PEARSON EDEXCEL IAL CHEMISTRY · YCH11

CHEMISTRY



EXAM QUESTION PACK

UNIT 1: SHAPES OF MOLECULES

SCORE	PERCENTAGE
/169	%

STEMUP

These questions belong to Pearson Edexcel, not to us.

The examination questions, mark schemes and examiner comments in this pack were written and published by Pearson Edexcel. They are past assessment materials, reproduced here so that students can revise from them.

What we do not own

STEMUP is not affiliated with Pearson Edexcel and does not own, and makes no claim to own, any of the question, mark scheme or examiner report material in this pack. Pearson Edexcel has not endorsed, approved or been involved in the production of it. Pearson Edexcel and the qualification titles used here belong to their respective owners and appear for identification only.

Where to find the originals

Pearson Edexcel publishes its past papers, mark schemes and examiner reports free of charge. Always check the current specification at qualifications.pearson.com before you revise, because content and wording can change between series.

If you hold the rights to any material in this pack and would like it amended or removed, contact admin@stemup.co.uk and we will act on it.

Q1.

This question is about the compound ammonium dichromate(VI), $(NH_4)_2Cr_2O_7$.

(a) $(NH_4)_2Cr_2O_7$ breaks down at around 180 °C, producing an oxide of chromium, nitrogen and water as the only products.

(i) Write an equation for the reaction.

State symbols are not required.

(2)

(ii) Give a name for this type of reaction.

(1)

.....

(b) When 0.00100 mol of ammonium dichromate(VI) was heated, 25.2 cm^3 of nitrogen gas, measured at laboratory temperature, was formed.

Calculate the temperature in the laboratory, in degrees Celsius, using the ideal gas equation. Use atmospheric pressure = 101 kPa.

$$[pV = nRT \quad R = 8.31\,J\,mol^{-1}\,K^{-1}]$$

(4)

(c) (i) Draw a dot-and-cross diagram of the ammonium ion.

Use dots (●) for the nitrogen electrons and crosses (X) for the hydrogen electrons.

(2)

(ii) Explain the shape of the ammonium ion using electron-pair repulsion theory.

(2)

.....

.....

.....

.....

.....

.....

(d) Ammonium dichromate(VI) comes with several warnings on its packaging.

- This compound is toxic when inhaled and by passing through the skin.
- Handle with extreme caution.
- Contact can irritate and burn the skin and eyes, with possible eye damage.
- Inhaling can irritate the nose and throat.
- Ammonium dichromate(VI) is a strong oxidiser that enhances the combustion of other substances.

(i) Some of the symbols shown are used for ammonium dichromate(VI).

Identify the symbols for ammonium dichromate(VI) by placing a tick (✓) in the box under each relevant symbol.

(2)

(ii) Suggest why ammonium dichromate(VI) is **not** stored in the same cupboard as alkanes.

(1)

.....

.....

.....

.....

.....

(Total for question = 14 marks)

Q2.

This question is about compounds containing chlorine.

(a) A precipitate of silver chloride is formed when silver nitrate solution reacts with sodium chloride solution.

A student wrote an ionic equation for the reaction.

$$Ag^{2+}(l) + 2Cl^{-}(l) \rightarrow AgCl_2(s)$$

Explain why this equation is incorrect, even though it is balanced.

(2)

.....

.....

.....

.....

.....

.....

(b) A sample of a compound is analysed and found to contain **only** 3.09 g carbon, 0.26 g hydrogen and 9.15 g chlorine.

The molar mass of the compound is 97.0 g mol^{-1}.

Calculate the molecular formula of this compound.

You **must** show your working.

(3)

(c) Nitrogen trichloride has the formula NCl_3.

(i) A sample of nitrogen trichloride contained only nitrogen atoms with mass number 14, and chlorine atoms with mass numbers 35 and 37.

Give the formula and mass/charge ratio for each of the **four** ions responsible for the molecular ion peaks in the mass spectrum of nitrogen trichloride.

(2)

(ii) Complete the table to predict the shape and Cl—N—Cl bond angle in nitrogen trichloride.

(3)

Number of bonding pairs of electrons on nitrogen	
Number of lone pairs of electrons on nitrogen	
Shape of molecule	
Cl—N—Cl bond angle	

(d) Aluminium chloride exists as an ionic lattice in the solid state and as a covalent dimer, Al_2Cl_6, in the gas phase, just above its boiling temperature.

(i) Explain why aluminium chloride in the solid state has significant covalent character.

(2)

.....

.....

.....

.....

.....

.....

.....

.....

(ii) Describe how two $AlCl_3$ molecules are joined together in the dimer.

Include a diagram in your answer.

(2)

.....

.....

.....

.....

(Total for question = 14 marks)

Q3.

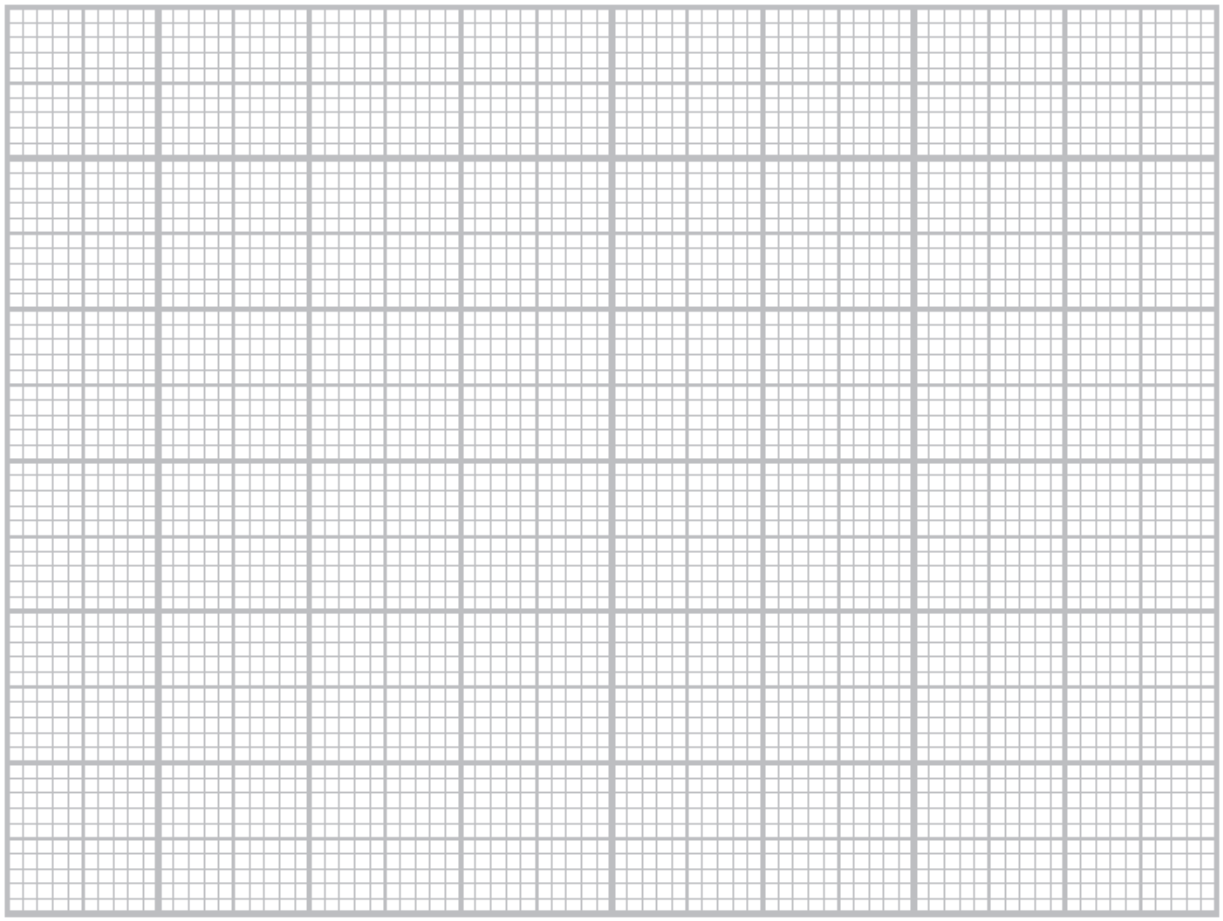
This question is about the elements in Period 3 of the Periodic Table, and some of their compounds.

(a) The atomic radii of six of the elements are given.

Symbol	Na	Mg	Al	Si	P	S	Cl	Ar
Atomic number	11	12	13	14	15	16	17	18
Atomic radius / nm	0.191	0.160	0.130			0.102	0.099	0.095

(i) Plot a graph of atomic radius against atomic number.

(2)



(ii) Use the graph to estimate the atomic radius of silicon, Si.

(1)

.....

(iii) Suggest an explanation for the decrease in atomic radius as atomic number increases across a period.

(3)

.....

.....

.....

.....

.....

.....

.....

.....

.....

(b) The melting temperatures of sodium, sodium chloride and chlorine are given in the table.

Complete the table to show the type of structure, the type of bond or force broken on melting and the particles involved.

(6)

Substance	Sodium	Sodium chloride	Chlorine
Melting temperature / °C	98	801	−101
Type of structure	giant		simple molecular
Type of bond or force broken on melting			
Particles involved			chlorine molecules

(c) Solid phosphorus(V) chloride contains PCl_4^+ ions.

(i) Draw a dot-and-cross diagram of a PCl_4^+ ion.

Show only outer shell electrons.

(1)

(ii) Predict the shape of a PCl_4^+ ion.

Justify your answer.

(3)

Shape .....

Justification

.....

.....

.....

.....

.....

.....

.....

(Total for question = 16 marks)

Q4.

Answer the question with a cross in the box you think is correct ☒. If you change your mind about an answer, put a line through the box ☒ and then mark your new answer with a cross ☒.

In which sequence are the molecules in order of **decreasing** bond angle?

☐ **A** $BeCl_2 > BCl_3 > CH_4$

☐ **B** $BeCl_2 > NH_3 > CH_4$

☐ **C** $CH_4 > BCl_3 > BeCl_2$

☐ **D** $CH_4 > NH_3 > BeCl_2$

(Total for question = 1 mark)

Q5.

This question is about bonding.

(a) Draw an electron density map for a molecule of oxygen.

(1)

(b) Draw a diagram to show the shape of a water molecule.

Give the bond angle.

(2)

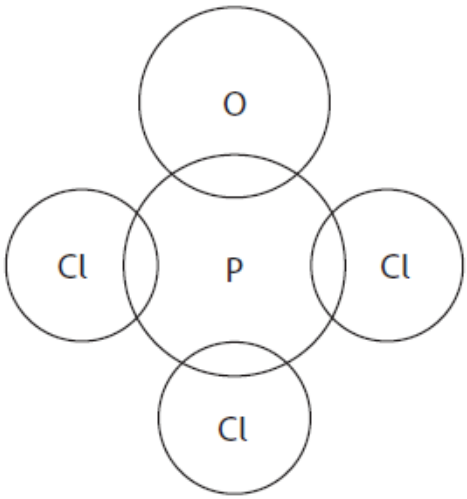
Bond angle .....

