

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.



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
-

114. 9701_s20_qp_11 Q: 3

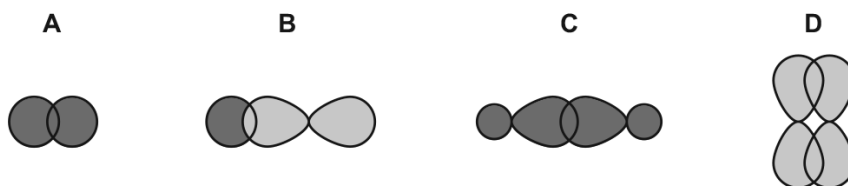
When considering one molecule of ethene, which row describes both the hybridisation of the atomic orbitals in the carbon atoms and the overall bonding?

	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

115. 9701_s19_qp_12 Q: 4

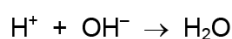
A σ bond is made between two carbon atoms in a molecule of ethene.

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



116. 9701_m18_qp_12 Q: 6

Sodium hydroxide neutralises acid.



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

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.

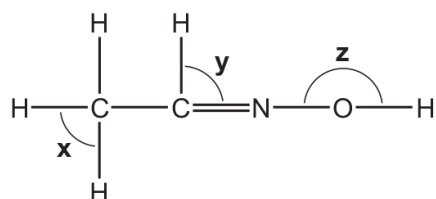
Phosphorus(V) chloride is an ionic solid. One of the ions present is $[\text{PCl}_4]^+$.

What is the shape of the PCl_3 molecule and the $[\text{PCl}_4]^+$ ion?

	PCl_3	$[\text{PCl}_4]^+$
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

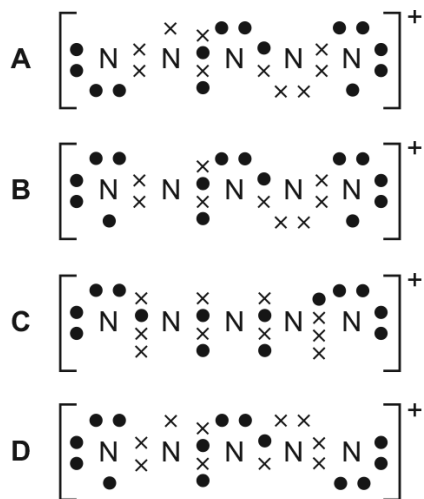
Which molecule does **not** have any 90° or 180° bond angles?

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

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?



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

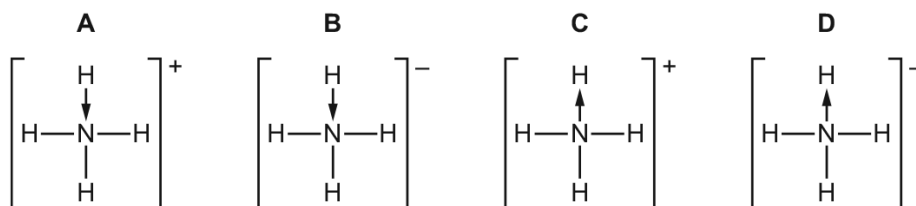
Which mass of solid residue is obtained from the thermal decomposition of 4.10g of anhydrous calcium nitrate?

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

134. 9701_s18_qp_12 Q: 18

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

Which diagram of an ammonium ion is correct?



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), $-(\text{CH}_2\text{CH}_2)_n-$
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** $\text{CH}_4 \rightarrow \text{BF}_3 \rightarrow \text{NH}_3$
- B** $\text{H}_2\text{O} \rightarrow \text{CO}_2 \rightarrow \text{BF}_3$
- C** $\text{NH}_3 \rightarrow \text{CH}_4 \rightarrow \text{CO}_2$
- D** $\text{NH}_3 \rightarrow \text{CH}_4 \rightarrow \text{H}_2\text{O}$

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 $\text{C}=\text{C}=\text{O}$. 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.

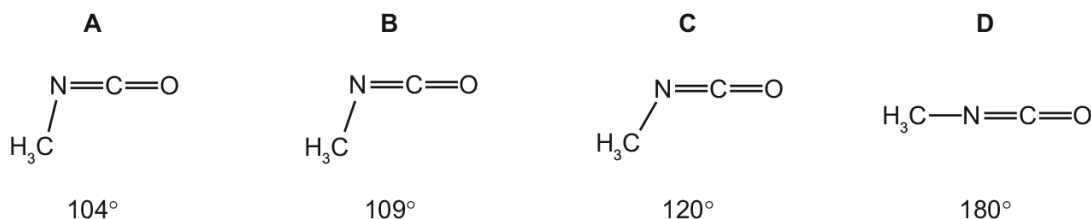
Which species is **not** planar?

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

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?



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 ₃ OH	Al ₂ Cl ₆	CH ₂ Cl ₂
B	Al ₂ Cl ₆	CH ₂ Cl ₂	CH ₄
C	CH ₂ Cl ₂	CH ₄	CH ₃ OH
D	CH ₄	CH ₃ OH	H ₂ O

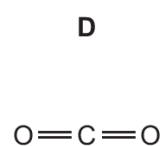
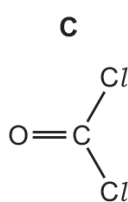
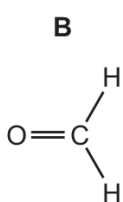
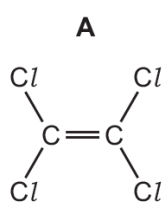
148. 9701_w21_qp_11 Q: 5

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

149. 9701_w21_qp_12 Q: 6

Which molecule has the largest overall dipole?



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 ₂ O	373

Which statement and reason about these hydrides is correct?

- A The boiling point of PH₃ is much lower than the boiling point of H₂O because PH₃ 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 H₂O is higher than the boiling point of HF because each hydrogen bond between the H₂O molecules is stronger than each hydrogen bond between HF molecules.
 - D The boiling points of PH₃ and HCl are similar because the molecules of PH₃ and HCl have the same number of electrons and similar intermolecular forces.
-

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 C₂H₅OH(l) → C₂H₅OH(g)
 - B H₂O(s) → H₂O(l)
 - C O₂(s) → O₂(l)
 - D C₄H₁₀(l) → C₄H₁₀(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
-

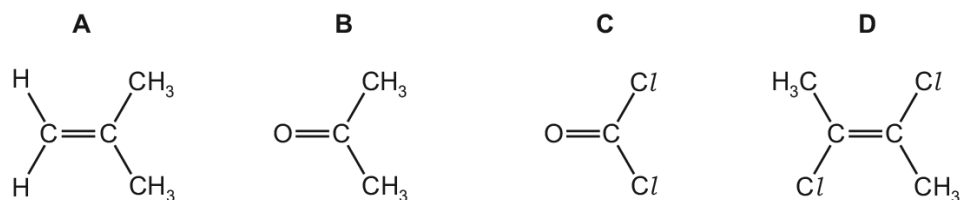
154. 9701_s18_qp_11 Q: 5

Which molecule has no overall dipole?

- A CH_3Cl
 - B CH_2Cl_2
 - C CHCl_3
 - D CCl_4
-

155. 9701_s17_qp_11 Q: 5

Which molecule has the largest overall dipole?



156. 9701_s17_qp_12 Q: 4

Which organic compound has the highest boiling point?

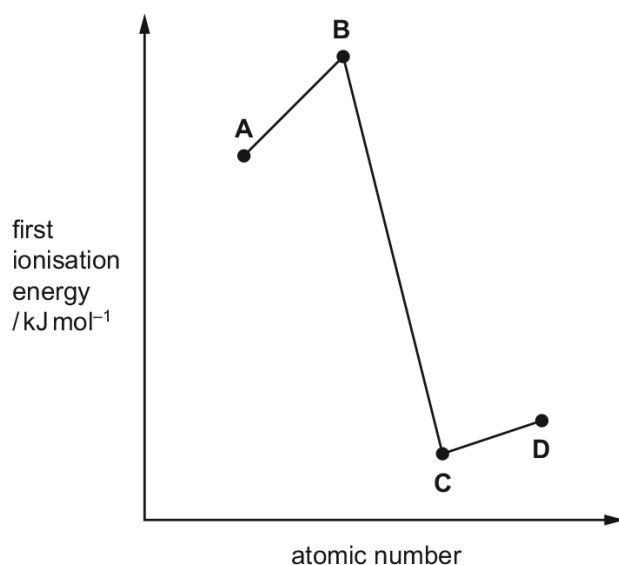
- A $\text{C}(\text{CH}_3)_4$
 - B $\text{CH}_3\text{CH}_2\text{CH}_2\text{CH}_2\text{CH}_3$
 - C $\text{CH}_3\text{COCH}_2\text{CH}_3$
 - D $\text{CH}_3\text{CH}(\text{OH})\text{CH}_2\text{CH}_3$
-

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 $\text{N}\equiv\text{N}$ bond, CO has a $\text{C}=\text{O}$ bond.
 - D The CO molecule has more electrons than the N_2 molecule.
-

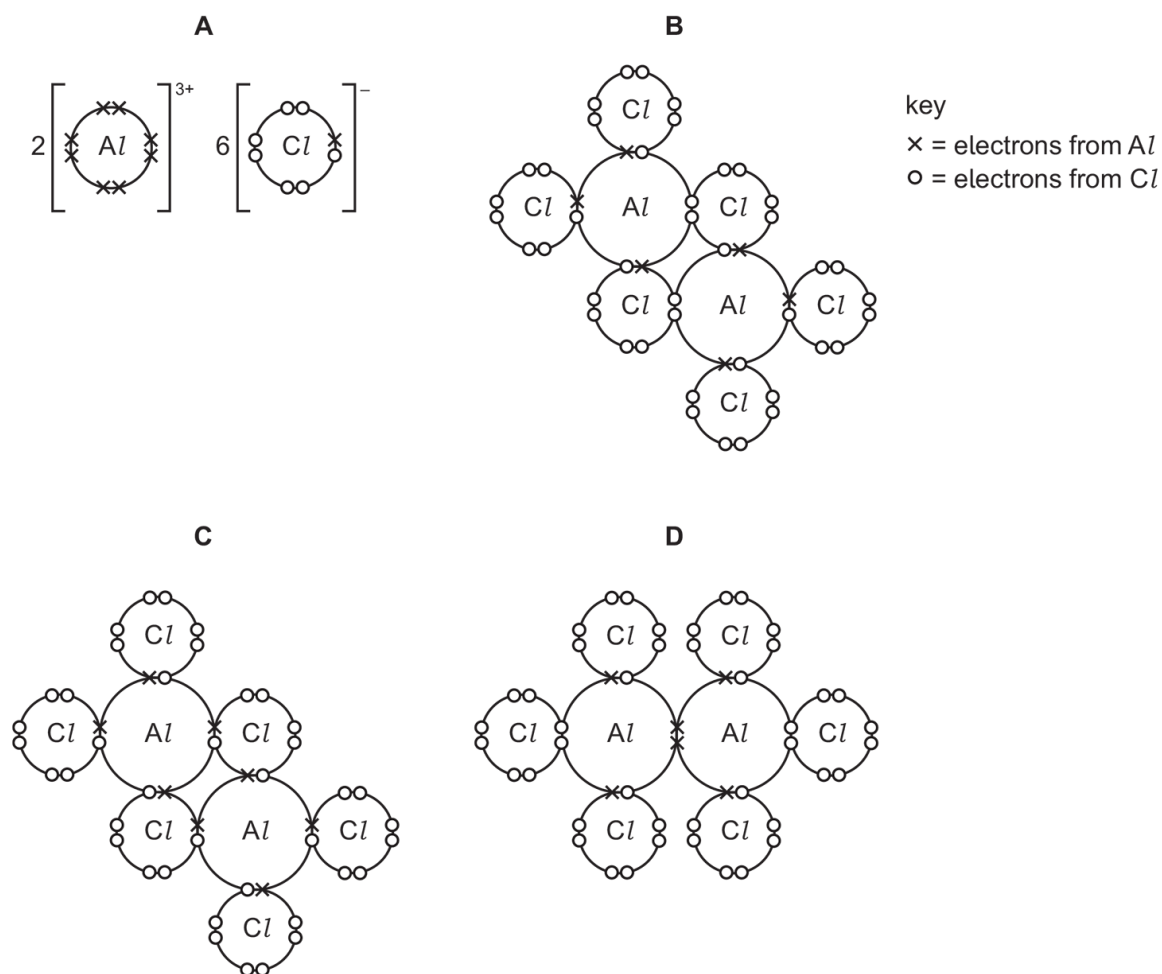
164. 9701_w15_qp_12 Q: 1

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 ?

