nitrogen atom and a sulfur atom in S_4N_4.

nitrogen atom .....

sulfur atom .....

(ii) Which bond angle, a or b, in the S_4N_4 molecule will be smaller? Explain your answer.

.....

.....

[2]

Q12.

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3 With the prospect that fossil fuels will become increasingly scarce in the future, many compounds are being considered for use in internal combustion engines. One of these is DME or dimethyl ether, CH_3OCH_3. DME is a gas which can be synthesised from methanol. Methanol can be obtained from biomass, such as plant waste from agriculture.

(d) DME is a gas at room temperature while ethanol is a liquid.

(i) Which intermolecular force exists between ethanol molecules, which causes ethanol to be a liquid at room temperature?

.....

(ii) Draw a diagram that clearly shows this intermolecular force.
Your diagram should show any lone pairs or dipoles present that you consider to be important. You should represent at least two molecules in your diagram.

[4]

Q13.

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1 Carbon disulfide, CS_2, is a volatile, flammable liquid which is produced in small quantities in volcanoes.

(a) The sequence of atoms in the CS_2 molecule is sulfur to carbon to sulfur.

(i) Draw a 'dot-and-cross' diagram of the carbon disulfide molecule.
Show outer electrons only.

(ii) Suggest the shape of the molecule and state the bond angle.

shape .....

bond angle .....

[3]

Q14.

3 The oxides of the third period include the following:

Na_2O; MgO; Al_2O_3; SO_2; SO_3.

(a) Showing outer electrons only, draw a dot-and-cross electron diagram for magnesium oxide, MgO.

[1]

Q15.

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1 **(a)** Salt, sodium chloride, forms transparent colourless crystals. Describe the bonding in sodium chloride crystals, give the formula of each particle and sketch part of the crystal structure.

[3]

(b) Explain why crystals of sodium chloride do not conduct electricity, but molten sodium chloride does.

.....

.....

.....[2]

Q16.

2 Carbon disulphide, CS_2, is a volatile, stinking liquid which is used to manufacture viscose rayon and cellophane.

(a) The carbon atom is in the centre of the CS_2 molecule.

Draw a 'dot-and-cross' diagram of the carbon disulphide molecule.

Show outer electrons only.

[2]

(b) Suggest the shape of the molecule and give its bond angle.

shape .....

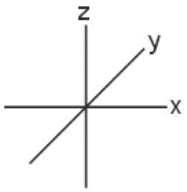
bond angle ..... [2]

Q17.

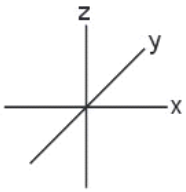
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1 This question is about the bonding of covalent compounds.

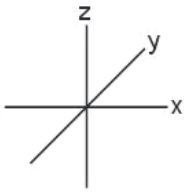
(a) On the axes below, sketch the shapes of a 1s, a 2s, and a $2p_x$ orbital.



1s



2s



$2p_x$

[3]

(b) Covalent bonding occurs when two atoms share a pair of electrons. Covalent bonding may also be described in terms of orbital overlap with the formation of σ bonds.

(i) How are the two atoms in a covalent bond held together? In your answer, state which particles are attracted to one another and the nature of the force of attraction.

.....

.....

(ii) Draw sketches to show orbital overlap that produces the σ bonding in the H_2 **and** HC*l* molecules.

H_2	HC*l*

[4]

(c) The bond in the HC*l* molecule is said to be 'polar'.

(i) What is meant by the term *bond polarity*?

.....

(ii) Explain why the HC*l* molecule is polar.

.....

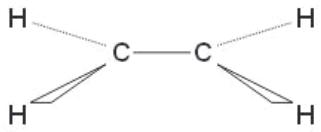
.....

[2]

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(d) The bonding in ethene may be described as a mixture of σ and π bonding.

Each carbon atom in ethene forms three σ bonds as shown below.



On the diagram, sketch the π bond that is also present in ethene. [1]

(e) Carbon, hydrogen and ethene each burn exothermically in an excess of air.

$C(s) + O_2(g) \rightarrow CO_2(g)$ $\quad \Delta H_c^\ominus = -393.7\,kJmol^{-1}$

$H_2(g) + \frac{1}{2}O_2(g) \rightarrow H_2O(l)$ $\quad \Delta H_c^\ominus = -285.9\,kJmol^{-1}$

$C_2H_4(g) + 3O_2(g) \rightarrow 2CO_2(g) + 2H_2O(l)$ $\quad \Delta H_c^\ominus = -1411.0\,kJmol^{-1}$

Use the data to calculate the standard enthalpy change of formation, $\Delta H_f^\ominus$, in $kJmol^{-1}$, of ethene at 298K.

$2C(s) + 2H_2(g) \rightarrow C_2H_4(g)$

$\Delta H_f^\ominus$ = ... $kJmol^{-1}$

[3]

[Total: 13]

Q18.

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(b) Suggest, in terms of the structure and bonding, explanations for the following. You should draw diagrams where you think they will help your answer.

(i) the high melting point of sodium chloride

(ii) the low melting point of silicon tetrachloride

[4]

(e) When solid aluminium chloride is heated above 451 K, a vapour is formed which has M_r = 267.
When this vapour is heated above 1100 K, the vapour has M_r = 133.5.

(i) What are the molecular formulae of these two forms of aluminium chloride?

at 460 K ..... at 1150 K .....

(ii) Draw a 'dot-and-cross' diagram of the form of aluminium chloride that exists at the **higher** temperature.

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(iii) Draw a displayed formula of the form of aluminium chloride that exists at the **lower** temperature. Indicate clearly the different types of bonds present.

[5]

Q19.

2 Ketene, C_2H_2O, is a member of a class of unsaturated organic compounds that is widely used in pharmaceutical research for the synthesis of organic compounds.

For Examiner Use

$CH_2=C=O$

ketene

(a) (i) Suggest values for the H-C-H and C=C=O bond angles in ketene.

H-C-H ..... C=C=O .....

(ii) By considering the structure of the molecule, suggest why the name *ketene* is used.

.....

..... [3]

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(b) Ketene burns completely in air to form carbon dioxide and water.

(i) Write a balanced equation for this reaction.

.....

(ii) Use your equation to calculate the volume of CO_2, in dm^3, measured at room temperature and pressure, which will be formed when 3.5 g of ketene are burned in an excess of air.

Give your answer to **two** significant figures.

volume of CO_2 = ... dm^3 **[4]**

Q20.

1 The elements carbon and silicon are both in Group IV of the Periodic Table.
Carbon is the second most abundant element by mass in the human body and silicon is the second most common element in the Earth's crust.

Carbon and silicon each form an oxide of general formula XO_2.
At room temperature, CO_2 is a gas while SiO_2 is a solid with a high melting point.

(a) Briefly explain, in terms of the chemical bonds and intermolecular forces present in **each** compound, why CO_2 is a gas and SiO_2 is a solid at room temperature.

.....

.....

.....

..... **[3]**

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(b) Draw a simple diagram to show the structure of SiO_2. Your diagram should contain at least **two** silicon atoms **and** show clearly how many bonds each atom forms.

[2]

CO_2 does not behave as an ideal gas.

(c) **(i)** State the basic assumptions of the kinetic theory as applied to an ideal gas.

.....

.....

.....

.....

.....

.....

(ii) Suggest **one** reason why CO_2 does not behave as an ideal gas.

.....

[5]

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Carbon exists in a number of forms, one of which is a conductor of electricity and one of which is a non-conductor of electricity. Silicon is the main component of most semi-conductors.

(d) Graphite is the form of carbon that is a conductor of electricity. Give a simple explanation for this property.

.....

..... [1]

When carbon and silicon(IV) oxide are heated together at about 2000 °C, silicon carbide, SiC, is formed. Silicon carbide is a hard material which is widely used as an abrasive and in ceramics.

(e) **(i)** Construct an equation for the reaction of carbon and silicon(IV) oxide.

.....

(ii) SiC has a similar structure to one of the common forms of carbon.
Which form is this? Give a reason for your answer.

form .....

reason .....
[2]

[Total: 13]

Q21.