(c) The compound $POCl_3$ has a simple molecular structure.

(i) Complete the dot-and-cross diagram for the $POCl_3$ molecule.

Use crosses (✕) for the phosphorus electrons, dots (●) for the chlorine electrons and circles (○) for the oxygen electrons.

(2)



(ii) Explain the shape of this molecule using the electron-pair repulsion theory.

(3)

.....

.....

.....

.....

.....

.....

.....

.....

.....

(d) The properties of metals depend on their structure and bonding.

(i) Draw a labelled diagram to show the metallic bonding in calcium.

(2)

(ii) Explain how the electrical conductivity, high melting temperature and malleability of metals depend on their structure and bonding.

(3)

Electrical conductivity.....

.....

.....

High melting temperature
.....

.....

.....

Malleability .....

.....

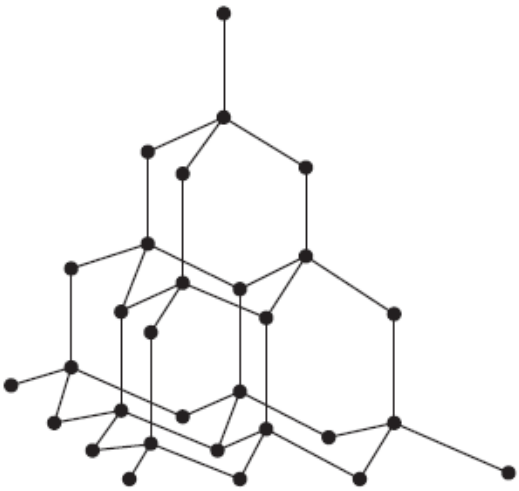
.....

(e) Diamond, graphite and graphene are all forms of carbon.

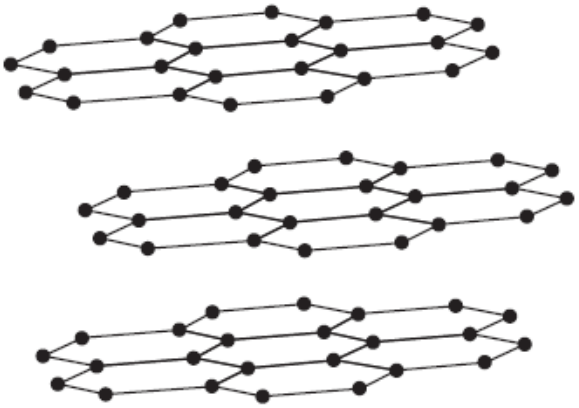
(i) Explain **two** ways in which the physical properties of diamond and graphite differ.

Refer to their structure and bonding in your answer.

(4)



diamond



graphite

.....

.....

.....

.....

.....

.....

.....

.....

(ii) State how the structure of graphene is related to the structure of graphite.

(1)

.....

.....

(iii) State a use for graphene, identifying the property that makes it suitable for that use.

(2)

.....

.....

.....

.....

(Total for question = 20 marks)

Q6.

This question is about the bonding in the elements of Period 3 in the Periodic Table.

The melting temperatures of the Period 3 elements are shown in the table.

Element	Na	Mg	Al	Si	P	S	Cl	Ar
Melting temperature / °C	98	650	660	1423	44	120	–101	–189

(a) Sodium, magnesium and aluminium are metals.

(i) State what is meant by metallic bonding.

(1)

.....

.....

.....

(ii) Melting temperature depends on the strength of metallic bonding.

Explain why the metallic bonding in magnesium is much stronger than that in sodium.

(3)

.....

.....

.....

.....

.....

.....

.....

.....

.....

(b) (i) In the elements silicon, phosphorus, sulfur and chlorine, the atoms are joined by covalent bonds.

Describe the attraction between the atoms in a covalent bond.

(1)

.....

.....

(ii) Explain why the melting temperature of silicon is much higher than that of phosphorus, by referring to their structures.

(3)

.....

.....

.....

.....

.....

.....

.....

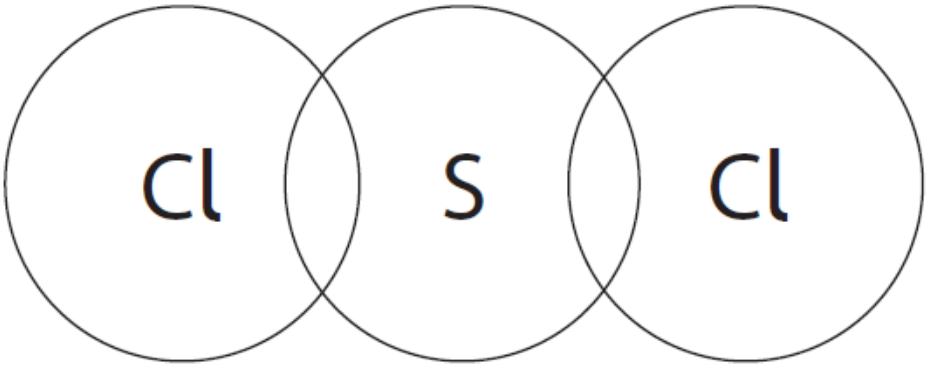
.....

.....

(c) Sulfur reacts with chlorine to form sulfur dichloride, SCl_2.

(i) Complete the dot-and-cross diagram of a molecule of sulfur dichloride. Use dots (•) for the chlorine electrons and crosses (×) for the sulfur electrons. Show the outer shell electrons only.

(2)



(ii) Suggest a value for the Cl—S—Cl bond angle. Justify your answer.

(3)

.....

.....

.....

.....

.....

.....

.....

(Total for question = 13 marks)

Q7.

The elements carbon and silicon both form dioxides.

(a) Carbon dioxide is a simple covalent molecule but silicon dioxide has a giant covalent structure.

(i) Describe the covalent bond between a silicon atom and an oxygen atom in silicon dioxide, in terms of the particles involved.

(2)

.....

.....

.....

.....

.....

.....

(ii) Compare and contrast the covalent bonding in carbon dioxide and silicon dioxide in terms of orbital overlap.

(3)

.....

.....

.....

.....

.....

.....

.....

.....

(b) The shape of the carbon dioxide molecule affects its physical properties.

(i) Explain the shape of the carbon dioxide molecule.

(3)

.....

.....

.....

.....

.....

.....

.....

.....

(ii) Explain the polarity of the carbon–oxygen bond.

(2)

.....

.....

.....

.....

.....

.....

(iii) State whether or not the carbon dioxide molecule is polar.

Justify your answer.

(1)

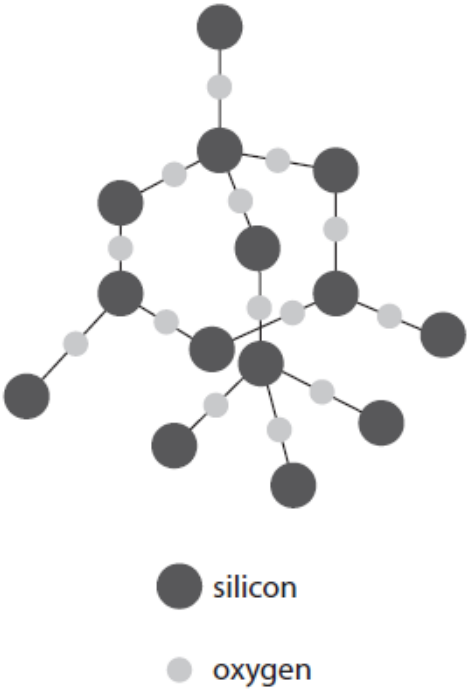
.....

.....

.....

.....

(c) The structure of silicon dioxide may be referred to as a diamond structure.



(i) Using your knowledge of the structure of diamond, suggest how the structure of silicon dioxide is similar to that of diamond.

(1)

.....

.....

.....

.....

(ii) Give a possible reason why silicon dioxide has a lower melting temperature than diamond, even though the Si—O bond is stronger than the C—C bond.

(1)

.....

.....

.....

.....

.....

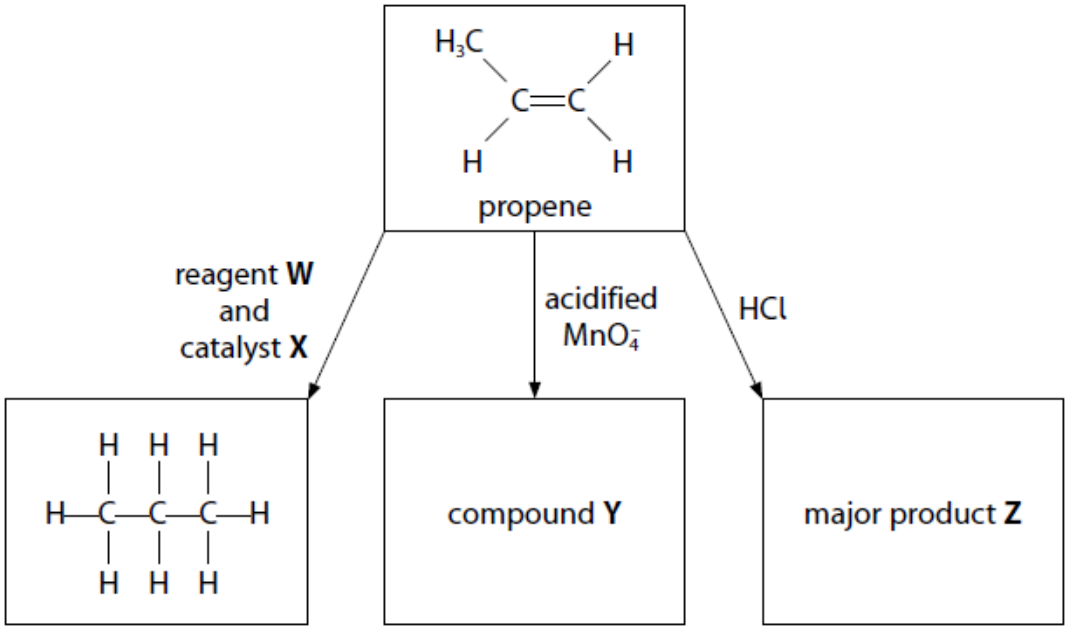
.....

(Total for question = 13 marks)

Q8.

Alkenes contain a double bond between two carbon atoms.

(a) Some reactions of propene are shown.



(i) Give the names of reagent **W** and catalyst **X**.

(2)

Reagent **W**

.....

Catalyst **X**

.....

(ii) Draw the displayed formula of compound **Y**.

(1)

(iii) Draw the skeletal formula of the major product **Z**.

