

Cambridge AS & A Level

# CHEMISTRY

## Paper 1

Topical Past Paper Questions  
+ Answer Scheme

2015 - 2021



## 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  $630 \text{ kJ mol}^{-1}$
- B  $810 \text{ kJ mol}^{-1}$
- C  $1260 \text{ kJ mol}^{-1}$
- D  $1620 \text{ kJ mol}^{-1}$

114. 9701\_s20\_qp\_11 Q: 3

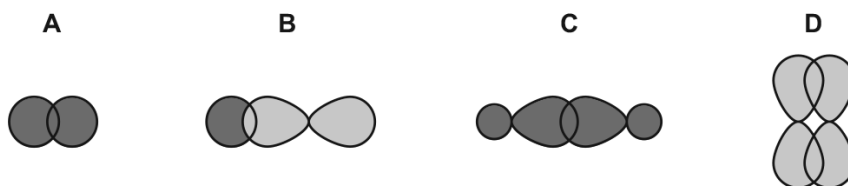
When considering one molecule of ethene, which row describes both the hybridisation of the atomic orbitals in the carbon atoms and the overall bonding?

|   | hybridisation | bonding                       |
|---|---------------|-------------------------------|
| A | $sp^2$        | 4 $\sigma$ bonds 1 $\pi$ bond |
| B | $sp^2$        | 5 $\sigma$ bonds 1 $\pi$ bond |
| C | $sp^3$        | 4 $\sigma$ bonds 1 $\pi$ bond |
| D | $sp^3$        | 5 $\sigma$ bonds 1 $\pi$ bond |

115. 9701\_s19\_qp\_12 Q: 4

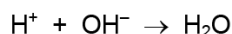
A  $\sigma$  bond is made between two carbon atoms in a molecule of ethene.

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  $\pi$  bond between an s orbital and an  $\text{sp}^2$  orbital  
**B** a  $\pi$  bond between an s orbital and an  $\text{sp}^3$  orbital  
**C** a  $\sigma$  bond between an s orbital and an  $\text{sp}^2$  orbital  
**D** a  $\sigma$  bond between an s orbital and an  $\text{sp}^3$  orbital

118. 9701\_s16\_qp\_11 Q: 2

What is the correct number of bonds of each type in the  $\text{Al}_2\text{Cl}_6$  molecule?

|          | covalent | co-ordinate<br>(dative covalent) |
|----------|----------|----------------------------------|
| <b>A</b> | 6        | 1                                |
| <b>B</b> | 6        | 2                                |
| <b>C</b> | 7        | 0                                |
| <b>D</b> | 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  $\sigma$  bond and one  $\pi$  bond.

Which orbitals overlap to form each of these bonds?

|   | $\sigma$ bond | $\pi$ 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,  $\text{NH}_3$ , is dissolved in water, a small concentration of ammonium ions,  $\text{NH}_4^+$ , 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 |
|----------|---|--|
| <b>A</b> | 8                                       | decreases  |
| <b>B</b> | 8                                       | increases  |
| <b>C</b> | 10                                      | decreases  |
| <b>D</b> | 10                                      | increases  |

123. 9701\_s21\_qp\_11 Q: 3

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

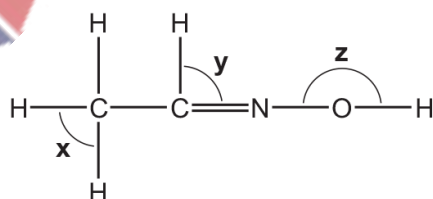
Phosphorus(V) chloride is an ionic solid. One of the ions present is  $[\text{PCl}_4]^+$ .