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Sodium hydride, NaH, is a colourless crystalline solid which melts at 800 °C and has the same crystal structure as sodium chloride which has a melting point of 808 °C. When molten sodium chloride is electrolysed using graphite electrodes, a shiny deposit, **D**, forms on the cathode and a greenish-yellow gas is evolved from the anode. When molten sodium hydride is electrolysed, under suitable conditions using graphite electrodes, the same shiny deposit **D** is formed on the cathode and a colourless gas, **G**, is evolved from the anode.

(b) (i) Describe with the aid of a diagram the bonding in a sodium chloride crystal.

(ii) Suggest the type of bonding that is present in sodium hydride.

.....

(iii) What is the oxidation number of hydrogen in sodium hydride?

.....

(iv) Draw a 'dot-and-cross' diagram for sodium hydride. Show outer electrons only.

(v) The metals magnesium and aluminium form hydrides with formulae MgH_2 and AlH_3. The non-metals phosphorus and sulfur form hydrides with formulae PH_3 and H_2S.
By considering their positions in the Periodic Table, suggest oxidation numbers for these four elements in their hydrides.

compound	MgH_2	AlH_3	PH_3	H_2S
oxidation number of element in the hydride				

[8]

Q22.

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1 Valence Shell Electron Pair Repulsion theory (VSEPR) is a model of electron-pair repulsion (including lone pairs) that can be used to deduce the shapes of, and bond angles in, simple molecules.

(a) Complete the table below by using simple hydrogen-containing compounds. One example has been included.

number of bond pairs	number of lone pairs	shape of molecule	formula of a molecule with this shape
3	0	trigonal planar	BH_3
4	0		
3	1		
2	2		

[3]

(b) Tellurium, Te, proton number 52, is used in photovoltaic cells.

When fluorine gas is passed over tellurium at 150 °C, the colourless gas TeF_6 is formed.

(i) Draw a 'dot-and-cross' diagram of the TeF_6 molecule, showing outer electrons only.

(ii) What will be the shape of the TeF_6 molecule?

.....

(iii) What is the F–Te–F bond angle in TeF_6?

.....

[3]

[Total: 6]

Q23.

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1 Ammonia, NH_3, and methane, CH_4, are the hydrides of elements which are next to one another in the Periodic Table.

(a) In the boxes below, draw the 'dot-and-cross' diagram of a molecule of **each** of these compounds. Show outer electrons only.
State the shape of **each** molecule.

NH_3	CH_4
shape	shape

[3]

(b) Ammonia is polar whereas methane is non-polar. The physical properties of the two compounds are different.

(i) Explain, using ammonia as the example, the meaning of the term *bond polarity*.

.....

.....

.....

(ii) Explain why the ammonia molecule is polar.

.....

.....

(iii) State **one** physical property of ammonia which is caused by its polarity.

.....

.....

[4]

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(c) When ammonia gas is mixed with hydrogen chloride, white, solid ammonium chloride is formed.

State **each type** of bond that is present in one formula unit of ammonium chloride and how many of each type are present.
You may draw diagrams.

.....

.....

.....

.....

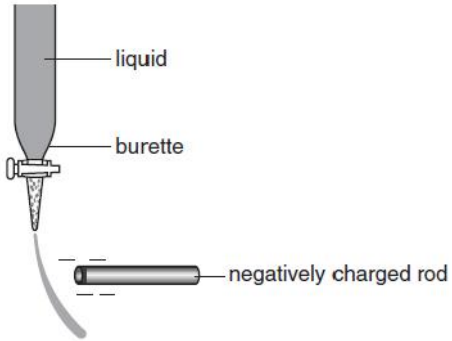
..... [3]

[Total: 10]

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1.

A slow stream of water from a tap can be deflected by an electrostatically charged plastic roc because water is a polar molecule.



Why is a water molecule polar?

A Molecules are bonded together by hydrogen bonds.

B The oxygen and hydrogen atoms have different electronegativities.

C The oxygen atom has two lone pairs of electrons.

D Water is able to dissociate into ions.

[2002 M/J (4)]

2.

In which sequences are the molecules quoted in order of increasing bond angle within the molecule?

1	H_2O	NH_3	CH_4
2	H_2O	SF_6	BF_3
3	CH_4	CO_2	SF_6

[2002 M/J (32)]

3.

Which of the following molecules has **no** permanent dipole?

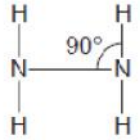
A CCl_2F_2 **B** $CHCl_3$ **C** C_2Cl_4 **D** C_2H_5Cl

[2002 O/N (5)]

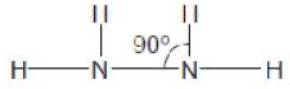
4.

Which is the most likely shape of a molecule of hydrazine, N_2H_4?

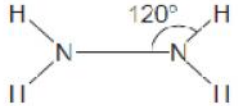
A



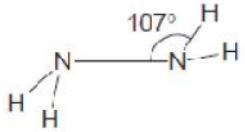
B



C



D



[2002 O/N (6)]

5.

Which of the following solids has a simple molecular lattice?

A magnesium oxide

B sodium

C silicon(IV) oxide

D sulphur

[2003 M/J (5)]

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6.

Silicon tetrachloride, $SiCl_4$, is a liquid of low boiling point. In the presence of water it decomposes to form silicon(IV) oxide and hydrogen chloride.

What types of bonding occur in $SiCl_4(l)$?

1 co–ordinate bonding

2 covalent bonding

3 van der Waals forces

[2003 M/J (31)]

7.

Which molecule contains only six bonding electrons?

A C_2H_4 **B** C_2F_6 **C** H_2O **D** NF_3

[2003 O/N (6)]

8.

Chemists have been interested in the properties of hydrogen selenide, H_2Se, to compare it with 'bad egg' gas hydrogen sulphide, H_2S.

Which set of data would the hydrogen selenide molecule be expected to have?

	number of lone pairs on Se atom	bond angle
A	1	104°
B	2	104°
C	2	109°
D	2	180°

[2003 O/N (7)]

9.

Magnesium oxide is used to line industrial furnaces because it has a very high melting point.

Which type of bond needs to be broken for magnesium oxide to melt?

A co-ordinate

B covalent

C ionic

D metallic

[2004 M/J (6)]

10.

Which solid exhibits more than one kind of chemical bonding?

A brass

B copper

C diamond

D ice

[2004 M/J (7)]

11.

Which ion is most polarising?

A Al^{3+}

B Ba^{2+}

C Mg^{2+}

D Na^{+}

[2004 M/J (14)]

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12.
Which molecule is planar?

A NF_3

B C_2Cl_4

C C_3H_6

D C_3H_8

[2004 M/J (20)]

13.
Which pairs of compounds contain one that is giant ionic and one that is simple molecular?

1 Al_2O_3 and Al_2Cl_6

2 SiO_2 and $SiCl_4$

3 P_4O_{10} and PCl_3

[2004 M/J (34)]

14.
The gecko, a small lizard, can climb up a smooth glass window. The gecko has millions of microscopic hairs on its toes and each hair has thousands of pads at its tip. The result is that the molecules in the pads are extremely close to the glass surface on which the gecko is climbing.

What is the attraction between the gecko's toe pads and the glass surface?

A co-ordinate bonds

B covalent bonds

C ionic bonds

D van der Waals' forces

[2004 O/N (6)]

15.
What are the bond angles in the PH_3 molecule likely to be?

A 90° **B** 104° **C** 109° **D** 120°

[2004 O/N (7)]

16.
Which of the following molecules and ions have a regular trigonal planar shape?

1 $AlCl_3$

2 CH_3^+

3 PH_3

[2005 M/J (31)]

17.
Which molecules are planar?

1 BCl_3

2 NH_3

3 PH_3

[2005 O/N (32)]

18.
In which process are hydrogen bonds broken?

A $H_2(l) \rightarrow H_2(g)$

B $NH_3(l) \rightarrow NH_3(g)$

C $2HI(g) \rightarrow H_2(g) + I_2(g)$

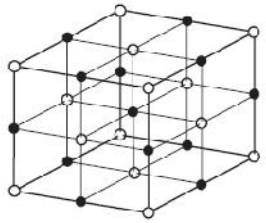
D $CH_4(g) \rightarrow C(g) + 4H(g)$

[2006 M/J (5)]

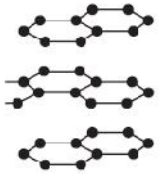
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19.

The diagram shows part of the lattice structures of solids **X** and **Y**. [In **X**, ○ and ● represent particles of different elements.]