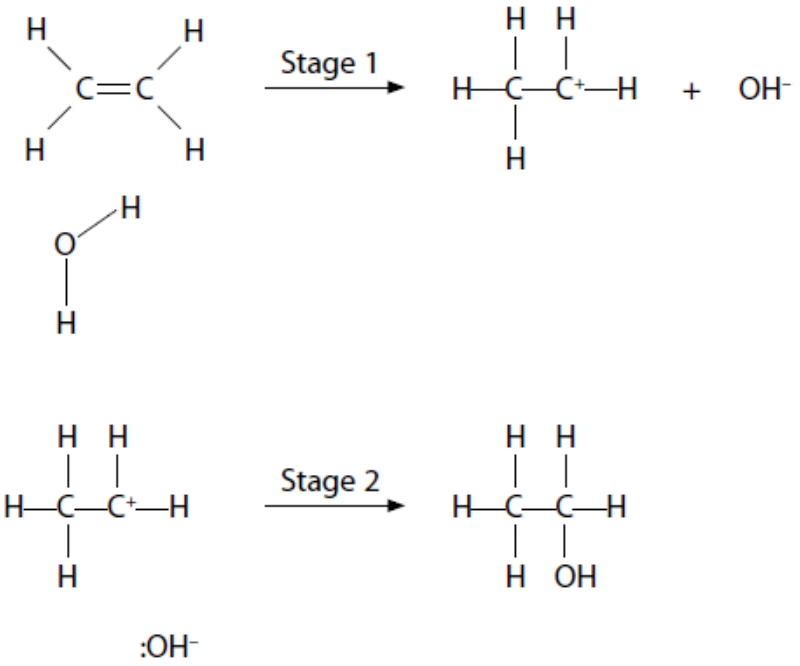
(1)

(b) Ethene reacts with steam in the presence of a catalyst to form ethanol.

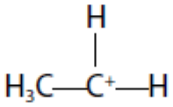
The mechanism takes place in two stages.

(i) Complete the simplified mechanism for the reaction by adding curly arrows and the relevant dipole.

(4)



(ii) Predict the shape of the intermediate ion with reference to the positively-charged carbon. Justify your answer.



(3)

.....

.....

.....

.....

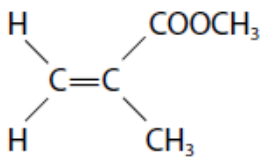
.....

.....

.....

.....

(c) Methyl 2-methylpropenoate has the structure:



Draw a section of the polymer formed from methyl 2-methylpropenoate, showing two repeat units.

(2)

(Total for question = 13 marks)

Q9.

This question is about the chlorides of beryllium and calcium.

(a) Complete the electronic configurations of the atoms of beryllium and calcium using the s, p, d notation.

(2)

Be $1s^2$

.....

Ca $1s^2$

.....

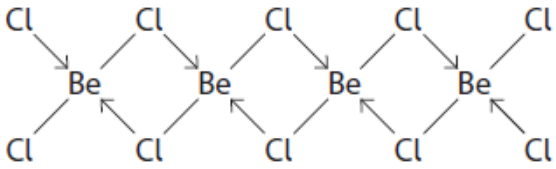
(b) In the gaseous state, beryllium chloride is molecular.

Draw a dot-and-cross diagram to show the bonding in a molecule of beryllium chloride, $BeCl_2$.

(2)

(c) In the solid state, beryllium chloride forms a polymeric structure.

The diagram shows part of this structure.



The diagram uses lines and arrows to represent the two different types of covalent bond.

Describe how each type of bond is formed.

(2)

.....

.....

.....

.....

.....

.....

(d) The Cl—Be—Cl bond angle is different in the two forms of beryllium chloride.

Predict the two bond angles, justifying your answers by referring to electron-pair repulsion theory.

(4)

.....

.....

.....

.....

.....

.....

.....

.....

.....

.....

(e) Anhydrous calcium chloride is a crystalline, ionic solid which melts at 772 °C.

Draw a dot-and-cross diagram for calcium chloride.
Show the outer electrons only.

(2)

(f) Explain why gaseous beryllium chloride and solid calcium chloride have different types of bonding.

(3)

.....

.....

.....

.....

.....

.....

.....

.....

.....

(Total for question = 15 marks)

Q10.

This question is about the Group 4 element germanium and some of its compounds.

(a) Naturally-occurring germanium consists of five stable isotopes.

Explain what is meant by the term isotopes.

(2)

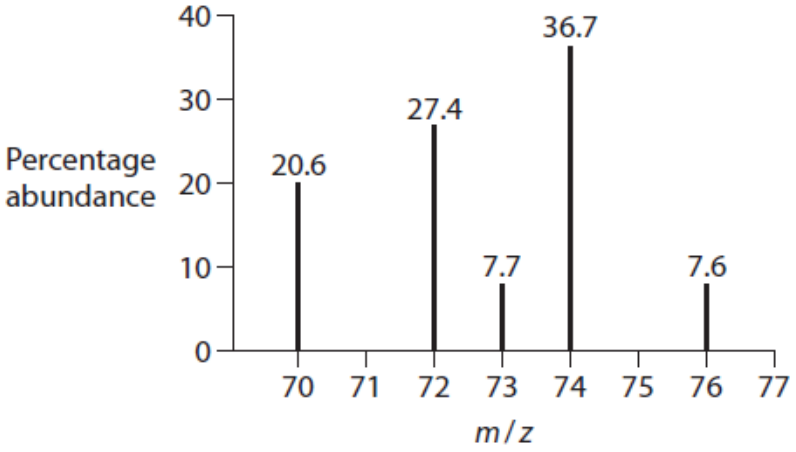
.....

.....

.....

.....

(b) The mass spectrum of a sample of germanium is shown.



Calculate the relative atomic mass of this sample of germanium.

(2)

(c) Give the electronic configuration of a germanium atom.

(1)

.....

(d) Germane is a compound with the formula GeH_4.

It can be formed by the reaction shown.

$$Na_2GeO_3 + NaBH_4 + H_2O \rightarrow GeH_4 + 2NaOH + NaBO_2$$

(i) Calculate the atom economy, by mass, for the formation of germane.

Use A_r of Ge = 72.6

(2)

(ii) Germane can donate a proton to ammonia, forming the ion GeH_3^-.

$$NH_3 + GeH_4 \rightarrow NH_4^+ + GeH_3^-$$

Draw a dot-and-cross diagram of the ion GeH_3^-. Show the outer electrons only.

(2)

(iii) Use your answer to (d)(ii) and electron-pair repulsion theory to predict the name of the shape and bond angle of the ion GeH_3^-

(2)

Name of the shape

.....

Bond angle

.....

(iv) Germane is toxic and the maximum permitted concentration is 0.640 mg m^{-3} in air.

Calculate the maximum number of germane molecules permitted in a laboratory with a volume of 231 m^3.

[Avogadro constant (L) = 6.02×10^{23} mol^{-1}]

(4)

(e) A halide of germanium, GeX_4, reacts with water as shown.

$$GeX_4 + 2H_2O \rightarrow GeO_2 + 4HX$$

1.50 g of GeX_4 was added to excess water.
The insoluble GeO_2 was removed by filtration.
The solution of hydrogen halide formed was then added to excess magnesium carbonate, forming 335.5 cm^3 of carbon dioxide at room temperature and pressure (r.t.p.).

$$MgCO_3 + 2HX \rightarrow MgX_2 + CO_2 + H_2O$$

[Molar volume of a gas at r.t.p. = 24 000 cm^3 mol^{-1}]

(i) Calculate the number of moles of carbon dioxide formed.

(1)

(ii) Deduce the number of moles of HX formed when GeX_4 reacted with the excess water.

(1)

(iii) Deduce the number of moles of GeX_4 that reacted with the excess water.

(1)

(iv) Calculate the molar mass of GeX_4 and hence identify X.

(2)

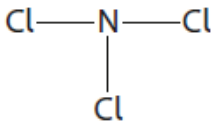
(Total for question = 20 marks)

Q11.

This question is about the structure and bonding of Group 5 chlorides.

(a) Nitrogen trichloride, NCl_3 , has a molecular structure.

The displayed formula of a molecule of NCl_3 is shown.



Complete the table for this molecule.

(3)

Number of bond pairs around N atom	
Number of lone pairs around N atom	
Cl-N-Cl bond angle	
Name of shape of molecule	

(b) Under standard conditions, phosphorus(V) chloride (PCl_5) is a solid made up of PCl_4^+ cations and PCl_6^- anions.

Antimony(V) chloride ($SbCl_5$) is a liquid made up of $SbCl_5$ molecules.

(i) Explain why PCl_5 has a higher melting temperature than $SbCl_5$.

(2)

.....

.....

.....

.....

.....

.....

(ii) Draw a dot-and-cross diagram to show the bonding in a molecule of $SbCl_5$.

Use dots (•) to represent the Sb electrons, and crosses (**x**) to represent the Cl electrons. Show outer electrons only.

(2)

(c) At low temperatures, $SbCl_5$ converts to Sb_2Cl_{10} which contains dative covalent bonds.

(i) State what is meant by the term dative covalent bond.

(1)

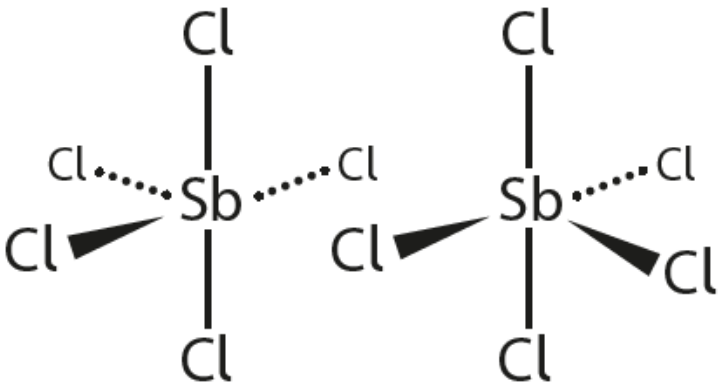
.....

.....

.....

(ii) Complete the diagram to show the dative covalent bonds in Sb_2Cl_{10} .

(1)



(d) Arsenic also forms a pentachloride with the formula $AsCl_5$.

Give **one** possible reason why nitrogen is the only Group 5 element that does **not** form a pentachloride.

(1)

.....

.....

.....

.....

(Total for question = 10 marks)

Q12.

Which species is **not** tetrahedral?

- ☒ **A** CCl_4
- ☒ **B** CH_4
- ☒ **C** ICl_4^-
- ☒ **D** NH_4^+

(Total for question = 1 mark)

Q13.

This question is about phosphorus and some of its compounds.

(a) The atomic number of phosphorus is 15.

(i) Complete the electronic configuration of a phosphorus atom using the electrons-in-boxes notation.

(1)



(ii) Explain why the first ionisation energy of phosphorus is greater than that of sulfur.

(2)

.....

.....

.....

.....

.....

.....

(b) Phosphorus has a melting temperature of 44 °C.

Silicon has a melting temperature of 1410 °C.

Explain why the melting temperature of phosphorus is much lower than that of silicon.

(3)

.....

.....

.....

.....

.....

.....

.....

.....

.....

.....

.....

(c) Phosphorus(V) chloride, PCl_5 , exists as covalent molecules in the gaseous state.

(i) Complete the table for a PCl_5 molecule.

(3)

Number of bonding pairs of electrons on phosphorus		
Number of lone pairs of electrons on phosphorus		
Shape of molecule		
Cl—P—Cl bond **angles**		

(ii) In the solid state, phosphorus(V) chloride is ionic.