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
-

Paper 1 Multiple Choice Answers: Chemical Bonding

Question	Paper	Q. No.	Answer
112	9701_w20_qp_11	5	B
113	9701_s21_qp_12	8	A
114	9701_s20_qp_11	3	B
115	9701_s19_qp_12	4	C
116	9701_m18_qp_12	6	D
117	9701_s18_qp_13	4	C
118	9701_s16_qp_11	2	B
119	9701_w16_qp_12	6	A
120	9701_s15_qp_11	10	A
121	9701_s15_qp_12	3	A
122	9701_m22_qp_12	25	D
123	9701_s21_qp_11	3	B
124	9701_s21_qp_13	4	A
125	9701_w21_qp_12	5	B
126	9701_m20_qp_12	3	A
127	9701_m20_qp_12	8	C
128	9701_s20_qp_13	2	A
129	9701_s20_qp_13	9	B
130	9701_m19_qp_12	4	C
131	9701_s19_qp_11	5	C
132	9701_w19_qp_11	3	D
133	9701_m18_qp_12	5	C
134	9701_s18_qp_12	18	C
135	9701_w18_qp_12	4	D
136	9701_w17_qp_11	3	D
137	9701_w17_qp_12	4	C
138	9701_m16_qp_12	6	C
139	9701_m16_qp_12	15	A
140	9701_s16_qp_11	5	C
141	9701_s16_qp_12	5	D
142	9701_s16_qp_13	7	C
143	9701_w16_qp_12	7	D
144	9701_s15_qp_13	4	C
145	9701_m22_qp_12	4	D
146	9701_m21_qp_12	5	C
147	9701_s21_qp_13	5	C
148	9701_w21_qp_11	5	C
149	9701_w21_qp_12	6	B
150	9701_w21_qp_12	7	D
151	9701_w21_qp_13	5	C
152	9701_s20_qp_12	8	C
153	9701_w20_qp_11	4	A
154	9701_s18_qp_11	5	D
155	9701_s17_qp_11	5	B
156	9701_s17_qp_12	4	D
157	9701_w17_qp_11	2	A

Paper 1 Multiple Choice Answers: Chemical Bonding (continued)

Question	Paper	Q. No.	Answer
158	9701_s16_qp_11	7	C
159	9701_s16_qp_13	6	A
160	9701_w16_qp_12	13	A
161	9701_s15_qp_11	2	D
162	9701_s15_qp_13	6	A
163	9701_w15_qp_11	4	A
164	9701_w15_qp_12	1	B
165	9701_m22_qp_12	5	B
166	9701_s21_qp_13	6	B

Chapter 3

Chemical bonding

3.1 Ionic bonding

11. 9701_S15_qp_21 Q: 1

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

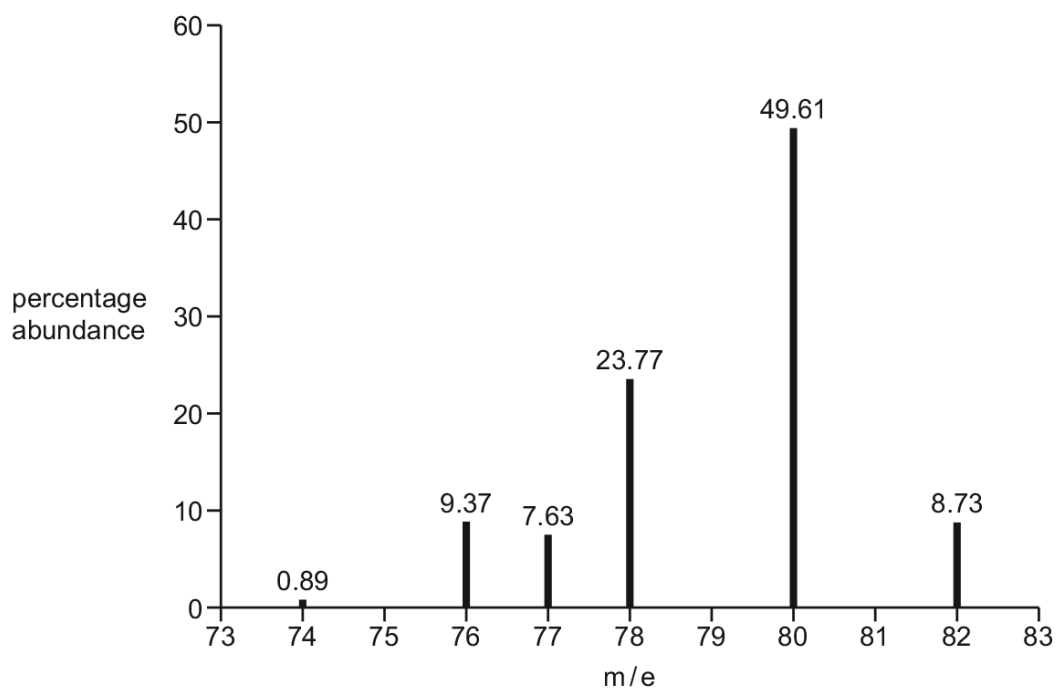
Complete the following table with their names and properties.

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/ $^{\circ}\text{C}$	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 angle	shape 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]

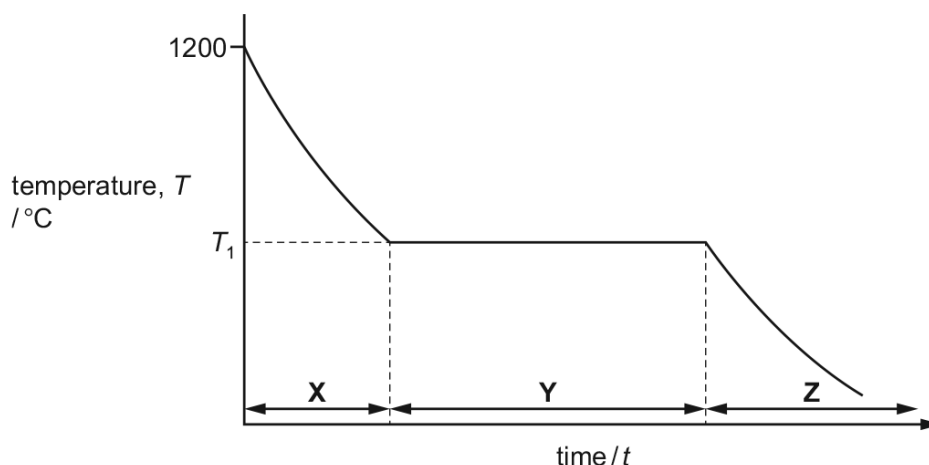
(b) (i) Name the strongest type of intermolecular force in ice.

..... [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.

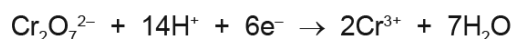
- (a) A 3.35 g piece of the wire was reacted with dilute sulfuric acid, in the absence of air, so that all of the iron atoms were converted to iron(II) ions. The resulting solution was made up to 250 cm³.

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

..... [1]

A 25.0 cm³ sample of this solution was acidified and titrated with 0.0250 mol dm⁻³ potassium dichromate(VI). 32.0 cm³ 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.



- (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 cm³ 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.

1s² [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 cm³.

(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	${}^{37}_{17}\text{Cl}^-$	
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 ₃ OH
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.

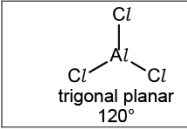
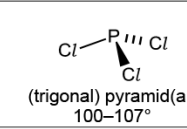
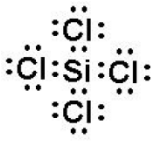
.....
.....
..... [2]

[Total: 17]

11. 9701_S15_ms_21 Q: 1

(a)	sub-atomic particle	relative mass	relative charge	
	neutron	1	0	[1]
	electron	1/1836	-1	[1]
	proton	1	+1	[1]
(b) (i)	RAM = mean/average mass of the isotopes/an atom(s) relative to 1/12 the mass of an atom of ^{12}C /on a scale where an atom of ^{12}C is (exactly) 12 (units)			[1] [1]
	isotope = atoms with the same number of protons/atomic number/proton number with different mass numbers/numbers of neutrons/nucleon number			[1]
(ii)	$\frac{(0.89 \times 74) + (9.37 \times 76) + (7.63 \times 77) + (23.77 \times 78) + (49.61 \times 80) + (8.73 \times 82)}{100}$			[1]
	= 79.04 (2 d.p.) AND Se			[1]
(c) (i)	Te	Cl		
	$\frac{47.4}{128}$	$\frac{52.6}{35.5}$		[1]
	$\frac{0.370}{0.370}$	$\frac{1.48}{0.370}$		
	1	4	so EF = TeCl_4	[1]
	Empirical Formula Mass = 270 so MF = TeCl_4			[1]
(c) (ii)	Covalent AND simple/molecular			[1]
	low melting point/reaction with water			[1]
(iii)	$\text{TeCl}_4 + 3\text{H}_2\text{O} \rightarrow \text{H}_2\text{TeO}_3 + 4\text{HCl}$ OR $\text{TeCl}_4 + 2\text{H}_2\text{O} \rightarrow \text{TeO}_2 + 4\text{HCl}$			[1]
(d) (i)	Yellow/orange flame			[1]
	White fumes/solid			[1]
	Yellow/green gas disappears			[1]
(ii)	NaCl giant/lattice AND ionic			[1]
	SiCl_4 simple/molecular AND covalent			[1]
	For NaCl large difference in electronegativity (of sodium/Na and chlorine/Cl/ Cl_2) (indicates electron transfer/ions)			[1]
	For SiCl_4 smaller difference (indicates sharing/covalency) with (weak) van der Waals'/IM forces (between molecules) ora			[1]

12. 9701_w17_ms_22 Q: 1

(a)	 trigonal planar 120°  (trigonal) pyramid(al) 100–107° 3 marking points for each box: diagram, name and shape. for each box: all three correct = 2 marks two correct = 1 mark	4
(b)(i)	SiCl ₄ simple / molecular AND Van der Waals' / id-id forces / London / dispersion forces / IMFs	1
	NaCl ionic OR giant	1
	bonding (in NaCl) stronger (than forces in SiCl ₄) owtte	1
(b)(ii)	SiCl ₄ has more electrons OR A	1
	stronger Van der Waals' / id-id forces / London / dispersion forces / IMFs	1
(b)(iii)		1

13. 9701_s17_ms_21 Q: 2

(a)	substance	type of bonding	type of lattice structure	1
	copper	metallic	giant/metallic	
	ice	covalent OR hydrogen(-bonding) / H(-bonding)	hydrogen-bonded / simple / molecular	
	silicon(IV) oxide	covalent	giant (molecular) / macromolecular	
	iodine	covalent	simple / molecular	
	sodium chloride	ionic	giant / ionic	
(b)(i)	hydrogen bonding			1
(b)(ii)	H-bond between O and H of different molecules			1
	minimum three partial charges (in a row) over two H ₂ O molecules, i.e.: either $\delta^- \text{O} - \text{H}^{\delta+} \cdots \delta^- \text{O}$ or $\text{H}^{\delta+} \cdots \delta^- \text{O} - \text{H}^{\delta+}$			1
	lone pair of electrons on O of H-bond, in line with H-bond			1
(c)(i)	X = liquid AND Z = solid			1
	Y = liquid and solid OR 'liquid / solid' OR 'liquid OR solid'			1
(c)(ii)	(kinetic) energy reducing			1
	motion slowing <i>owtte</i>			1
(c)(iii)	energy given out / released forming bonds / forming bonds exothermic			1
	compensates for / counteracts heat loss / cooling <i>owtte</i>			1
	Total:			15

