PEARSON EDEXCEL IAL CHEMISTRY · YCH11

# CHEMISTRY



## EXAM QUESTION PACK

### UNIT 1: COVALENT BONDING

| SCORE | PERCENTAGE |
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STEMUP

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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)**

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(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)**

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(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)**

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

**(1)**

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**(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)**

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(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)**

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

Include a diagram in your answer.

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**(Total for question = 14 marks)**

Q3.

This question is about nitrogen.

(a) The table shows the successive ionisation energies of nitrogen.

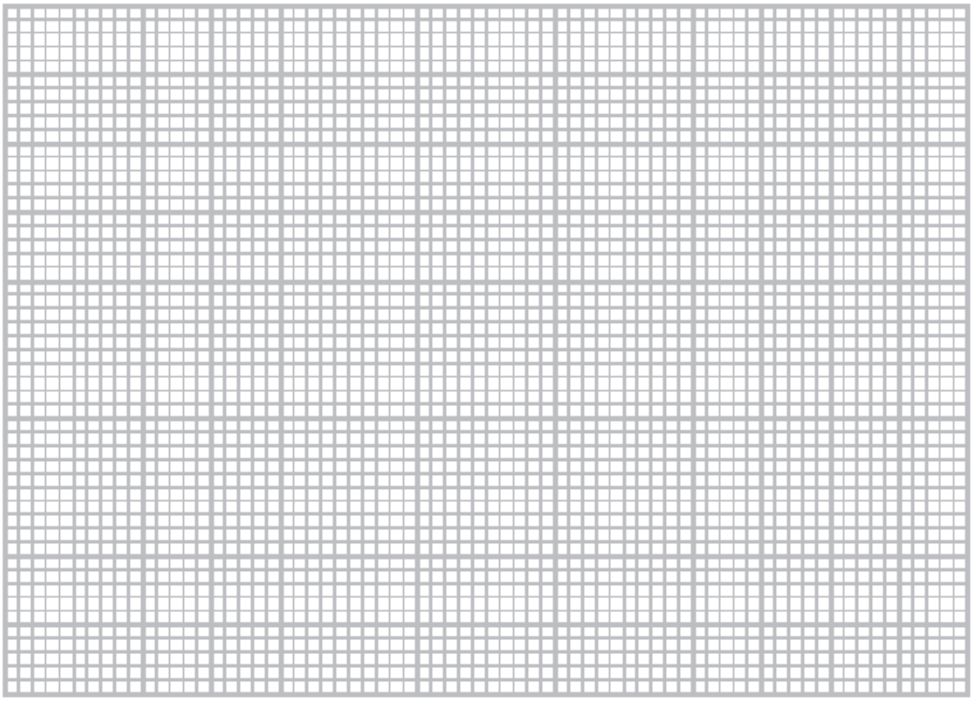
| Ionisation number | Ionisation energy / kJ mol$^{-1}$ | log (ionisation energy) |
|---|---|---|
| 1 | 1 402 | 3.15 |
| 2 | 2 856 | 3.46 |
| 3 | 4 578 | 3.66 |
| 4 | 7 475 | 3.87 |
| 5 | 9 445 | 3.98 |
| 6 | 53 268 | |
| 7 | 64 362 | |

(i) Complete the table.

**(1)**

(ii) Plot a graph of log (ionisation energy) against ionisation number.

**(3)**



(iii) Give a reason why the logarithm of the ionisation energy, rather than just the ionisation energy, is used to plot this graph.

**(1)**

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(iv) Explain what can be deduced from the graph about the electronic structure of nitrogen.

**(3)**

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(v) Explain why the first ionisation energy of oxygen is lower than that of nitrogen.

**(3)**

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(b) Nitrogen gas consists of nitrogen molecules.

(i) Draw a dot-and-cross diagram to show the bonding in a molecule of nitrogen.

**(1)**

(ii) Calculate the number of nitrogen **atoms** in 5.60 g of nitrogen gas.

[Avogadro constant = $6.02 \times 10_{23}$ $mol^{-1}$]

**(2)**

(iii) A sample of nitrogen gas occupied 108 $cm^3$ at a temperature of 25 °C and a pressure of $1.36 \times 10^5$ Pa.

Using the ideal gas equation, calculate the number of moles of nitrogen gas in this sample.

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

**(4)**

**(Total for question = 18 marks)**

Q4.