X



Y

What are the types of bonding present in **X** and **Y**?

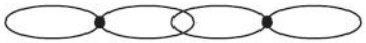
	X	Y
A	covalent	metallic
B	ionic	covalent
C	ionic	metallic
D	metallic	ionic

[2006 M/J (7)]

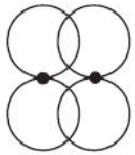
20.

Which diagram describes the formation of a π bond from the overlap of its orbitals?

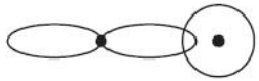
A



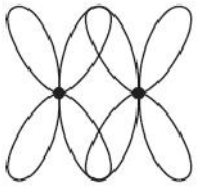
B



C



D



[2006 O/N (5)]

21.

The CN ion is widely used in the synthesis of organic compounds.

What is the pattern of electron pairs in this ion?

	bonding pairs of electrons	lone pairs on carbon atom	lone pairs on nitrogen atom
A	2	1	1
B	2	2	1
C	3	1	1
D	3	1	2

[2007 M/J (5)]

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22.

Which chlorine compound has bonding that can be described as ionic with some covalent character?

A $NaCl$ **B** $MgCl_2$ **C** $AlCl_3$ **D** $SiCl_4$

[2007 M/J (12)]

23.

Which of the following solids contain more than one type of chemical bond?

1 brass (an alloy of copper and zinc)

2 graphite

3 ice

[2007 M/J (32)]

24.

Use of the Data Booklet is relevant to this question.

In forming ionic compounds, elements generally form an ion with the electronic structure of a noble gas.

Which ion does **not** have a noble gas electronic structure?

A I^- **B** Rb^+ **C** Sn^{2+} **D** Sr^{2+}

[2007 O/N (2)]

25.

Lycra® is a polyurethane fibre used in the fashion industry. It is a polymer made from two monomers, one of which has the following formula.

$$O=C=N-(CH_2)_n-N=C=O$$

What is the O–C–N bond angle in this molecule?

A 90° **B** 109° **C** 120° **D** 180°

[2007 O/N (6)]

26.

What are the lattice structures of solid diamond, iodine and silicon(IV) oxide?

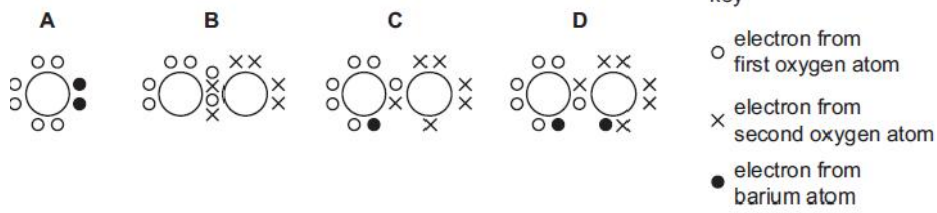
	giant molecular	simple molecular
A	diamond, silicon(IV) oxide	iodine
B	diamond, iodine	silicon(IV) oxide
C	iodine	diamond, silicon(IV) oxide
D	silicon(IV) oxide	diamond, iodine

[2007 O/N (7)]

27.

When barium metal burns in oxygen, the ionic compound barium peroxide, BaO_2, is formed.

Which dot-and-cross diagram represents the electronic structure of the peroxide anion in BaO_2?



[2008 M/J (4)]

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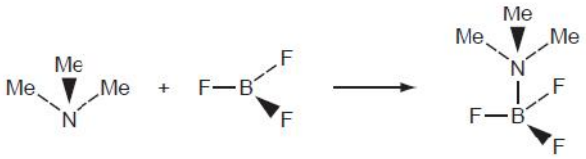
28.

In this question, the methyl group, CH_3, is represented by Me.

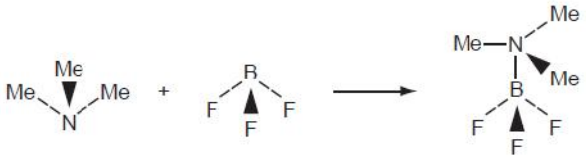
Trimethylamine, Me_3N, reacts with boron trifluoride, BF_3, to form a compound of formula $Me_3N.BF_3$.

How may this reaction be written in terms of the shapes of the reactants and products?

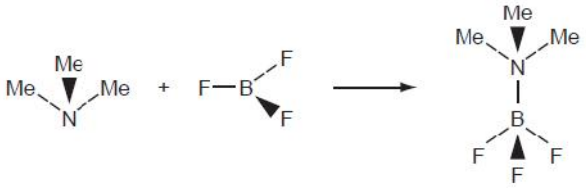
A



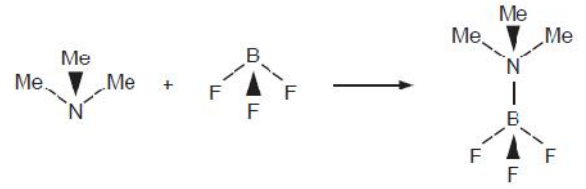
B



C



D



[2008 M/J (5)]

29.

Which pair of elements have bonds of the same type between their atoms in the solid state?

A aluminium and phosphorus

B chlorine and argon

C magnesium and silicon

D sulphur and chlorine

[2008 M/J (7)]

30.

In which reaction does the carbon-containing product have a smaller bond angle than the organic reactant?

A bromoethane refluxed with ethanolic sodium hydroxide

B complete combustion of methane in air

C methane and an excess of chlorine under ultraviolet light

D polymerisation of ethene

[2009 M/J (6)]

31.

A crystal of iodine produces a purple vapour when gently heated.

Which pair of statements correctly describes this process?

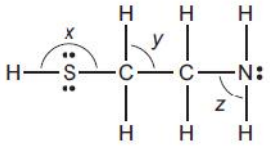
	type of bond broken	formula of purple species
A	covalent	I
B	covalent	I_2
C	induced dipole-dipole	I_2
D	permanent dipole-dipole	I_2

[2009 M/J (7)]

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32.

The antidote molecule shown can help to prevent liver damage if someone takes too many paracetamol tablets.



What is the order of **decreasing** size of the bond angles *x*, *y* and *z*?

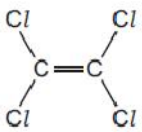
	largest ⟶		smallest
A	*x*	*y*	*z*
B	*x*	*z*	*y*
C	*y*	*z*	*x*
D	*z*	*y*	*x*

[2009 O/N-11 (4)]

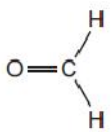
33.

Which molecule has the largest overall dipole?

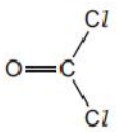
A



B



C



D

[2009 O/N-11 (5)]

34.

Which physical properties are due to hydrogen bonding between water molecules?

1 Water has a higher boiling point than H_2S.

2 Ice floats on water.

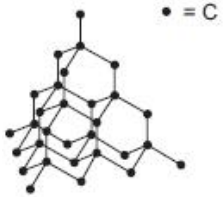
3 The H–O–H bond angle in water is approximately 104°.

[2009 O/N-11 (32)]

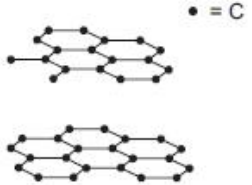
35.

I Which diagrams represent part of a giant molecular structure?

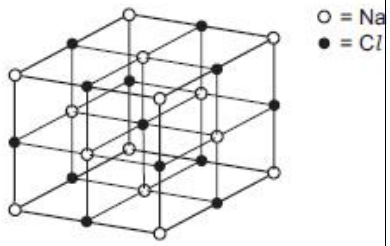
1



2



3

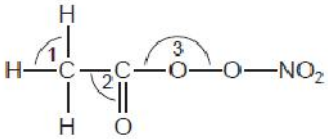


[2010 M/J-11 (31)]

36.

Organic nitrates in photochemical smog can cause breathing difficulties.

The diagram shows an example of an organic nitrate molecule.



What is the correct order of the bond angles shown in ascending order (smallest first)?

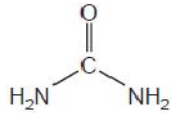
A 1 → 2 → 3 **B** 2 → 1 → 3 **C** 3 → 1 → 2 **D** 3 → 2 → 1

[2010 O/N-11 (7)]

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37.

