

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

..... [1]

May/June 2017 9701/21 · Q2 (b)(i)

(iii) State the bond angles normally associated with each type of hybridisation in carbon atoms.

sp^2

sp^3

[2]

May/June 2017 9701/21 · Q4 (a)(iii)

- (a) Some bond energies are shown in the table.

	bond energy / kJ mol^{-1}
H–Br	366
H–H	436
Br–Br	193

Use these data to calculate a value for the enthalpy change, ΔH , for the thermal decomposition of hydrogen bromide, HBr, according to the equation shown.

$$\Delta H = \dots\dots\dots \text{kJ mol}^{-1} \quad [1]$$

- (ii) With reference to the curves, state and explain the effect of increasing temperature on the **rate** of decomposition of HBr.

.....

.....

.....

..... [3]

May/June 2017 9701/22 · Q3 (a), (b)(ii), (b)(iv), (c)(i), (d)(ii) (continued ·)

- (iv) At 700 K HBr is approximately 10% decomposed but hydrogen iodide, HI, is approximately 20% decomposed.

Explain this difference with reference to bond strengths and the factors that affect them.

.....

.....

.....

..... [3]

- (c) At temperatures above 1500 K, HCl will decompose.

A sample of 0.300 mol of HCl decomposed in a sealed container.

The resulting equilibrium mixture was found to contain 1.50×10^{-2} mol of Cl_2 .

- (i) Calculate the amounts, in mol, of H_2 and HCl present in the equilibrium mixture.

$\text{H}_2 = \dots\dots\dots$ mol

HCl = $\dots\dots\dots$ mol
[2]

- (ii) Explain why the total pressure of the system does **not** need to be known for K_p to be calculated for this experiment.

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

May/June 2017 9701/22 · Q3 (a), (b)(ii), (b)(iv), (c)(i), (d)(ii) (cont.)

- (ii) The hydrocarbon **A**, C_4H_{10} , has a branched isomer.

Suggest why unbranched **A** has a higher boiling point than its branched isomer.

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

May/June 2017 9701/22 · Q4 (a)(ii)

(a) C_{60} and diamond are allotropes of carbon.

(i) Describe the lattice structure of solid C_{60} .

.....

.....

.....

..... [2]

(ii) C_{60} sublimes (turns directly from solid to gas) at about 800 K. Diamond also sublimes but only above 3800 K.

Explain why C_{60} and diamond sublime at such different temperatures.

.....

.....

.....

.....

.....

.....

.....

.....

..... [4]

(ii) Describe a test to indicate the presence of double bonds between carbon atoms in $C_{60}H_{18}$. Give the result of the test.

test

.....

result

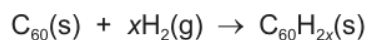
..... [2]

March 2018 9701/22 · Q2 (a)(i), (a)(ii), (b)(ii), (c)(i), (d)(i), (d)(iii), (d)(iv) (continued ·)

- (c) 0.144 g of C_{60} was placed in a 100 cm^3 container of hydrogen gas at 20°C and $1.00 \times 10^5\text{ Pa}$.

The container was heated to make the C_{60} and hydrogen gas react.

The reaction occurred as shown in the equation.



After the reaction, the container was allowed to cool to 20°C . The pressure decreased to $2.21 \times 10^4\text{ Pa}$. All of the C_{60} had reacted.

- (i) Name the type of reaction that occurred.

..... [1]

- (d) Silicon shows the same kind of bonding and structure as diamond.

- (i) State the type of bonding and structure shown by silicon.

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

- (iii) Solid Mg_2Si reacts with dilute hydrochloric acid to form gaseous SiH_4 and a solution of magnesium chloride.

Write an equation to show the reaction of solid Mg_2Si with dilute hydrochloric acid.

Include state symbols.

..... [2]

- (iv) Predict the shape of the SiH_4 molecule.

..... [1]

March 2018 9701/22 · Q2 (a)(i), (a)(ii), (b)(ii), (c)(i), (d)(i), (d)(iii), (d)(iv) (cont.)

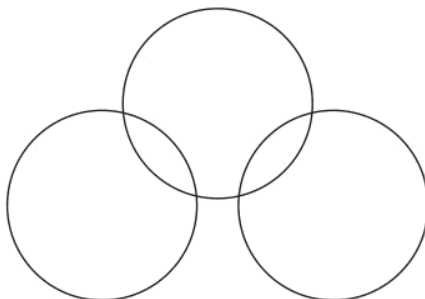
- (b) Calcium ethanedioate is formed when calcium reacts with ethanedioic acid, $(CO_2H)_2$. The compound contains one cation and one anion.

- (i) Draw the 'dot-and-cross' diagram of the cation present in calcium ethanedioate. Show **all** electrons.

[1]

March 2018 9701/22 · Q3 (b)(i)

- (f) SO_2 reacts with water to form sulfurous acid.
Sulfurous acid is a weak Brønsted-Lowry acid, while sulfuric acid is a strong Brønsted-Lowry acid.
- (i) Complete the 'dot-and-cross' diagram to show the bonding in a molecule of SO_2 . Show outer electrons only.



[1]

May/June 2018 9701/21 · Q1 (f)(i)

- (b) One of the cations in ammonium iron(II) sulfate is the ammonium ion, NH_4^+ .
- (i) Draw a 'dot-and-cross' diagram of an ammonium ion. Show outer shell electrons only.
- Use $\times$ to show electrons from nitrogen.
Use $\bullet$ to show electrons from hydrogen.

[2]

- (ii) Suggest the shape of an ammonium ion and predict the bond angle.

shape

bond angle

[2]

May/June 2018 9701/22 · Q2 (b)(i), (b)(ii)

- (d) Reaction 2 is carried out by adding a mixture of HCN and NaCN to **W**.
The product, **X**, is formed as a mixture of two isomers.

- (i) Complete the mechanism for this reaction.

Include the structure of the intermediate formed and all necessary charges, dipoles, lone pairs and curly arrows.



[4]

May/June 2018 9701/22 · Q4 (d)(i)

- (a) Draw a diagram to show the shape of the molecule of each of the oxides, SO_3 and Cl_2O .
Name each shape.
In SO_3 each oxygen atom forms a double bond with the sulfur atom.



[4]

- (b) (i) Explain why the melting point of MgO is higher than that of Na_2O .

.....

.....

.....

.....

..... [2]

- (ii) Explain why the melting point of SiO_2 is much higher than that of SO_3 .

.....

.....

.....

.....

.....

..... [2]

- (ii) Explain why the gradients of the SO_2 and O_2 lines decrease with time.

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

- (iii) Explain why all three lines become horizontal.

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

- (iv) Suggest a reason why the initial gradient of the SO_2 line is steeper than that of the O_2 line.

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

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[Turn over**4**

- (ii) Calculate the amount, in moles, of $\text{SO}_2(\text{g})$ and $\text{O}_2(\text{g})$ in the equilibrium mixture.

 $\text{SO}_2(\text{g}) = \dots\dots\dots \text{mol}$ $\text{O}_2(\text{g}) = \dots\dots\dots \text{mol}$
[2]

May/June 2018 9701/23 · Q1 (a), (b)(i), (b)(ii), (c)(ii), (c)(iii), (c)(iv), (d)(ii) (cont.)

- (ii) F_2 and HCl are both covalent molecules.

Suggest why the boiling point of HCl is higher than that of F_2 .

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

- (iii) Explain why CaF_2 has a very high boiling point.

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

- (c) HOF is the only known molecule that contains only the elements hydrogen, oxygen and fluorine.

- (i) Draw a 'dot-and-cross' diagram to represent the bonding in a molecule of HOF.

Show the outer shell electrons only.

[2]

- (iv) Pure HF is a colourless liquid at 273 K. The liquid contains HF molecules that have strong hydrogen bonds between them.

Draw a fully labelled diagram to suggest how a hydrogen bond can form between two HF molecules.

[3]

- (a) Draw a 'dot-and-cross' diagram to show the arrangement of outer electrons present in a formula unit of Mg_2Si . Assume magnesium silicide is an ionic compound.

[2]

- (b) When solid Mg_2Si is added to water, silane gas, SiH_4 , and a solution of magnesium hydroxide are produced.

Construct the equation for this reaction. Include state symbols.

[2]

- (c) Suggest, with reference to structure and bonding, why SiH_4 is a gas at room temperature.

[2]

- (d) The table shows the electronegativity values of carbon, hydrogen and silicon.

element	carbon	hydrogen	silicon
electronegativity	2.5	2.1	1.8

- (i) C–H and Si–H bonds have weak dipoles.

Use the electronegativity values in the table to show the polarity of the C–H and Si–H bonds.



[2]

- (ii) Explain why methane, CH₄, has no overall dipole moment.

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

- (e) SiH₄ reacts in air without heating but CH₄ must be ignited before combustion occurs.