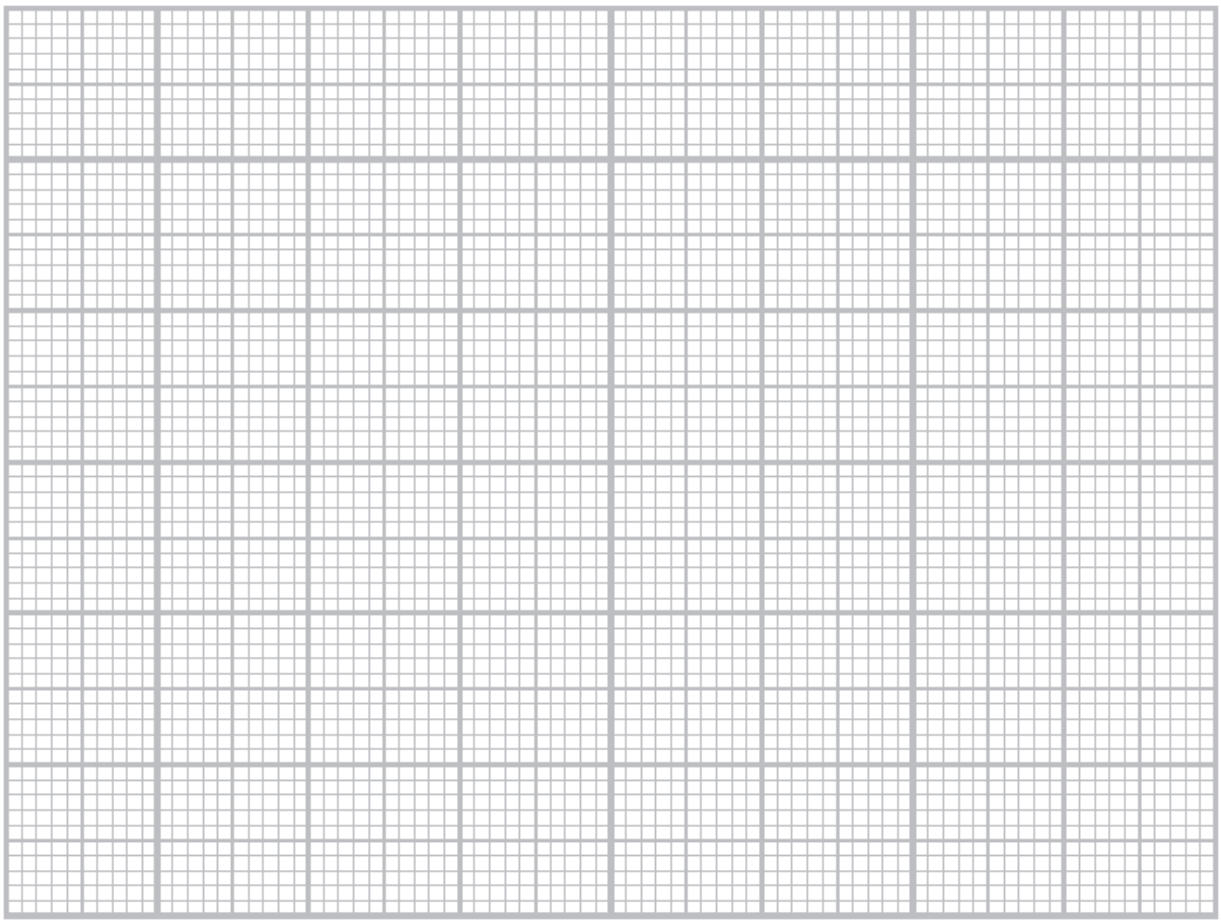
This question is about the elements in Period 3 of the Periodic Table, and some of their compounds.

(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)**

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

**(3)**

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(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

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**(Total for question = 16 marks)**

Q5.

This question is about atomic structure and gases.

(a) Chlorine exists as two isotopes with mass numbers 35 and 37.

(i) State the number and type of each of the particles in the **nucleus** of a chlorine-35 atom.

**(2)**

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(ii) Complete the electronic configuration of a chloride **ion**, $Cl^-$, using the s, p, d notation.

**(1)**

$1s^2$ .....

(iii) A sample of chlorine contains 75.53 % of chlorine-35 atoms.

Calculate the relative atomic mass of this sample of chlorine.
Give your answer to **two** decimal places.

**(2)**

(b) Fluorine has one naturally occurring isotope with mass number 19.

Chlorine and fluorine react to form chlorine trifluoride, $ClF_3$ .

(i) Draw a dot-and-cross diagram to show the bonding in a molecule of chlorine trifluoride.

Show the outer shell electrons only.

**(2)**

(ii) State, in terms of electrons, what is unusual about the dot-and-cross diagram you have drawn.