Which types of intermolecular forces can exist between adjacent urea molecules?



urea

1 hydrogen bonding

2 permanent dipole-dipole forces

3 temporary induced dipole-dipole forces

[2010 O/N-11 (33)]

38.

The ability of an atom in a covalent bond to attract electrons to itself is called its electronegativity.

The greater the difference between the electronegativities of the two atoms in the bond, the more polar is the bond.

Which pair will form the most polar covalent bond between the atoms?

A chlorine and bromine

B chlorine and iodine

C fluorine and chlorine

D fluorine and iodine

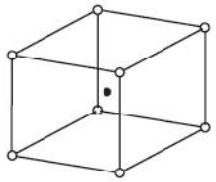
[2010 O/N-12 (1)]

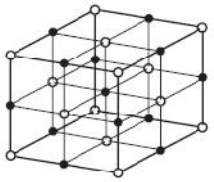
39.

The table gives the radii, in pm, of some ions. [1pm = 10^{-12} m]

ion	radii
Na^+	102
Mg^{2+}	72
Cs^+	167
Cl^-	181
O^{2-}	140

Caesium chloride, CsCl, has a different lattice structure from both sodium chloride, NaCl, and magnesium oxide, MgO.


CsCl lattice


NaCl and MgO lattice

Which factor appears to determine the type of lattice for these three compounds?

A the charge on the cation

B the ratio of the ionic charges

C the ratio of the ionic radii

D the sum of the ionic charges

[2010 O/N-12 (3)]

40.

Which solid has a simple molecular lattice?

A calcium fluoride

B nickel

C silicon(IV) oxide

D sulfur

[2010 O/N-12 (5)]

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41.

Which molecule or structure does **not** contain three atoms bonded at an angle between 109° and 110°?

A ethanoic acid

B graphite

C propane

D silicon(IV) oxide

[2010 O/N-12 (10)]

42.

Which statements about covalent bonds are correct?

1 A triple bond consists of one π bond and two σ bonds.

2 The electron density in a σ bond is highest along the axis between the two bonded atoms.

3 A π bond restricts rotation about the σ bond axis.

[2010 O/N-12 (33)]

43.

Which are features of the structure of metallic copper?

1 a lattice of ions

2 delocalised electrons

3 ionic bonds

[2011 M/J-11 (32)]

44.

Which descriptions of the ammonium ion are correct?

1 It contains ten electrons.

2 It has a bond angle of 109.5°.

3 It has only three bonding pairs of electrons.

[2011 M/J-11 (37)]

45.

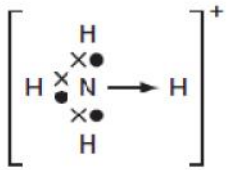
Which diagram correctly shows the bonding in the ammonium ion, NH_4^+?

key

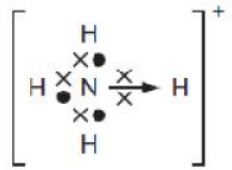
● N electron

× H electron

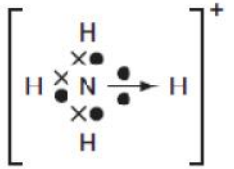
A



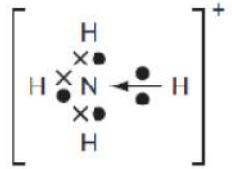
B



C



D



[2011 M/J-12 (2)]

46.

What is involved when a hydrogen bond is formed between two molecules?

1 a hydrogen atom bonded to an atom less electronegative than itself

2 a lone pair of electrons

3 an electrostatic attraction between opposite charges

[2011 M/J-12 (32)]

47.

In which change would only van der Waals' forces have to be overcome?

A	evaporation of ethanol	$C_2H_5OH(l) \rightarrow C_2H_5OH(g)$
B	melting of ice	$H_2O(s) \rightarrow H_2O(l)$
C	melting of solid carbon dioxide	$CO_2(s) \rightarrow CO_2(l)$
D	solidification of butane	$C_4H_{10}(l) \rightarrow C_4H_{10}(s)$

[2011 M/J-13 (10)]

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48.

Which element shows the greatest tendency to form some covalent compounds?

A aluminium

B magnesium

C neon

D potassium

[2011 O/N-11 (13)]

49.

Why does aluminium chloride, Al_2Cl_6, sublime at the relatively low temperature of 180 °C?

1 The intermolecular forces between the Al_2Cl_6 molecules are weak.

2 The co-ordinate bonds between aluminium and chlorine are weak.

3 The covalent bonds between aluminium and chlorine are weak.

[2011 O/N-11 (32)]

50.

The three statements that follow are all true.

Which of these can be explained, at least in part, by reference to hydrogen bonding?

1 At 0 °C ice floats on water.

2 The boiling point of propan-2-ol is 82 °C. The boiling point of propanone is 56 °C.

3 At 20 °C propanone and propanal mix completely.

[2011 O/N-11 (33)]

51.

The presence of dipoles helps to explain why the element Br_2 and the compound $CHCl_3$ exist as liquids at room temperature.

Which types of dipole are involved?

	Br_2	$CHCl_3$
A	induced dipoles and permanent dipoles	induced dipoles and permanent dipoles
B	induced dipoles and permanent dipoles	induced dipoles only
C	induced dipoles only	induced dipoles and permanent dipoles
D	induced dipoles only	induced dipoles only

[2011 O/N-12 (5)]

52.

Which statements about bond angles are correct?

1 The bond angle in SO_2 is smaller than the bond angle in CO_2.

2 The bond angle in H_2O is smaller than the bond angle in CH_4.

3 The bond angle in NH_3 is smaller than the bond angle in BF_3.

[2011 O/N-12 (31)]

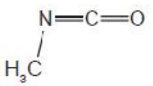
53.

Methyl isocyanate, CH_3NCO, is a toxic liquid which is used in the manufacture of some pesticides.

In the methyl isocyanate molecule, the sequence of atoms is $H_3C—N=C=O$.

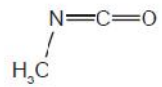
What is the approximate angle between the bonds formed by the N atom?

A



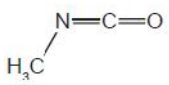
104°

B



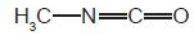
109°

C



120°

D



180°

[2011 O/N-13 (5)]

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54.

Two conversions are outlined below.

$NH_4^+ \rightarrow NH_3$

$C_2H_4 \rightarrow C_2H_6$

What similar feature do these two conversions have?

A a lone pair of electrons in the product

B change in oxidation state of an element

C decrease in bond angle of the species involved

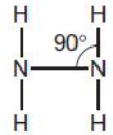
D disappearance of a π bond

[2012 M/J-11 (5)]

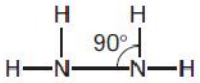
55.

What is the **most** likely shape of a molecule of hydrazine, N_2H_4?

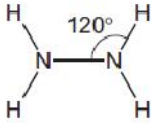
A



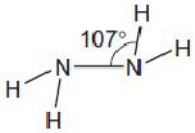
B



C



D



[2012 M/J-12 (3)]

56.

Which solid contains more than one kind of bonding?

A iodine

B silicon dioxide

C sodium chloride

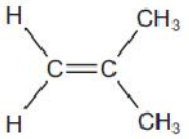
D zinc

[2012 M/J-12 (5)]

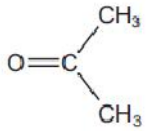
57.

Which molecule has the largest overall dipole?

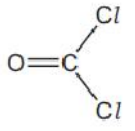
A



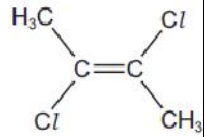
B



C



D



[2012 M/J-12 (10)]

58.

Which of the following molecules and ions have a regular trigonal planar shape?

1 BF_3

2 CH_3^+

3 $AlCl_3$

[2012 M/J-12 (31)]

59.

Sodium borohydride, $NaBH_4$, and boron trifluoride, BF_3, are compounds of boron.

What are the shapes around boron in the borohydride ion and in boron trifluoride?

	borohydride ion	boron trifluoride
A	square planar	pyramidal
B	square planar	trigonal planar
C	tetrahedral	pyramidal
D	tetrahedral	trigonal planar

[2012 O/N-11 (3)]

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60.
In which pair do the molecules have the same shape as each other?