Suggest, with reference to bond energies from the *Data Booklet*, why SiH₄ reacts in air without heating but CH₄ must be ignited.

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

- (f) Silicon dioxide reacts with hot, concentrated sodium hydroxide.

- (i) Identify the **two** products formed during this reaction.

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

- (ii) Describe the behaviour of the silicon dioxide during this reaction.

..... [1]

[Total: 15]

6

May/June 2019 9701/21 · Q2 (a), (b), (c), (d)(i), (d)(ii), (e), (f)(i), (f)(ii) (cont.)

(b) Predict the values for the bond angles a and b shown in the diagram.

a

b [2]

May/June 2019 9701/21 · Q4 (b)

(iv) For H_3O^+ , predict its shape and the H–O–H bond angle.

shape

bond angle [2]

[Total: 11]

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5

May/June 2019 9701/22 · Q2 (c)(iv)

(iv) Explain, in terms of electronegativity, why the bonding in NaCl is different from the bonding in SiCl_4 .

.....

.....

.....

..... [3]

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[Turn over**6**

May/June 2019 9701/22 · Q3 (a)(iv)

- (b) (i) Explain why the boiling point of SiO_2 is much higher than the boiling point of SO_3 .

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

- (c) Selenium is a Group 16 element which shows similar chemical reactions to sulfur.

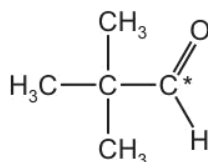
- (i) Selenium reacts with fluorine to form SeF_6 molecules.

Predict the shape of a molecule of SeF_6 .

..... [1]

Oct/Nov 2019 9701/21 · Q2 (b)(i), (c)(i)

- (ii) State the hybridisation of the carbon atom labelled with an asterisk, *.



..... [1]

- (ii) **A**, $(\text{CH}_3)_3\text{CCO}_2\text{H}$, is a solid at room temperature.

B, $\text{CH}_3\text{CO}_2(\text{CH}_2)_2\text{CH}_3$, is an isomer of **A**. **B** is a liquid at room temperature.

Explain the difference in the physical states of **A** and **B**, with reference to any intermolecular forces that may exist.

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

Oct/Nov 2019 9701/21 · Q4 (a)(ii), (b)(ii)

- (iii) The peroxide ion, O_2^{2-} , has a single covalent bond between the two oxygen atoms. Each oxygen atom carries a negative charge.

Draw a 'dot-and-cross' diagram for the peroxide ion. Show outer electrons only.

[2]

[Total: 11]

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[Turn over

8

Oct/Nov 2019 9701/22 · Q2 (c)(iii)

- (ii) Draw the three-dimensional shape of the ammonium ion, NH_4^+ . Give the bond angle.

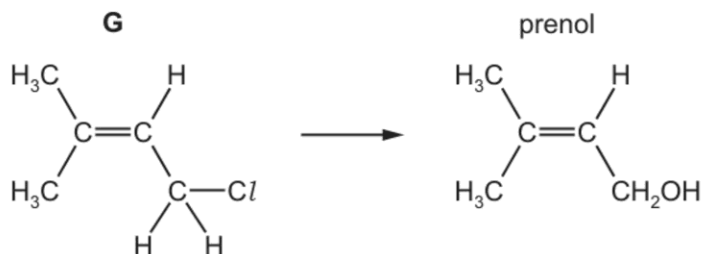
bond angle = ° [1]

Oct/Nov 2019 9701/22 · Q3 (b)(ii)

- (a) Prenol can be formed by the reaction of **G** with NaOH(aq).

Complete the diagram to show the mechanism of the reaction between **G** and NaOH(aq) to form prenol.

Include all relevant charges, partial charges, lone pairs and curly arrows.



[2]

- (ii) Give the structural formula of **K** and **L**.

..... [1]

- (ii) Isoprenol is a liquid.

Ni acts as a catalyst for reaction 1.

Identify the type of catalysis shown by Ni in reaction 1.

..... [1]

- (ii) State the reagent(s) needed for reaction **II**.

..... [1]

- (iii) Name the type of reaction that occurs in reaction **III**.

..... [1]

Oct/Nov 2019 9701/22 · Q4 (a), (b)(ii), (d)(ii), (e)(ii), (e)(iii), (e)(iv) (continued ·)

(iv) The yield of reaction **I** is very low.

Explain why.

.....

.....

..... [2]

[Total: 17]

14

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(d) Beryllium oxide reacts with hydrochloric acid to form molecules of BeCl_2 .

Deduce the bond angle in BeCl_2 .

..... [1]

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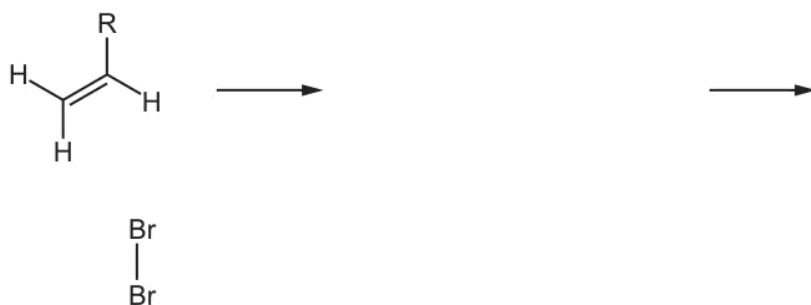
March 2020 9701/22 · Q1 (d)

(iii) Unsaturated acids are often brominated before being added to soft drinks.

Complete the mechanism for the addition of Br_2 to 4-pentenoic acid.

- Include the structures of the intermediate and the product of the reaction.
- Include all charges, partial charges, lone pairs and curly arrows.

In the mechanism, R has been used to represent $(\text{CH}_2)_2\text{COOH}$.



[4]

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12

[Turn over

March 2020 9701/22 · Q3 (c)(iii)

(c) Complete the table to name the shape and give the bond angle of each species.

	name of shape	bond angle / °
CO ₂		
NH ₃		
H ₂ O		

[3]

[Total: 6]

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8

[Turn over

May/June 2020 9701/21 · Q4 (c)

(ii) From the list, identify **two** species which can attack the π bond in ethene.

..... [1]

May/June 2020 9701/21 · Q5 (a)(ii)

- (d) When gallium is heated in excess chlorine, gallium trichloride, GaCl_3 , is made.

Draw the shape of the gallium trichloride molecule and suggest the Cl-Ga-Cl bond angle.

shape of molecule

bond angle

[2]

May/June 2020 9701/22 · Q1 (d)

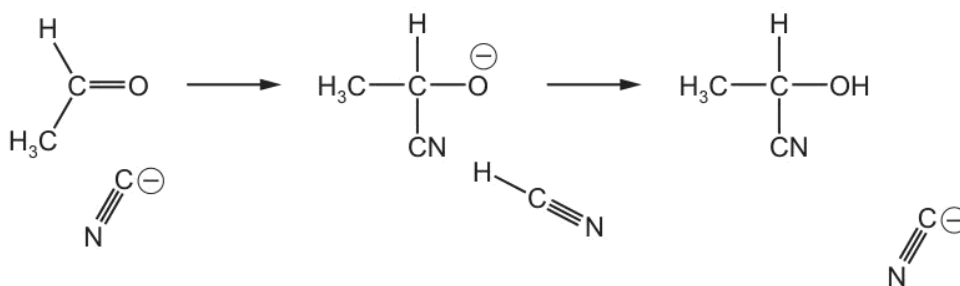
- (b) Draw a 'dot-and-cross' diagram to show the arrangement of outer electrons in a molecule of ammonia.

[1]

May/June 2020 9701/22 · Q2 (b)

- (b) In reaction 3 the organic molecule reacts with HCN and a KCN catalyst.

- (i) Complete the diagram to show the mechanism of the reaction occurring. Include all relevant dipoles, lone pairs and curly arrows in your answer.



[3]

May/June 2020 9701/22 · Q5 (b)(i)

- (ii) In terms of σ and π bonds, describe any similarities and differences in the type of carbon-carbon bonds in **B** and the type of carbon-carbon bonds in hexane.

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

[Total: 12]

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[Turn over

10

May/June 2020 9701/23 · Q4 (d)(ii)

- (d) Chlorine forms several oxides, including Cl_2O , ClO_2 and Cl_2O_6 .

- (i) Draw a 'dot-and-cross' diagram of Cl_2O . Show outer-shell electrons only.

[1]

Oct/Nov 2020 9701/21 · Q2 (d)(i)

- (ii) At 1000 °C, aluminium chloride exists as $\text{AlCl}_3(\text{g})$.

State the bond angle in $\text{AlCl}_3(\text{g})$.

..... ° [1]

- (iv) LiAlH_4 decomposes slowly to form $\text{LiAl}(\text{s})$ and $\text{H}_2(\text{g})$.



$\text{LiAl}(\text{s})$ shows metallic bonding.

Describe metallic bonding.