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        |

124. 9701\_s21\_qp\_13 Q: 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

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

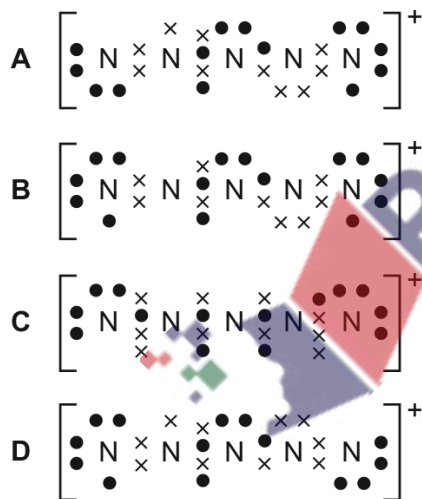
Which molecule does **not** have any  $90^\circ$  or  $180^\circ$  bond angles?

- 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 |
|----------|----------------|-----------------------|------------|
| <b>A</b> | 6              | 2                     | 0          |
| <b>B</b> | 6              | 2                     | 16         |
| <b>C</b> | 6              | 2                     | 18         |
| <b>D</b> | 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**  $\text{BeCl}_2$  and  $\text{CO}_2$   
**B**  $\text{CH}_4$  and  $\text{NH}_4^+$   
**C**  $\text{NH}_3$  and  $\text{BF}_3$   
**D**  $\text{SCl}_2$  and  $\text{H}_2\text{O}$

131. 9701\_s19\_qp\_11 Q: 5

In which species is there a lone pair of electrons?

- A**  $\text{CH}_3$       **B**  $\text{CH}_3^+$       **C**  $\text{CH}_3^-$       **D**  $\text{CH}_4$

132. 9701\_w19\_qp\_11 Q: 3

Which molecule or ion contains the smallest bond angle?

- A**  $\text{C}_2\text{H}_4$       **B**  $\text{CH}_3\text{COCH}_3$       **C**  $\text{NH}_4^+$       **D**  $\text{NH}_3$

133. 9701\_m18\_qp\_12 Q: 5

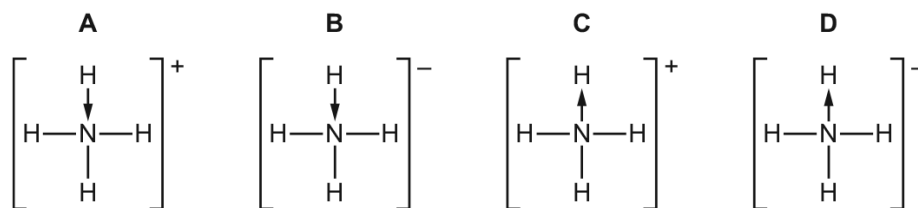
Which mass of solid residue is obtained from the thermal decomposition of 4.10g of anhydrous calcium nitrate?

- 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  $\text{AlCl}_3$ ,  $\text{BF}_3$ ,  $\text{PH}_3$
- B  $\text{AlCl}_3$ ,  $\text{CO}_2$ ,  $\text{NH}_3$
- C  $\text{BF}_3$ ,  $\text{C}_2\text{H}_4$ ,  $\text{C}_3\text{H}_6$
- D  $\text{C}_2\text{H}_4$ ,  $\text{CO}_2$ ,  $\text{H}_2\text{O}$

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,  $\text{C}_3\text{H}_8$
- C silicon tetrachloride,  $\text{SiCl}_4$
- D sulfur hexafluoride,  $\text{SF}_6$

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 | $90^\circ$    | $104.5^\circ$ and $180^\circ$ |
| B | $90^\circ$    | $109.5^\circ$ and $120^\circ$ |
| C | $109.5^\circ$ | $104.5^\circ$ and $180^\circ$ |
| D | $109.5^\circ$ | $109.5^\circ$ and $180^\circ$ |



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 |
| <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           | $\pi$            | $\sigma$     |

140. 9701\_s16\_qp\_11 Q: 5

 Dicarbon monoxide,  $\text{C}_2\text{O}$ , 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  $\text{C}_2\text{O}$ ?

- 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.