A H_2O and CO_2

B H_2O and SCl_2

C NH_3 and BH_3

D SCl_2 and $BeCl_2$

[2012 O/N-11 (12)]

61.
Which of these substances have a giant structure?

1 silicon(IV) oxide

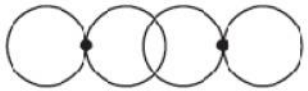
2 baked clay found in crockery

3 phosphorus(V) oxide

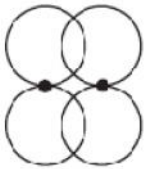
[2012 O/N-11 (33)]

62.
Which diagram represents the overlap of two orbitals which will form a π bond?

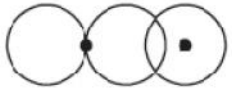
A



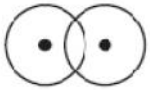
B



C



D



[2012 O/N-13 (6)]

63.
Which molecule is planar?

A C_2Cl_4 **B** C_3H_6 **C** C_3H_8 **D** NF_3

[2012 O/N-13 (11)]

64.
Valence shell electron pair repulsion theory should be used to answer this question.

Which species are trigonal planar?

1 BH_3

2 CH_3^+

3 PH_3

[2013 M/J-11 (33)]

65.
Which pair of elements has chemical bonds of the same type between their atoms in the solid state?

A aluminium and phosphorus

B chlorine and argon

C magnesium and silicon

D sulfur and chlorine

[2013 M/J-12 (6)]

66.
Dicarbon monoxide, C_2O, is found in dust clouds in space. Analysis of it shows that the sequence of atoms in this molecule is C–C–O. All bonds are double bonds and there are no unpaired electrons.

How many lone pairs of electrons are present in a molecule of C_2O?

A 1 **B** 2 **C** 3 **D** 4

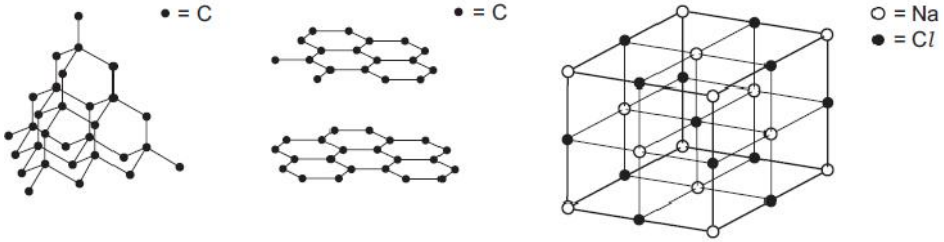
[2013 M/J-12 (9)]

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67.

Which diagrams represent part of a giant molecular structure?

1 2 3



[2013 M/J-13 (34)]

68.

Which types of bonding are present in ammonium carbonate, $(NH_4)_2CO_3$?

1 ionic

2 covalent

3 co-ordinate (dative covalent)

[2013 O/N-11 (35)]

69.

Which solid contains more than one kind of bonding?

A copper

B diamond

C ice

D magnesium oxide

[2013 O/N-13 (8)]

70.

$AlCl_3$ vapour forms molecules with formula Al_2Cl_6 as it is cooled.

What happens to the bond angles during the change from $AlCl_3$ to Al_2Cl_6?

A Some decrease, some remain the same.

B Some increase, some remain the same.

C They all decrease.

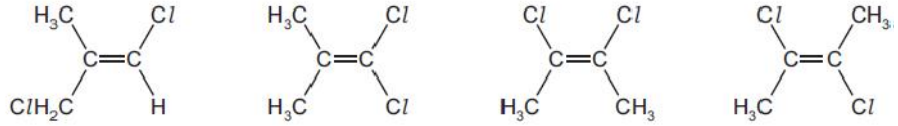
D They all increase.

[2014 M/J-11 (6)]

71.

Which molecular structure will have the **smallest** overall dipole?

A B C D



[2014 M/J-11 (9)]

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72.

Substances X, Y and Z are all solids. Some of their physical properties are given in the table.

substance	X	Y	Z
melting point/°C	772	114	1610
boiling point/°C	1407	183	2205
electrical conductivity of the liquid state	conducts	does not conduct	does not conduct

What type of lattice could each substance have?

	X	Y	Z
A	giant molecular	simple molecular	ionic
B	ionic	giant molecular	simple molecular
C	ionic	simple molecular	giant molecular
D	simple molecular	ionic	giant molecular

[2014 M/J-12 (2)]

73.

Which elements have atoms which can form π bonds with atoms of other elements?

1 oxygen

2 nitrogen

3 fluorine

[2014 M/J-12 (33)]

74.

Which compound has the greatest total number of lone pairs of electrons in the valence shells of all of its atoms?

A CH_3Cl B CO_2 C N_2H_4 D NH_4CN

[2014 M/J-13 (2)]

75.

Four substances have the physical properties shown.

Which substance is an ionic solid?

	melting point /°C	boiling point /°C	electrical conductivity of solid	electrical conductivity of molten substance	electrical conductivity of aqueous solution
A	–115	–85	poor	poor	good
B	660	2470	good	good	insoluble
C	993	1695	poor	good	good
D	1610	2230	poor	poor	insoluble

[2014 M/J-13 (8)]

76.

X is an element in Period 2.

In which fluoride is the F–X–F angle the largest?

A BF_3 B CF_4 C NF_3 D OF_2

[2014 M/J-13 (10)]

77.

P and Q are two liquid compounds with similar M_r values. Molecules of P attract each other by hydrogen bonds. Molecules of Q attract each other by van der Waals' forces only.

How do the properties of P and Q differ?

1 P has higher surface tension than Q.

2 P has a higher boiling point than Q.

3 P is less viscous than Q.

[2014 M/J-13 (32)]

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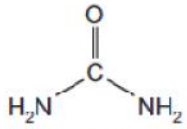
78.
Copper and iodine are both shiny crystalline solids.

Which forces exist between particles in solid copper and between neighbouring iodine molecules in solid iodine?

	copper	iodine
A	ionic bonds	covalent bonds
B	ionic bonds	van der Waals' forces
C	metallic bonds	covalent bonds
D	metallic bonds	van der Waals' forces

[2014 O/N-13 (7)]

79.
Which types of intermolecular forces can exist between adjacent urea molecules?



urea

1 hydrogen bonding

2 permanent dipole-dipole forces

3 instantaneous dipole-induced dipole forces

[2014 O/N-13 (33)]

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Chemical bonding – 2021 AS

1. Nov/2021/Paper_11/No.5

Which type of interaction exists between water molecules and metal cations in aqueous solution?

A dipole-dipole interactions

B hydrogen bonds

C ion-dipole interactions

D ionic bonds

2. Nov/2021/Paper_11/No.6

Which substance shows the greatest deviation from the properties of an ideal gas under room conditions?

A $CO_2(g)$ **B** $H_2(g)$ **C** Ne(g) **D** $NH_3(g)$

3. Nov/2021/Paper_11/No.18

Which row is correct?

	shape		bonds present	
	ammonia molecule	ammonium ion	ammonia molecule	ammonium ion
A	pyramidal	regular tetrahedral	σ	σ
B	pyramidal	regular tetrahedral	σ	π
C	regular tetrahedral	pyramidal	σ	σ
D	regular tetrahedral	pyramidal	π	σ

4. Nov/2021/Paper_11/No.19

The table describes two possible environmental consequences of adding too much ammonium nitrate fertiliser to the soil.

Which row is correct?

	increased plant growth in rivers	photochemical smog
A	✗	✗
B	✓	✗
C	✗	✓
D	✓	✓

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5. Nov/2021/Paper_11/No.34

Which molecules contain at least one unpaired electron?

1 NO

2 NO_2

3 NH_3

6. Nov/2021/Paper_11/No.35

Which elements form a chloride in which both covalent bonding and coordinate (dative covalent) bonding are present?

1 A*l*

2 Si

3 Mg

7. Nov/2021/Paper_12/No.5

Atom X is the central atom in a molecule.

In this molecule, atom X has four pairs of valence electrons in its outer shell.

The four pairs of valence electrons include at least one bond pair and at least one lone pair.

What could be a possible shape for the molecule?

A linear

B non-linear

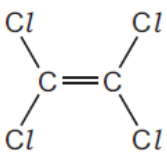
C trigonal bipyramidal

D trigonal planar

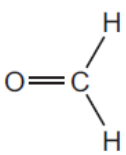
8. Nov/2021/Paper_12/No.6

Which molecule has the largest overall dipole?