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

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9

Oct/Nov 2020 9701/21 · Q3 (a)(ii), (a)(iv)

- (iii) The table shows the electronegativity values for hydrogen, fluorine and iodine.

element	electronegativity value
H	2.1
F	4.0
I	2.5

Explain, in terms of intermolecular forces, why HI has a lower boiling point than HF.

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

Oct/Nov 2020 9701/21 · Q4 (a)(iii)

- (d) Explain why phosphorus(V) oxide has a low melting point of approximately 300 °C but magnesium oxide has a high melting point of approximately 2850 °C.

.....

.....

.....

.....

.....

..... [3]

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5

Oct/Nov 2020 9701/22 · Q2 (d)

- (d) NCl_3 is a yellow liquid that can be used to bleach flour.

- (i) Predict the shape of the NCl_3 molecule and the Cl-N-Cl bond angle.

shape

bond angle

[2]

Oct/Nov 2020 9701/22 · Q3 (d)(i)

- (e) Aluminium reacts with chlorine to form aluminium chloride.

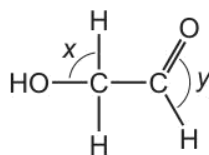
Aluminium chloride can exist as the gaseous molecule $Al_2Cl_6(g)$. This molecule contains coordinate bonds.

- (i) Draw a diagram that clearly shows all the types of bond present in $Al_2Cl_6(g)$.

[2]

March 2021 9701/22 · Q2 (e)(i)

- (a) Predict the bond angles labelled x and y in the diagram of hydroxyethanal.



$x = \dots\dots\dots^\circ$

$y = \dots\dots\dots^\circ$
[2]

- (ii) State and explain any other necessary conditions for this reaction to be successful.

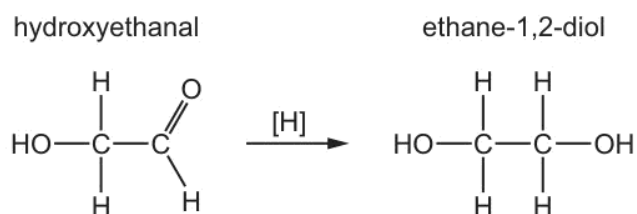
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.....
..... [2]

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9701/22/F/M/21
12

[Turn over

- (d) Hydroxyethanal can be reduced to ethane-1,2-diol, $(\text{CH}_2\text{OH})_2$, as shown.



- (i) Write an equation for the reduction of hydroxyethanal to $(\text{CH}_2\text{OH})_2$.

Use $[\text{H}]$ to represent an atom of hydrogen from the reducing agent.

..... [1]

- (ii) Identify a reagent for this reduction reaction.

..... [1]

- (iii) $(\text{CH}_2\text{OH})_2$ also forms when an alkene **A** reacts with cold, dilute, acidified manganate(VII) ions.

Name **A**.

..... [1]

[Total: 10]

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March 2021 9701/22 · Q4 (a), (c)(ii), (d)(i), (d)(ii), (d)(iii) (cont.)

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

	C	N	O
electronegativity	2.5	3.0	3.5

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

	N ₂	CO
number of electrons per molecule		
type(s) of intermolecular (van der Waals') force		

[2]

- (b) N₂(g) is less reactive than CO(g) even though N₂(g) has a lower bond energy than CO(g).

Suggest why CO(g) is more reactive than N₂(g).

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

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

[3]

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

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

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

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

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

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

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

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

(ii) Draw a 'dot-and-cross' diagram of the CS_2 molecule.

[2]

(iii) Suggest the bond angle in a molecule of CS_2 .

..... [1]

Oct/Nov 2021 9701/21 · Q1 (a)(ii), (a)(iii)

- (a) Phosphorus has several allotropes. Details of two allotropes are given.

allotrope of phosphorus	formula	melting point/°C
white	P ₄	44
red	P	590

- (i) White phosphorus and red phosphorus both have covalent bonding.

Suggest the types of structure shown by white phosphorus (P₄) and red phosphorus (P).

Explain why red phosphorus (P) has a higher melting point than white phosphorus (P₄).

structure of P₄

structure of P

explanation

.....

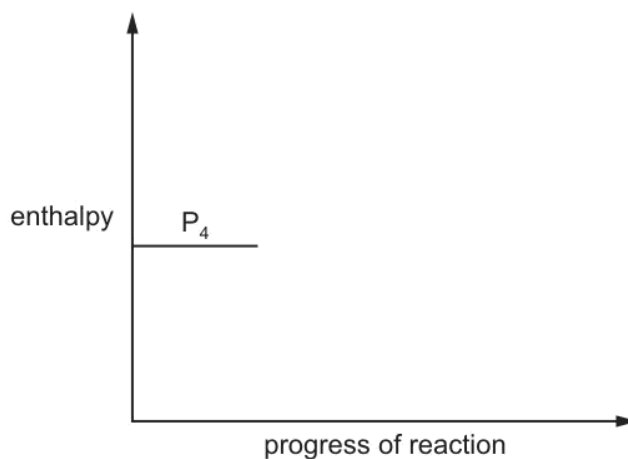
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[3]

- (ii) Red phosphorus (P) forms when white phosphorus (P₄) is exposed to sunlight.

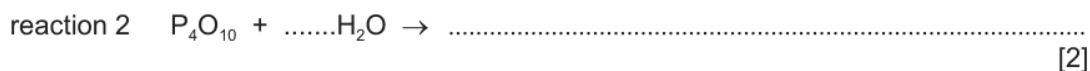
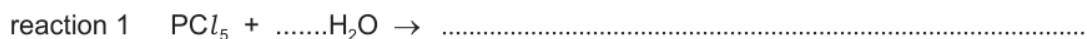


Use this information to draw a reaction pathway diagram to show the formation of red phosphorus (P) from white phosphorus (P₄).



[1]

- (ii) Deduce the identity of **Q** and hence construct chemical equations for reactions 1 and 2.

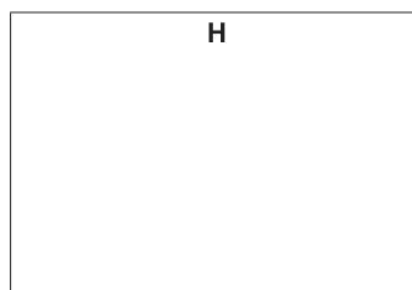
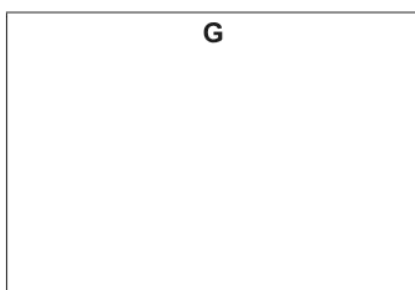


- (ii) State the types of reaction that occur in stages 1 and 2.

stage 1

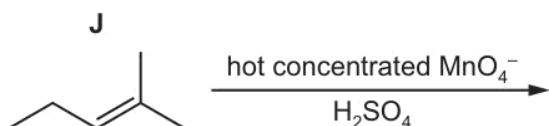
stage 2 [2]

- (iii) Draw the structures of **G** and **H** in the boxes provided.



[2]

- (d) Identify the organic products formed when compound **J**, shown below, is heated with hot concentrated acidified manganate(VII) ions.



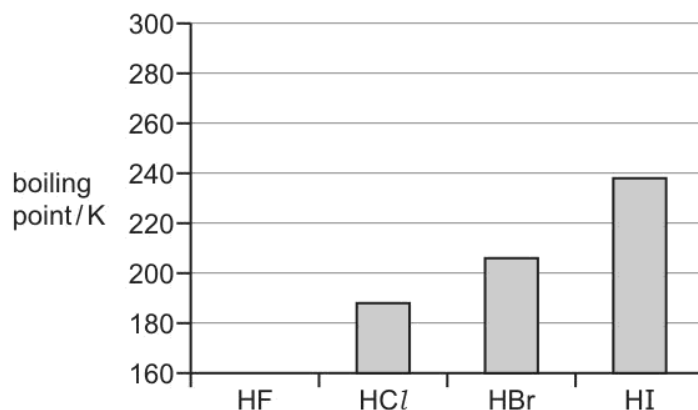
[2]

[Total: 14]

- (a) (i) Explain why HI has a higher boiling point than HCl and HBr.

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

- (ii) The bar chart shows the boiling points of HCl, HBr and HI. The boiling point of HF is not shown.



Hydrogen bonds form between HF molecules.

Draw a bar on the bar chart to predict the boiling point of HF.

Explain your answer.

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

Oct/Nov 2021 9701/22 · Q1 (a)(i), (a)(ii), (c)(iii), (d)(i), (e), (f)(i), (f)(ii), (f)(iii), (f)(iv), (g)(i), (g)(ii) (continued ·)

- (iii) State how the value of K_p would change, if at all, if the reaction were carried out at 100 °C rather than 200 °C.