14. 9701_s16_ms_23 Q: 1

(a) (i)	$\text{Fe} + \text{H}_2\text{SO}_4 \rightarrow \text{FeSO}_4 + \text{H}_2$	[1]
(ii)	$\text{Cr}_2\text{O}_7^{2-} + 14\text{H}^+ + 6\text{Fe}^{2+} \rightarrow 2\text{Cr}^{3+} + 6\text{Fe}^{3+} + 7\text{H}_2\text{O}$	[1]
(iii)	$(0.025 \times 32.0/1000) = 8 \times 10^{-4}$	[1]
(iv)	$(8 \times 10^{-4} \times 6) = 4.8 \times 10^{-3}$	[1]
(v)	$(4.8 \times 10^{-3} \times 250/25.0) = 4.8 \times 10^{-2}$	[1]
(vi)	$(4.8 \times 10^{-2} \times 55.8) = 2.68/2.678$	[1]
(vii)	$(2.68/3.35) = 80\%$	[1]
(b) (i)	covalent small(er) difference in electronegativity between Fe and Cl (than between Al and Cl)	[1] [1]
(ii)	$\text{FeCl}_3 + 6\text{H}_2\text{O} \rightarrow [\text{Fe}(\text{H}_2\text{O})_6]^{3+} 3\text{Cl}^-$ OR $\text{FeCl}_3 + 6\text{H}_2\text{O} \rightarrow [\text{Fe}(\text{H}_2\text{O})_6\text{OH}]^{2+} + \text{H}^+ + 3\text{Cl}^-$	[1]

15. 9701_S15_ms_23 Q: 1

(a)	$(1s^2)2s^22p^6$	[1]
(b) (i)	The amount of energy required/energy change when one electron is removed from each atom in one mol of gaseous atoms	[1] [1] [1]
(ii)	Greater nuclear charge/number of protons Same shielding/number of shells/energy level	[1] [1]
(c) (i)	mean/average mass of the isotopes/an atom(s) relative to 1/12 of the mass of an atom of ^{12}C /on a scale where an atom of ^{12}C is (exactly) 12	[1] [1]
(ii)	$20.2 = \frac{(20 \times 90.48) + (21 \times 0.27) + (9.25y)}{100}$ $\frac{2020 - 1815.27}{9.25} = 22.133$ $y = 22$	[1] [1]
(d) (i)	$pV = \frac{nRT}{M_r}$ $M_r = \frac{nRT}{pV} = \frac{0.275 \times 8.31 \times 298}{100 \times 10^3 \times 200 \times 10^{-6}}$ $M_r = 34.05/34.1$	[1] [1]
(ii)	(Let % Ne = x so % Ar = 100-x) $\frac{20.2x + 39.9(100 - x)}{100} = 34.05$ % Ne = 29.7	[1]
(e) (i)	Van der Waal's/London/dispersion Uneven electron distribution/temporary dipole Induced dipole-dipole attraction	[1] [1] [1]
(ii)	more electrons more polarisable/greater attraction/stronger IMFs	[1] [1]

16. 9701_w15_ms_22 Q: 1

(a)	name of isotope	type of particle	charge	symbol	electron configuration	[5]
	carbon-13	atom	0	$^{13}_6\text{C}$	$1s^2 2s^2 2p^2$	
	chloride(-37)	anion	1-	Cl^-	$1s^2 2s^2 2p^6 3s^2 3p^6$	
	sulfur-34	atom	0	$^{34}_{16}\text{S}$	$1s^2 2s^2 2p^6 3s^2 3p^4$	
	iron-54	cation	2+	$^{54}_{26}\text{Fe}^{(2+)}$	$1s^2 2s^2 2p^6 3s^2 3p^6 3d^6$	
(b) (i)	ability/tendency/power of an atom/nucleus to attract/pull electron(s)					[1]
	in a covalent bond/shared pair of electrons/bonding pair of electrons					[1]
(ii)	Covalent overlap of orbitals OR shared <u>pair</u> (s) (of electrons)					[1]
	OR metallic positive ions/cations surrounded by delocalised electrons					[1]
(iii)	Ionic/electrovalent (electrostatic) Attraction between oppositely charged/ +ve and -ve <u>ions</u>					[1]
(c) (i)	similar strength/amount/number of intermolecular forces/induced dipole/van der Waals'/VdW/London forces/LDF/dispersion forces					[1]
	therefore similar energy needed					[1]
(ii)	M1 HCl polar/has a dipole AND F_2 non-polar/has no dipole OR (permanent) dipole (-dipole) attractions/forces between HCl (molecules) AND induced dipole (-induced dipole) attractions/forces/LDFs between F_2 (molecules)					[1]
	M2 more energy needed for HCl than F_2 OR pd-pd forces stronger than id-id forces OR IMFs/VdWs in HCl stronger than in F_2					[1]
(iii)	Hydrogen bonding (between methanol molecules)					[1]
	Stronger than IMFs/van der Waals' in other three/is the strongest intermolecular force					[1]

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.

- 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 3400K. Ex

(a) Ethyne is a linear molecule with a triple bond, $C \equiv C$, 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. Lam
U

	C_2H_4	N_2H_4
melting point/ $^{\circ}C$	-169	+2
boiling point/ $^{\circ}C$	-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]

- (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 HCl , a solid compound of formula $\text{N}_2\text{H}_5\text{Cl}$ may be isolated. When an excess of HCl is used, a second solid, $\text{N}_2\text{H}_6\text{Cl}_2$, is formed.

- (i) Suggest what type of reaction occurs between hydrazine and HCl .

.....

- (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 HCl .

.....

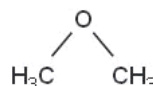
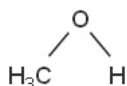
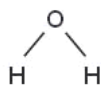
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[3]

[Total: 16]

Q5.

- 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 $\text{CH}_3\text{CH}_2\text{OH}$

methoxymethane CH_3OCH_3

2-methylpropane $(\text{CH}_3)_2\text{CHCH}_3$

[4]

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

- (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, $\text{C}_2\text{H}_5\text{OC}_2\text{H}_5$, 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]

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]

F
Exam
U

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.

- Explain these observations.**

..... [2]

- Suggest why N_2 has a lower boiling point than CO .

..... [2]

-
- $$\text{:C} \equiv \text{O:}$$

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]

- (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 / kJ mol^{-1}
$\text{C}\equiv\text{N}$ in HCN	890
$\text{N}=\text{N}$	994
$\text{C}=\text{O}$	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.

- (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.

(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.

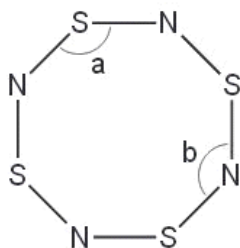
(ii) Suggest a value for the O–C–S bond angle.

.....

[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.

- 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.

ε

(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.

- 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:



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

[1]

Q15.

- 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.

Ex#

- (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

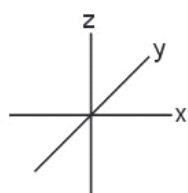
bond angle

[2]

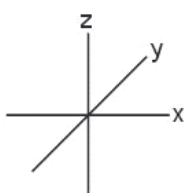
Q17.

1 This question is about the bonding of covalent compounds.

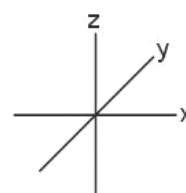
(a) On the axes below, sketch the shapes of a 1s, a 2s, and a $2p_x$ orbital.



1s



2s



$2p_x$

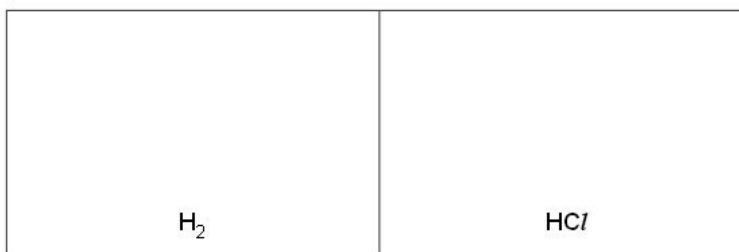
[3]

(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 HCl molecules.



[4]

(c) The bond in the HCl molecule is said to be 'polar'.

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

.....

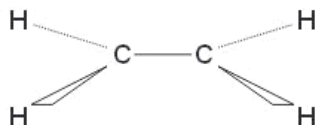
(ii) Explain why the HCl molecule is polar.

.....
.....

[2]

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

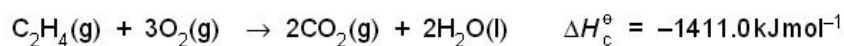
Each carbon atom in ethene forms three σ bonds as shown below.



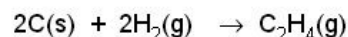
On the diagram, sketch the π bond that is also present in ethene.

[1]

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



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



$$\Delta H_f^\ominus = \dots\dots\dots \text{ kJ mol}^{-1}$$

[3]

[Total: 13]

Q18.

- (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.

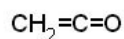
- (iii) Draw a displayed formula of the form of aluminium chloride that exists at the lower temperature. Indicate clearly the different types of bonds present.

[5]

Q19.

- 2 Ketene, $\text{C}_2\text{H}_2\text{O}$, is a member of a class of unsaturated organic compounds that is widely used in pharmaceutical research for the synthesis of organic compounds.

For
Examin
Use



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]

(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]

- (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]

f
Ex am
l

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.

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.

- 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 TeF₆ is formed.

(i) Draw a 'dot-and-cross' diagram of the TeF₆ molecule, showing outer electrons only.

(ii) What will be the shape of the TeF₆ molecule?

.....

(iii) What is the F–Te–F bond angle in TeF₆?

.....

[3]

[Total: 6]

Q23.

- 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]

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

F
Exam
U

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.

.....

.....

.....

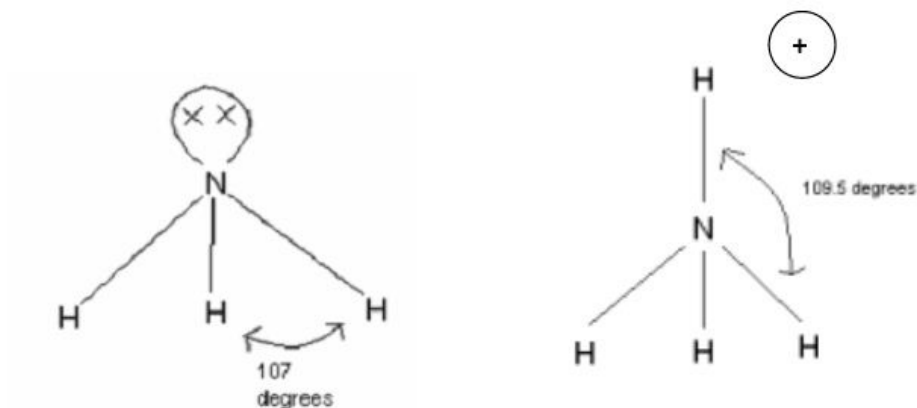
.....

..... [3]

[Total: 10]

Q1.

(d)

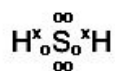


1 mark for each diagram, 1 mark for each correct bond angle
If not 3-dimensional diagram – 1 penalty.

[4]

Q2.

(c) (i)



(1)

(ii) non-linear/bent/V-shaped

(1)

(iii) H_2O has hydrogen bonds/ H_2S does not or
 H_2S has van der Waals' forces only

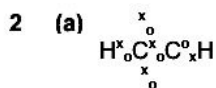
(1)

hydrogen bonds are stronger
than van der Waals' forces or
 H_2S has weaker intermolecular bonds
than H_2O

(1)

[4]

Q3.



(1)

[1]

Q4.

1 (a) (i) between 117° and 120° [1]

(ii)



14 electrons must be shown

single N-N bond

lone pair on each N atom

[1]

[1]

(iii) between 107° and 109°

[1] [4]

(b) ethene – van der Waals' forces

[1]

hydrazine – hydrogen bonds

[1]

hydrogen bonds are stronger

or van der Waals' forces are weaker

[1] [3]

(c) correct dipole on O—H and N—H bonds

[1]

labelled hydrogen bond shown

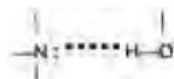
between an O atom of H_2O and a H atom of N_2H_4

or between an N atom of N_2H_4 and a H atom of H_2O

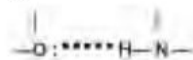
[1]

lone pair on O atom or on N atom *in the H bond*

i.e.



or



[1] [3]

(e) (i) acid – base/neutralization

[1]

(ii) N atom has a lone pair of electrons

or N atom can behave as a base

or N atom can form dative bond

[1]

(iii) each N atom has a lone pair

or each nitrogen atom can behave as a base

or each nitrogen atom can form a dative bond

[1] [3]

Q5.