**(1)**

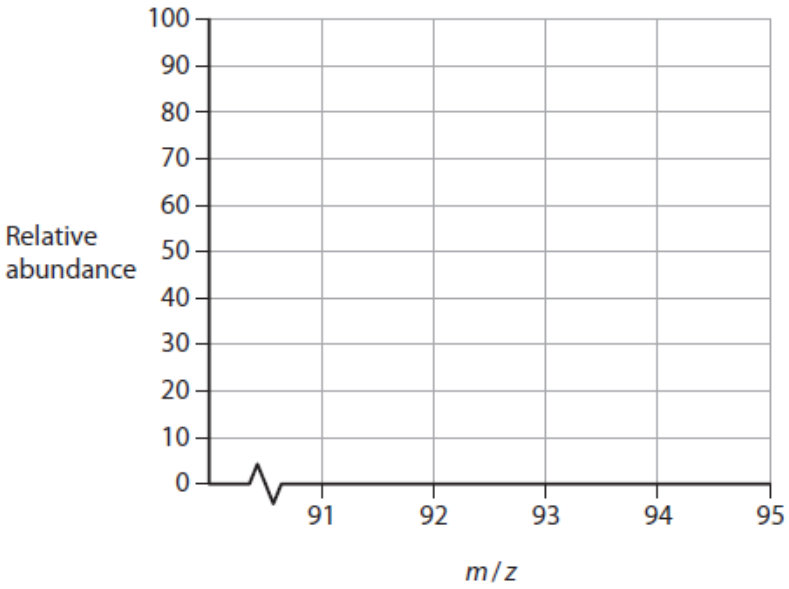
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(iii) Complete the mass spectrum to show the peaks you would expect for the molecular ion $ClF_3^+$ .

**(3)**




(iv) Calculate, using the ideal gas equation, the volume in **$cm^3$** occupied by 0.0200 mol of $ClF_3$ gas at a temperature of 60 °C and a pressure of $1.28 \times 10^5$ Pa.

Give your answer to an appropriate number of significant figures.

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

**(4)**

**(Total for question = 15 marks)**

Q6.

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)**

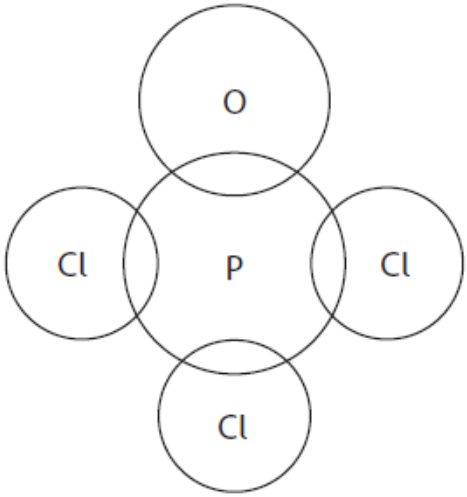
Bond angle .....

(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)**

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(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.....

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High melting temperature
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Malleability .....

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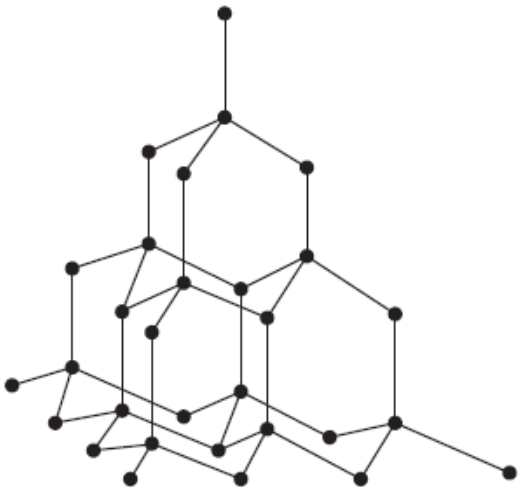
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(e) Diamond, graphite and graphene are all forms of carbon.

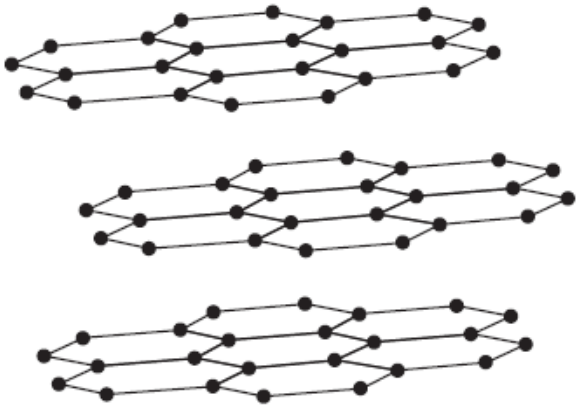
(i) Explain **two** ways in which the physical properties of diamond and graphite differ.

Refer to their structure and bonding in your answer.

**(4)**



diamond



graphite

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

**(1)**

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

**(2)**

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**(Total for question = 20 marks)**

Q7.