Explain your answer.

.....

.....

.....

..... [2]

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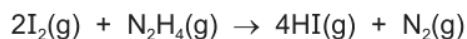
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- (d) HI reacts with oxygen to form iodine and water.

- (i) Construct an equation for the reaction of HI with oxygen.

..... [1]

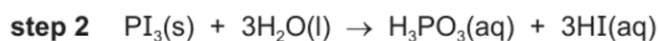
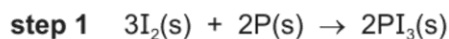
(e) HI(g) can also be formed by the reaction of I₂(g) with hydrazine, N₂H₄(g).



State the change in pressure that would occur when 2 mol I₂(g) fully reacts with 1 mol N₂H₄(g) in a sealed container at constant temperature. Explain your answer.

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

(f) In the laboratory, HI(aq) can be formed in a two-step process.



(i) Draw a 'dot-and-cross' diagram of a PI_3 molecule.

[2]

(ii) Name the type of reaction in **step 2**.

..... [1]

(iii) $\text{H}_3\text{PO}_3(\text{aq})$ and $\text{HI}(\text{aq})$ are both strong Brønsted–Lowry acids.

Give the meaning of the term *strong Brønsted–Lowry acid*.

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

(iv) Give the formula of the conjugate base of H_3PO_3 .

..... [1]

6

(g) HI(g) reacts with propene, $\text{CH}_3\text{CH}=\text{CH}_2(\text{g})$ to form a mixture of 1-iodopropane and 2-iodopropane.

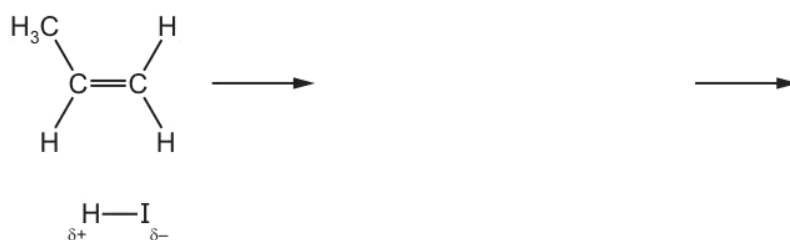
(i) Identify which of 1-iodopropane and 2-iodopropane is the major product of this reaction.

Explain your answer.

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

(ii) Complete the diagram to show the mechanism of the reaction between HI and $\text{CH}_3\text{CH}=\text{CH}_2$ that forms the major product identified in (g)(i).

Include curly arrows, lone pairs of electrons and charges as necessary.



[3]

[Total: 26]

7

Oct/Nov 2021 9701/22 · Q1 (a)(i), (a)(ii), (c)(iii), (d)(i), (e), (f)(i), (f)(ii), (f)(iii), (f)(iv), (g)(i), (g)(ii) (cont.)

(ii) State the hybridisation of the two carbon atoms between which the pi (π) bond forms.

..... [1]

Oct/Nov 2021 9701/22 · Q3 (c)(ii)

- (a) Describe how the triple covalent bond forms in a $\text{N}_2(\text{g})$ molecule. Refer to orbital overlap and hybridisation in your answer.

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

- (b) Nitrogen oxides, NO_2 and NO , are produced in internal combustion engines. Release of these gases into the atmosphere leads to the formation of photochemical smog.

- (i) Outline how nitrogen oxides are involved in the formation of photochemical smog.

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

- (ii) Construct an equation to demonstrate how a catalytic converter reduces the amount of nitrogen oxide gases released into the atmosphere.

..... [1]

- (c) $\text{N}_2(\text{g})$ is very unreactive. It is difficult to make ammonia, $\text{NH}_3(\text{g})$, directly from its elements but it can be made from $\text{NH}_4\text{Cl}(\text{s})$.

Identify a reagent and the conditions required to make $\text{NH}_3(\text{g})$ from $\text{NH}_4\text{Cl}(\text{s})$.

..... [1]

(d) 25 cm^3 of $0.10\text{ mol dm}^{-3}\text{ HCl(aq)}$ is added to a beaker and its pH is recorded.

50 cm^3 of $0.10\text{ mol dm}^{-3}\text{ NH}_3\text{(aq)}$ is added to the HCl(aq) in 5 cm^3 portions.

The pH of the mixture is monitored until all the $\text{NH}_3\text{(aq)}$ is added.

HCl is a strong Brønsted-Lowry acid.

(i) Describe what is meant by a strong Brønsted-Lowry acid.

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

(ii) NH_3 is a weak base.

Construct an equation that shows the behaviour of NH_3 as a weak Brønsted-Lowry base when dissolved in water.

..... [1]

(iii) On Fig. 2.1 sketch a graph to show the change in pH which occurs when HCl(aq) is titrated with $\text{NH}_3\text{(aq)}$ as described in (d).

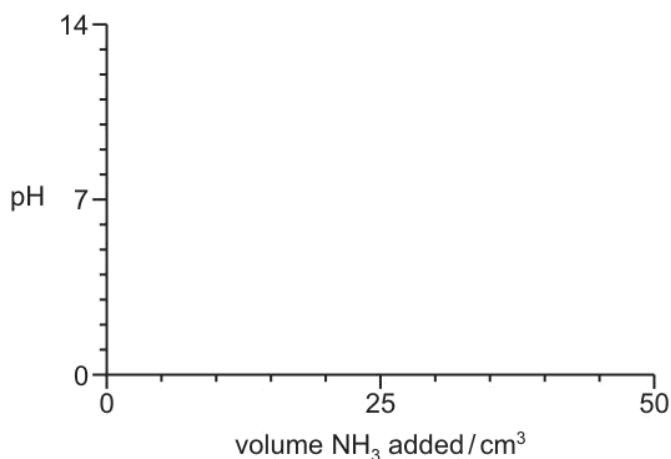


Fig. 2.1

[2]

[Total: 12]

7

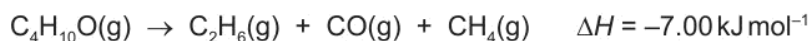
May/June 2022 9701/21 · Q2 (a), (b)(i), (b)(ii), (c), (d)(i), (d)(ii), (d)(iii) (cont.)

(b) Draw a dot-and-cross diagram to show the arrangement of outer electrons in RaCl_2 .

[1]

May/June 2022 9701/22 · Q2 (b)

- (a) When **G**, $\text{C}_4\text{H}_{10}\text{O}$, 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]

- (ii) Calculate the bond energy of $\text{C}\equiv\text{O}$ using the bond energy values in Table 3.1 and the enthalpy change, ΔH , for the thermal decomposition of **G**. Show your working.

Table 3.1

bond	bond energy / kJ mol^{-1}
C–C	350
C–O (in G)	360
C–H	410

bond energy ($\text{C}\equiv\text{O}$) = kJ mol^{-1}
[2]

- (iv) Thermal decomposition of **G** in the presence of I_2 affects the activation energy, E_a , for the reaction. Table 3.2 shows E_a for the thermal decomposition of **G** with and without I_2 .

Table 3.2

reaction	E_a (with I_2)/kJ mol ⁻¹	E_a /kJ mol ⁻¹
$C_4H_{10}O(g) \rightarrow C_2H_6(g) + CO(g) + CH_4(g)$	143	224

State what effect adding I_2 to the reaction mixture has on the value of K_c .
Explain your answer.

.....

 [2]

- (v) Fig. 3.2 shows the Boltzmann distribution of energies for molecules of **G** at constant temperature, $T^\circ\text{C}$.

Sketch, on Fig. 3.2, the Boltzmann distribution of energies for molecules of **G** at a higher temperature, $(T+100)^\circ\text{C}$.