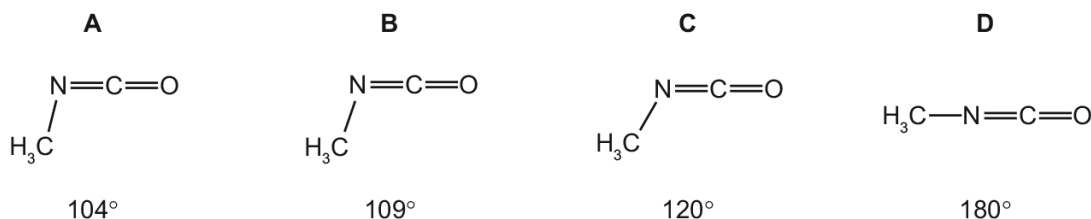
 Which species is **not** planar?

- A**  $\text{BF}_3$                       **B**  $\text{CH}_3^+$                       **C**  $\text{C}_2\text{H}_4$                       **D**  $\text{NH}_3$

142. 9701\_s16\_qp\_13 Q: 7

Methyl isocyanate,  $\text{CH}_3\text{NCO}$ , 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**  $\text{BH}_3$       **B**  $\text{CH}_4$       **C**  $\text{C}_2\text{H}_6$       **D**  $\text{NH}_3$

144. 9701\_s15\_qp\_13 Q: 4

Which pair has species with different shapes?

- A**  $\text{BeCl}_2$  and  $\text{CO}_2$   
**B**  $\text{CH}_4$  and  $\text{NH}_4^+$   
**C**  $\text{NH}_3$  and  $\text{BF}_3$   
**D**  $\text{SCl}_2$  and  $\text{H}_2\text{O}$

### 3.4 Intermolecular forces, electronegativity and bond properties

145. 9701\_m22\_qp\_12 Q: 4

For which molecule is the dipole moment zero?

- A**  $\text{CH}_3\text{Cl}$       **B**  $\text{CH}_2\text{Cl}_2$       **C**  $\text{CHCl}_3$       **D**  $\text{CCl}_4$

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                     |
|----------|---------------------------------|---------------------------------|---------------------------------|
| <b>A</b> | CH <sub>3</sub> OH              | Al <sub>2</sub> Cl <sub>6</sub> | CH <sub>2</sub> Cl <sub>2</sub> |
| <b>B</b> | Al <sub>2</sub> Cl <sub>6</sub> | CH <sub>2</sub> Cl <sub>2</sub> | CH <sub>4</sub>                 |
| <b>C</b> | CH <sub>2</sub> Cl <sub>2</sub> | CH <sub>4</sub>                 | CH <sub>3</sub> OH              |
| <b>D</b> | CH <sub>4</sub>                 | CH <sub>3</sub> OH              | H <sub>2</sub> O                |

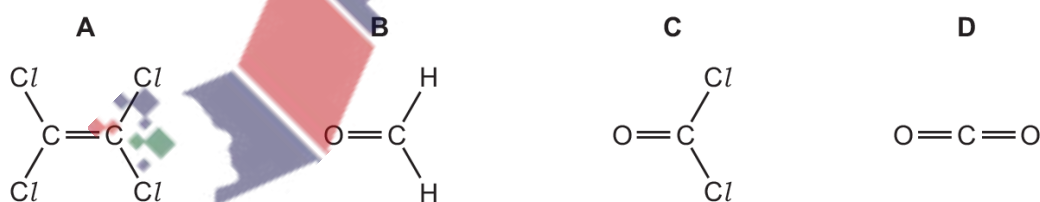
148. 9701\_w21\_qp\_11 Q: 5

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 <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.