1 (a) (i) 2 (1)

(ii) between 104° and 105° (1)

[2]

(b) ethanal CH_3CHO A (1)

ethanol $\text{CH}_3\text{CH}_2\text{OH}$ C (1)

methoxymethane CH_3OCH_3 A (1)

2-methylpropane $(\text{CH}_3)_2\text{CHCH}_3$ B (1)

[4]

(c) (i) hydrogen bonds (1)

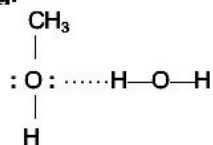
(c) (i) hydrogen bonds (1)

(ii) correct dipole on an -O-H bond (1)

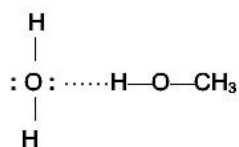
hydrogen bond shown between the lone pair
of an O and a H atom in an -OH group (1)

lone pair on O atom of CH_3OH or H_2O
clearly shown in the hydrogen bond (1)

e.g.



or



[4]

(d) hydrogen bonds exist between H_2O molecules (1)

hydrogen bonds cannot form
between $\text{C}_2\text{H}_5\text{OC}_2\text{H}_5$ molecules (1)

[2]

[Total: 12]

Q6.

- 1 (a) Al $1s^2 2s^2 2p^6 3s^2 3p^1$ (1)
- Ti $1s^2 2s^2 2p^6 3s^2 3p^6 3d^2 4s^2$ or (1)
- $1s^2 2s^2 2p^6 3s^2 3p^6 4s^2 3d^2$ penalise any error (1) [2]
- (b) (i) pass chlorine gas (1)
over heated aluminium (1)
- (ii) aluminium glows (1)
white/yellow solid formed (1)
chlorine colour disappears/fades (1) (any 2)
- (iii)
- ```

 x x
 x Cl x
 x x
 x x x • x x
 x Cl • Al x Cl x
 x x x x
 x • x • x x
 x Cl x Al x Cl x
 x x x x
 x • x x
 x Cl x
 x x

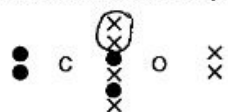
```
- correct numbers of electrons, i.e.
- 3 • per Al atom and 7x per Cl atom
- i.e. 6 • and 42 x in total (1)
- dative bond Cl to Al clearly shown by x (1) [6]
- (c) chlorine is a strong/powerful oxidising agent (1) [1]

- (d) (i)  $n(\text{Ti}) = \frac{0.72}{47.9} = 0.015$  (1)
- (ii)  $n(\text{Cl}) = \frac{(2.85 - 0.72)}{35.5} = 0.06$  (1)
- (iii)  $0.015 : 0.06 = 1:4$   
 empirical formula of **A** is  $\text{TiCl}_4$   
 Allow ecf on answers to (i) and/or (ii). (1)
- (iv)  $\text{Ti} + 2\text{Cl}_2 \rightarrow \text{TiCl}_4$  (1)  
 Allow ecf on answers to (iii). [4]
- (e) covalent/not ionic (1)  
 simple molecular **or**  
 mention of weak intermolecular forces **or**  
 weak van der Waals's forces between molecules (1) [2]
- [Total: 14 max]**

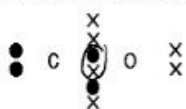
## Q7.

- 1 (a) fewer electrons in  $\text{Cl}_2$  than in  $\text{Br}_2$  (1)  
 smaller van der Waals' forces in  $\text{Cl}_2$  **or** stronger van der Waals' forces in  $\text{Br}_2$  (1) [2]
- (b) CO has a permanent dipole **or**  $\text{N}_2$  does not (1)  
 permanent dipole-permanent dipole interactions are stronger than those from induced dipoles (1) [2]

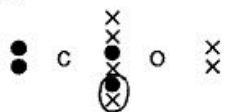
(c) (i) a co-ordinate bond (1)



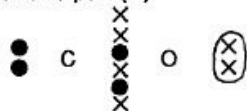
(ii) a covalent bond (1)



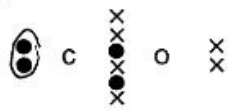
or



(iii) a lone pair (1)



or



penalise any groups of 3 or 4 electrons that are circled

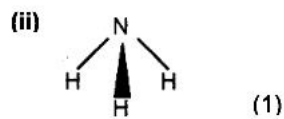
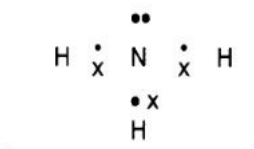
[3]

(d) CO and HCN both have a dipole or N<sub>2</sub> does not have a dipole (1)

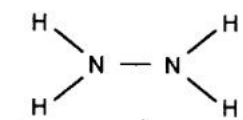
[1]

Q8.

(c) (i) 'dot-and-cross' diagram (1)



(iii) minimum is



allow bond angle around N atom between  $109^\circ$  and  $104^\circ$  (1)

[4]

(d)  $-2$  (1)

[1]

Q9.

(f) (i) both have very similar/same van der Waals' forces

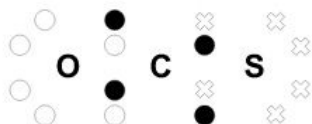
(1)

(ii)  $\text{CH}_3\text{F}$  has permanent dipole

(1) [2]

Q10.

(f) (i)



(1)

(ii)  $180^\circ$

(1) [2]

Q11.

(c) (i) around the N atom there is only one lone pair  
around the S atom there are two lone pairs

both (1)

(ii) angle (a) or sulfur – **no mark for this**

**because** two lone pairs repel more than one lone pair or  
lone pair-lone pair repulsions are stronger  
than lone pair-bond pair repulsions

(1) [2]

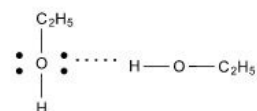
Q12.

(d) (i) hydrogen bonds (1)

(ii) lone pair on O atom of C<sub>2</sub>H<sub>5</sub>OH (1)

correct dipole O<sup>δ-</sup>—H<sup>δ+</sup> on bond in one molecule of ethanol (1)

hydrogen bond shown between lone pair of an O atom and a hydrogen atom, i.e.



(1) [4]

Q13.

1 (a) (i)

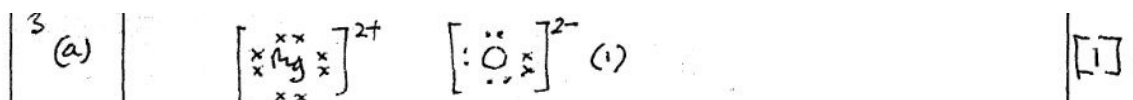


S atom has 6 **and** C atom has 4 electrons (1)

S=C double bonds (4 electrons) clearly shown (1)

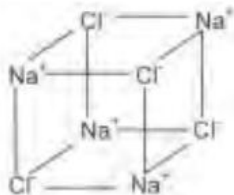
(ii) linear **and** 180° (1) [3]

Q14.



Q15.

- 1 (a) ionic<sup>-</sup> (1)
- $\text{Na}^+$  and  $\text{Cl}^-$  (1)
- arranged in cubic lattice (diagram required)



(1)

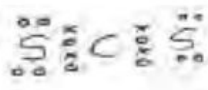
each  $\text{Na}^+$  ion surrounded by six  $\text{Cl}^-$  ions  
or each  $\text{Cl}^-$  ion surrounded by six  $\text{Na}^+$  ions  
may be in diagram or stated in words

(1) [4]

- (b) in the solid, the ions cannot move (1)
- in the melt, the ions move  
or carry the charge/current (1) [2]

## Q16.

(a)



sulphur atom has 6 /carbon atom has 4 electrons (1)

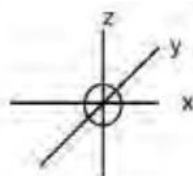
$\text{S}=\text{C}$  double bonds (4 electrons) clearly shown (1) [2]

- (b) linear (1)

$180^\circ$  (1) [2]

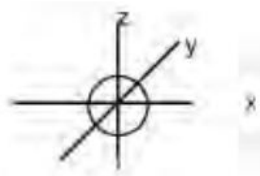
## Q17.

1 (a)



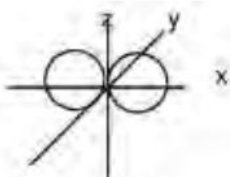
1s

spherical (1)



2s

larger spherical (1)



2p<sub>x</sub>

double lobes along the x-axis (1)

[3]

(b) (i) attraction between bonding electrons and nuclei (1)

attraction is electrostatic (1)

(ii) H<sub>2</sub> s-s **overlap** clearly shown

must **not** be normal dot/cross diagram (1)

HCl s-p **overlap** clearly shown

overlap must involve s and p orbitals (1)

[4]

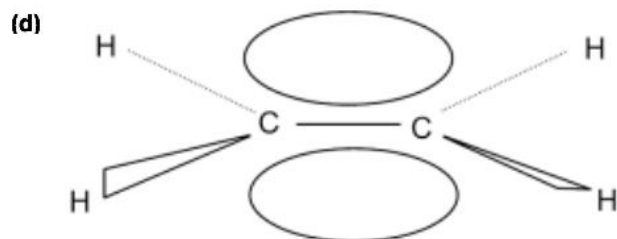
(c) (i) bonding electrons are unequally shared **or**

the molecule has a dipole/δ+ and δ- ends to molecule (1)

(ii) the H and Cl atoms have different electronegativities

**or** chlorine is more electronegative than hydrogen (1)

[2]



**allow** two 'sausages' above **and** below the C-C axis

**or** two p orbitals **overlapping** sideways  
to form one (localised)  $\pi$  bond over two carbon atoms

(1) [1]

(e)  $\Delta H_f^\circ = 2(-393.7) + 2(-285.9) - (-1411)$

$= + 51.8 \text{ kJ mol}^{-1}$  (units given in qu.)

(3)

penalise errors: no 2 for  $-393.7$   
no 2 for  $-285.9$   
wrong sign for  $-(-1411)$

[3]

**[Total: 13]**

## Q18.

(b) (i) giant ionic lattice (may be in diag.)

(1)

strong ionic bonds

(1)

(ii) simple molecular **or** discrete molecules

(may be shown in a diagram)

(1)

with weak intermolecular forces **or**

weak van der Waals' forces

between them

(1)

[4]

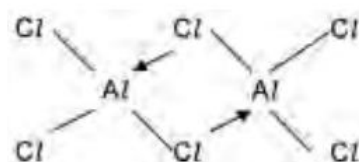
(e) (i) 460 K  $Al_2Cl_6$  (1)

1150 K  $AlCl_3$  (1)

(ii) correct **dot-and-cross** diagram for  $AlCl_3$  (1)

(iii) correct displayed structure for  $Al_2Cl_6$  (1)

two correct co-ordinate bonds (1)



[5]

### Q19.

2 (a) (i) H-C-H 117 to 120° (1)  
C=C=O 180° (1)

(ii) molecule contains **both** ketone **and** alkene (1)

[3]

(b) (i)  $C_2H_2O + 2O_2 \rightarrow 2CO_2 + H_2O$  (1)

(ii) from eqn.,  $42 \text{ g } C_2H_2O \rightarrow 48 \text{ dm}^3 \text{ of } CO_2$  (1)  
whence  $3.5 \text{ g } C_2H_2O \rightarrow \frac{48 \times 3.5}{42} \text{ dm}^3 \text{ of } CO_2$  (1)  
 $= 4.0 \text{ dm}^3 \text{ of } CO_2$  (1)

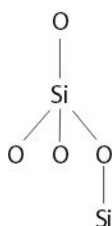
or  $n(C_2H_2O) = \frac{42}{3.5} = 0.0833$  (1)  
 $n(CO_2) = 2 \times 0.083 = 0.0166$  (1)  
vol. of  $CO_2 = 0.0166 \times 24 = 4.0 \text{ dm}^3$  (1)  
allow e.c.f. on wrong eqn. in (b)(i)  
penalise significant figure error

[4]

### Q20.

- 1 (a) CO<sub>2</sub> is simple molecular/simple covalent/has discrete molecules (1)  
 CO<sub>2</sub> has induced dipole – induced dipole interactions/ (1)  
 van der Waals' forces/weak intermolecular forces (1)  
 SiO<sub>2</sub> is giant molecular/giant covalent/macromolecular (1)  
 SiO<sub>2</sub> has strong covalent bonds (1) [any 3]

- (b) minimum is 4-valent Si-O (1)  
 and at least one Si-O-Si (1)  
 i.e.



