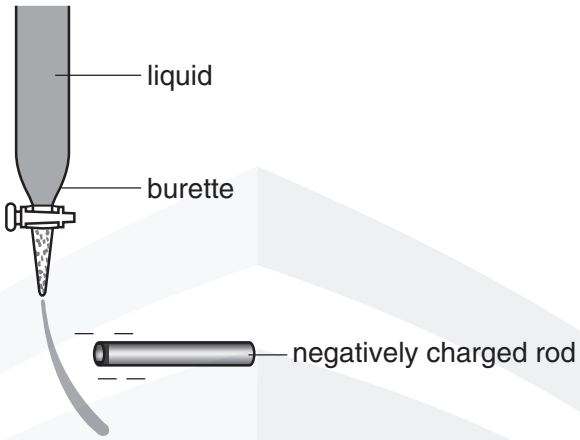
INTERMOLECULAR FORCES

SECTION A

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.

[S'02 Q4]

2 When heated, solid iodine readily forms iodine vapour.

What does this information suggest about the nature of the particles in these two physical states of iodine?

	solid	*vapour*
A	ionic	atomic
B	ionic	molecular
C	molecular	atomic
D	molecular	molecular

[S'02 Q7]

3 The African weaver ant defends its territory by spraying an intruder with a mixture of compounds. The ease by which these compounds are detected by other ants depends upon the volatility, which decreases as the strength of the intermolecular forces in the compound increases.

Which compound would be the most volatile?

A $CH_3CH_2CH_2CH_2CH_2CH_3$

B $CH_3CH_2CH_2CH_2CH_2CHO$

C $CH_3CH_2CH_2CH_2CH_2NH_2$

D $CH_3CH_2CH_2CH_2CH_2OH$

[W'02 Q4]

4 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

[W'04 Q6]

5 In which process are hydrogen bonds broken?

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

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

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

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

[S'06 Q5]

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

Which pair of statements correctly describes this process?

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

[S'09 1 Q7]

7 Why is the boiling point of ammonia, NH_3, higher than the boiling point of phosphine, PH_3?

A Ammonia molecules are polar; phosphine molecules are not.

B Ammonia molecules have significant hydrogen bonding; phosphine molecules do not.

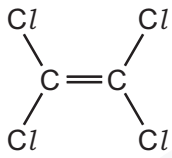
C N–H covalent bonds are stronger than P–H covalent bonds.

D There is one lone pair in each ammonia molecule but no lone pair in each phosphine molecule.

[S'18 3 Q1]

8 Which molecule has the largest overall dipole?

A



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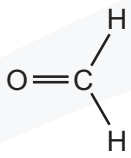

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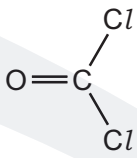

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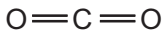


[W'09 1 Q5]

9 Which statement explains why the boiling point of methane is higher than that of neon?
[A_r: H, 1; C, 12; Ne, 20]

A A molecule of methane has a greater mass than a molecule of neon.

B Molecules of methane form hydrogen bonds, but those of neon do not.

C Molecules of methane have stronger intermolecular forces than those of neon.

D The molecule of methane is polar, but that of neon is not.

[S'09 1 Q5]

10 The boiling points of methane, ethane, propane and butane are given.

compound	CH_4	CH_3CH_3	$CH_3CH_2CH_3$	$CH_3CH_2CH_2CH_3$
boiling point / K	112	185	231	273

Which statement explains the increase in boiling point from methane to butane?

A Closer packing of molecules results in stronger van der Waals' forces.

B More covalent bonds are present and therefore more energy is required to break the bonds.

C More electrons in the molecules results in stronger van der Waals' forces.

D More hydrogen atoms in the molecules results in stronger hydrogen bonding.