151. 9701\_w21\_qp\_13 Q: 5

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

- A** dipole-dipole interactions
- B** hydrogen bonds
- C** ion-dipole interactions
- D** ionic bonds

152. 9701\_s20\_qp\_12 Q: 8

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

- A** C<sub>2</sub>H<sub>5</sub>OH(l) → C<sub>2</sub>H<sub>5</sub>OH(g)
- B** H<sub>2</sub>O(s) → H<sub>2</sub>O(l)
- C** O<sub>2</sub>(s) → O<sub>2</sub>(l)
- D** C<sub>4</sub>H<sub>10</sub>(l) → C<sub>4</sub>H<sub>10</sub>(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

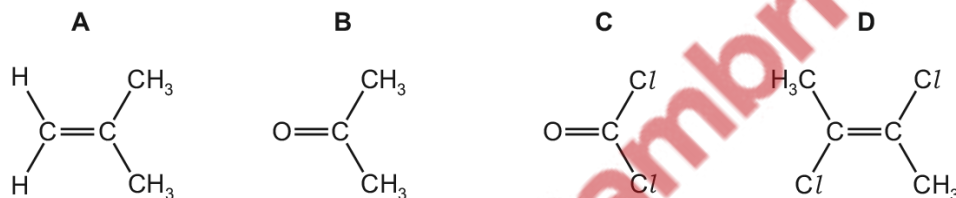
154. 9701\_s18\_qp\_11 Q: 5

Which molecule has no overall dipole?

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

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?

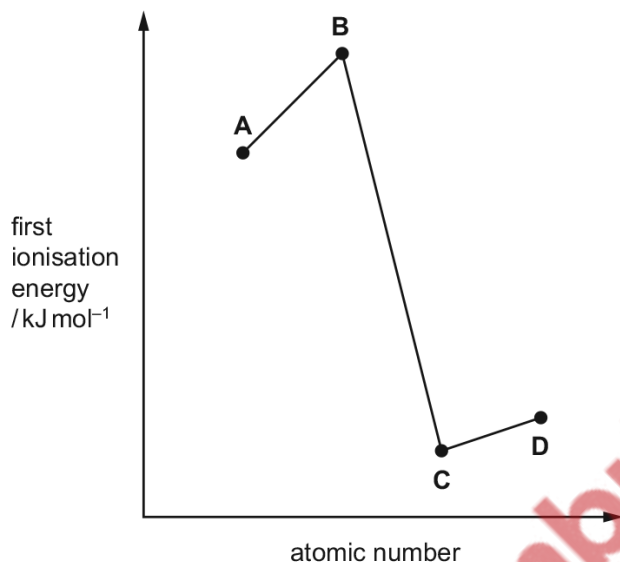
- A  $\text{C}(\text{CH}_3)_4$
- B  $\text{CH}_3\text{CH}_2\text{CH}_2\text{CH}_2\text{CH}_3$
- C  $\text{CH}_3\text{COCH}_2\text{CH}_3$
- D  $\text{CH}_3\text{CH}(\text{OH})\text{CH}_2\text{CH}_3$

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<sub>2</sub>O is a liquid and H<sub>2</sub>S 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<sub>2</sub>O molecules but not between H<sub>2</sub>S molecules.
- D The instantaneous dipole-induced dipole forces between H<sub>2</sub>O molecules are stronger than the instantaneous dipole-induced dipole forces between H<sub>2</sub>S 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,  $\text{SiH}_4$ .
  - 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,  $\text{N}_2$ , and carbon monoxide,  $\text{CO}$ , both have  $M_r = 28$ .

The boiling point of  $\text{N}_2$  is 77 K.

The boiling point of  $\text{CO}$  is 82 K.

What could be responsible for this difference in boiling points?