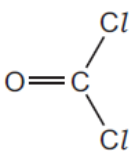
A



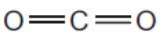
B



C



D



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9. Nov/2021/Paper_12/No.7

The strength of hydrogen bonding increases as the electronegativity of the element bonded to hydrogen increases.

Some information for a range of hydrides is given.

hydride	boiling point / K
PH_3	185
HCl	188
HF	293
H_2O	373

Which statement and reason about these hydrides is correct?

A The boiling point of PH_3 is much lower than the boiling point of H_2O because PH_3 does not form hydrogen bonds or instantaneous dipole-induced dipole forces between its molecules.

B The boiling point of HF is higher than the boiling point of HCl because the bond energy of H–F is greater than the bond energy of H–Cl.

C The boiling point of H_2O is higher than the boiling point of HF because each hydrogen bond between the H_2O molecules is stronger than each hydrogen bond between HF molecules.

D The boiling points of PH_3 and HCl are similar because the molecules of PH_3 and HCl have the same number of electrons and similar intermolecular forces.

10. Nov/2021/Paper_12/No.35

The following statements compare some properties of the oxides and chlorides of sodium and silicon.

Which statements are correct?

1 The melting point of $SiCl_4$ is higher than the melting point of SiO_2.

2 $SiCl_4$ reacts with water, $NaCl$ does not.

3 The melting point of $SiCl_4$ is lower than the melting point of $NaCl$.

The responses **A** to **D** should be selected on the basis of

A	B	C	D
1, **2** and **3** are correct	**1** and **2** only are correct	**2** and **3** only are correct	**1** only is correct

No other combination of statements is used as a correct response.

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11. Nov/2021/Paper_13/No.18

Which row is correct?

	shape		bonds present	
	ammonia molecule	ammonium ion	ammonia molecule	ammonium ion
A	pyramidal	regular tetrahedral	σ	σ
B	pyramidal	regular tetrahedral	σ	π
C	regular tetrahedral	pyramidal	σ	σ
D	regular tetrahedral	pyramidal	π	σ

12. Nov/2021/Paper_13/No.35

Which elements form a chloride in which both covalent bonding and coordinate (dative covalent) bonding are present?

1 A*l*

2 Si

3 Mg

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13. March/2021/Paper_12/No/.12

Which observations are made when a sample of silicon chloride, $SiCl_4$, is added to a beaker of water?

A No visible change is observed.

B Steamy fumes and a precipitate are both observed.

C The appearance of a precipitate is the only observation.

D The appearance of steamy fumes is the only observation.

14. March/2021/Paper_12/No/.34

Which species can accept a lone pair of electrons to form a coordinate (dative covalent) bond?

1 BF_3

2 H^+

3 CH_3^+

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15. June/2021/Paper_11/No.3

Phosphorus forms two chlorides. Phosphorus(III) chloride, PCl_3, is a covalent liquid.

Phosphorus(V) chloride is an ionic solid. One of the ions present is $[PCl_4]^+$.

What is the shape of the PCl_3 molecule and the $[PCl_4]^+$ ion?

	PCl_3	$[PCl_4]^+$
A	pyramidal	square planar
B	pyramidal	tetrahedral
C	tetrahedral	square planar
D	trigonal planar	tetrahedral

16. June/2021/Paper_11/No.34

Which molecules contain at least one bond angle of 120°?

1 C_2H_4

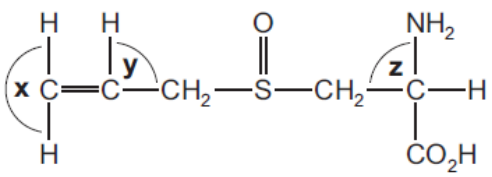
2 PF_5

3 NCl_3

17. June/2021/Paper_12/No.4

The structural formula of alliin is shown.

alliin

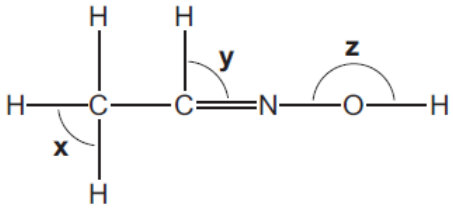


What are the approximate bond angles **x**, **y** and **z** in a molecule of alliin?

	x	**y**	**z**
A	90°	90°	109°
B	120°	109°	90°
C	120°	120°	109°
D	180°	109°	109°

18. June/2021/Paper_13/No.4

Ethanal reacts with hydroxylamine, NH_2OH, to form the molecule shown.



What is the order of **increasing** bond angle in this structure from smallest to largest?

A z, x, y **B** y, z, x **C** x, z, y **D** z, y, x

19. June/2021/Paper_13/No.5

Descriptions of the bonding in three substances are given.

substance 1 strong covalent bonds between atoms, permanent dipole-dipole attractions between molecules

substance 2 strong covalent bonds between atoms, weak forces between molecules

substance 3 strong covalent bonds between atoms, hydrogen bonding between molecules

Which compounds could be substances 1, 2 and 3?

	substance 1	substance 2	substance 3
A	CH_3OH	Al_2Cl_6	CH_2Cl_2
B	Al_2Cl_6	CH_2Cl_2	CH_4
C	CH_2Cl_2	CH_4	CH_3OH
D	CH_4	CH_3OH	H_2O

20. June/2021/Paper_13/No.6

Which type of bonding is **never** found in elements?

A covalent

B ionic

C metallic

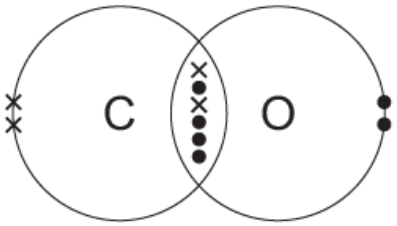
D van der Waals' forces

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21. June/2021/Paper_21/No.2

Carbon monoxide gas, CO(g), and nitrogen gas, $N_2(g)$, are both diatomic molecules.

(a) The diagram shows the arrangement of outer electrons in a molecule of CO(g).



(i) State **one** similarity and **one** difference in the way the atoms in a carbon monoxide molecule are bonded together compared to the atoms in a nitrogen molecule.

.....

.....

..... [2]

(ii) The table states the electronegativity values of carbon, nitrogen and oxygen atoms.

	C	N	O
electronegativity	2.5	3.0	3.5

Use the electronegativity values and relevant details from the *Data Booklet* to complete the table below.

	N_2	CO
number of electrons per molecule		
type(s) of intermolecular (van der Waals') force		

[2]

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(b) $N_2(g)$ is less reactive than CO(g) even though $N_2(g)$ has a lower bond energy than CO(g).

Suggest why CO(g) is more reactive than $N_2(g)$.

.....

..... [1]

(c) Both carbon monoxide and nitrogen are gases at room temperature and pressure.

They both behave like ideal gases under certain conditions.

(i) State the **two** conditions necessary for these two gases to approach ideal gas behaviour.

.....

..... [1]

(ii) Explain why $N_2(g)$ behaves more like an ideal gas than CO(g) does at 20.0 °C and 101 kPa.

.....

.....

..... [2]

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(d) Calculate the amount, in mol, of pure nitrogen gas which occupies 100 cm^3 at 101 kPa and 20.0 °C.

Use relevant information from the *Data Booklet*. Show your working.

Assume nitrogen behaves as an ideal gas.

..... mol
[3]

[Total: 11]

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22. June/2021/Paper_22/No.2

The strength of interaction between particles determines whether the substance is a solid, liquid or gas at room temperature.

(a) Lithium sulfide, Li_2S, is a crystalline solid with a melting point of 938 °C. It conducts electricity when it is molten.

(i) Give the formulae of the particles present in solid lithium sulfide.

..... [1]

(ii) Explain, in terms of the structure of the crystalline solid, why lithium sulfide has a high melting point.

.....

..... [2]

(b) Carbon monoxide, CO, is a gas at room temperature and pressure. It contains a coordinate bond.

(i) Explain what is meant by *coordinate bond*.

.....

..... [1]

(ii) Draw a 'dot-and-cross' diagram to show the arrangement of outer electrons in CO.

Show the electrons belonging to the C atom as ×.

Show the electrons belonging to the O atom as ●.