[2]

- (c) (i) for an ideal gas, **any four** from the following (1)  
 the molecules behave as rigid spheres (1)  
 there are no/negligible intermolecular forces (1)  
 between the molecules (1)  
 collisions between the molecules are perfectly elastic (1)  
 the molecules have no/negligible volume (1)  
 the molecules move in random motion (1)  
 the molecules move in straight lines (1)  
 the kinetic energy of the molecules is (1)  
 directly proportional to the temperature (1)  
 the pressure exerted by the gas is due to the collisions (1)  
 between the gas molecules and the walls of the container (1)  
**not** an ideal gas obeys  $pV = nRT$  (1)  
 (max 4)
- (ii) there are intermolecular forces between CO<sub>2</sub> molecules/ (1)  
 CO<sub>2</sub> molecules have volume [5]
- (d) graphite has delocalised electrons (1) [1]
- (e) (i) SiO<sub>2</sub> + 2C → SiC + CO<sub>2</sub> **or** (1)  
 SiO<sub>2</sub> + 3C → SiC + 2CO (1)
- (ii) diamond **because** SiC is hard (1) [2]

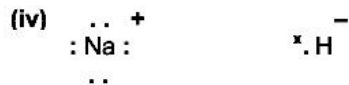
[Total: 13]

Q21.

(b) (i) giant lattice (may be in diagram) (1)  
with strong ionic bonding (1)

(ii) ionic (1)

(iii) -1 (1)



correct numbers of electrons (1)

correct charges (1)

(v)

| compound                                   | MgH <sub>2</sub> | AlH <sub>3</sub> | PH <sub>3</sub> | H <sub>2</sub> S |
|--------------------------------------------|------------------|------------------|-----------------|------------------|
| oxidation number of element in the hydride | +2               | +3               | -3              | -2               |

correct oxidation nos. for MgH<sub>2</sub> and AlH<sub>3</sub> (1)

correct oxidation nos. for PH<sub>3</sub> and H<sub>2</sub>S (1)

[8]

Q22.

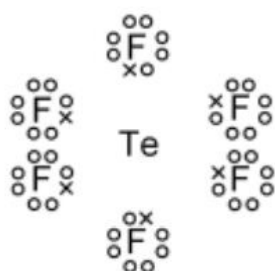
1 (a)

| number of bond pairs | number of lone pairs | shape of molecule               | formula of a molecule with this shape             |
|----------------------|----------------------|---------------------------------|---------------------------------------------------|
| 3                    | 0                    | trigonal planar                 | BH <sub>3</sub>                                   |
| 4                    | 0                    | tetrahedral                     | CH <sub>4</sub><br>allow other Group IV hydrides  |
| 3                    | 1                    | pyramidal or trigonal pyramidal | NH <sub>3</sub><br>allow other Group V hydrides   |
| 2                    | 2                    | non-linear or bent or V-shaped  | H <sub>2</sub> O<br>allow other Group VI hydrides |

1 mark for each correct row

(3 × 1) [3]

(b) (i)



(1)

(ii) octahedral **or** square-based bipyramid

(1)

(iii)  $90^\circ$

(1) [3]

**[Total: 6]**

Q23.

1 (a)

| NH <sub>3</sub> | CH <sub>4</sub> |
|-----------------|-----------------|
|                 |                 |
| pyramidal       | tetrahedral     |

**both** 'dot-and-cross' diagrams correct  
 NH<sub>3</sub> is pyramidal **or** trigonal pyramidal  
 CH<sub>4</sub> is tetrahedral

(1)

(1)

(1) [3]

(b) (i) nitrogen and hydrogen have different electronegativities

(1)

N—H bond has a dipole **or**

$N^{\delta-}-H^{\delta+}$  **or**

bonding pair is unequally shared

(1)

(ii) molecule is not symmetrical **or**

dipoles do not cancel out

(1)

- (iii)  $\text{NH}_3$  has higher boiling point than expected from  $M_r$  value **or**  
has higher boiling point than methane  
**or**  $\text{NH}_3$  is soluble in water

(1) [4]

- (c) three covalent N–H bonds  
one co-ordinate (dative covalent) N–H bond  
one ionic bond between  $\text{NH}_4^+$  and  $\text{Cl}^-$

(1)

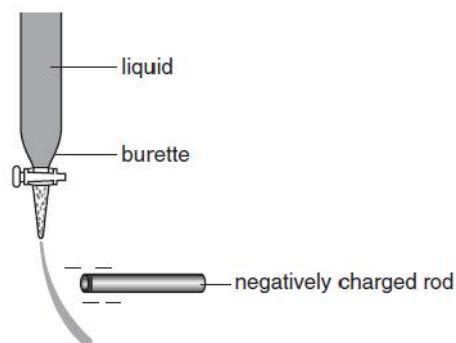
(1)

(1) [3]

**[Total: 10]**

1.

A slow stream of water from a tap can be deflected by an electrostatically charged plastic rod 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  $\text{H}_2\text{O}$      $\text{NH}_3$      $\text{CH}_4$
- 2  $\text{H}_2\text{O}$      $\text{SF}_6$      $\text{BF}_3$
- 3  $\text{CH}_4$      $\text{CO}_2$      $\text{SF}_6$

[2002 M/J (32)]

3.

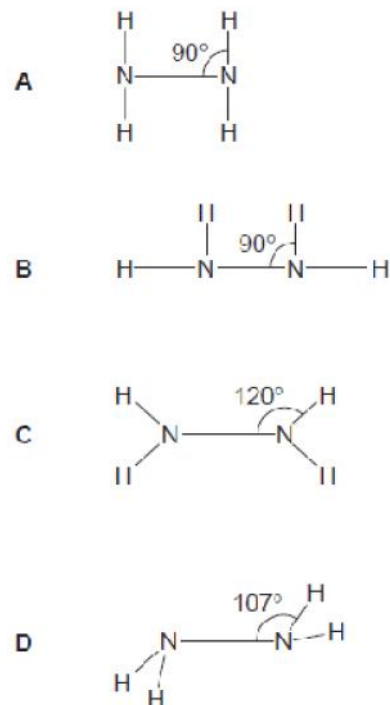
Which of the following molecules has **no** permanent dipole?

- A  $\text{CCl}_2\text{F}_2$     B  $\text{CHCl}_3$     C  $\text{C}_2\text{Cl}_4$     D  $\text{C}_2\text{H}_5\text{Cl}$

[2002 O/N (5)]

4.

Which is the most likely shape of a molecule of hydrazine,  $\text{N}_2\text{H}_4$ ?



[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)]

6. Silicon tetrachloride,  $\text{SiCl}_4$ , 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  $\text{SiCl}_4(\text{l})$ ?

- 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  $\text{C}_2\text{H}_4$       B  $\text{C}_2\text{F}_6$       C  $\text{H}_2\text{O}$       D  $\text{NF}_3$

[2003 O/N (6)]

8. Chemists have been interested in the properties of hydrogen selenide,  $\text{H}_2\text{Se}$ , to compare it with 'bad egg' gas hydrogen sulphide,  $\text{H}_2\text{S}$ .

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

|   | number of lone pairs on Se atom | bond angle  |
|---|---------------------------------|-------------|
| A | 1                               | $104^\circ$ |
| B | 2                               | $104^\circ$ |
| C | 2                               | $109^\circ$ |
| D | 2                               | $180^\circ$ |

[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  $\text{Al}^{3+}$
- B  $\text{Ba}^{2+}$
- C  $\text{Mg}^{2+}$
- D  $\text{Na}^+$

[2004 M/J (14)]

12.  
Which molecule is planar?

- A  $\text{NF}_3$
- B  $\text{C}_2\text{Cl}_4$
- C  $\text{C}_3\text{H}_6$
- D  $\text{C}_3\text{H}_8$

[2004 M/J (20)]

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

- 1  $\text{Al}_2\text{O}_3$  and  $\text{Al}_2\text{Cl}_6$
- 2  $\text{SiO}_2$  and  $\text{SiCl}_4$
- 3  $\text{P}_4\text{O}_{10}$  and  $\text{PCl}_3$

[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  $\text{PH}_3$  molecule likely to be?

- A  $90^\circ$
- B  $104^\circ$
- C  $109^\circ$
- D  $120^\circ$

[2004 O/N (7)]

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

- 1  $\text{AlCl}_3$
- 2  $\text{CH}_3^+$
- 3  $\text{PH}_3$

[2005 M/J (31)]

17.  
Which molecules are planar?

- 1  $\text{BCl}_3$
- 2  $\text{NH}_3$
- 3  $\text{PH}_3$

[2005 O/N (32)]

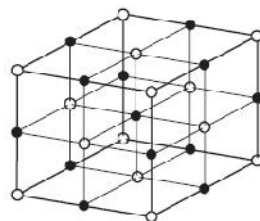
18.  
In which process are hydrogen bonds broken?

- A  $\text{H}_2(\text{l}) \rightarrow \text{H}_2(\text{g})$
- B  $\text{NH}_3(\text{l}) \rightarrow \text{NH}_3(\text{g})$
- C  $2\text{HI}(\text{g}) \rightarrow \text{H}_2(\text{g}) + \text{I}_2(\text{g})$
- D  $\text{CH}_4(\text{g}) \rightarrow \text{C}(\text{g}) + 4\text{H}(\text{g})$

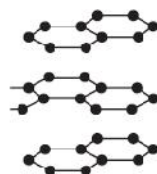
[2006 M/J (5)]

19.

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



**X**



**Y**

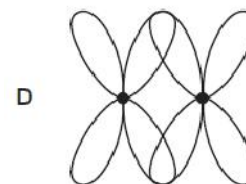
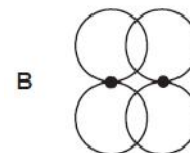
What are the types of bonding present in **X** and **Y**?

|          | <b>X</b> | <b>Y</b> |
|----------|----------|----------|
| <b>A</b> | covalent | metallic |
| <b>B</b> | ionic    | covalent |
| <b>C</b> | ionic    | metallic |
| <b>D</b> | metallic | ionic    |

[2006 M/J (7)]

20.

Which diagram describes the formation of a  $\pi$  bond from the overlap of its orbitals?



[2006 O/N (5)]

21.

The  $\text{CN}^-$  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 |
|----------|----------------------------|---------------------------|-----------------------------|
| <b>A</b> | 2                          | 1                         | 1                           |
| <b>B</b> | 2                          | 2                         | 1                           |
| <b>C</b> | 3                          | 1                         | 1                           |
| <b>D</b> | 3                          | 1                         | 2                           |

[2007 M/J (5)]

22.

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

- A  $\text{NaCl}$       B  $\text{MgCl}_2$       C  $\text{AlCl}_3$       D  $\text{SiCl}_4$

[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.

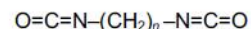
Which ion does **not** have a noble gas electronic structure?

- A I      B  $\text{Rb}^+$       C  $\text{Sn}^{2+}$       D  $\text{Sr}^{2+}$

[2007 O/N (2)]

25.

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



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

- A  $90^\circ$       B  $109^\circ$       C  $120^\circ$       D  $180^\circ$

[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,  $\text{BaO}_2$ , is formed.