[M'17 2 Q4]

11 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

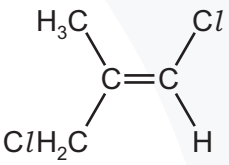
[W'10 2 Q1]

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

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

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

A



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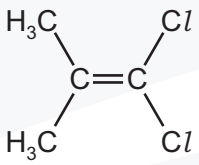

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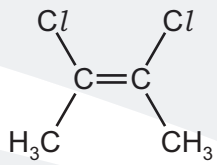

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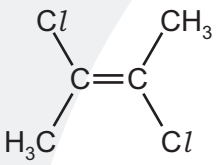


[W'09 2 Q4]

14 How do the strengths of the covalent bonds within molecules, and the van der Waals' forces between molecules, vary going down Group VII from chlorine to bromine to iodine?

	strength of covalent bonds	strength of van der Waals' forces
A	decrease	decrease
B	decrease	increase
C	increase	decrease
D	increase	increase

[S'13 3 Q16]

15 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.

[S'16 1 Q7]

16 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

[W'11 2 Q5]

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

The boiling point of N_2 is 77 K.

The boiling point of CO is 82 K.

What could be responsible for this difference in boiling points?

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

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

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

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

[W'15 1 Q4]

18 The boiling points of methane, ethane, propane and butane are given.

compound	CH_4	CH_3CH_3	$CH_3CH_2CH_3$	$CH_3CH_2CH_2CH_3$
boiling point / K	112	185	231	273

Which statement explains the increase in boiling point from methane to butane?

A Closer packing of molecules results in stronger van der Waals' forces.

B More covalent bonds are present and therefore more energy is required to break the bonds.

C More electrons in the molecules results in stronger van der Waals' forces.

D More hydrogen atoms in the molecules results in stronger hydrogen bonding.

[M'17 2 Q4]

19 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.

[W'12 3 Q2]

20 The boiling points of methane, ethane, propane and butane are given.

compound	CH_4	CH_3CH_3	$CH_3CH_2CH_3$	$CH_3CH_2CH_2CH_3$
boiling point / K	112	185	231	273

Which statement explains the increase in boiling point from methane to butane?

A Closer packing of molecules results in stronger van der Waals' forces.

B More covalent bonds are present and therefore more energy is required to break the bonds.

C More electrons in the molecules results in stronger van der Waals' forces.

D More hydrogen atoms in the molecules results in stronger hydrogen bonding.

[M'17 2 Q4]

SECTION B

For each of the questions in this section, one or more of the three numbered statements **1** to **3** may be correct.

Decide whether each of the statements is or is not correct (you may find it helpful to put a tick against the statements that you consider to be correct).

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.

1 Boron is a non-metallic element which is placed above aluminium in Group III of the Periodic Table. It forms a compound with nitrogen known as boron nitride which has a graphite structure.

Which of the following conclusions can be drawn from this information?

1 The empirical formula of boron nitride is BN.

2 The boron and nitride atoms are likely to be arranged alternately in a hexagonal pattern.

3 Boron nitride has a layer structure with van der Waals' forces between the layers.

[W'05 Q33]

2 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

[S'11 2 Q34]

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

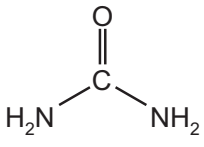
1 Water has a higher boiling point than H_2S.

2 Ice floats on water.

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

[W'09 Q32]

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



urea

1 hydrogen bonding

2 permanent dipole-dipole forces

3 temporary induced dipole-dipole forces

[W'10 1 Q33]

5 The concepts of bond energy, bond length and bond polarity are useful when comparing the behaviour of similar molecules, e.g. thermal stability.

For example, it could be said

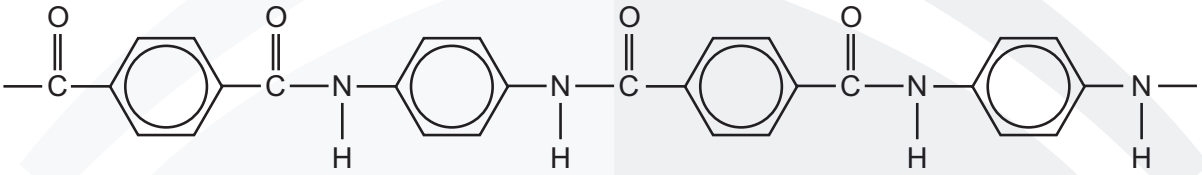
*"Compared with the HCl molecule, the bond …….**X**……. of the HI molecule is ……..**Y**…….. ."*

Which pairs of words correctly complete the above sentence?