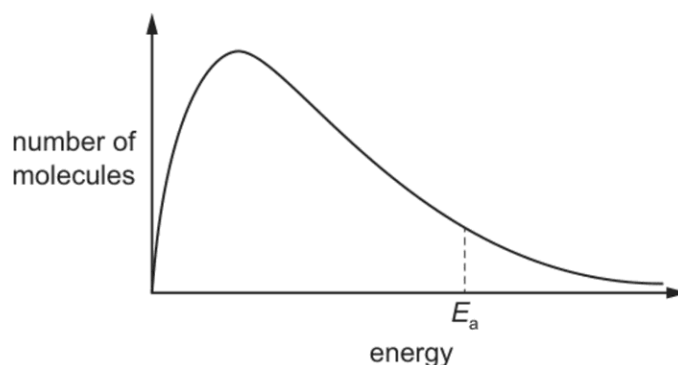


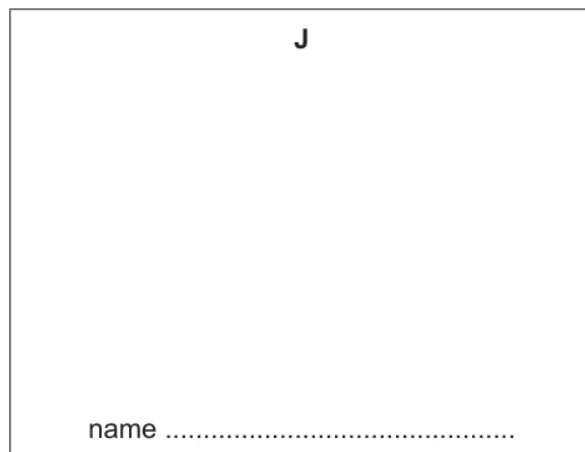
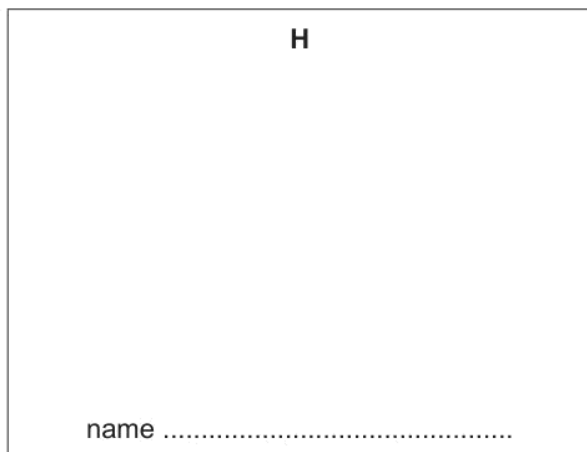
Fig. 3.2

[2]

- (ii) Identify the type of structural isomerism shown between **H** and **J** using the information in Table 3.3.

..... [1]

(iii) Draw a possible structure for **H** and for **J**. State the systematic name for each structure.



[3]

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9

May/June 2022 9701/23 · Q3 (a)(i), (a)(ii), (a)(iv), (a)(v), (b)(ii), (b)(iii) (cont.)

- 4 (a) 2-methylpropene reacts with HCl(g) at room temperature. The major organic product is 2-chloro-2-methylpropane.

- (i) Complete Fig. 4.1 to show the structure of the intermediate and mechanism for this reaction. Include charges, dipoles, lone pairs of electrons and curly arrows as appropriate.



Fig. 4.1

[3]

- (ii) Explain why, in this reaction, 2-chloro-2-methylpropane is produced at a higher yield than 1-chloro-2-methylpropane.

.....

 [2]

- (iv) When pure **T** is added to alkaline $\text{I}_2(\text{aq})$, a yellow precipitate and an anion, **L**, are made. Identify the anion **L**.

..... [1]

May/June 2022 9701/23 · Q4 (a)(i), (a)(ii), (b)(iv)

- (b) **C1** has melting point -94°C and boiling point $+49^\circ\text{C}$.

Explain these properties by referring to the type of van der Waals' forces between molecules.

.....

 [2]

- (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]

- (ii) When $\text{NH}_4^+(\text{aq})$ is heated with $\text{NaOH}(\text{aq})$, a pungent gas is produced.

Write an ionic equation for this reaction.

..... [1]

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3

- (iii) The nitrogen atom in NH_4^+ is sp^3 hybridised. sp^3 orbitals form from the mixing of one 2s and three 2p orbitals.

Sketch the shapes of a 2s and a 2p_x orbital on the axes in Fig. 1.1.

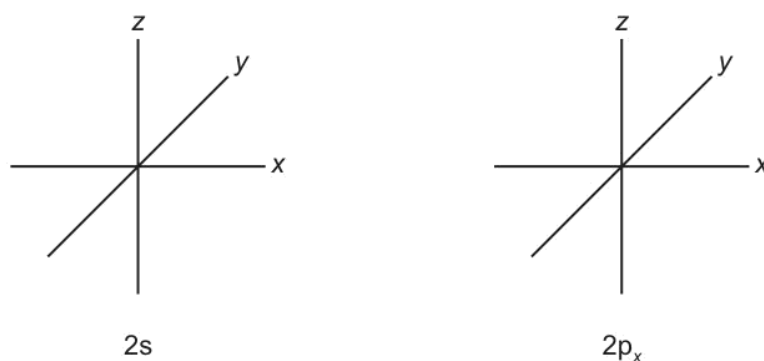


Fig. 1.1

[2]

- (d) There are many naturally occurring hydrated compounds that contain the anion PO_4^{3-} .

- (i) Name the anion PO_4^{3-} .

..... [1]

- (ii) Struvite is a soft hydrated mineral with $M_r = 245.3$. The anhydrous form of the mineral has the formula NH_4MgPO_4 .

Calculate the number of molecules of water of crystallisation in struvite.

Give your answer to the nearest integer. Show your working.

number of molecules of water of crystallisation = [2]

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[Turn over

4

- (ii) 2-bromo-2-methylpropane is a tertiary bromoalkane.

Define tertiary bromoalkane.

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

Oct/Nov 2022 9701/22 · Q1 (a), (c)(ii), (c)(iii), (d)(i), (d)(ii), (e)(ii) (cont.)

(a) From this list, identify:

(i) all the chlorides that have giant ionic structures in the solid state

..... [1]

(ii) all the chlorides that react vigorously with water to form strongly acidic solutions

..... [1]

(iii) the chloride that dissolves in water to form a neutral solution

..... [1]

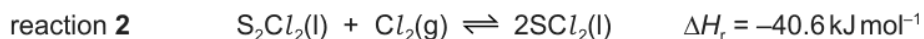
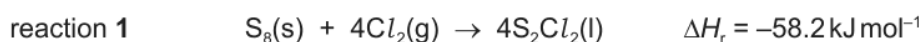
(iv) the chloride formed from the **element** with the highest melting point.

..... [1]

(ii) Draw the structure of the organic product formed in the reaction of an excess of PCl_5 with butane-1,3-diol.

[1]

- (d) Sulfur, S_8 , reacts with chlorine to form several different chlorides. The most common are S_2Cl_2 and SCl_2 . SCl_2 forms when sulfur reacts with an excess of chlorine.



- (i) SCl_2 is a cherry-red liquid that reacts vigorously with water to form an acidic solution.

Use this information to deduce the bonding and structure shown by SCl_2 .
Explain your answer.

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

- (v) Suggest a value for the $Cl-S-S$ bond angle in isomer I. Explain your answer.

bond angle = °

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

- (vi) Draw a dot-and-cross diagram to show the bonding in isomer II. Show outer shell electrons only.

[2]

[Total: 18]

Question 4 starts on the next page.

10

Oct/Nov 2022 9701/23 · Q3 (a)(i), (a)(ii), (a)(iii), (a)(iv), (c)(ii), (d)(i), (d)(v), (d)(vi) (cont.)

- (e) Te reacts with F_2 at $150^\circ C$ to form TeF_x . Molecules of TeF_x are octahedral with bond angles of 90° .

Explain why TeF_x is octahedral with bond angles of 90° .

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

May/June 2023 9701/21 · Q1 (e)

- (iii) Complete Table 4.1 to show the number of sp^2 and sp^3 hybridised carbon atoms that are present in a molecule of **V**.

Table 4.1

type of hybridisation	sp^2	sp^3
number of carbon atoms in V		

[2]

May/June 2023 9701/21 · Q4 (b)(iii)

- (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]

- (c) Complete Table 3.1 to show the number of sigma bonds (σ) and pi bonds (π) present in a molecule of **X**.

Table 3.1

type of bond	number of bonds in X
sigma (σ)	
pi (π)	

[2]

[Total: 8]

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7

May/June 2023 9701/22 · Q3 (c)

- (a) Use the bond energy values in Table 4.1 to calculate the enthalpy change, ΔH_r , for reaction 1.

Table 4.1

bond	bond energy / kJ mol^{-1}
C—C	350
C=C	610
C $\equiv$ C	840
C—H	410
C—O	360
C=O	740
O—H	460

$$\Delta H_r = \dots\dots\dots \text{kJ mol}^{-1} \quad [2]$$

- (iii) Complete Fig. 4.2 to show the mechanism for step 3 of reaction 1. Include charges, dipoles, lone pairs of electrons and curly arrows, as appropriate.

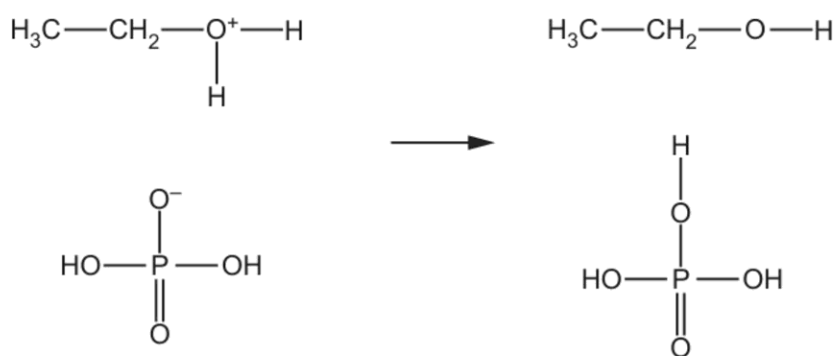


Fig. 4.2

[2]

- (iv) Describe how a catalyst affects a reaction. Explain your answer.