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)**

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(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)**

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(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)**

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

**(3)**

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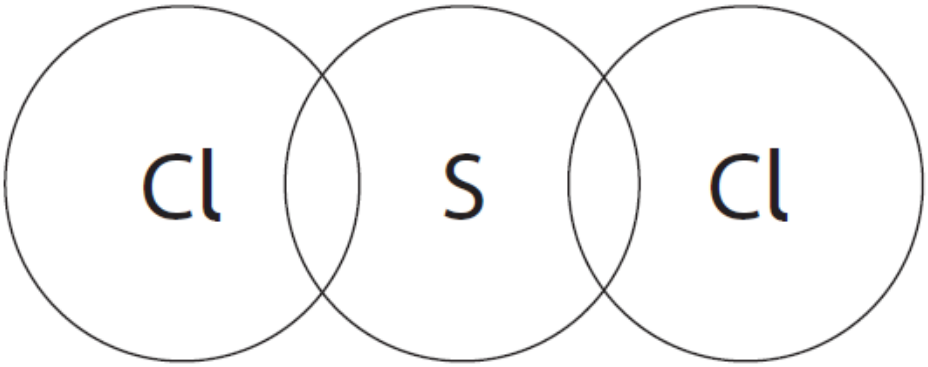
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(c) Sulfur reacts with chlorine to form sulfur dichloride, $SCl_2$.

(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)**

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**(Total for question = 13 marks)**

Q8.

The bonding **within** an ammonium ion, $NH_4^+$, is formed by

**(1)**

☒ **A** covalent bonding only

☒ **B** covalent and dative covalent bonding only

☒ **C** covalent and ionic bonding only

☒ **D** covalent, dative covalent and ionic bonding

**(Total for question = 1 mark)**

Q9.

Water reacts with $H^+$ ions to form $H_3O^+$ ions.

Identify the bonding **within** the $H_3O^+$ ion.

**(1)**

☒ **A** covalent bonding only

☒ **B** covalent and dative covalent bonding only

☒ **C** covalent, dative covalent and ionic bonding

☒ **D** ionic bonding only

**(Total for question = 1 mark)**

Q10.

Naturally occurring bromine has two isotopes: bromine-79 and bromine-81.

(a) State what is meant by the term isotopes.

**(1)**

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(b) Complete the table to show the numbers of subatomic particles in the two isotopes of bromine.

**(2)**

| Isotope | Protons | Neutrons | Electrons |
|---|---|---|---|
| bromine-79 | | | |
| bromine-81 | | | |

(c) The mass spectrum of a sample of bromine is obtained.

(i) Draw a dot-and-cross diagram to show the bonding in a molecule of bromine.

Only the outer electrons should be shown.

**(2)**

(ii) Describe the formation of the molecular ion of bromine in the mass spectrometer. Include an equation.

State symbols are not required.

**(2)**

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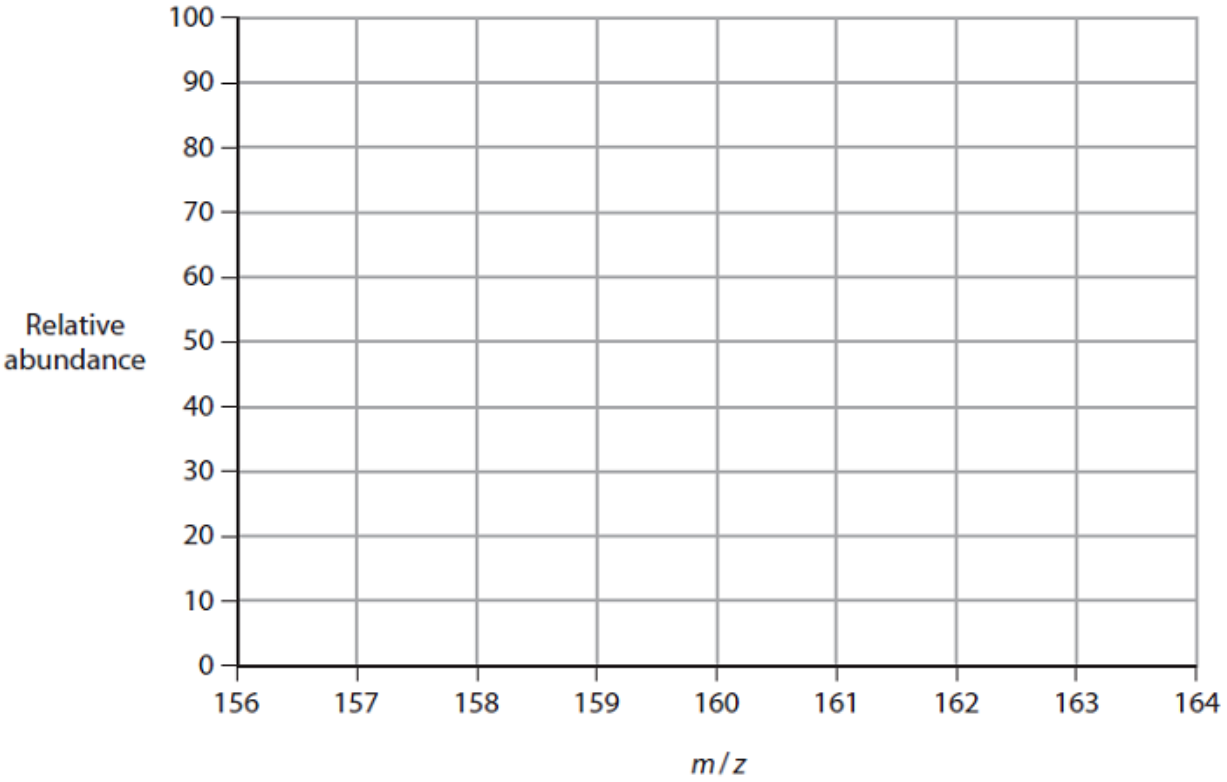
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(iii) On the mass spectrum grid, draw the peaks for the bromine molecular ions, showing the relative peak heights.