The cation and anion each have one phosphorus atom but a different number of chlorine atoms.

The cation is tetrahedral and the anion is octahedral.

Predict the formula of each ion. Include the charge on each ion.

(2)

.....

.....

(d) In an experiment, 8.00 cm^3 of 0.250 mol dm^{-3} sodium hydroxide, NaOH, reacted completely with 10.0 cm^3 of 0.100 mol dm^{-3} phosphoric acid, H_3PO_4 .

Use these data to deduce the balanced equation for this reaction.
You **must** show your working.

(3)

(e) Hydrated magnesium phosphate has the formula $Mg_3(PO_4)_2.\mathbf{y}H_2O$.

A sample of this compound contains 78.5% by mass of anhydrous magnesium phosphate.

Deduce the value of **y**.

You **must** show your working.

[Molar mass of anhydrous magnesium phosphate, $Mg_3(PO_4)_2$ = 262.9 g mol^{-1}]

(2)

(Total for question = 16 marks)

Q14.

Answer the question with a cross in the box you think is correct ☒. If you change your mind about an answer, put a line through the box ☒ and then mark your new answer with a cross ☒.

Which molecule is planar?

☒ **A** CF_4

☒ **B** C_2F_4

☒ **C** PF_5

☒ **D** SF_6

(Total for question = 1 mark)

Q15.

What are the shapes of the $AlCl_3$ and PH_3 molecules?

	Shape of $AlCl_3$ molecule	Shape of PH_3 molecule
☒ **A**	pyramidal	pyramidal
☒ **B**	pyramidal	trigonal planar
☒ **C**	trigonal planar	trigonal planar
☒ **D**	trigonal planar	pyramidal

(Total for question = 1 mark)

Q16.

Answer the question with a cross in the box you think is correct ☒. If you change your mind about an answer, put a line through the box ☒ and then mark your new answer with a cross ☒.

How many lone pairs of electrons are there in the outer shell of the sulfur atom in a molecule of H_2S?

☒ **A** zero

☒ **B** one

☒ **C** two

☒ **D** four

(Total for question = 1 mark)

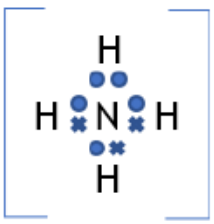
Mark Scheme

Q1.

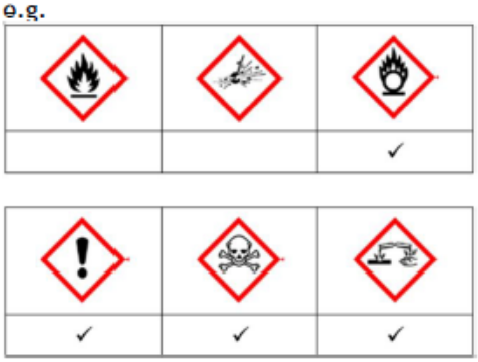
Question Number	Answer	Additional guidance	Mark
(a)(i)	• $(NH_4)_2Cr_2O_7 \rightarrow N_2 + 4H_2O + Cr_2O_3$	1 mark for Cr_2O_3 1 mark for all the rest being correct Allow multiples Marks are standalone	(2)

Question Number	Answer	Additional guidance	Mark
(a)(ii)	• (thermal) decomposition **or** redox	Ignore oxidation or reduction on their own	(1)

Question Number	Answer	Additional guidance	Mark
(b)	• conversion of units for *P* and *V* (1) • substitution in equation and rearrange (1) • answer in K (1) • convert to °C (1)	Example of calculation: $P = 101000 / 1.01 \times 10^5$ Pa $V = 0.0000252 / 2.52 \times 10^{-5}$ m^3 Allow incorrect use standard form e.g. 10.1×10^4 Pa $T = \frac{101000 \times 0.0000252}{0.001 \times 8.31}$ T = 306.28 (K) T = 33.3(°C) (33.1°C if 273.15 is used for conversion of kelvin to Celsius) Ignore SF except 1 SF on final answer TE throughout but only award for MP4 if final answer in °C is between 0 and 50°C Units if given must be correct *Comment:* *Correct answer with no working scores 4* *306.28(K) scores 3* *30.85 °C scores 3* *33.7 °C scores 3 as they have used R as 8.3* *33.55 °C scores 3 using 8.3 and 273.15* *306.7K scores 2 as they have used R as 8.3*	(4)

Question Number	Answer	Additional guidance	Mark
(c)(i)	A drawing that shows: • four pairs of electrons and 4 hydrogen atoms around nitrogen (1) • one dative covalent bond **and** plus sign (1)	 Allow answers without brackets Allow use of any symbol for the electrons as long as it is clear which is the dative covalent bond (e.g. by use of an arrow) Ignore placement of positive sign	(2)

Question Number	Answer	Additional guidance	Mark
(c)(ii)	An explanation that makes reference to: • tetrahedral / tetrahedron (1) • (four) **pairs of electrons** arranged in position of minimum repulsion / maximum separation (1)	MP1 may be scored with a 3D diagram or an answer given in 19(c)(i) Allow phonetic spelling Allow equal repulsion of electron-pairs Allow reference to bonding pairs Ignore reference to bonds Ignore all bond angles Do not award references to lone pairs Marks are standalone	(2)

Question Number	Answer	Additional guidance	Mark
(d)(i)	Four correct ticks scores 2 marks, Three correct ticks scores 1 mark Four correct ticks and one incorrect tick scores 1 mark	e.g.  	(2)

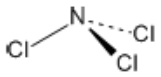
Question Number	Answer	Additional guidance	Mark
(d)(ii)	An answer containing an appropriate suggestion: • dichromate/oxidising agents promote(s) combustion/burning of alkanes/fuels OR alkanes are flammable/combustible **and** dichromate is an oxidising agent	Allow fuels/alkanes would catch fire more easily Ignore dichromate causes alkanes to burn Do not award dichromate catches fire	(1)

Q2.

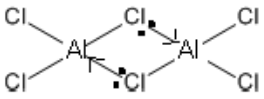
Question number	Answer	Additional guidance	Mark
24(a)	An explanation that makes reference to the following points: • (I) is incorrect because the solutions are aqueous **or** ions are (in the) aqueous (state) the state symbols should be (aq) instead of (I) • silver ions should have one positive charge / Ag^+ **or** silver chloride is AgCl	Allow silver nitrate and sodium chloride are aqueous Do not award if incorrect state symbol for one of the species in the equation e.g. Ag is (s) / AgCl is (aq) Ignore just the charge on the silver ion is incorrect / the formula of silver chloride is incorrect	(2)

Question number	Answer	Additional guidance	Mark
(b)	• calculation of mol of C, H and Cl **(1)** • calculation of empirical formula **(1)** • calculation of molecular formula **(1)**	Example of calculation: C : H : Cl mol $\frac{3.09}{12} : \frac{0.26}{1} : \frac{9.15}{35.5}$ = 0.2575 : 0.26 : 0.2577 (ratio 1 : 1 : 1) Empirical formula is CHCl molar mass CHCl = 12 + 1 + 35.5 = 48.5 $\frac{\text{molar mass } (CHCl)_n}{\text{molar mass CHCl}} = \frac{97}{48.5} = 2$ Molecular formula is $C_2H_2Cl_2$ Allow symbols in any order Do not award 2CHCl Ignore SF in mol and ratio Correct molecular formula with some working scores (3) **Alternative method** scores (3) no. C atoms = $\frac{3.09 \times 97}{12.5 \times 12} = 2 / 1.9982$ no. H atoms = $\frac{0.26 \times 97}{12.5 \times 1} = 2(.0176)$ no. Cl atoms = $\frac{9.15 \times 97}{12.5 \times 35.5} = 2$	**(3)**

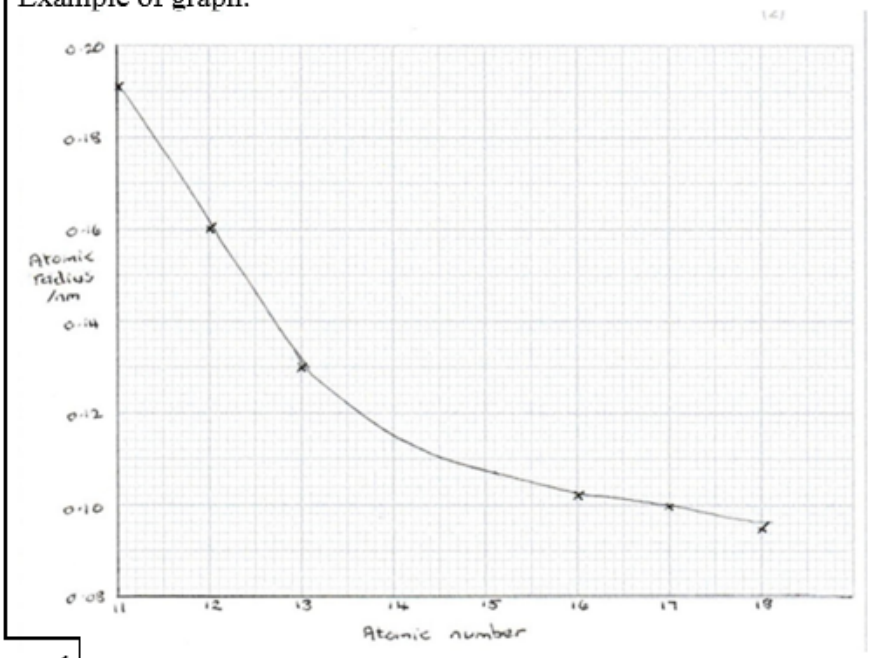
Question number	Answer	Additional guidance	Mark
(c)(i)	• all 4 ion formulae • all 4 (corresponding) *m* / *z* values	Example of answer: ions *m* / *z* $N(^{35}Cl)_3^+$ 119 $N(^{35}Cl)_2{}^{37}Cl^+$ 121 $N^{35}Cl(^{37}Cl)_2^+$ 123 $N(^{37}Cl)_3^+$ 125 Allow any other unambiguous way of representing the formulae e.g. in words Allow (1) for any two *m* / *z* values with corresponding ion formulae Ignore missing / incorrect charge on ion Ignore mass number on N Ignore bonds or + between Cl atoms / order of atoms e.g. $N\text{-}^{35}Cl\text{-}^{35}Cl\text{-}^{35}Cl$	(2)

Question number	Answer	Additional guidance	Mark
(c)(ii)	• number of bonding pairs **and** number of lone pairs • shape • bond angle	Example of table: Number of bonding pairs of electrons on nitrogen: 3 Number of lone pairs on electrons on nitrogen: 1 Shape of molecule: trigonal pyramidal Bond angle: 107° **Shape:** Allow 3-dimensional drawing e.g.  There must be at least 1 dotted/dashed line or wedge for 3-d Allow just 'pyramidal' Allow pyramid for pyramidal Do not award tetrahedral **Bond angle:** Allow any number in the range 106-108° Ignore missing °	(3)

Question number	Answer	Additional guidance	Mark
24(d)(i)	An explanation that makes reference to one of the following pairs of points: **Polarisation route** • an aluminium ion / cation is (very) small **and** highly charged **or** Al^{3+} has a small ionic radius / is small • so it polarises / distorts the chloride ion / Cl^- / anion **Allow Electronegativity route** • there is a (relatively) small difference in electronegativity between aluminium and chlorine • so the electrons are (partially) shared	Marks must come from the same route – maximum 1 mark if one point from one route and one point from the other route Allow the aluminium ion has a high charge density Allow a description of polarisation Allow chlorine anion / ion Ignore the aluminium chloride is polarised Ignore size of chloride ion	(2)

Question number	Answer	Additional guidance	Mark
24(d)(ii)	A description including the following points: • diagram showing two $AlCl_3$ molecules joined through two chlorine atoms • dative (covalent) bonds **or** coordinate bonds	Example of diagram:  Allow dot-and-cross diagram Ignore missing arrow heads and lone pairs from diagram Do not award diagram with Al-Al / Cl-Cl bond(s) Allow dative covalent bonds labelled on diagram / shown as arrows from Cl to Al Allow description of dative bonds Allow M2 even if only 1 dative bond shown / mentioned Do not award M2 if dative bonds starting from aluminium Do not award M2 for any answer that mentions ions / ionic bonds	**(2)**

Q3.