Which dot-and-cross diagram represents the electronic structure of the peroxide anion in  $\text{BaO}_2$ ?

key

- electron from first oxygen atom
- × electron from second oxygen atom
- electron from barium atom

A

B

C

D

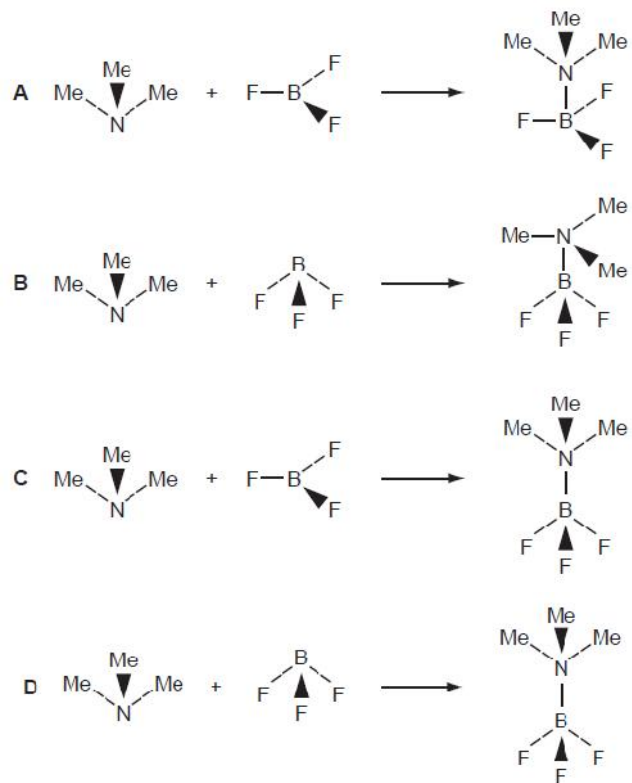
[2008 M/J (4)]

28.

In this question, the methyl group, CH<sub>3</sub>, is represented by Me.

Trimethylamine, Me<sub>3</sub>N, reacts with boron trifluoride, BF<sub>3</sub>, to form a compound of formula Me<sub>3</sub>N.BF<sub>3</sub>.

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



[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.

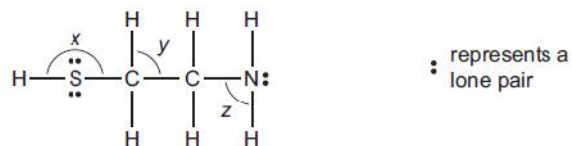
Which pair of statements correctly describes this process?

|   | type of bond broken     | formula of purple species |
|---|-------------------------|---------------------------|
| A | covalent                | I                         |
| B | covalent                | I <sub>2</sub>            |
| C | induced dipole-dipole   | I <sub>2</sub>            |
| D | permanent dipole-dipole | I <sub>2</sub>            |

[2009 M/J (7)]

32.

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



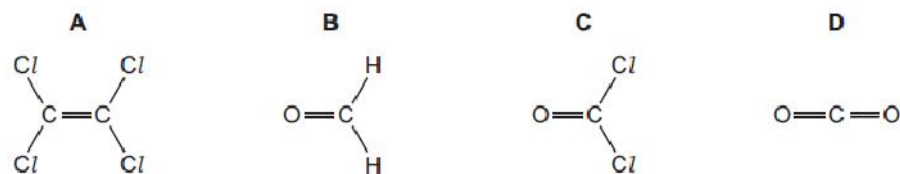
What is the order of **decreasing** size of the bond angles x, y and z?

|          | largest | → | smallest |
|----------|---------|---|----------|
| <b>A</b> | x       | y | z        |
| <b>B</b> | x       | z | y        |
| <b>C</b> | y       | z | x        |
| <b>D</b> | z       | y | x        |

[2009 O/N-11 (4)]

33.

Which molecule has the largest overall dipole?



[2009 O/N-11 (5)]

34.

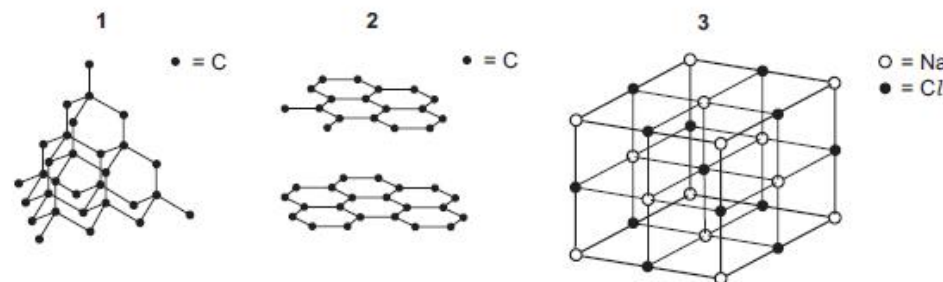
Which physical properties are due to hydrogen bonding between water molecules?

- 1 Water has a higher boiling point than  $\text{H}_2\text{S}$ .
- 2 Ice floats on water.
- 3 The H-O-H bond angle in water is approximately  $104^\circ$ .

[2009 O/N-11 (32)]

35.

Which diagrams represent part of a giant molecular structure?

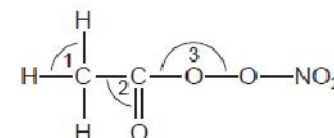


[2010 M/J-11 (31)]

36.

Organic nitrates in photochemical smog can cause breathing difficulties.

The diagram shows an example of an organic nitrate molecule.



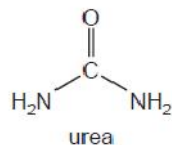
What is the correct order of the bond angles shown in ascending order (smallest first)?

- A**  $1 \rightarrow 2 \rightarrow 3$  **B**  $2 \rightarrow 1 \rightarrow 3$  **C**  $3 \rightarrow 1 \rightarrow 2$  **D**  $3 \rightarrow 2 \rightarrow 1$

[2010 O/N-11 (7)]

37.

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



- 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

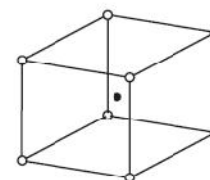
[2010 O/N-12 (1)]

39.

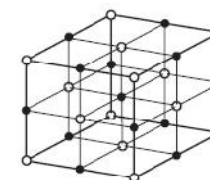
The table gives the radii, in pm, of some ions. [ $1\text{ pm} = 10^{-12}\text{ m}$ ]

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

Caesium chloride,  $\text{CsCl}$ , has a different lattice structure from both sodium chloride,  $\text{NaCl}$ , and magnesium oxide,  $\text{MgO}$ .



$\text{CsCl}$  lattice



$\text{NaCl}$  and  $\text{MgO}$  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)]

41.

Which molecule or structure does **not** contain three atoms bonded at an angle between  $109^\circ$  and  $110^\circ$ ?

- 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  $\pi$  bond and two  $\sigma$  bonds.
- 2 The electron density in a  $\sigma$  bond is highest along the axis between the two bonded atoms.
- 3 A  $\pi$  bond restricts rotation about the  $\sigma$  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  $109.5^\circ$ .
- 3 It has only three bonding pairs of electrons.

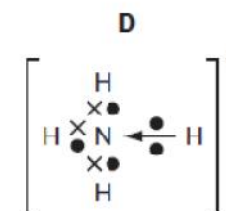
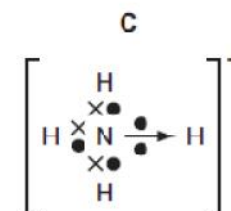
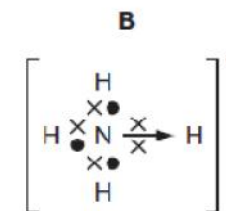
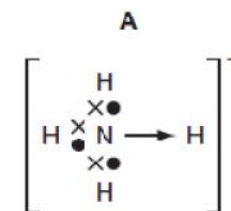
[2011 M/J-11 (37)]

45.

Which diagram correctly shows the bonding in the ammonium ion,  $\text{NH}_4^+$ ?

key

- N electron
- × H electron



[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  $\text{C}_2\text{H}_5\text{OH(l)} \rightarrow \text{C}_2\text{H}_5\text{OH(g)}$
- B melting of ice  $\text{H}_2\text{O(s)} \rightarrow \text{H}_2\text{O(l)}$
- C melting of solid carbon dioxide  $\text{CO}_2\text{(s)} \rightarrow \text{CO}_2\text{(l)}$
- D solidification of butane  $\text{C}_4\text{H}_{10\text{(l)}} \rightarrow \text{C}_4\text{H}_{10\text{(s)}}$

[2011 M/J-13 (10)]

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  $180^\circ\text{C}$ ?

- 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  $0^\circ\text{C}$  ice floats on water.
- 2 The boiling point of propan-2-ol is  $82^\circ\text{C}$ . The boiling point of propanone is  $56^\circ\text{C}$ .
- 3 At  $20^\circ\text{C}$  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  $BF_3$ .

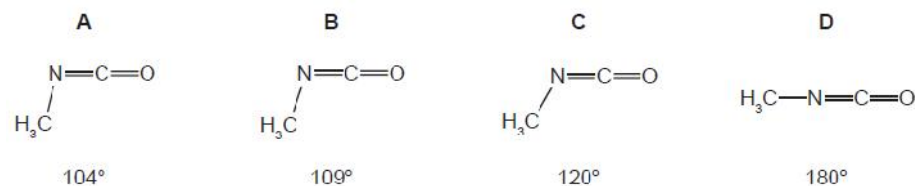
[2011 O/N-12 (31)]

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  $H_3C-N=C=O$ .

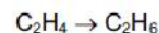
What is the approximate angle between the bonds formed by the N atom?



[2011 O/N-13 (5)]

54.

Two conversions are outlined below.



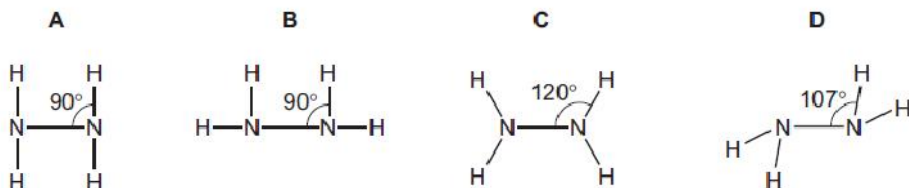
What similar feature do these two conversions have?

- 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  $\pi$  bond

[2012 M/J-11 (5)]

55.

What is the most likely shape of a molecule of hydrazine,  $\text{N}_2\text{H}_4$ ?



[2012 M/J-12 (3)]

56.

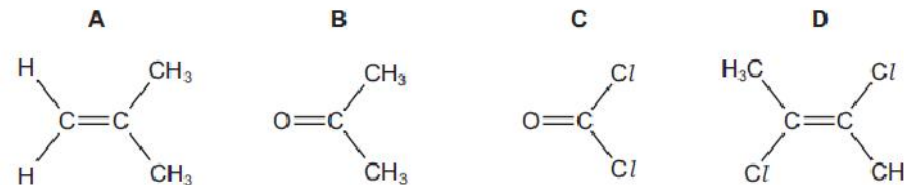
Which solid contains more than one kind of bonding?

- A iodine
- B silicon dioxide
- C sodium chloride
- D zinc

[2012 M/J-12 (5)]

57.

Which molecule has the largest overall dipole?



[2012 M/J-12 (10)]

58.

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

- 1  $\text{BF}_3$
- 2  $\text{CH}_3^+$
- 3  $\text{AlCl}_3$

[2012 M/J-12 (31)]

59.

Sodium borohydride,  $\text{NaBH}_4$ , and boron trifluoride,  $\text{BF}_3$ , 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)]

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

- A  $\text{H}_2\text{O}$  and  $\text{CO}_2$
- B  $\text{H}_2\text{O}$  and  $\text{SCl}_2$
- C  $\text{NH}_3$  and  $\text{BH}_3$
- D  $\text{SCl}_2$  and  $\text{BeCl}_2$

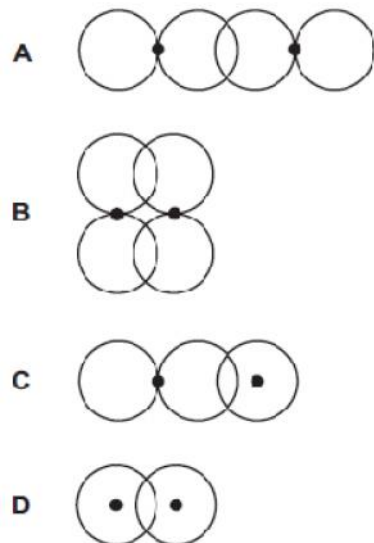
[2012 O/N-11 (12)]

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  $\pi$  bond?