[2]

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(c) Nitrogen, N_2, is also a gas at room temperature and pressure. Neither CO nor N_2 is an ideal gas.

(i) State two assumptions that are made about the behaviour of particles in an ideal gas.

1 .....

.....

2 .....

.....

[2]

(ii) Explain why N_2 does not behave as an ideal gas at very high pressures.

.....

.....

.....

..... [2]

(iii) Complete the table by naming **all** the types of intermolecular forces (van der Waals') in separate samples of $N_2(g)$ and CO(g).

	$N_2(g)$	CO(g)
number of electrons per molecule	14	14
presence of a dipole moment	✗	✓
boiling point/°C	–195.8	–191.5
intermolecular forces (van der Waals')		

[2]

(iv) Suggest why the bond in a molecule of CO contains a dipole moment.

..... [1]

[Total: 13]

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23. June/2021/Paper_23/No.2

Methanol, CH_3OH, is soluble in water because it forms hydrogen bonds with water molecules.

(a) Draw a fully labelled diagram to show how a hydrogen bond forms between a water molecule and a methanol molecule.

[3]

(b) Methanol has a melting point of –97.6 °C and a boiling point of 64.7 °C.

A sample of pure liquid methanol is added to a flask and then sealed. The sealed flask is left for several days at constant temperature. The vapour pressure is then measured as 17 kPa.

(i) Describe what is meant by the term *vapour pressure of methanol*.

.....

.....

..... [2]

(ii) Explain why some of the liquid becomes a vapour.

.....

.....

..... [1]

(iii) Suggest and explain why the vapour pressure of water at room temperature is lower than the vapour pressure of methanol at room temperature. Refer to the correct intermolecular forces in your answer.

.....

.....

..... [2]

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(c) Methanol is made by reacting carbon monoxide with hydrogen.

$$CO(g) + 2H_2(g) \rightleftharpoons CH_3OH(g)$$

Carbon monoxide and hydrogen react at 1.0×10^7 Pa and 200 °C. Eventually the reaction mixture reaches dynamic equilibrium.

The table shows the amounts of each species present in the mixture.

	CO(g)	$H_2(g)$	$CH_3OH(g)$
initial amount / mol	1.0	2.0	0
equilibrium amount / mol	0.030	0.060	0.97

(i) Explain what is meant by *dynamic equilibrium*.

.....

.....

..... [2]

(ii) Calculate the partial pressure of methanol vapour at equilibrium under these conditions. Show your working.

..... Pa [2]

(iii) Write an expression for the equilibrium constant, K_p, for this reaction. State the units in your answer.

K_p =

units = ... [2]

[Total: 14]

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Chemical bonding – 2022 June AS Chemistry 9701

1. June/2022/Paper_11/No.5

In which structure are three atoms bonded together in a straight line?

A poly(ethene), $-(-CH_2CH_2-)_n-$

B propane, C_3H_8

C silicon tetrachloride, $SiCl_4$

D sulfur hexafluoride, SF_6

2. June/2022/Paper_11/No.6

Which statement about aluminium chloride is correct?

A Aluminium chloride has a much higher melting point than magnesium chloride due to the small size of the aluminium ion.

B Anhydrous aluminium chloride reacts vigorously with water to form a solution with a pH greater than 7.

C Each Al_2Cl_6 molecule found in aluminium chloride vapour contains two coordinate bonds.

D The bonding between aluminium and chlorine is strongly ionic due to the large difference in electronegativity.

3. June/2022/Paper_13/No.5

Which compound has the smallest difference in electronegativity between its two elements?

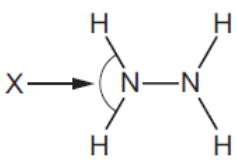
A KF **B** KBr **C** LiF **D** LiBr

4. June/2022/Paper_13/No.6

VSEPR theory should be used to answer this question.

Hydrazine has the following structure.

hydrazine



What is the predicted bond angle X?

A 90° **B** 107° **C** 109.5° **D** 120°

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5. June/2022/Paper_22/No.1(a)

(a) Magnesium has a melting point of 650 °C and high electrical conductivity.

Explain these properties of magnesium by referring to its structure and bonding.

.....

..... [2]

6. June/2022/Paper_23/No.3a (i)

G belongs to a group of compounds called ethers.

G

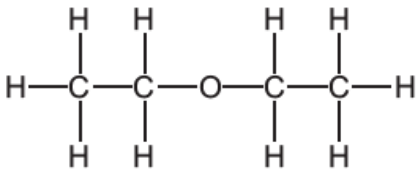


Fig. 3.1

(a) When **G**, $C_4H_{10}O$, is heated, thermal decomposition occurs.

$$C_4H_{10}O(g) \rightarrow C_2H_6(g) + CO(g) + CH_4(g) \qquad \Delta H = -7.00\,kJ\,mol^{-1}$$

(i) The atoms in a molecule of CO are held together by a triple covalent bond. One of these bonds is a coordinate (dative covalent) bond.

Draw a dot-and-cross diagram to show the arrangement of outer electrons in a CO molecule.

Use ● to represent electrons from an oxygen atom.
Use × to represent electrons from a carbon atom.

[1]

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Chemical bonding – Nov June AS Chemistry 9701

1. Nov/2022/Paper_11/No.6

Which molecule has an equal number of bonding electrons and lone-pair electrons?

A BH_3 **B** CO_2 **C** F_2O **D** SO_2

2. Nov/2022/Paper_11/No.7

The table shows properties of four solids held together by different types of bonding.

Which row correctly describes the properties of a solid with a giant covalent structure?

	melting point	solubility in polar solvents
A	high	insoluble
B	high	soluble
C	low	insoluble
D	low	soluble

3. Nov/2022/Paper_12/No.12

The compound $(CH_3)_3NAlCl_3$ has a simple molecular structure.

Which statement about $(CH_3)_3NAlCl_3$ is correct?

A $(CH_3)_3NAlCl_3$ molecules attract each other by hydrogen bonds.

B The Al atom in $(CH_3)_3NAlCl_3$ has an incomplete valence shell of electrons.

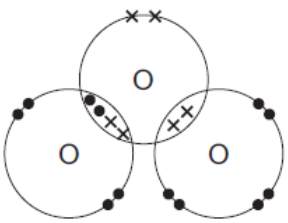
C The bonds around the Al atom are planar.

D The molecules contain coordinate bonding.

4. Nov/2022/Paper_12/No.13

VSEPR theory should be used in answering this question.

The dot-and-cross diagram for an ozone, O_3, molecule is shown.



What is the predicted bond angle in this molecule?

A 107° **B** 109.5° **C** 117° **D** 120°

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5. Nov/2022/Paper_22/No.1(a)

Species such as NH_4^+, CO_3^{2-} and PO_4^{3-} are examples of molecular ions.

(a) Ionic and covalent bonds both involve an electrostatic attraction between different species.

Identify the species that are electrostatically attracted to one another in:

- an ionic bond

.....

- a covalent bond.

.....

[2]

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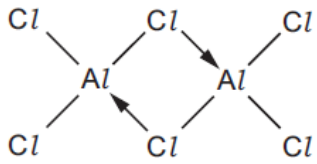
Chemical bonding – 2023 AS Chemistry 9701

1. Nov/2023/Paper_ 9701/11/No.5

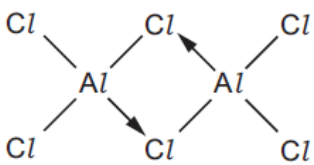
Solid aluminium chloride sublimes at 178 °C.

Which structure best represents the species in the vapour at this temperature?

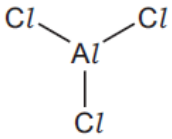
A



B



C



D

$Al^{3+}(Cl^{-})_3$

2. Nov/2023/Paper_ 9701/11/No.6

Which row is correct?

	shape of H_3O^+	shape of SCl_2
A	pyramidal	non-linear
B	pyramidal	linear
C	trigonal planar	non-linear
D	trigonal planar	linear

3. Nov/2023/Paper_ 9701/12/No.5

Ammonium ions, NH_4^+, are formed when ammonia gas reacts with hydrogen chloride gas.

Which statement about the changes that occur in this reaction is correct?

A The dipole moment of an ammonium ion is greater than the dipole moment of an ammonia molecule.