.....

..... [2]

- (v) Use Fig. 4.1 and Fig. 4.2 to justify why H_3PO_4 is described as a catalyst in reaction 1.

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

- (d) Describe the covalent bonds present between the carbon atoms in an ethene molecule by completing Table 4.2.

Table 4.2

	sigma (σ)	pi (π)
type of orbitals involved in bond		
how the orbitals overlap		

[2]

[Total: 15]

[Turn over]

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10

May/June 2023 9701/22 · Q4 (a), (c)(iii), (c)(iv), (c)(v), (d) (cont.)

- (a) Bismuth has metallic bonding.

Draw a labelled diagram to show the metallic bonding in bismuth.

[1]

- (ii) Bi_2O_3 is a yellow insoluble solid that melts at 1090 K. The molten compound conducts electricity.

Deduce the structure and bonding of Bi_2O_3 . Explain your answer.

.....

 [2]

- (ii) Compound X forms when methylbut-2-ene reacts with KMnO_4 .

State the essential conditions for this reaction.

..... [1]

March 2024 9701/22 · Q1 (a), (b)(ii), (d)(ii)

- (c) An excess of Cl_2 reacts with phosphorus to form PCl_5 .

- (i) PCl_5 is a simple molecule in the gas phase.

It also exists in a solid form as two ions, PCl_4^+ and PCl_6^- .

Complete Table 2.2 to identify the shapes of each of these species.

Table 2.2

species	PCl_5	PCl_4^+	PCl_6^-
shape		tetrahedral	

[2]

March 2024 9701/22 · Q2 (c)(i)

(d) The N_2F_2 molecule has a double covalent bond between its nitrogen atoms. This consists of a σ and a π bond.

(i) Complete Fig. 3.2 to show the dot-and-cross diagram for N_2F_2 .

Show outer electrons only.

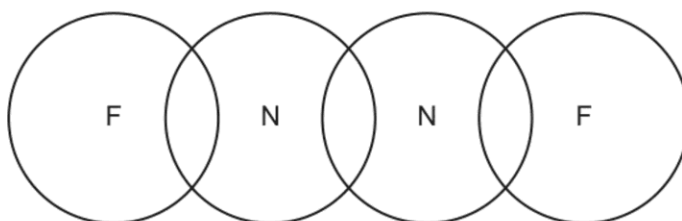


Fig. 3.2

[2]

(ii) Deduce the hybridisation of the N atoms in N_2F_2 .

..... [1]

(iii) Draw a diagram of the π bond between the N atoms in N_2F_2 and describe how it forms.

.....
.....

[2]

[Total: 15]

March 2024 9701/22 · Q3 (d)(i), (d)(ii), (d)(iii) (cont.)

- (b) A molecule of SCl_2 contains two S–Cl covalent bonds.
- (i) Complete the dot-and-cross diagram in Fig. 2.1 to show the arrangement of the outer electrons in a molecule of SCl_2 .
- Use × to show electrons from the chlorine atoms.
Use • to show electrons from the sulfur atom.

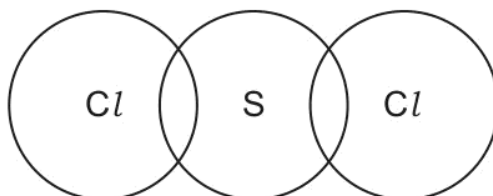


Fig. 2.1

[2]

- (ii) Predict the shape of, and bond angle in, a molecule of SCl_2 by using VSEPR theory.

shape

bond angle

[2]

- (d) Boron nitride is a white solid that melts above 2900°C .

Fig. 2.2 shows part of the lattice structure of a crystal of boron nitride.

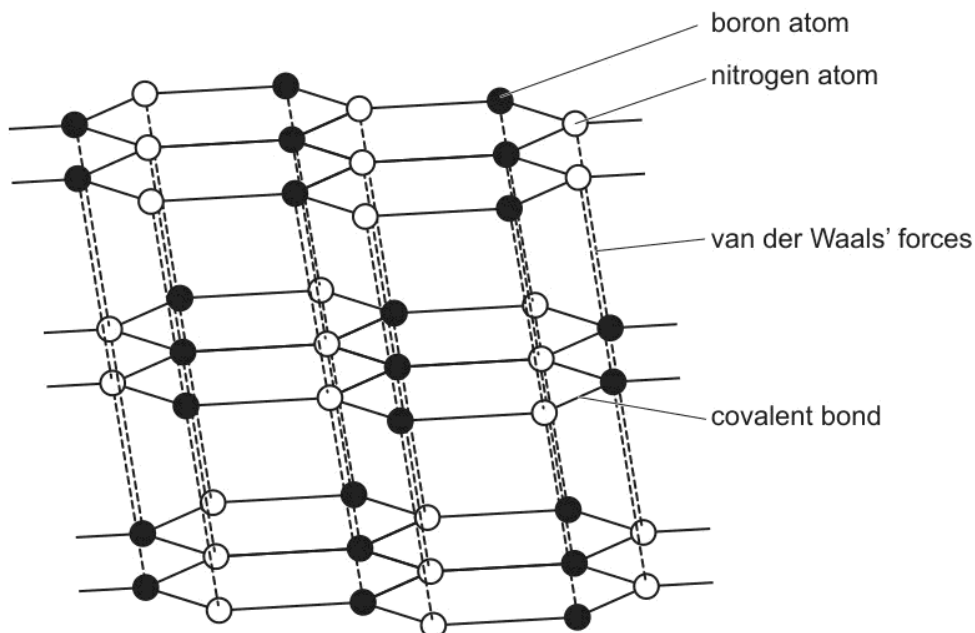


Fig. 2.2

- (i) Use Fig. 2.2 to deduce the empirical formula of boron nitride.

..... [1]

(a) Define covalent bond.

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

(b) A C=C bond in an alkene is made from a σ bond and a π bond.

(i) Identify the hybridisation of the carbon atoms in a C=C bond in an alkene.

..... [1]

(ii) Draw labelled diagrams to show, in terms of orbital overlap, how the σ and π bonds are made in a C=C bond.

σ bond

π bond

[2]

May/June 2024 9701/21 · Q5 (a), (b)(i), (b)(ii)

(d) $\text{SCN}^-(\text{aq})$ is colourless.

Complete the dot-and-cross diagram in Fig. 3.1 to show the arrangement of outer electrons in an SCN^- ion.

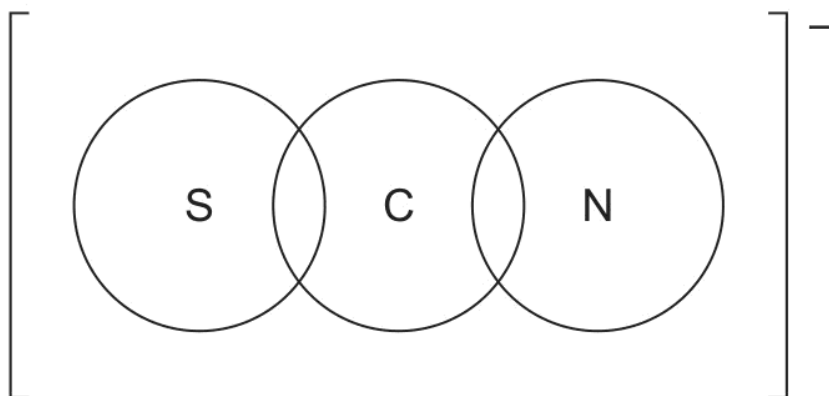


Fig. 3.1

[2]

[Total: 12]



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May/June 2024 9701/22 · Q3 (d) (cont.)

- (e) (i) Both σ and π bonds are present in a molecule of **E** as a result of different types of hybridisation in the carbon atoms.

Complete Table 4.2 to show the number of carbon atoms with each type of hybridisation in a molecule of **E**.

Table 4.2

	number of carbon atoms		
	sp hybridised	sp ² hybridised	sp ³ hybridised
E			

[2]

- (ii) Describe the essential feature of an unbranched hydrocarbon that causes its molecules to show stereoisomerism. Explain how this feature leads to stereoisomerism.

.....

.....

..... [3]

[Total: 15]



12

May/June 2024 9701/22 · Q4 (e)(ii)

Turn over

- 1 (a) (i) Explain the lack of reactivity of nitrogen gas, $\text{N}_2(\text{g})$.

.....

 [2]

- (ii) Covalent bonds can be σ bonds or π bonds.

Complete Table 1.1 to show the number of σ and π bonds in a molecule of N_2 and to describe how the orbitals overlap to form σ and π bonds.