[2012 O/N-13 (6)]

63. Which molecule is planar?

- A  $\text{C}_2\text{Cl}_4$
- B  $\text{C}_3\text{H}_6$
- C  $\text{C}_3\text{H}_8$
- D  $\text{NF}_3$

[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  $\text{BH}_3$
- 2  $\text{CH}_3^+$
- 3  $\text{PH}_3$

[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)]

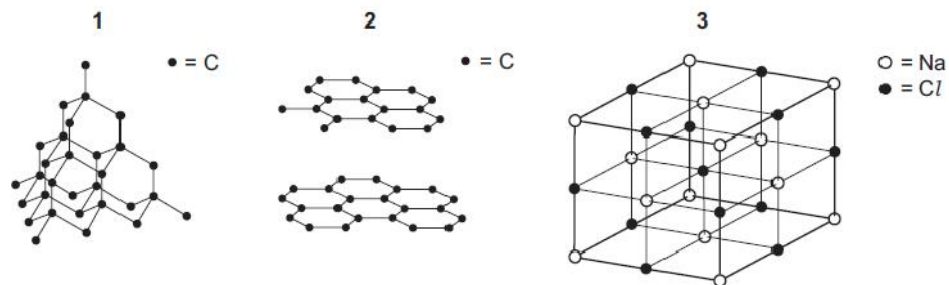
66. Dicarbon monoxide,  $\text{C}_2\text{O}$ , is found in dust clouds in space. Analysis of it shows that the sequence of atoms in this molecule is  $\text{C}-\text{C}-\text{O}$ . All bonds are double bonds and there are no unpaired electrons.

How many lone pairs of electrons are present in a molecule of  $\text{C}_2\text{O}$ ?

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

[2013 M/J-12 (9)]

67.  
Which diagrams represent part of a giant molecular structure?



[2013 M/J-13 (34)]

68.  
Which types of bonding are present in ammonium carbonate,  $(\text{NH}_4)_2\text{CO}_3$ ?

- 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)]

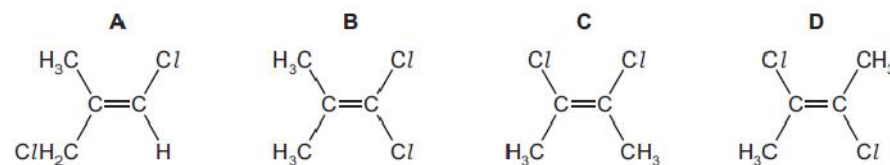
70.  
 $\text{AlCl}_3$  vapour forms molecules with formula  $\text{Al}_2\text{Cl}_6$  as it is cooled.

What happens to the bond angles during the change from  $\text{AlCl}_3$  to  $\text{Al}_2\text{Cl}_6$ ?

- 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?



[2014 M/J-11 (9)]

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/ $^{\circ}\text{C}$           | 772      | 114              | 1610             |
| boiling point/ $^{\circ}\text{C}$           | 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  $\pi$  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  $\text{CH}_3\text{Cl}$       B  $\text{CO}_2$       C  $\text{N}_2\text{H}_4$       D  $\text{NH}_4\text{CN}$

[2014 M/J-13 (2)]

75.

Four substances have the physical properties shown.

Which substance is an ionic solid?

|   | melting point<br>$^{\circ}\text{C}$ | boiling point<br>$^{\circ}\text{C}$ | electrical<br>conductivity<br>of solid | electrical<br>conductivity<br>of molten<br>substance | electrical<br>conductivity<br>of aqueous<br>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  $\text{F}-\text{X}-\text{F}$  angle the largest?

- A  $\text{BF}_3$       B  $\text{CF}_4$       C  $\text{NF}_3$       D  $\text{OF}_2$

[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)]

78.

Copper and iodine are both shiny crystalline solids.

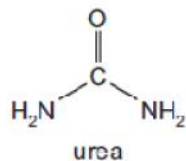
Which forces exist between particles in solid copper and between neighbouring iodine molecules in solid iodine?

|          | copper         | iodine                |
|----------|----------------|-----------------------|
| <b>A</b> | ionic bonds    | covalent bonds        |
| <b>B</b> | ionic bonds    | van der Waals' forces |
| <b>C</b> | metallic bonds | covalent bonds        |
| <b>D</b> | metallic bonds | van der Waals' forces |

[2014 O/N-13 (7)]

79.

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



- 1 hydrogen bonding
- 2 permanent dipole-dipole forces
- 3 instantaneous dipole-induced dipole forces

[2014 O/N-13 (33)]

**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**  $\text{CO}_2(\text{g})$       **B**  $\text{H}_2(\text{g})$       **C**  $\text{Ne}(\text{g})$       **D**  $\text{NH}_3(\text{g})$

**3. Nov/2021/Paper\_11/No.18**

Which row is correct?

|          | shape               |                     | bonds present    |              |
|----------|---------------------|---------------------|------------------|--------------|
|          | ammonia molecule    | ammonium ion        | ammonia molecule | ammonium ion |
| <b>A</b> | pyramidal           | regular tetrahedral | $\sigma$         | $\sigma$     |
| <b>B</b> | pyramidal           | regular tetrahedral | $\sigma$         | $\pi$        |
| <b>C</b> | regular tetrahedral | pyramidal           | $\sigma$         | $\sigma$     |
| <b>D</b> | regular tetrahedral | pyramidal           | $\pi$            | $\sigma$     |

**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 |
|----------|----------------------------------|--------------------|
| <b>A</b> | x                                | x                  |
| <b>B</b> | ✓                                | x                  |
| <b>C</b> | x                                | ✓                  |
| <b>D</b> | ✓                                | ✓                  |

5. Nov/2021/Paper\_11/No.34

Which molecules contain at least one unpaired electron?

- 1 NO
- 2 NO<sub>2</sub>
- 3 NH<sub>3</sub>

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 Al
- 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.

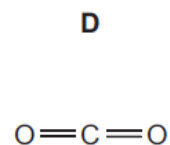
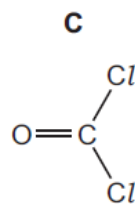
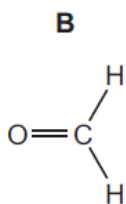
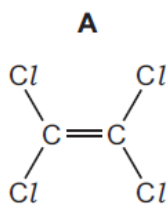
The four pairs of valence electrons include at least one bond pair and at least one lone pair.

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?



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 <sub>3</sub>  | 185              |
| HCl              | 188              |
| HF               | 293              |
| H <sub>2</sub> O | 373              |

Which statement and reason about these hydrides is correct?

- A The boiling point of PH<sub>3</sub> is much lower than the boiling point of H<sub>2</sub>O because PH<sub>3</sub> 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<sub>2</sub>O is higher than the boiling point of HF because each hydrogen bond between the H<sub>2</sub>O molecules is stronger than each hydrogen bond between HF molecules.
- D The boiling points of PH<sub>3</sub> and HCl are similar because the molecules of PH<sub>3</sub> 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<sub>4</sub> is higher than the melting point of SiO<sub>2</sub>.
- 2 SiCl<sub>4</sub> reacts with water, NaCl does not.
- 3 The melting point of SiCl<sub>4</sub> 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.

11. Nov/2021/Paper\_13/No.18

Which row is correct?

|          | shape               |                     | bonds present    |              |
|----------|---------------------|---------------------|------------------|--------------|
|          | ammonia molecule    | ammonium ion        | ammonia molecule | ammonium ion |
| <b>A</b> | pyramidal           | regular tetrahedral | $\sigma$         | $\sigma$     |
| <b>B</b> | pyramidal           | regular tetrahedral | $\sigma$         | $\pi$        |
| <b>C</b> | regular tetrahedral | pyramidal           | $\sigma$         | $\sigma$     |
| <b>D</b> | regular tetrahedral | pyramidal           | $\pi$            | $\sigma$     |

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 Al
- 2 Si
- 3 Mg

13. **March/2021/Paper\_12/No/.12**

Which observations are made when a sample of silicon chloride,  $\text{SiCl}_4$ , 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  $\text{BF}_3$
- 2  $\text{H}^+$
- 3  $\text{CH}_3^+$

15. June/2021/Paper\_11/No.3

Phosphorus forms two chlorides. Phosphorus(III) chloride,  $\text{PCl}_3$ , is a covalent liquid.

Phosphorus(V) chloride is an ionic solid. One of the ions present is  $[\text{PCl}_4]^+$ .

What is the shape of the  $\text{PCl}_3$  molecule and the  $[\text{PCl}_4]^+$  ion?

|          | $\text{PCl}_3$  | $[\text{PCl}_4]^+$ |
|----------|-----------------|--------------------|
| <b>A</b> | pyramidal       | square planar      |
| <b>B</b> | pyramidal       | tetrahedral        |
| <b>C</b> | tetrahedral     | square planar      |
| <b>D</b> | trigonal planar | tetrahedral        |

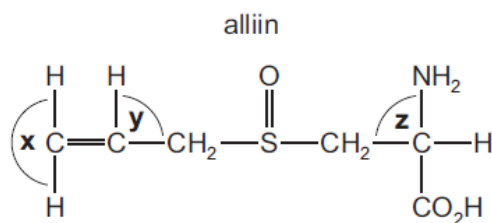
16. June/2021/Paper\_11/No.34

Which molecules contain at least one bond angle of  $120^\circ$ ?

- 1  $\text{C}_2\text{H}_4$
- 2  $\text{PF}_5$
- 3  $\text{NCl}_3$

17. June/2021/Paper\_12/No.4

The structural formula of alliin is shown.

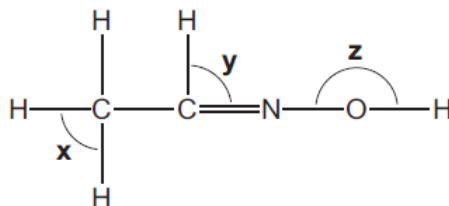


What are the approximate bond angles **x**, **y** and **z** in a molecule of alliin?

|          | <b>x</b>    | <b>y</b>    | <b>z</b>    |
|----------|-------------|-------------|-------------|
| <b>A</b> | $90^\circ$  | $90^\circ$  | $109^\circ$ |
| <b>B</b> | $120^\circ$ | $109^\circ$ | $90^\circ$  |
| <b>C</b> | $120^\circ$ | $120^\circ$ | $109^\circ$ |
| <b>D</b> | $180^\circ$ | $109^\circ$ | $109^\circ$ |

18. June/2021/Paper\_13/No.4

Ethanal reacts with hydroxylamine,  $\text{NH}_2\text{OH}$ , 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 | $\text{CH}_3\text{OH}$   | $\text{Al}_2\text{Cl}_6$ | $\text{CH}_2\text{Cl}_2$ |
| B | $\text{Al}_2\text{Cl}_6$ | $\text{CH}_2\text{Cl}_2$ | $\text{CH}_4$            |
| C | $\text{CH}_2\text{Cl}_2$ | $\text{CH}_4$            | $\text{CH}_3\text{OH}$   |
| D | $\text{CH}_4$            | $\text{CH}_3\text{OH}$   | $\text{H}_2\text{O}$     |

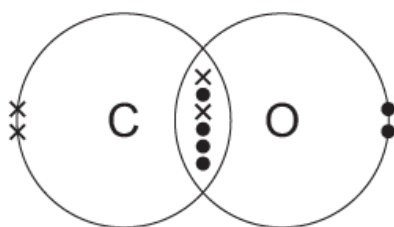
20. June/2021/Paper\_13/No.6

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

- A covalent
- B ionic
- C metallic
- D van der Waals' forces

Carbon monoxide gas,  $\text{CO(g)}$ , and nitrogen gas,  $\text{N}_2(\text{g})$ , are both diatomic molecules.

(a) The diagram shows the arrangement of outer electrons in a molecule of  $\text{CO(g)}$ .