The bromine isotopes in this sample have the **same** relative abundance.

**(2)**




(d) The percentage abundances of the isotopes in a different sample of bromine are shown.

| Isotope | Percentage abundance |
|---|---|
| bromine-79 | 56.38% |
| bromine-81 | 43.62% |

Calculate the relative **molecular** mass of this sample of bromine, giving your answer to **two** decimal places.

**(3)**

**(Total for question = 12 marks)**

Q11.

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)**

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

**(3)**

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

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

**(3)**

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

**(2)**

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

Justify your answer.

**(1)**

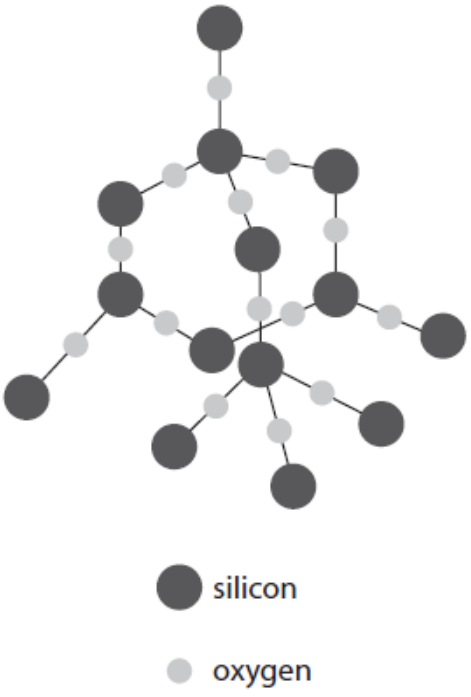
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(c) The structure of silicon dioxide may be referred to as a diamond structure.




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

**(1)**

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(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)**

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**(Total for question = 13 marks)**

Q12.

**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 ☒.**

Covalent bonding is best described as the electrostatic attraction between

☒ **A** oppositely charged ions

☒ **B** positive ions and delocalised electrons

☒ **C** a shared pair of electrons

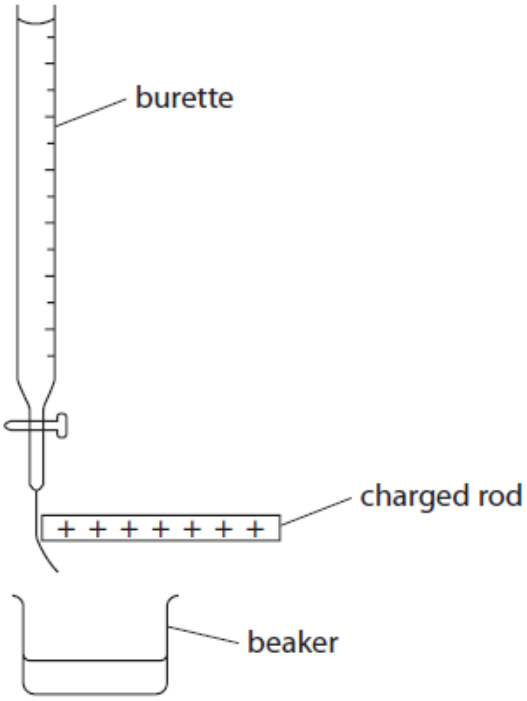
☒ **D** two nuclei and a shared pair of electrons

**(Total for question = 1 mark)**

Q13.

**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 ☒.**

A stream of liquid from a burette is deflected by a charged rod.




Which substance, in its liquid state, will be deflected the most?

☒ **A** $C_5H_{12}$

☒ **B** $CCl_4$

☒ **C** $BCl_3$

☒ **D** $CH_2Cl_2$

**(Total for question = 1 mark)**

**Use this space for any rough working. Anything you write in this space will gain no credit.**

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 of these has the **greatest** electrical conductivity?