Q	Answer	Additional guidance	Mark
(a)(i)		Example of graph:  	**2**
	• axes correct and labelled with atomic radius /nm and atomic number **(1)**	Allow y axis with 191 etc and label as pm or x 10^{-3} nm Ignore symbols on x axis Do not award M1 if x axis scale starts at 0	
	• points plotted correctly **(1)**	The points for Si / atomic number 14 and P / atomic number 15 do not need to be marked Accept graph with or without line drawn **Comment** If atomic radius is plotted on the x axis, allow (1) for correct graph	

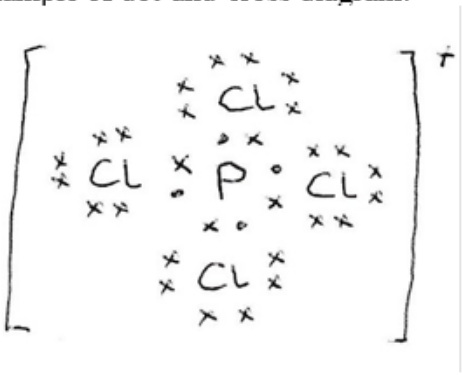
Q	Answer	Additional guidance	Mark
(a)(ii)	• value in allowed range	Allow 0.112 to 0.118 (nm) Allow value written in table Ignore any value given for phosphorus	**1**

Q	Answer	Additional guidance	Mark
(a)(iii)	An explanation that makes reference to the following points: • (as the atomic number increases / across the period) the nuclear charge increases / the number of protons (in the nucleus) increases **(1)** **Any two from:** • this is only partially offset by the increased electron (-electron) repulsion as the number of electrons in the (outer) shell increases **(1)** • the electrons are all the same (quantum) shell / experience similar shielding **(1)** • so there is an increase in attractive force between the nucleus and (outer) electrons **(1)**	Allow effective nuclear charge increases Allow the same amount of shielding Allow same number of (occupied quantum) shells Do not award electrons in the same subshell / orbital	**3**

Q	Answer	Additional guidance	Mark
(b)	• giant for structure of sodium chloride **(1)** • metallic bonding for sodium **(1)** • ionic bonding for sodium chloride **(1)** • intermolecular (forces) for chlorine **(1)** • Na^+ **and** electrons / cations **and** electrons (particles in sodium) **(1)** • Na^+ **and** Cl^- /cations **and** anions (particles in sodium chloride) **(1)**	Allow giant ionic / (giant) lattice Ignore metal Ignore ion(s) Ignore electrostatic attractions in M2 and M3 Accept London / dispersion (forces) Allow van der Waals' (forces) Ignore weak (forces) Allow positive ions **and** electrons Allow sodium atoms / ions **and** electrons Allow positive (sodium) ion and negative (chloride / chlorine) ion Ignore just sodium ions and chloride ions Penalise incorrect charge on an ion once only e.g. Na^{2+}	**6**

Example of table:

Substance	Sodium	Sodium chloride	Chlorine
Melting temperature /°C	(98)	(801)	(−101)
Type of structure	(giant)	giant	(simple molecular)
Type of bond or force broken on melting	metallic	ionic	intermolecular forces
Particles involved	Na^+ **and** electrons / cations **and** electrons	Na^+ **and** Cl^- /cations **and** anions	(chlorine molecules)

Q	Answer	Additional guidance	Mark
(c)(i)	• correct dot-and-cross diagram	Example of dot-and-cross diagram:  Allow any combination of dots and crosses, including all dots or all crosses Allow overlapping circles Allow electrons in bonds along the axis of the bond Ignore missing bracket and charge Ignore lines representing covalent bonds e.g. x	1

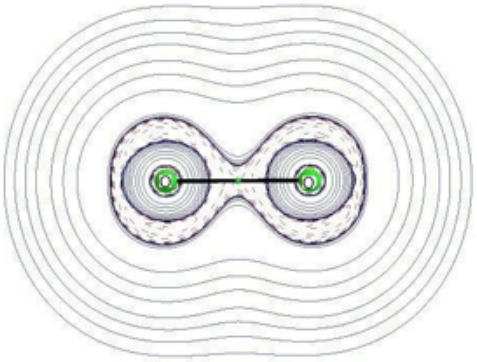
Q	Answer	Additional guidance	Mark
(c)(ii)	• Shape – tetrahedral **(1)** • Justification – (four) bonding pairs /pairs of electrons (around P) **(1)** • (electron pairs) arranged to minimise repulsion **(1)**	Stand alone No TE on (c)(i) for shape Allow the number of electron pairs shown in (c)(i) Allow regions of electron density for electron pairs Ignore reference to lone pair-lone pair / lone pair-bond pair repulsion Allow (electron pairs) arranged for maximum separation / as far apart as possible Ignore electron pairs repel equally Penalise use of bonds for electron pairs once only in M2 and M3	3
			(Total for Question = 16 marks)

STEMUP.CO.UK

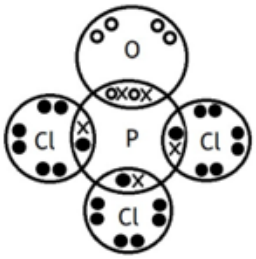
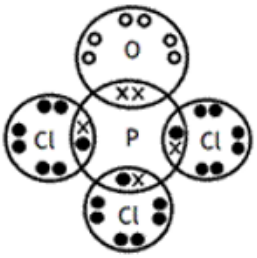
Q4.

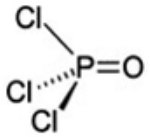
Question number	Answer	Mark
	The only correct answer is A ($BeCl_2 > BCl_3 > CH_4$) *B is incorrect because the bond angle in methane is larger than that in ammonia* *C is incorrect because this is the order of increasing bond angle* *D is incorrect because the bond angle in beryllium chloride is bigger than that in ammonia*	(1)

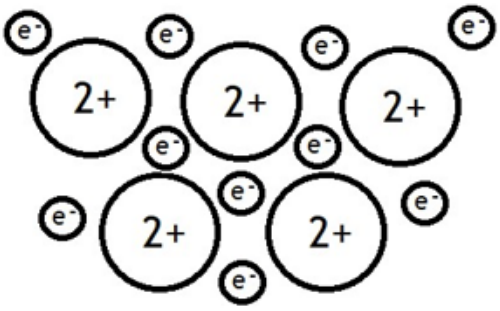
Q5.

Question Number	Answer	Additional guidance	Mark
(a)	A sketch showing: • two atoms with high electron density and a symmetrical cloud around both	e.g.  At least one separate circle around each atom **and** at least one contour line with an indentation above and below the axis **and** circling both atoms ie  is the minimum Allow nuclei shown as + signs Allow dashed contour lines	**(1)**

Question Number	Answer	Additional guidance	Mark
(b)	A diagram that includes: • shape of H_2O **(1)** • bond angle **(1)**	CHECK THE ANSWER LINE ON BOTTOM RIGHT CORNER! (as well as angles on diagram)  Allow dot-cross diagrams if in the correct shape Allow 3D representations showing lone pairs Ignore the presence of lone/bonding pairs of electrons Ignore charges or partial charges even if incorrect Do not award double bonds Accept bond angle from 104° to 105 ° Allow bond angle labelled <u>correctly</u> on diagram Do not award M2 if one correct and one incorrect bond angle stated	**(2)**

Question Number	Answer	Additional guidance	Mark
(c)(i)	A diagram that includes: • phosphorus singly covalently bonded to three chlorine atoms and three lone pairs on each chlorine **(1)** • phosphorus doubly bonded to an oxygen atom and two lone pairs on the oxygen or a dative covalent bond from the phosphorus and three lone pairs on the oxygen **(1)**	 OR  Penalise absence of lone pairs once only Allow lone pairs to appear as separate electrons Allow any representation of electrons **but** electrons in a dative covalent bond must appear to be the same	**(2)**

Question Number	Answer	Additional guidance	Mark
(c)(ii)	An answer that makes reference to the following points: • (based on) tetrahedron / tetrahedral (arrangement) **(1)** • four regions of bonding electrons **(1)** • adopt the positions of minimum repulsion **(1)**	MP1 can be given for a 3-D diagram  Accept 5 bonding pairs, where two (in double bond) behave as one. Allow 4 bonding pairs Allow phosphorous bonds to 4 other atoms Accept repel to maximum separation Allow maximise the distance between the bonding pairs Allow to achieve lowest (potential) energy state Ignore to become most stable Do not award maximum repulsion Ignore bond angles throughout Ignore lone pairs throughout	**(3)**

Question Number	Answer	Additional guidance	Mark
(d)(i)	A diagram that includes:	The diagram must include at least four ions in two rows 	(2)
	• positive (2+) ions / cations **(1)**	Accept 1+ ions Accept close packed ions Allow +1/+2 (oxidation state instead of charge)	
	• surrounded by randomly arranged delocalised electrons with approximately equal positive and negative charges **(1)**	Accept reference to "sea of electrons" Allow "e" or "–" to represent electrons Ignore "electron cloud"	

Question Number	Answer	Additional guidance	Mark
(d)(ii)	An explanation that makes reference to the following points: Electrical conductivity: • the <u>electrons</u> can flow (under a potential difference) **(1)** High melting temperature: • <u>strong</u> force of attraction between the (positive) ions and electrons **(1)** Malleability: • the ions can <u>slide</u> past each other (while still being held together by the electrons) **(1)**	Accept "move" Accept "carry charge/current" Allow "mobile" "Delocalised electrons" alone is insufficient Allow bond strength instead of force of attraction Allow metallic bonds are <u>strong</u> Do not award protons instead of cations Do not award negative ions instead of electrons Do not award strong intermolecular bonds Accept ions can <u>move over</u> each other Allow atoms/layers slide over each other Ignore "mobile ions"	**(3)**