(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.

|                                                  | $\text{N}_2$ | $\text{CO}$ |
|--------------------------------------------------|--------------|-------------|
| number of electrons per molecule                 |              |             |
| type(s) of intermolecular (van der Waals') force |              |             |

[2]

(b)  $\text{N}_2(\text{g})$  is less reactive than  $\text{CO}(\text{g})$  even though  $\text{N}_2(\text{g})$  has a lower bond energy than  $\text{CO}(\text{g})$ .

Suggest why  $\text{CO}(\text{g})$  is more reactive than  $\text{N}_2(\text{g})$ .

.....  
..... [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  $\text{N}_2(\text{g})$  behaves more like an ideal gas than  $\text{CO}(\text{g})$  does at  $20.0^\circ\text{C}$  and  $101\text{ kPa}$ .

.....  
.....  
..... [2]

- (d) Calculate the amount, in mol, of pure nitrogen gas which occupies  $100\text{ cm}^3$  at  $101\text{ kPa}$  and  $20.0^\circ\text{C}$ .

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

Assume nitrogen behaves as an ideal gas.

..... mol  
[3]

[Total: 11]

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

- (a) Lithium sulfide,  $\text{Li}_2\text{S}$ , is a crystalline solid with a melting point of  $938^\circ\text{C}$ . 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,  $\text{CO}$ , 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  $\text{CO}$ .

Show the electrons belonging to the C atom as  $\times$ .

Show the electrons belonging to the O atom as  $\bullet$ .

[2]

(c) Nitrogen,  $\text{N}_2$ , is also a gas at room temperature and pressure. Neither CO nor  $\text{N}_2$  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  $\text{N}_2$  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  $\text{N}_2(\text{g})$  and  $\text{CO}(\text{g})$ .

|                                        | $\text{N}_2(\text{g})$ | $\text{CO}(\text{g})$ |
|----------------------------------------|------------------------|-----------------------|
| number of electrons per molecule       | 14                     | 14                    |
| presence of a dipole moment            | $\times$               | $\checkmark$          |
| boiling point/ $^{\circ}\text{C}$      | -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]

Methanol,  $\text{CH}_3\text{OH}$ , 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  $-97.6^\circ\text{C}$  and a boiling point of  $64.7^\circ\text{C}$ .

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]

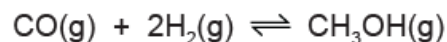
- (ii) Explain why some of the liquid becomes a vapour.

.....  
.....  
..... [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]

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



Carbon monoxide and hydrogen react at  $1.0 \times 10^7 \text{ Pa}$  and  $200^\circ\text{C}$ . Eventually the reaction mixture reaches dynamic equilibrium.

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

|                        | CO(g) | H <sub>2</sub> (g) | CH <sub>3</sub> OH(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]

**1. June/2022/Paper\_11/No.5**

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

- A poly(ethene),  $-(\text{CH}_2\text{CH}_2)_n-$
- B propane,  $\text{C}_3\text{H}_8$
- C silicon tetrachloride,  $\text{SiCl}_4$
- D sulfur hexafluoride,  $\text{SF}_6$

**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  $\text{Al}_2\text{Cl}_6$  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**

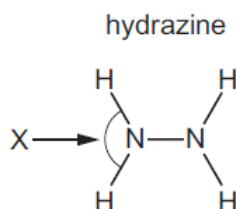
Which compound has the smallest difference in electronegativity between its two elements?

- 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.



What is the predicted bond angle X?

- A  $90^\circ$                       B  $107^\circ$                       C  $109.5^\circ$                       D  $120^\circ$

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.

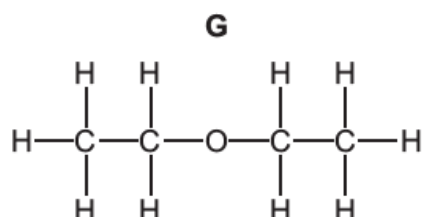
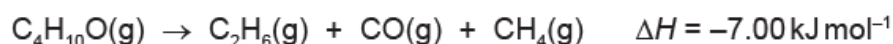


Fig. 3.1

(a) When **G**, C<sub>4</sub>H<sub>10</sub>O, is heated, thermal decomposition occurs.



(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.

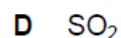
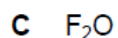
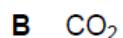
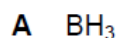
Use ● to represent electrons from an oxygen atom.

Use × to represent electrons from a carbon atom.

[1]

**1. Nov/2022/Paper\_11/No.6**

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

**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 |
|----------|---------------|------------------------------|
| <b>A</b> | high          | insoluble                    |
| <b>B</b> | high          | soluble                      |
| <b>C</b> | low           | insoluble                    |
| <b>D</b> | low           | soluble                      |

**3. Nov/2022/Paper\_12/No.12**

The compound  $(\text{CH}_3)_3\text{NAlCl}_3$  has a simple molecular structure.

Which statement about  $(\text{CH}_3)_3\text{NAlCl}_3$  is correct?

**A**  $(\text{CH}_3)_3\text{NAlCl}_3$  molecules attract each other by hydrogen bonds.

**B** The Al atom in  $(\text{CH}_3)_3\text{NAlCl}_3$  has an incomplete valence shell of electrons.

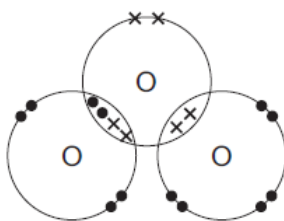
**C** The bonds around the Al atom are planar.

**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,  $\text{O}_3$ , molecule is shown.



What is the predicted bond angle in this molecule?

**A**  $107^\circ$

**B**  $109.5^\circ$

**C**  $117^\circ$

**D**  $120^\circ$

5. Nov/2022/Paper\_22/No.1(a)

Species such as  $\text{NH}_4^+$ ,  $\text{CO}_3^{2-}$  and  $\text{PO}_4^{3-}$  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.

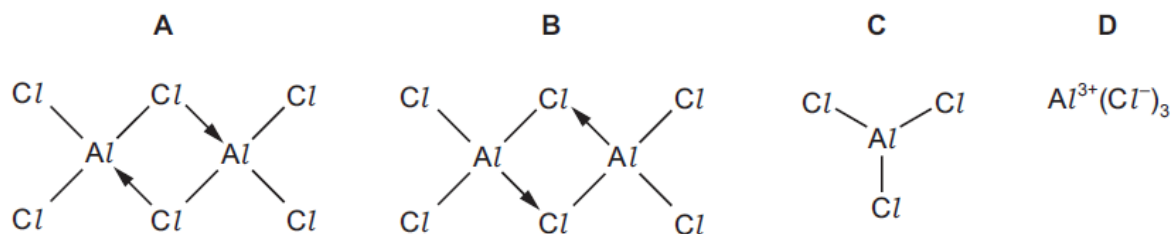
.....

[2]

**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?

**2. Nov/2023/Paper\_9701/11/No.6**

Which row is correct?

|          | shape of $H_3O^{+}$ | shape of $SCl_2$ |
|----------|---------------------|------------------|
| <b>A</b> | pyramidal           | non-linear       |
| <b>B</b> | pyramidal           | linear           |
| <b>C</b> | trigonal planar     | non-linear       |
| <b>D</b> | 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,  $\text{NaBH}_4$ , and boron trifluoride,  $\text{BF}_3$ .

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

|          | borohydride ion | boron trifluoride |
|----------|-----------------|-------------------|
| <b>A</b> | square planar   | pyramidal         |
| <b>B</b> | square planar   | trigonal planar   |
| <b>C</b> | tetrahedral     | pyramidal         |
| <b>D</b> | tetrahedral     | trigonal planar   |

5. Nov/2023/Paper\_ 9701/21/No.1(c, d)

(c) A student does three tests on separate samples of  $\text{NaCl(aq)}$ .

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 $\text{Br}_2(\text{aq})$             |              |
| 2    | addition of a few drops of concentrated $\text{H}_2\text{SO}_4$ |              |
| 3    | addition of a few drops of dilute $\text{AgNO}_3(\text{aq})$    |              |

[3]

(d)  $\text{POCl}_3$  shows similar chemical properties to  $\text{PCl}_5$ .

$\text{POCl}_3$  has a melting point of  $1^\circ\text{C}$  and a boiling point of  $106^\circ\text{C}$ .

$\text{POCl}_3$  reacts vigorously with water, forming misty fumes and an acidic solution.

- (i) Explain how the information in (d) suggests the structure and bonding of  $\text{POCl}_3$  is simple covalent.

.....  
.....  
..... [2]

- (ii) Construct an equation for the reaction of  $\text{POCl}_3$  with water.

$\text{POCl}_3 + \dots\dots\dots \rightarrow \dots\dots\dots$  [1]

- (iii)  $\text{POCl}_3$  contains a double covalent bond between P and O.

Complete the dot-and-cross diagram, in Fig. 1.1, to show the bonding in  $\text{POCl}_3$ .

Show outer shell electrons only.

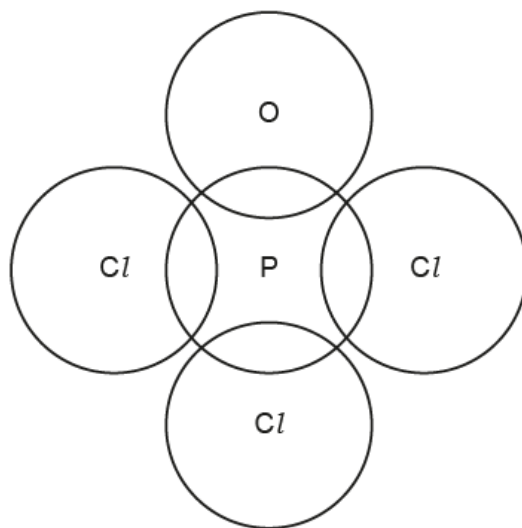
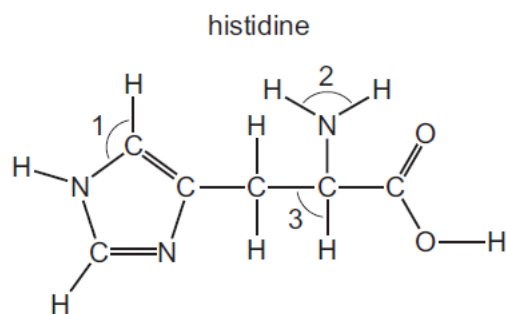


Fig. 1.1

[2]

6. June/2023/Paper\_9701/11/No.7

Histidine is an amino acid.



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

|          | 1      | 2    | 3      |
|----------|--------|------|--------|
| <b>A</b> | 109.5° | 107° | 90°    |
| <b>B</b> | 120°   | 107° | 109.5° |
| <b>C</b> | 120°   | 120° | 90°    |
| <b>D</b> | 120°   | 120° | 109.5° |

7. June/2023/Paper\_9701/12/No.6

Which statement about the  $Cl-N=O$  molecule is correct?

- A** Each molecule contains one  $\sigma$  and two  $\pi$  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 |
|----------|----------|---------------------|-----------------------------------------------------------------------------|
| <b>A</b> | $CO_2$   | linear              | two                                                                         |
| <b>B</b> | $BF_3$   | trigonal planar     | three                                                                       |
| <b>C</b> | $NH_3$   | regular tetrahedral | four                                                                        |
| <b>D</b> | $PF_5$   | octahedral          | six                                                                         |

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.

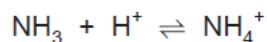
- 1 Element L contains covalent bonds.
- 2 Element L has a higher atomic number than element M.
- 3 A compound of L and M contains ionic bonds.

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.



Which row is correct?

|          | shape of $\text{NH}_4^+$ | bond angle in $\text{NH}_4^+$ / ° |
|----------|--------------------------|-----------------------------------|
| <b>A</b> | pyramidal                | 107                               |
| <b>B</b> | pyramidal                | 109.5                             |
| <b>C</b> | tetrahedral              | 107                               |
| <b>D</b> | tetrahedral              | 109.5                             |

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]

(iii) Name the strongest intermolecular force that exists between  $\text{NH}_3(\text{l})$  molecules.

..... [1]

(iv) Draw a diagram to show the formation of the strongest intermolecular force between **two** molecules of  $\text{NH}_3(\text{l})$ .

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]

(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]

(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?



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.

.....

..... [1]