☒ **A** $SF_6(g)$

☒ **B** $H_2O(l)$

☒ **C** Hg(l)

☒ **D** $Na_2O(s)$

**(Total for question = 1 mark)**

Q15.

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 $1s^2$

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Ca $1s^2$

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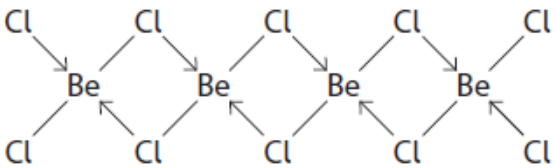
(b) In the gaseous state, beryllium chloride is molecular.

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)**

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(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)**

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(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)**

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**(Total for question = 15 marks)**

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 ☒ .**

Which of these does **not** have a structure formed by a giant lattice of carbon atoms?

☒ **A** $C_{60}$ fullerene

☒ **B** diamond

☒ **C** graphene

☒ **D** graphite

**(Total for question = 1 mark)**

Q17.

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)**

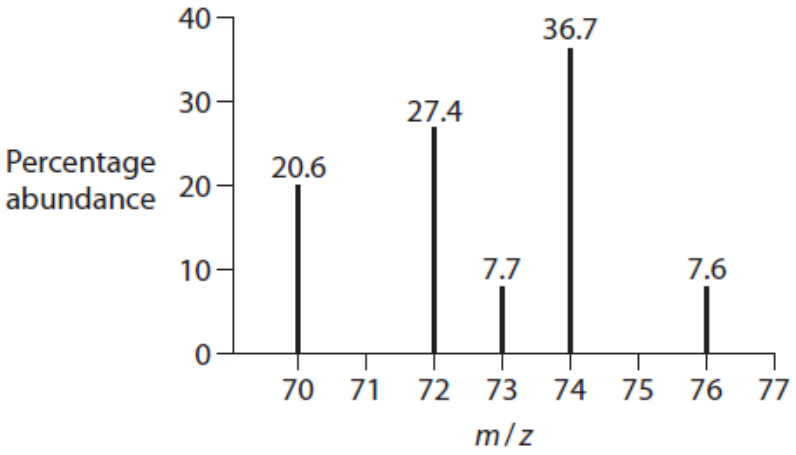
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(b) The mass spectrum of a sample of germanium is shown.




Calculate the relative atomic mass of this sample of germanium.

**(2)**

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

**(1)**

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(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

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(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 ($L$) = $6.02 \times 10^{23}$ $mol^{-1}$]

**(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)**

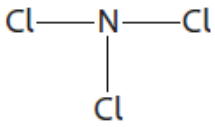
**(Total for question = 20 marks)**

Q18.

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)**

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(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)**

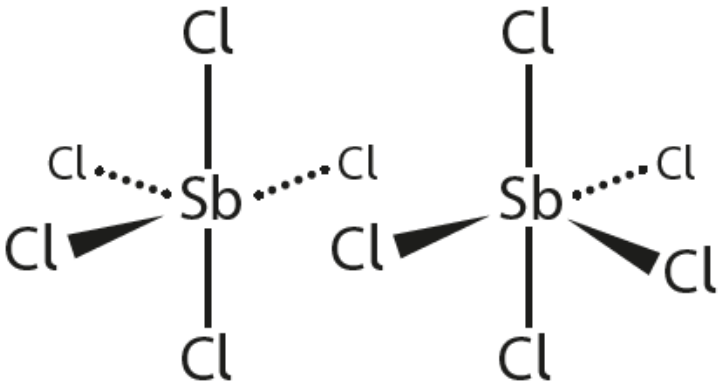
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(ii) Complete the diagram to show the dative covalent bonds in $Sb_2Cl_{10}$ .

**(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)**

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**(Total for question = 10 marks)**

Q19.

**For each question, select one answer from A to D and put a cross in the box ☒. If you change your mind about an answer, put a line through the box ☒ and then mark your new answer with a cross ☒.**

Which of these molecules is **not** polar?

☒ **A** $CO_2$

☒ **B** HCl

☒ **C** $H_2O$

☒ **D** $NH_3$

**(Total for question = 1 mark)**

Q20.

Which row gives the correct polarities of the S—F bond and the $SF_6$ molecule?

| | | Polarity of S—F bond | Polarity of $SF_6$ molecule |
|---|---|---|---|
| ☒ | **A** | polar | polar |
| ☒ | **B** | polar | non-polar |
| ☒ | **C** | non-polar | polar |
| ☒ | **D** | non-polar | non-polar |

**(Total for question = 1 mark)**

Q21.

**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 compound has bonds that are the most polar?

☒ **A** $H_2O$

☒ **B** $H_2S$

☒ **C** $NH_3$

☒ **D** $PH_3$

**(Total for question = 1 mark)**

Q22.