Question Number	Answer	Additional guidance	Mark
(e)(i)	An explanation that makes reference to the following points: • diamond is hard **and** graphite is soft **(1)** • because diamond has a rigid lattice / weak forces between the layers in graphite (allow the layers to slide over one another) **(1)** • graphite conducts (electricity) **and** diamond does not **(1)** • because graphite has delocalised electrons (which are free to move) / diamond does not **(1)**	Ignore strong in place of hard Accept "diamond has covalent bonds in a 3D structure" Ignore diamond has a tetrahedral structure Accept that electrons are free to move in graphite Allow free electrons Marks are independent. I.e. Comments on properties without comparison score 2 for MP2 and MP4. Ignore additional properties e.g. melting temperature	**(4)**

Question Number	Answer	Additional guidance	Mark
(e)(ii)	• single layer / monolayer	Accept "one atom thick layer" Allow "graphene is one layer of graphite" or "individual layer of graphite" Ignore references to the structures and bonding of graphite and graphene Do not award "thin sheet of graphite" NB Assume "it" refers to graphene	(1)

Question Number	Answer	Additional guidance	Mark
(e)(iii)	• potential use (1) • (use linked to) at least one property (1)	Examples: • flexible electronics • as only one atom thick or conducts electricity or • transparent electrodes scores • as only one atom thick or conducts electricity or • oxidation resistant layer • as is unreactive or • data storage • as is lightweight or conducts electricity or is durable Marks are independent but to score 2, the property must have a plausible link to the named application Ignore lubricant Ignore used as electric wires Do not award reference to: • pencils as a use • making carbon brushes as a use • electrodes as a use (without a small size reference) • layers as a property	(2)

Example uses of Graphene (non-exhaustive!)
• added to other materials e.g. drill tips, roads, bullet proof clothing, body armour • heat sinks e.g. thermal foils for mobile phones • coatings on spacecraft • microelectronics • (small) batteries • supercapacitors • enhancing fuel cells • non-stick coatings e.g. do not allow just "frying pan" • anti-corrosion coatings or paints e.g. for self-healing pipes, NB do not allow "aeroplanes" or "industrial equipment" without qualification • efficient and precise sensors • faster electronics • micro electrodes • flexible displays • touchscreens / mobile (phone) screen • solar panels / photo(voltaic) cells • making nanotubes • composites • microtubules or microfibres in drug delivery / medicine • low friction coatings • used to make electric wires

Properties of graphene
• thin • flexible • transparent • oxidation resistant • reduces friction between surfaces • low density • high melting point • durable • strong • thermal conductor • electrical conductor • can be made into nanotubes
(Total for Question = 20 marks)

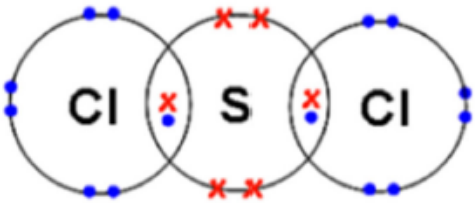
Q6.

Question Number	Answer	Additional Guidance	Mark
(a)(i)	• (metallic bonding is) the **attraction** between positive ions/cations and **delocalised** electrons	Can be shown as a labelled diagram including the word **attraction.** Allow **electrostatic forces** as an alternative to **attraction** Allow **attraction** between metal ions and **delocalised** electrons Allow **attraction** between (positive) nuclei and **delocalised** electrons Ignore just 'ions' Ignore free moving electrons/ sea of electrons	**(1)**

Question Number	Answer	Additional Guidance	Mark
(a)(ii)	An explanation that makes reference to three of the following points • M1 Mg has more **delocalised** electrons **(1)** • M2 **Mg^{2+}** is smaller (than Na^+) **(1)** • M3 **Mg^{2+}** has a higher charge (than Na^+) **(1)** • M4 Greater attraction between the **delocalised** electrons and the Mg^{2+} ions/ Mg^{2+} nuclei **(1)**	Allow Mg loses two electrons **and** Na one to form **delocalised** electrons Ignore free moving electrons Allow Mg ion is smaller (than Na^+) Allow Mg smaller ionic radius Do not award atomic radius Allow Mg ion has a higher charge (than Na^+) Ignore the number of protons Just Mg^{2+} 'has a greater charge density' scores (1) for M2 & M3 Allow greater attraction between the delocalised electrons and Mg Ignore attraction to the protons Ignore outer shell electrons Allow reverse argument for all points	**(3)**

Question Number	Answer	Additional Guidance	Mark
(b)(i)	• (the electrostatic attraction between) the shared (pair of) electrons and the (two) nuclei (of the bonded atoms)	Allow single nucleus	**(1)**

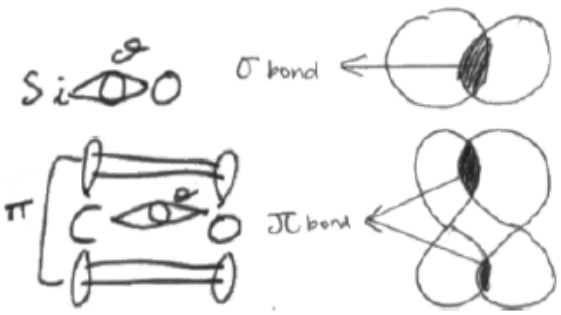
Question Number	Answer	Additional Guidance	Mark
(b)(ii)	An explanation that makes reference to the following points: • phosphorus (P) simple molecular (1) • silicon (Si) giant (covalent/molecular) structure (1) • when phosphorus melts weak London forces are broken **and** when silicon melts strong covalent bonds are broken (1)	Allow (small) molecules/ P_4/ just 'molecular'/simple covalent Allow lattice instead of giant Ignore macromolecular Do not award giant metallic/ionic Allow / dispersion /van der Waals forces/ instantaneous dipole-induced dipole/intermolecular forces Do not award if any mention of intermolecular forces for silicon.	(3)

Question Number	Answer	Additional Guidance	Mark
(c)(i)	An explanation that makes reference to the following points: • dot-and-cross diagram showing two shared pairs of electrons between S and Cls (1) • rest of diagram correct (1)	Example of dot-and-cross diagram  Allow all dots/all crosses/dots crosses the wrong way round Allow the non-bonded pairs of electrons on S and Cl anywhere and allow non-bonding electrons unpaired. Ignore inner shells Charged species/ions scores 0	(2)

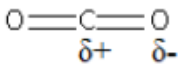
Question Number	Answer	Additional Guidance	Mark
(c)(ii)	An answer that makes reference to the following points: • bond angle 104.5(°) (1) • four pairs of electrons/ 2 bonding pairs and 2 lone pairs occupy a position of minimum repulsion (1) • (2)lone pairs repel more than bonding pairs (so the angle is reduced from 109.5 (°)) (1)	Allow 102-105 (actual answer 103°) Allow just electron pairs occupying a position of minimum repulsion and do not penalise for an incorrect number of electron pairs if quoted. Allow maximum separation Ignore bonds/ areas of electron density/atoms Ignore any reference to shapes e.g. angular, V-shaped	(3)

Q7.

Question number	Answer	Additional guidance	Mark
(a)(i)	An answer that makes reference to the following points: • the (strong electrostatic) **attraction** between the **shared** pair of **electrons** of the covalent bond (1) • and the nuclei (of the silicon atom and the oxygen atom) (1)	Allow attraction between 2 shared electrons Ignore plurals Ignore bonding pair of electrons Allow "silicone" in place of silicon Allow references to protons instead of nuclei Do not award M2 for carbon atoms Ignore numbers of bonds Ignore references to giant/simple, double bonds, polar bonds, sigma bonds or orbital overlap Both marks may be scored by a clearly labelled diagram	2

Question number	Answer	Additional guidance	Mark
(a)(ii)	An answer that makes reference to the following points: Similarities: • both molecules contain a σ-bond (1) • description of end-on overlap (1) Difference: • carbon dioxide (also) contains sideways overlap of orbitals / π–bond (with the oxygen atom) (1)	All marks may be scored by clearly labelled diagrams e.g.  Allow any indication that the σ overlap is between the atoms and the π overlap is above and below the plane of the atoms e.g. "end-on", "horizontal", "head on" for axial "sideways" or "parallel" for lateral	3

Question number	Answer	Additional guidance	Mark
(b)(i)	An explanation that makes reference to the following points: • there are two sets of bonding electrons (and no lone pairs) about the carbon atom (1) • which arrange to minimise repulsion (1) • resulting in a linear shape / bond angle of 180° (1)	Any indication of two regions of electrons (this includes a correct diagram) e.g. O=C=O Allow two double bonds Do not award MP1 for just "two bonding pairs" or just "4 bonding pairs" Allow maximum separation / to be as far apart as possible Do not award repulsion between atoms Accept bond angle labelled on a diagram Do not award linear with any angle other than 180° Ignore references to symmetry Ignore references to lone pairs on oxygen All marks are independent No TE for any mark	3

Question number	Answer	Additional guidance	Mark
(b)(ii)	An explanation that makes reference to the following points: • the carbon atom is slightly positive / δ+ **and** the oxygen atom slightly negative / δ– (1) • because oxygen is more electronegative than carbon (1)	Accept shown on a diagram e.g.  Allow single C—O bond with dipole Allow use of dipole symbol  Do not award full charges Accept reverse argument Ignore "they have different electronegativities"	2

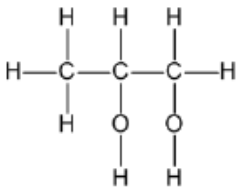
Question number	Answer	Additional guidance	Mark
(b)(iii)	An answer that makes reference to the following point: • the carbon dioxide molecule is not polar **and** because (it is a linear molecule) the dipoles cancel	(No TE on (b)(i)) Allow the polar bonds cancel Allow dipoles balance Allow symmetrical molecule Do not award "the charges cancel"	1

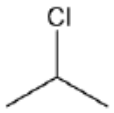
Question number	Answer	Additional guidance	Mark
(c)(i)	An answer that makes reference to the following: • each silicon atom has four silicon atoms in a **tetrahedral** arrangement as nearest silicon atom neighbours or each silicon is bonded to four oxygen atoms in a **tetrahedral** arrangement or each carbon is bonded to 4 carbon atoms in a **tetrahedral** arrangement (in diamond)	Allow "giant tetrahedral structure(s)" Do not award each silicon is tetrahedrally bonded to four other silicon atoms Ignore just "the silicon atoms are in a diamond structure" Do not award (simple) molecule(s) anywhere in the response	1

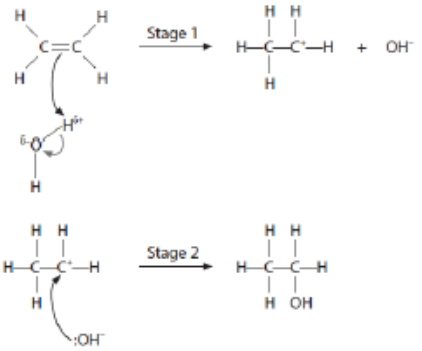
Question number	Answer	Additional guidance	Mark
(c)(ii)	An answer that makes reference to the following point: • There are fewer bonds (per atom) in the structure of silicon dioxide	Allow reverse argument Allow oxygen only forms two bonds Allow bond strength is an average Allow oxygen has lone pairs of electrons Ignore silicon-oxygen bond is polar Ignore references to sizes of atoms Do not award reference to intermolecular forces	1

Q8.