Table 1.1

	σ bond	π bond
number of bonds in N_2		
how the orbitals overlap		

[4]

- (c) Separate samples of aluminium oxide, Al_2O_3 , and phosphorus(V) oxide, P_4O_{10} , react with an excess of $\text{NaOH}(\text{aq})$ at room temperature.

- (i) Give the state of Al_2O_3 and P_4O_{10} at room temperature.

Al_2O_3
 P_4O_{10} [1]

- (ii) Write an equation for the reaction of each oxide with an excess of $\text{NaOH}(\text{aq})$ at room temperature.

$\text{Al}_2\text{O}_3 +$
 $\text{P}_4\text{O}_{10} +$ [2]

May/June 2024 9701/23 · Q1 (a)(ii), (c)(i), (c)(ii), (d)(ii) (continued ·)

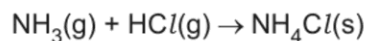
- (ii) Calcium oxide can be made from calcium carbonate in a single-step reaction.

Identify the type of reaction that occurs.

..... [1]

[Total: 13]

- 4 (a) $\text{NH}_3(\text{g})$ reacts with $\text{HCl}(\text{g})$ to produce $\text{NH}_4\text{Cl}(\text{s})$, as shown.



Draw a diagram to show the ionic, covalent and coordinate bonding present in a formula unit of NH_4Cl .

[2]

- (b) An exothermic reaction occurs when $\text{NH}_4^+(\text{aq})$ is added to $\text{OH}^-(\text{aq})$.

- (i) Identify the type of reaction.

..... [1]

- (ii) Construct an ionic equation for the reaction of NH_4^+ and OH^- .

..... [1]

- (ii) Suggest which species, NH_3 or OH^- , is more reactive during these reactions. Explain your answer.

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

- (iii) Give the systematic name for the organic product $\text{CH}_3\text{CH}(\text{NH}_2)\text{C}_2\text{H}_5$.

..... [1]

- (a) Table 3.1 shows some properties of two Group 14 elements, C and Sn, in their standard states. The table is incomplete.

Table 3.1

	C (graphite)	Sn
state and appearance in standard state	grey shiny solid	silvery solid
electrical conductivity		good
type of bonding		metallic
type of structure	giant	

- (i) Complete Table 3.1. [3]
- (ii) Identify the lattice structure shown by graphite.
 [1]
- (iii) Explain why Sn has good electrical conductivity.

 [1]
- (iii) Ammonium carbonate undergoes an acid–base reaction with NaOH(aq).
 Explain this statement.

 [2]



(d) Fig. 3.2 shows the boiling points of the simplest hydrides of the Group 14 elements, C to Pb.

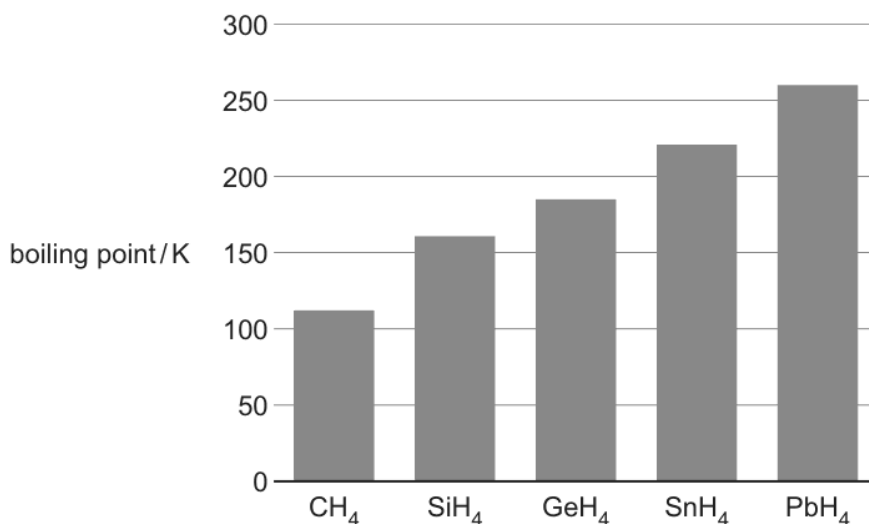


Fig. 3.2

(i) Explain the trend in the boiling points of the Group 14 hydrides shown in Fig. 3.2.

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

(ii) Deduce the shape of a molecule of SiH₄.

..... [1]

(e) Silicon readily reacts with elements of high electronegativity.

(i) Write an equation for the formation of SiCl_4 from its constituent elements.

..... [1]

(ii) Describe what is observed when a small sample of SiCl_4 is added to water.

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

(iii) SiO_2 is a white solid that melts above 1700°C .

SiCl_4 is a colourless liquid at room temperature.

Explain the difference in the melting points of these two compounds with reference to their structure and bonding.

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

(f) Tin forms an amphoteric oxide, SnO_2 .

Suggest the formula of the tin compound that forms when SnO_2 reacts with H_2SO_4 in an acid–base reaction.

..... [1]

[Total: 20]





Oct/Nov 2024 9701/21 · Q3 (a)(i), (a)(ii), (a)(iii), (b)(iii), (d)(i), (d)(ii), (e)(i), (e)(ii), (e)(iii), (f) (cont.)

(a) (i) Write equations for the following reactions.

- sodium and oxygen

.....

- sulfur and oxygen

.....

[2]

(ii) Draw a dot-and-cross diagram to show the species present in Al_2O_3 .

Draw outer electrons only.

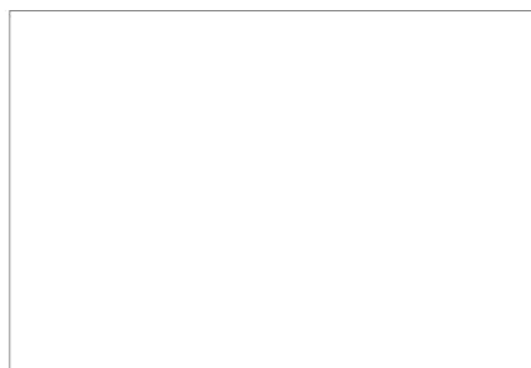
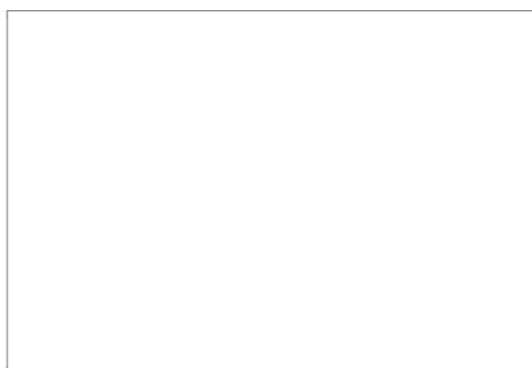
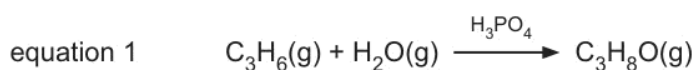
[1]

(ii) Write an equation for the reaction of CH_3CN with H_2O in acidic conditions.

$CH_3CN + \dots H_2O + \dots H^+ \dots$

[1]

(iii) Draw the structures of the two alcohols formed in the reaction shown in equation 1.



[2]

Oct/Nov 2024 9701/22 · Q2 (a)(ii), (b)(ii), (b)(iii), (b)(iv), (c)(i), (c)(ii) (continued ·)

(iv) Explain why alcohols are less acidic than water.

.....

.....

..... [2]

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9701/22/O/N/24

6

[Turn over]

(c) Fig. 2.1 shows the boiling points of H_2O and other Group 16 hydrides.

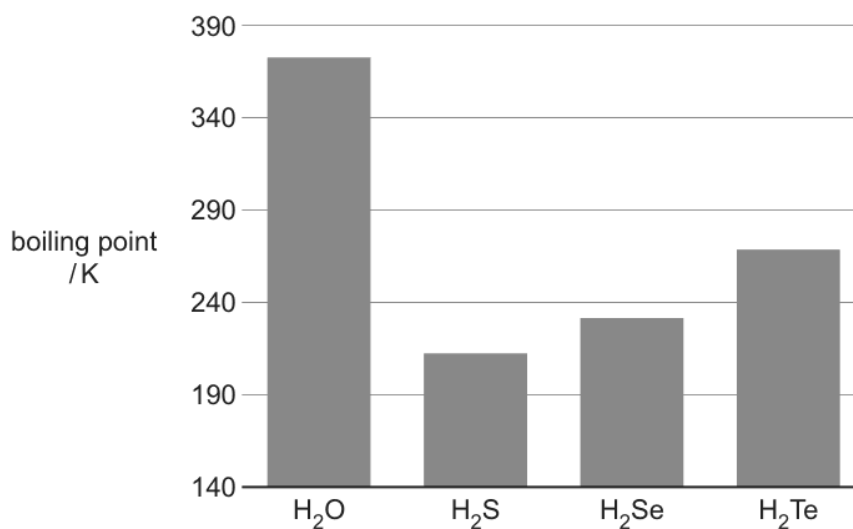


Fig. 2.1

(i) Explain the trend in the boiling points of the Group 16 hydrides H_2S to H_2Te .