Which of these molecules is the **most** polar?

☒ **A** H—H

☒ **B** H—F

☒ **C** H—Cl

☒ **D** H—Br

**(Total for question = 1 mark)**

Q23.

**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 of these molecules is the **most** polar?

☒ **A** HF

☒ **B** $OF_2$

☒ **C** $BF_3$

☒ **D** $CF_4$

**(Total for question = 1 mark)**

Q24.

What is the polarity of the Al—Cl bond and the polarity of a trigonal planar $AlCl_3$ molecule?

| | Polarity of Al—Cl bond | Polarity of $AlCl_3$ molecule |
|---|---|---|
| ☒ **A** | non-polar | non-polar |
| ☒ **B** | non-polar | polar |
| ☒ **C** | polar | non-polar |
| ☒ **D** | polar | polar |

**(Total for question = 1 mark)**

Q25.

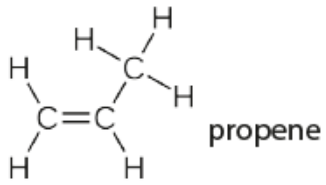
Which describes the polarity of the C—Cl bond and the polarity of the $CCl_4$ molecule?

| | Polarity of C—Cl bond | Polarity of $CCl_4$ molecule |
|---|---|---|
| ☒ **A** | non-polar | non-polar |
| ☒ **B** | non-polar | polar |
| ☒ **C** | polar | polar |
| ☒ **D** | polar | non-polar |

**(Total for question = 1 mark)**

Q26.

This question is about the reactions of propene.




(a) Write an equation for the incomplete combustion of **one mole** of propene to form carbon dioxide, carbon monoxide,
carbon and water as the only products. Include state symbols.

**(2)**

(b) State **one** similarity and **one** difference that would be **seen** when propene is mixed with separate samples of
acidified potassium manganate(VII) solution and of bromine water.

**(2)**

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(c) Propene reacts by addition polymerisation to form poly(propene).

Draw the structure of poly(propene), showing **two** repeat units.

**(1)**

(d) Propene reacts with bromine monochloride, BrCl, to form 1-bromo-2-chloropropane as the major product.

(i) Complete the diagram of bromine monochloride to show the dipole.

**(1)**

Br ——— Cl

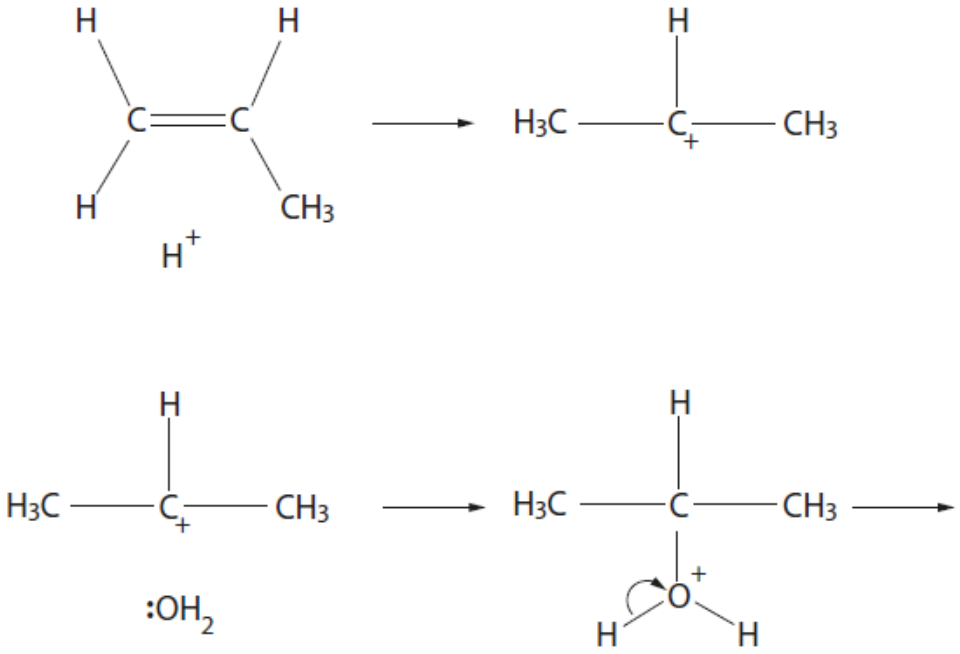
(ii) Draw the mechanism for the formation of 1-bromo-2-chloropropane in this reaction.
Include curly arrows, and relevant lone pairs.

**(3)**

(e) Propene reacts with steam in the presence of an acid catalyst to form a mixture of the alcohols propan-1-ol and propan-2-ol.

Complete the mechanism for the formation of propan-2-ol, by adding curly arrows.
Include the species formed in the final step.