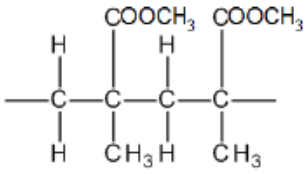
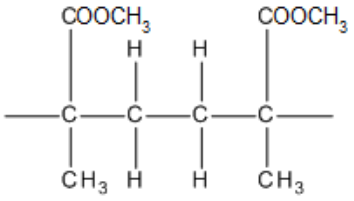
Question number	Answer		Additional guidance	Mark
(a)(i)	• (reagent W) hydrogen/H_2	(1)		2
	• (catalyst X) nickel	(1)	Allow nickel, Ni/platinum, Pt/palladium, Pd	

Question number	Answer	Additional guidance	Mark
(a)(ii)	• 	Allow OH Do not allow C-H-O	1

Question number	Answer	Additional guidance	Mark
(a)(iii)	• 		1

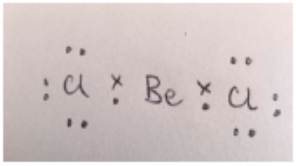
Question number	Answer		Additional guidance	Mark
(b)(i)	• correct dipole ($O^{\delta-}$ – $H^{\delta+}$)	(1)	Example of mechanism: 	4
	• curly arrow from C=C to H in H_2O	(1)		
	• curly arrow from O-H bond to O	(1)		
	• curly arrow from lone pair on O of OH^- to C^+	(1)		

Question number	Answer		Additional guidance	Mark
(b)(ii)	• trigonal planar	(1)	Allow M1 and M2 shown on a diagram	3
	• 3 bond pairs/electron pairs (around the carbon atom)	(1)	Allow bond pairs/electron pairs as far apart as possible	
	• bond pairs/electron pairs arranged to minimise repulsion	(1)		

Question number	Answer	Additional guidance	Mark
(c)	• 4 carbon backbone with continuation bonds (1) • all side chains correct (1)	Example of polymer:  or  Allow CO_2CH_3 in side chains Allow CH_3 and $COOCH_3$ groups above or below the carbon chain Ignore square brackets and n Any structure with C=C scores 0	2

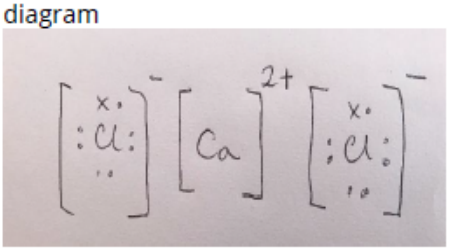
Q9.

Question Number	Answer	Additional Guidance	Mark
(a)	• $2s^2$ (1) • $2s^2\ 2p^6\ 3s^2\ 3p^6\ 4s^2$ (1)	Ignore extra $1s^2$ for both Be and Ca Accept $p_x^2\ p_y^2\ p_z^2$ for p^6	(2)

Question Number	Answer	Additional Guidance	Mark
(b)	Answer that shows ..... • 2 single covalent bonds **(1)** • 6 non-bonding electrons shown on chlorine **(1)**	Example of correct dot-and-cross diagram:  Allow non-bonding electrons unpaired Allow all dots or all crosses Allow shared electrons on the axis of the bond If Ca in place of Be Max 1 Ignore line showing covalent bond Ignore overlapping circles Ionic bond scores 0 overall Reject incorrect total number of electrons for M2	**(2)**

Question Number	Answer	Additional Guidance	Mark
(c)	• a line/covalent bond is when electron(s) come from both/each atom(s) **(1)** • arrow / dative covalent/ co-ordinate bond which is (a lone pair of) electrons donated from chlorine/ (only) one atom **(1)**	Ignore references to attraction between bonding pair and nucleus. Do not award any statement stating that the donation comes from Beryllium	**(2)**

Question Number	Answer	Additional Guidance	Mark
(d)	• bond angle in $BeCl_2$(g)/linear is 180° **(1)** • bond angle in $BeCl_2$(s)/polymeric is 109.5° **(1)** • electron pairs/bonds repel each other to minimise repulsion **(1)** • 4 electron pairs/bonds in solid **or** 2 bonding pairs/2 bonds (no lone pairs) in gas	Ignore references to shape ALLOW any bond angle between 110 ° and 95 °. [98° actual value] Ignore references to shape Allow to a maximum separation Do not award repulsion between atoms/elements or between lone pairs Ignore references to lp-lp/lp-bp repulsion	**(4)**

Question Number	Answer	Additional Guidance	Mark
(e)	• correct charges shown and two chloride ions (1) • electronic configuration of all ions (1)	Example of correct dot-and-cross diagram  Accept Ca with 8 electrons Allow all dots or all crosses or any combination Ignore inner electron shells	(2)

Question Number	Answer	Additional Guidance	Mark
(f)	• Beryllium is smaller /has fewer electron shells/ has a higher charge density (than calcium) OR beryllium is more electronegative (than calcium) (1) • Beryllium ion/ Be^{2+} is more polarising (than calcium /ion Ca^{2+}) OR calcium loses (outer) electrons more easily (than beryllium) OR difference in electronegativity between calcium and chlorine is greater (than between beryllium and chlorine) (1) • beryllium-chlorine bond has a higher degree of covalency (than calcium-chlorine bond)	Allow beryllium is more polarising than calcium Accept bonding in beryllium chloride is (more) covalent/ bonding in calcium chloride is (more) ionic. M3 is dependent on either M1 or M2 being scored Allow reverse arguments throughout	(3)

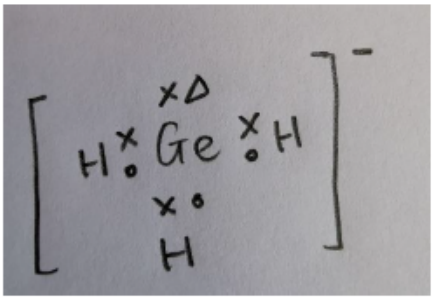
Q10.

Question Number	Acceptable Answers	Additional Guidance	Mark
(a)	An explanation that makes reference to the following points: • **atoms** (of the same element) with the same number of protons / **atoms** with same atomic number / **atoms** with same proton number **(1)** • with a different number of neutrons / neutron number / mass number **(1)**	NOTE answers with no reference to atoms can score 1 max for correct statements about the number of protons and neutrons or atomic number and mass number e.g. 'elements with same number of protons but different number of neutrons' scores 1 mark e.g. 'isotopes have the same atomic number and different mass number' scores 1 mark Ignore references to same number of electrons Ignore references to relative atomic mass	**2**

Question Number	Acceptable Answers	Additional Guidance	Mark
(b)	• numerator of weighted mean expression **(1)** • calculation of relative atomic mass **(1)**	Example of calculation $(70 \times 20.6) + (72 \times 27.4) + (73 \times 7.7) + (74 \times 36.7) + (76 \times 7.6)$ $\frac{(70 \times 20.6) + (72 \times 27.4) + (73 \times 7.7) + (74 \times 36.7) + (76 \times 7.6)}{100}$ = 72.703 / 72.70 / 72.7 TE on one transcription error Final answer must be to at least 1 decimal place Correct answer with no working scores 2 Ignore units	**2**

Question Number	Acceptable Answers	Additional Guidance	Mark
(c)	• $1s^2 2s^2 2p^6 3s^2 3p^6 3d^{10} 4s^2 4p^2$	Allow [Ar] $3d^{10}4s^2 4p^2$ Allow $4s^2$ immediately before $3d^{10}$ Allow $3p_x^2 3p_y^2 3p_z^2$ Allow numbers of electrons not shown as superscripts Allow upper case letters for 'S', 'P' and 'D'	**1**

Question Number	Acceptable Answers	Additional Guidance	Mark
(d)(i)	• calculation of $\sum M_r$ (all reactants) / $\sum M_r$ (all products) (1) • calculation of atom economy as a percentage (1)	Example of calculation 46+72.6 +48+23+10.8+4+18 = 222.4 / 72.6+4+80+23+10.8+32) = 222.4 (76.6 ÷ 222.4) × 100 = 34.442% Allow TE in M2 from M1 provided atom economy is less than 100% Allow use of A_r = 72.7 for Ge calculated in (b) which gives the answer 34.472% Ignore SF except 1 SF	2

Question Number	Acceptable Answers	Additional Guidance	Mark
(d) (ii)	An explanation that makes reference to the following points: • 3 bond pairs between Ge atom and **three** H atoms (1) • lone pair on Ge atom (and charge on ion) (1)	 Allow any combination of dots and / or crosses Ignore missing charge on ion Ignore lines showing covalent bonds	2

Question Number	Acceptable Answers	Additional Guidance	Mark
(d)(iii)	An answer that makes reference to the following points: • trigonal pyramid(al) (1) • angle between 106 and 108° (1)	Allow pyramidal Comment – the correct shape and angle are standalone marks. However allow trigonal planar and 120° for 2 marks if (d)(ii) shows only 3 bond pairs.	2

Question Number	Acceptable Answers	Additional Guidance	Mark
(d)(iv)	• calculation of maximum mass of germane in laboratory in mg **(1)** • conversion of mass from mg to g **(1)** • calculation of moles of germane **(1)** • calculation of maximum number of germane molecules in laboratory **(1)** NOTE – do not award M1 and M2 if there is evidence that candidates believe the values 147.84 / 0.14784 are moles. Such answers are likely to only be able to access M4	Example of calculation $0.640 \times 231 = 147.84$ (mg) $147.84 \div 1000 = 0.14784$ (g) Allow TE from M1 to M2 $= 0.14784 \div 76.6 = 1.9300 \times 10^{-3}$ (mol) Allow TE from M2 to M3 $1.9300 \times 10^{-3} \times 6.02 \times 10^{23} = 1.1619 \times 10^{21}$ (molecules) Allow TE from M3 to M4 Allow use of 76.7 for 76.6 giving 1.1604×10^{21} Correct answer with no working scores 4 marks Ignore SF except 1 SF	4

Question Number	Acceptable Answers	Additional Guidance	Mark
(e)(i)	• calculation of moles of carbon dioxide	$(335.5 \div 24000)$ $= 0.013979 / 1.3979 \times 10^{-2}$ (mol) Ignore SF except 1 SF	1

Question Number	Acceptable Answers	Additional Guidance	Mark
(e)(ii)	• answer to (i) × 2	(0.013979×2) $= 0.027958 / 2.7958 \times 10^{-2}$ (mol) Ignore SF except 1 SF Allow TE from (i)	1

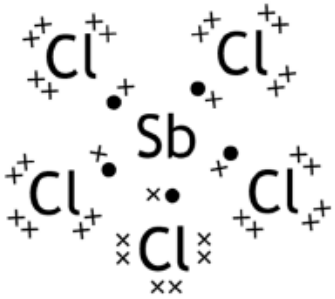
Question Number	Acceptable Answers	Additional Guidance	Mark	
(e)(iii)	• answer to (ii) ÷ 4	$(0.027958 \div 4)$ $= 0.0069896 / 6.9896 \times 10^{-3}$ (mol) Ignore SF except 1 SF Allow TE from (ii)	1	

Question Number	Acceptable Answers	Additional Guidance	Mark
(e)(iv)	• 1.50 ÷ (answer to (iii)) (1) • identification of X (1)	$1.50 \div 6.9897 \times 10^{-3} =$ 214.6 ($g\ mol^{-1}$) 214.6 – 72.6 = 142.01 142.01 ÷ 4 = 35.501 ; so X = Cl Allow TE from (iii) Must be some correct working to score M2	2

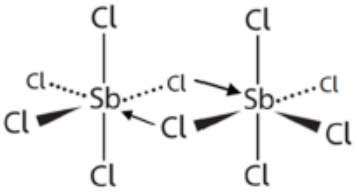
Q11.