.....

.....

.....

..... [2]

(ii) Explain why the boiling point of H_2O is much higher than that of H_2S .

.....

.....

..... [1]

[Total: 15]

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9701/22/O/N/24

7

Oct/Nov 2024 9701/22 · Q2 (a)(ii), (b)(ii), (b)(iii), (b)(iv), (c)(i), (c)(ii) (cont.)

- (iii) Ammonium carbonate undergoes an acid–base reaction with NaOH(aq) .

Explain this statement.

.....

.....

..... [2]

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9701/23/O/N/24

9



- (ii) Deduce the shape of a molecule of SiH_4 .

..... [1]

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9701/23/O/N/24

11



Oct/Nov 2024 9701/23 · Q3 (b)(iii), (d)(ii), (f) (continued ·)

(f) Tin forms an amphoteric oxide, SnO_2 .

Suggest the formula of the tin compound that forms when SnO_2 reacts with H_2SO_4 in an acid–base reaction.

..... [1]

[Total: 20]

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9701/23/O/N/24

[Turn over]

12

Oct/Nov 2024 9701/23 · Q3 (b)(iii), (d)(ii), (f) (cont.)

(ii) Predict the shape of a molecule of PCl_5 .

..... [1]

March 2025 9701/22 · Q1 (b)(ii)

(a) (i) Complete Table 3.1. [1]

(ii) The bond energy values in Table 3.1 refer to the X—X bond where X is the halogen.

Explain the trend in the bond strength of the X—X bond in the halogens.

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

(b) Explain, with the use of an equation, how chlorine, Cl_2 , is used in water purification. State the role of the active species produced.

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

(c) The sodium halides in Table 3.1 also show trends in chemical properties.

(i) Identify the sodium halide that reacts with concentrated H_2SO_4 to form H_2S .

..... [1]

(iii) A student adds a few drops of $\text{AgNO}_3(\text{aq})$ to a solution of $\text{NaBr}(\text{aq})$. State what is observed.

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

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9701/22/F/M/25

9



(d) Iodine monobromide, IBr , is a dark red solid that melts near room temperature.

IBr reacts with propene. The mechanism for this reaction is the same as the mechanism for that of HBr with propene.

(i) Identify **all** the intermolecular forces that exist between molecules of IBr .

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

- 1 (a) Diamond and graphite are both crystalline solids made from carbon atoms. Graphite conducts electricity. Diamond does **not** conduct electricity.
- (i) Name the type of lattice structure present in the crystalline solids diamond and graphite.
..... [1]
- (ii) Explain how graphite conducts electricity.
.....
..... [1]
- (iii) Explain why diamond does **not** conduct electricity.
.....
..... [1]
- (b) Separate samples of phosphorus(V) chloride and silicon(IV) chloride are each added to an excess of cold water.
- (i) Write an equation for each reaction.
.....
..... [2]
- (ii) Describe the appearance of phosphorus(V) chloride and silicon(IV) chloride at room temperature.
phosphorus(V) chloride
silicon(IV) chloride [2]
- (iii) Compare the appearance of the mixtures produced when each reaction is complete.
.....
..... [2]
- (c) Some oxides are amphoteric.
- (i) Describe what is meant by amphoteric.
.....
..... [1]

May/June 2025 9701/22 · Q1 (a)(i), (a)(ii), (a)(iii), (b)(i), (b)(ii), (b)(iii), (c)(i), (d)(i), (d)(ii) (continued ·)

(d) The melting points of different oxides are shown in Table 1.1.

Table 1.1

oxide	melting point/°C	force of attraction broken during melting
SO ₂	−73	
H ₂ O	0	
SiO ₂	1610	
Na ₂ O	1132	
MgO	2852	

(i) Complete Table 1.1 by identifying the strongest force of attraction in each oxide that is broken during melting. Use the abbreviations below.

i.d. = instantaneous dipole–induced dipole

p.d. = permanent dipole–permanent dipole

H = hydrogen bond

C = covalent bond

I = ionic bond

[3]

(ii) A student suggests the following hypothesis.

*The stronger the covalent bond between atoms in non-metal oxides,
the higher the melting point.*

Use Table 1.1 to deduce if this hypothesis is true or false or if there is **not** enough information to make a conclusion. Explain your answer.

.....

 [2]

[Total: 16]



May/June 2025 9701/22 · Q1 (a)(i), (a)(ii), (a)(iii), (b)(i), (b)(ii), (b)(iii), (c)(i), (d)(i), (d)(ii) (cont.)

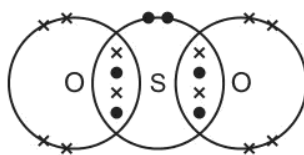
(b) Fig. 4.2 shows a possible arrangement of outer-shell electrons in one SO_2 molecule.

Fig. 4.2

(i) Use Fig. 4.2 to predict the shape and bond angle of a molecule of SO_2 .

shape

bond angle $^{\circ}$

[2]

May/June 2025 9701/23 · Q4 (b)(i)

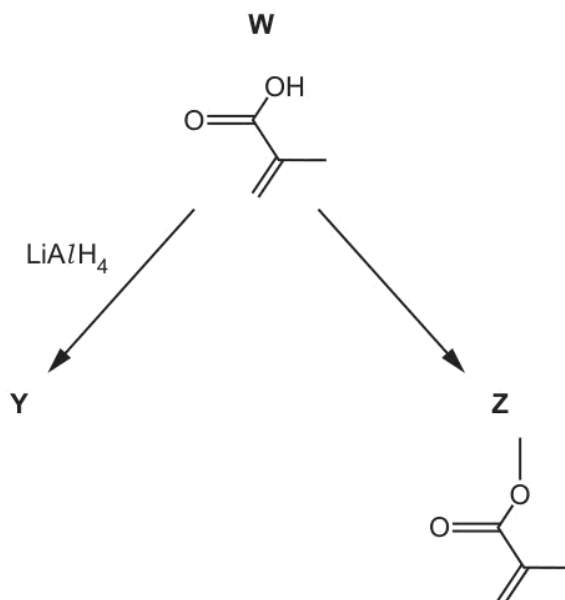
(b) Fig. 5.2 shows two reactions of **W** to produce organic compounds **Y** and **Z**.

Fig. 5.2

(i) Deduce the number of sigma (σ) bonds and pi (π) bonds present in **Z**.number of σ bondsnumber of π bonds

[2]

May/June 2025 9701/23 · Q5 (b)(i)

- 2 (a) Fig. 2.1 shows the covalent bonds and lone pairs of electrons in a molecule of SCl_2 .

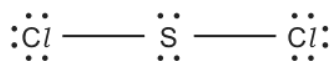


Fig. 2.1

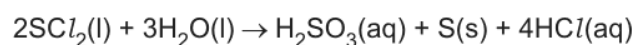
- (i) Use VSEPR theory to predict the shape of a molecule of SCl_2 .

..... [1]

- (ii) Predict the bond angle in a molecule of SCl_2 .

..... ° [1]

- (b) SCl_2 is a red liquid that reacts with water.



- (i) Describe **two** observations, other than temperature change, that are made when an excess of water is added to SCl_2 .

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

- (iii) State the general name to describe the type of reaction that occurs when a substance is broken down by water.

..... [1]

[Total: 7]



(v) I_2 reacts with NH_3 to form NI_3 .

Predict the shape of a molecule of NI_3 . Explain your answer.

shape

explanation

..... [2]

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9701/24/O/N/25

4

[Turn over]

Oct/Nov 2025 9701/24 · Q1 (b)(v)

- (a) The melting point of Al_2O_3 is $2072^\circ C$. The melting point of P_4O_{10} is $340^\circ C$.

Explain the difference in the melting points of these two compounds.

.....

.....

.....

..... [3]

- (iii) State and explain the effect, if any, on the value of K_c when the overall pressure in the sealed flask is increased.

.....

..... [1]

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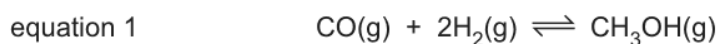


9701/24/O/N/25

7



- (c) P_4O_{10} catalyses the reversible reaction of CO with H_2 to form CH_3OH .



P_4O_{10} then acts as a dehydrating agent, causing CH_3OH to form CH_3OCH_3 .

- (i) Explain how the presence of a catalyst affects a chemical reaction.

.....

.....

..... [1]

- (ii) Construct an equation for the dehydration reaction of CH_3OH to form CH_3OCH_3 .

..... [1]

Oct/Nov 2025 9701/24 · Q2 (a), (b)(iii), (c)(i), (c)(ii)