- A  $\text{CO}$  molecules have a permanent dipole, the  $\text{N}_2$  molecules are not polar.
  - B  $\text{N}_2$  has  $\sigma$  and  $\pi$  bonding,  $\text{CO}$  has  $\sigma$  bonding only.
  - C  $\text{N}_2$  has a strong  $\text{N}\equiv\text{N}$  bond,  $\text{CO}$  has a  $\text{C}=\text{O}$  bond.
  - D The  $\text{CO}$  molecule has more electrons than the  $\text{N}_2$  molecule.
-

164. 9701\_w15\_qp\_12 Q: 1

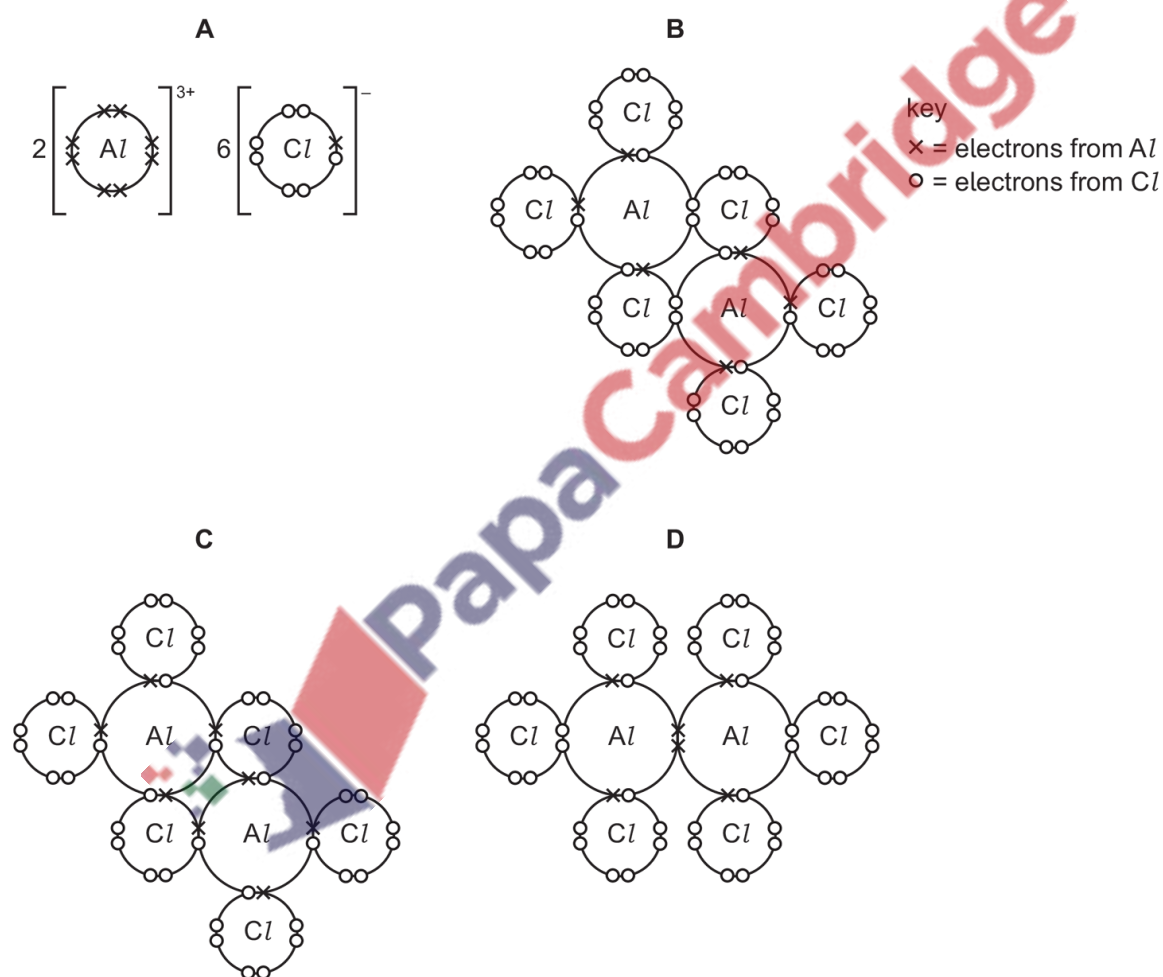
Which type of bonding is **never** found in elements?

- 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
- 

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