Question Number	Answer	Additional guidance	Mark
(a)	A completed table showing: • correct number of bond pairs **and** lone pairs (1) • correct Cl–N–Cl bond angle (1) • correct name of shape (1)	**Mark all points independently** Number of bond pairs around N atom: 3 Number of lone pairs around N atom: 1 Cl–N–Cl bond angle: 107(o) Allow 106(o) – 108(o) Name of shape of molecule: (Trigonal) pyramidal Allow pyramid Ignore tetrahedral Do not award bipyramidal	3

Question Number	Answer	Additional guidance	Mark
(b)(i)	An explanation that makes reference to the following points: • strong(er) (electrostatic) attraction between ions (in PCl_5) (1) • (than) weak intermolecular forces (in $SbCl_5$) (1)	**Mark M1 and M2 independently** Ignore reference to solid/liquid Allow strong ionic bonds / strong ionic lattice Allow strong attraction between positive and negative charges Allow strong attraction between cations and anions / PCl_4^+ and PCl_6^- Ignore just PCl_5 is (giant) ionic Do not award reference to PCl_5 molecules/ intermolecular forces Do not award reference to breaking of covalent bonds Accept just London/van der Waals/dispersion/ temporary-induced dipole/instantaneous-induced dipole forces Ignore just $SbCl_5$ is (simple) molecular Do not award reference to breaking of covalent/ionic bonds Ionic bonding is stronger than intermolecular forces scores (2)	2

Question Number	Answer	Additional guidance	Mark
(b)(ii)	Dot-and-cross diagram showing the following: • central Sb with five bond pairs and no lone pairs (1) • five Cl atoms each with one bond pair and three lone pairs (1)	**Mark M1 and M2 independently** Example of dot-and-cross diagram:  TE on M1 for three or four Cl atoms Allow any combination of crosses and dots Allow circles to indicate outer shells Ignore inner shells Ignore lines showing the covalent bonds	2

Question Number	Answer	Additional guidance	Mark
(c)(i)	• suitable description of a dative covalent bond	For credit to be awarded, it must be clear that: i) a pair of / two electrons are involved ii) these electrons are shared/bonding iii) these electrons come from the same atom eg shared electrons in which both electrons come from the same atom eg lone pair/full orbital from one atom overlaps with empty orbital of another Allow element for atom Allow just both electrons in the bond come from the same element Allow one element donates/gives/shares both electrons to the bond Allow one atom shares both electrons Do not award just one atom donates/gives both electrons (or any reference to ions being formed) Do not award ion/molecule/species for atom	1

Question Number	Answer	Additional guidance	Mark
(c)(ii)	• two correct dative covalent bonds shown as arrows	 Ignore lone pairs shown on Cl Do not award dative bonds from any other Cl atoms	1

Question Number	Answer	Additional guidance	Mark
(d)	An answer that makes reference to one of the following points: • no 2d orbitals **or** (nitrogen) cannot expand its octet **or** • (nitrogen is) too small (to bond to 5 atoms) **or** • repulsion between electron **pairs** would be too great	Accept reverse arguments Allow no d orbitals as only two (quantum) shells Allow no d orbitals (accessible) Allow (nitrogen) cannot have more than eight electrons in its outer shell Ignore just cannot expand its outer/valence shell Ignore just nitrogen obeys the octet rule Ignore just (nitrogen has a) very small/smallest atomic radius Ignore Cl atoms too large Ignore nitrogen has fewest/only two shells Ignore just repulsion between electron pairs Ignore repulsion between Cl atoms Ignore not enough room for 5 electron pairs	1

Q12.

Question number	Answer	Mark
	The only correct answer is C (ICl_4^-) ***A*** *is incorrect because* CCl_4 *is tetrahedral* ***B*** *is incorrect because* CH_4 *is tetrahedral* ***D*** *is incorrect because* NH_4^+ *is tetrahedral*	**(1)**

Q13.

Question number	Answer	Additional guidance	Mark
(a)(i)	• correct electronic configuration	Example of electronic configuration:  Allow half-arrow heads Allow three arrows pointing downwards in 3p orbitals Ignore numbers in the boxes e.g. 2	(1)

Question number	Answer	Additional guidance	Mark
(a)(ii)	An explanation that makes reference to the following points: **Phosphorus** • phosphorus has a half-filled p (sub)shell / one electron in each p orbital / the p orbitals are singly occupied (1) • more energy is required to remove an unpaired electron (than a paired electron) **or** an unpaired electron / electron removed has a lower energy (1) OR **Sulfur** • the outermost / 3p electron or the electron being removed in sulfur is paired (1) • less energy is required to remove a paired electron (than an unpaired electron) **or** repulsion between paired electrons (reduces the ionisation energy needed to remove it) **or** the paired electron has a higher energy (1)	**Both marks must come from the same pair** Allow 'electrons-in-boxes' / $3p_x3p_y3p_z$ to show electronic configurations Allow 'box' for orbital as this is in (i) Ignore references to shielding / nuclear charge / lone pairs Penalise 3 or more electrons in a p **orbital** once only Allow '(electron removed is from) a half-filled p orbital' Do not award just $3p^3$ Allow a half-filled subshell is (more) stable Allow sulfur is $3p^4$ Allow sulfur forms a half-filled p (sub)shell when it loses 1 electron Note – paired only needs to be mentioned once in M1 or M2 Do not award M2 if answer states more energy needed to remove electron in sulfur	(2)

Question number	Answer	Additional guidance	Mark
(b)	An explanation that makes reference to the following points: • there are intermolecular forces between P_4 / phosphorus (molecules) **or** phosphorus is made up of small molecules / discrete molecules / is simple molecular (1) • there are covalent bonds between the silicon atoms **or** silicon is a giant (covalent) structure / giant lattice (1) • (much) more energy is needed to break the (covalent) bonds in silicon than overcome the intermolecular forces in phosphorus **or** the (covalent) bonds in silicon are (much) stronger than the (intermolecular) forces in phosphorus (1)	Allow London / dispersion / van der Waals' forces for intermolecular forces Allow macromolecular / giant molecule Do not award ionic / metallic Do not award breaking bonds between phosphorus **atoms**	(3)

Question number	Answer	Additional guidance	Mark
(c)(I)	• number of bonding pairs **and** number of lone pairs (1) • shape (1) • **both** bond angles (1)	Example of table: <table><tr><td>Number of bonding pairs of electrons on phosphorus</td><td colspan="2">5</td></tr><tr><td>Number of lone pairs on electrons on phosphorus</td><td colspan="2">0</td></tr><tr><td>Shape of molecule</td><td colspan="2">trigonal bipyramidal</td></tr><tr><td>Cl-P-Cl bond angles</td><td>90°</td><td>120°</td></tr></table> Mark independently Allow bond angles in either order Ignore 180°	(3)

Question number	Answer	Additional guidance	Mark
(c)(II)	• PCl_4^+ (1) • PCl_6^- (1)	Ions can be in any order If no charges are shown or charges are incorrect, allow (1) for PCl_4 and PCl_6	(2)

Question number	Answer	Additional guidance	Mark
(d)	• calculation of mol of H_3PO_4 **and** calculation of mol of NaOH (1) • mol ratio (1) • balanced equation (1)	Example of calculation: mol H_3PO_4 = $\frac{10.0 \times 0.100}{1000}$ = 0.00100 / 1.00×10^{-3} **and** mol NaOH = $\frac{8.0 \times 0.250}{1000}$ = 0.00200 / 2.00×10^{-3} mol ratio H_3PO_4 : NaOH = 1 : 2 Mol ratio mark can be awarded from equation TE on mol H_3PO_4 and NaOH Do not award M2 if the mol ratio in the balanced equation contradicts the mol ratio from the mol calculations $H_3PO_4 + 2NaOH \rightarrow Na_2HPO_4 + 2H_2O$ Allow HNa_2PO_4 Allow $H_3PO_4 + 2OH^- \rightarrow HPO_4^{2-} + 2H_2O$ Allow multiples Ignore state symbols, even if incorrect Equation TE on mol ratio provided it is 1:1 or 1:3 $H_3PO_4 + NaOH \rightarrow NaH_2PO_4 + H_2O$ $H_3PO_4 + 3NaOH \rightarrow Na_3PO_4 + 3H_2O$	(3)

Question number	Answer	Additional guidance	Mark
(e)	• calculation of molar mass of hydrated magnesium phosphate (1) • calculation of **y** (1)	Examples of calculation: **Method 1** molar mass = 262.9 x $\frac{100}{78.5}$ = 334.9 (g) mass of water = 334.9 – 262.9 = 72 moles of water = $\frac{72}{18}$ = 4 so **y** = 4 Allow alternative methods, for example **Method 2** in 100 g of salt: mol $Mg_3(PO_4)_2$ = $\frac{78.5}{262.9}$ = 0.29859 (mol) **and** mol H_2O = $\frac{21.5}{18}$ = 1.1944(mol) (1) ratio $Mg_3(PO_4)_2$: H_2O = 0.29859 : 1.1944 = 1 : 4 so **y** = 4 (1) This could also be done using 0.785 g and 0.215 g **Method 3** $\frac{262.9}{262.9 + 18y}$ = 0.785 or $\frac{262.9}{262.9 + 18y}$ x 100 = 78.5(1) 262.9 = 206.4 + 14.13 **y** so **y** = 4 (1) Correct answer with no working or working that does not involve A_r or M_r or moles scores (0) Allow TE for **y** from correct working but an incorrect number used for one of the values	**(2)**

Q14.

Q	Answer	Mark
	The only correct answer is B (C_2F_4) ***A*** *is incorrect because CF_4 is tetrahedral* ***C*** *is incorrect because PF_5 is trigonal bipyramidal* ***D*** *is incorrect because SF_6 is octahedral*	**1**

Q15.

Question number	Answer	Mark
	D $AlCl_3$ trigonal planar, PH_3 pyramidal	1

Q16.

Question number	Answer	Mark
	The only correct answer is C (two) *A is incorrect because the four unbonded electrons on sulfur form two lone pairs* *B is incorrect because the four unbonded electrons on sulfur form two lone pairs* *D is incorrect because the four unbonded electrons on sulfur form two lone pairs*	(1)