	X	Y
1	energy	greater
2	length	greater
3	polarity	less

[S'02 Q33]

6 *Kevlar* has the structure below.



Compared to a steel rope of similar dimensions, a *Kevlar* rope is both lighter and stronger.

Which properties of *Kevlar* help to explain these facts?

1 The fibres of *Kevlar* align due to hydrogen bonding.

2 The mass per unit length is less in a *Kevlar* rope than in a steel rope.

3 The *Kevlar* molecule has no permanent dipole.

[W'08 Q31]

7 Water has some unusual physical properties compared to other hydrides of Group 16 elements. Some of these properties are due to hydrogen bonds. These intermolecular forces are much stronger in water than they are in H_2S, for example.

Which statements are correct?

1 Hydrogen bonds cause the melting point of ice to be higher than expected.

2 Hydrogen bonds cause the surface tension of water to be higher than expected.

3 Hydrogen bonds cause the viscosity of water to be higher than expected.

[S'16 3 Q32]

8 The three statements that follow are all true.

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

1 At 0 °C ice floats on water.

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

3 At 20 °C propanone and propanal mix completely.

[W'11 3 Q32]

9 The intermolecular forces between iodine molecules are instantaneous dipole-induced dipole forces.

Which statements explain why iodine has these intermolecular forces?

1 An iodine molecule is polar and experiences an attraction from a lone pair of electrons on an adjacent molecule.

2 An iodine molecule has a fluctuating dipole because the electrons in a molecule are more mobile than the nuclei.

3 The electron charge cloud within an I_2 molecule may become unsymmetrical and may then attract other I_2 molecules.

[S'14 3 Q36]

10 Which molecules have an overall dipole moment?

1 carbon monoxide, CO

2 phosphine, PH_3

3 carbon dioxide, CO_2

INTERMOLECULAR FORCES WS 2

SECTION A

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

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

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

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

.....

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

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

.....

[4]

(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.

.....

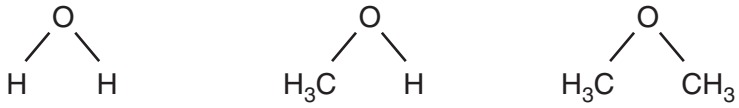
.....

.....

.....

.....[3]

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



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

.....

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

.....
[2]

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

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

A interactions involving permanent dipoles

B interactions involving temporary or induced dipoles

C hydrogen bonds

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

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

[4]

(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]

6 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]

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

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

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

Show outer electrons only.

[2]

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

shape .....

bond angle ..... [2]

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]

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

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

[5]

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

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

.....

.....

..... [2]

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

.....

.....

..... [2]

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

.....

.....

..... [2]

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

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

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

.....

.....

..... [2]

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

.....

.....

..... [2]

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

.....

.....

..... [2]

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

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

Explain these observations.

.....

.....

..... [2]

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

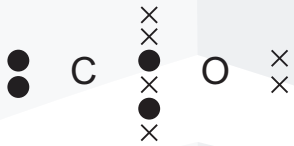
Suggest why N_2 has a lower boiling point than CO.

.....

.....

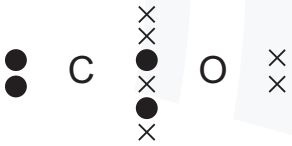
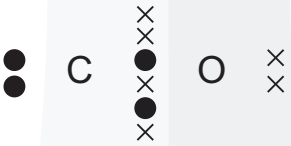
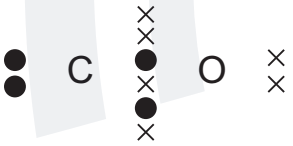
..... [2]

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



In the table below, there are three copies of this structure.

On the structures, draw a circle around a pair of electrons that is associated with **each** of the following.

a co-ordinate bond	a covalent bond	a lone pair
		

[3]