B The H–N–H bond angle decreases when an ammonium ion is formed.

C The hybridisation of nitrogen does **not** change.

D There is electron transfer from nitrogen to chlorine.

4. Nov/2023/Paper_ 9701/12/No.7

Two compounds of boron are sodium borohydride, $NaBH_4$, and boron trifluoride, BF_3.

What are the shapes of the borohydride ion and the boron trifluoride molecule?

	borohydride ion	boron trifluoride
A	square planar	pyramidal
B	square planar	trigonal planar
C	tetrahedral	pyramidal
D	tetrahedral	trigonal planar

5. Nov/2023/Paper_ 9701/21/No.1(c, d)

(c) A student does three tests on separate samples of NaC*l*(aq).

Complete Table 1.2 with the observations the student makes in each test.

Table 1.2

test	test	observations
1	addition of a few drops of $Br_2(aq)$	
2	addition of a few drops of concentrated H_2SO_4	
3	addition of a few drops of dilute $AgNO_3(aq)$	

[3]

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(d) $POCl_3$ shows similar chemical properties to PCl_5.

$POCl_3$ has a melting point of 1°C and a boiling point of 106 °C.

$POCl_3$ reacts vigorously with water, forming misty fumes and an acidic solution.

(i) Explain how the information in **(d)** suggests the structure and bonding of $POCl_3$ is simple covalent.

.....

.....

..... [2]

(ii) Construct an equation for the reaction of $POCl_3$ with water.

$POCl_3$ + ... → .....

[1]

(iii) $POCl_3$ contains a double covalent bond between P and O.

Complete the dot-and-cross diagram, in Fig. 1.1, to show the bonding in $POCl_3$.

Show outer shell electrons only.

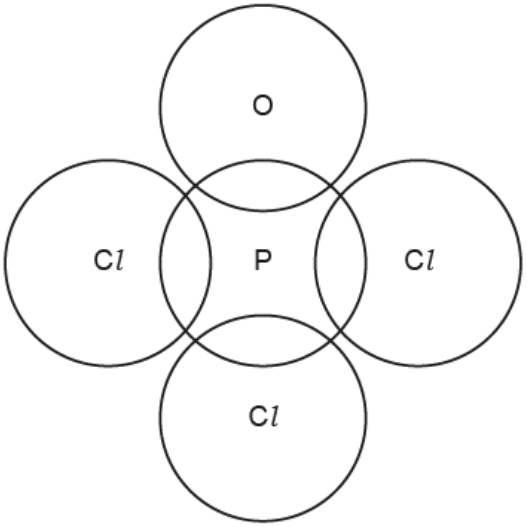


Fig. 1.1

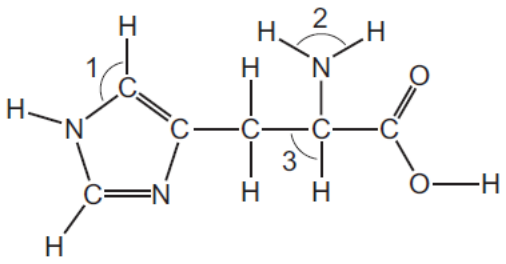
[2]

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6. June/2023/Paper_9701/11/No.7

Histidine is an amino acid.

histidine



What are the approximate bond angles 1, 2, and 3?

	1	2	3
A	109.5°	107°	90°
B	120°	107°	109.5°
C	120°	120°	90°
D	120°	120°	109.5°

7. June/2023/Paper_9701/12/No.6

Which statement about the C*l*–N=O molecule is correct?

A Each molecule contains one σ and two π bonds.

B It is a non-polar molecule.

C It is a linear molecule.

D The nitrogen atom is sp^2 hybridised .

8. June/2023/Paper_9701/12/No.7

Which row is correct?

	molecule	shape	total number of pairs of electrons in the valence shell of the central atom
A	CO_2	linear	two
B	BF_3	trigonal planar	three
C	NH_3	regular tetrahedral	four
D	PF_5	octahedral	six

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9. June/2023/Paper_9701/13/No.4

L and M are elements in Period 3 of the Periodic Table. Neither element is argon.

Information about the Pauling electronegativity values of L and M is given.

element	Pauling electronegativity value
L	the highest of the seven elements Na to Cl
M	the lowest of the seven elements Na to Cl

Three statements about elements L and M are given.

1 Element L contains covalent bonds.

2 Element L has a higher atomic number than element M.

3 A compound of L and M contains ionic bonds.

Which statements are correct?

A 1, 2 and 3 **B** 1 and 2 only **C** 1 and 3 only **D** 2 and 3 only

10. June/2023/Paper_9701/13/No.5

Ammonia reacts with acids to form the ammonium ion.

$$NH_3 + H^+ \rightleftharpoons NH_4^+$$

Which row is correct?

	shape of NH_4^+	bond angle in NH_4^+ / °
A	pyramidal	107
B	pyramidal	109.5
C	tetrahedral	107
D	tetrahedral	109.5

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11. June/2023/Paper_9701/22/No.1

The melting points of some solids are shown in Table 1.1.

Table 1.1

solid	melting point/K
magnesium	923
phosphorus	317
sodium chloride	1074
sulfur	392

(a) (i) State the type of bonding present in magnesium and in sodium chloride.

bonding in magnesium .....

bonding in sodium chloride .....

[1]

(ii) Explain the difference in the melting points of magnesium and sodium chloride.

.....

..... [1]

(iii) Explain the difference in the melting points of phosphorus and sulfur in terms of structure and bonding.

.....

.....

..... [2]

(b) (i) Define electronegativity.

.....

..... [1]

(ii) Explain why electronegativity increases across a period.

.....

.....

..... [2]

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(iii) Name the strongest intermolecular force that exists between $NH_3(l)$ molecules.

..... [1]

(iv) Draw a diagram to show the formation of the strongest intermolecular force between **two** molecules of $NH_3(l)$.

Include any relevant lone pairs of electrons and dipoles.

[2]

(v) The melting points of ice and ammonia are shown in Table 1.2.

Table 1.2

solid	melting point/K
ice	273
ammonia	195

Suggest **two** reasons for the difference in the melting points of ice and ammonia.

.....

.....

..... [2]

[Total: 12]

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12. June/2023/Paper_9701/23/No.2

(a) The reaction of pure aluminium is only observed if the aluminium oxide layer is removed first. When pure aluminium is added to cold water, bubbles of gas are seen.

(i) State **one** property of aluminium oxide that explains why an aluminium object does **not** react with cold water until the aluminium oxide layer is removed.

..... [1]

(ii) Write an equation, with state symbols, for the reaction of aluminium oxide with an excess of NaOH(aq).

..... [2]

(iii) Name **one** other Period 3 element that also produces bubbles of gas when added to cold water.

..... [1]

(b) Aluminium nitrate is a white soluble salt. On heating aluminium nitrate, thermal decomposition occurs and a brown gas is seen.

State the formula of the salt of another element in Period 3 which also decomposes on heating to produce a brown gas.

..... [1]

(c) Aluminium chloride and phosphorus chloride are both white solids.

(i) State the maximum oxidation number of aluminium and of phosphorus in these solid chloride salts.

maximum oxidation number of aluminium .....

maximum oxidation number of phosphorus .....

[1]

(ii) State why the maximum oxidation number of aluminium is different from that of phosphorus.

.....

..... [1]

(iii) Write an equation for the reaction of solid phosphorus chloride and excess water.

..... [1]

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(iv) Name the type of reaction that occurs when aluminium chloride is added to water.

..... [1]

(v) Explain why the solution produced after aluminium chloride is added to water has a pH of 1–2.

.....

..... [1]

[Total: 10]

13. March/2023/Paper_9701/12/No.8

In which species is there a lone pair of electrons?

A CH_3 **B** CH_3^+ **C** CH_3^- **D** CH_4

14. March/2023/Paper_9701/12/No.14

In a sample of pure water, what is the maximum number of hydrogen bonds that one molecule of water can be involved in?

A 1 **B** 2 **C** 3 **D** 4

15. March/2023/Paper_9701/22/No.2(a)

The Group 2 elements Mg to Ba are all silvery-white reactive metals.

(a) (i) Draw a labelled diagram to show the bonding and structure of the Group 2 metals at room temperature.

[2]

(ii) Explain why Mg has a higher electrical conductivity than Na.

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..... [1]

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