**(3)**




**(Total for question = 12 marks)**

Q27.

This question is about silicon and carbon.

(a) Silicon is a semiconductor.

(i) Data obtained using the mass spectrum of silicon are shown.

| Isotope mass number | Relative abundance |
|---|---|
| 28 | 92.17 |
| 29 | 4.71 |
| 30 | 3.12 |

Calculate the relative atomic mass of silicon to **two** decimal places.

**(2)**

(ii) Suggest a reason why there is a small peak in the mass spectrum of silicon at $m/z = 14$

**(1)**

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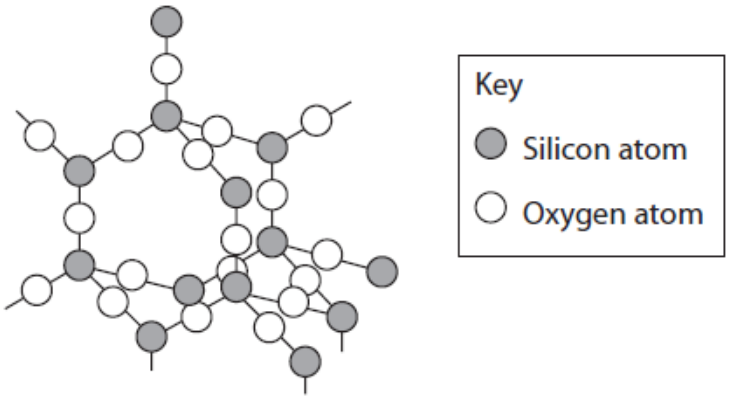
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(iii) Complete the table to show the number of protons and neutrons in each isotope of silicon.

| Isotope | Number of protons | Number of neutrons |
|---|---|---|
| $^{28}Si$ | | |
| $^{29}Si$ | | |
| $^{30}Si$ | | |

**(1)**

(b) Silicon dioxide, $SiO_2$, is the main constituent of sand and has a giant lattice structure similar to that of diamond.




Crystalline silicon dioxide is used on the surface of semiconductor devices to provide a heat-resistant, electrically insulating layer.

Explain how the structure and bonding of silicon dioxide make it useful for this application.

**(3)**

.....

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(c) Calcium silicate is formed in the removal of silicon dioxide impurities in the extraction of iron from its ores. A sample of calcium silicate composed of calcium, silicon and oxygen was found to contain 12.0 g of calcium, 8.43 g of silicon and 14.47 g of oxygen.

Determine the empirical formula of calcium silicate.
You **must** show your working.

**(3)**

(d) Carbon dioxide is a gas at room temperature. A fizzy drink is canned at 5.0 °C and $1.3 \times 10^5$ Pa and contains approximately 3 g of carbon dioxide.

Calculate the volume, in $cm^3$, occupied by 3.00 g of carbon dioxide gas at 5.0 °C and $1.3 \times 10^5$ Pa.

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

**(4)**

**(Total for question = 14 marks)**

Q28.

**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 ☒.**

Ammonium iron(II) sulfate, $(NH_4)_2Fe(SO_4)_2 \cdot 6H_2O$, is a double salt that is used as a source of iron(II) ions.

(a) What is the relative formula mass of the double salt?

[$A_r$ values: H = 1.0 N = 14.0 O = 16.0 S = 32.1 Fe = 55.8]

**(1)**

☐ **A** 277.9

☐ **B** 284.0

☐ **C** 392.0

☐ **D** 447.8

(b) Ammonium sulfate is used in the preparation of the double salt.

What types of bond are present in ammonium sulfate?

**(1)**

☒ **A** ionic only

☒ **B** covalent and ionic only

☒ **C** dative covalent and ionic only

☒ **D** ionic, covalent and dative covalent

(c) What is the **total** number of ions present in 0.1 mol of the double salt?

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

**(1)**

☒ **A** $1.80 \times 10^{23}$

☒ **B** $2.41 \times 10^{23}$

☒ **C** $3.01 \times 10^{23}$

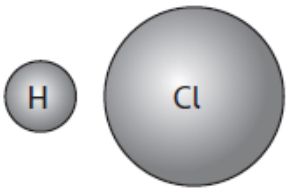
☒ **D** $6.62 \times 10^{23}$

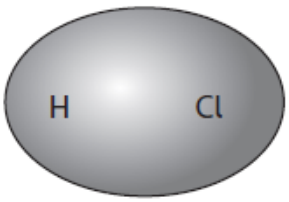
**(Total for question = 3 marks)**

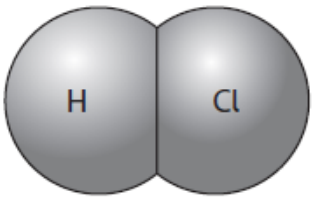
Q29.

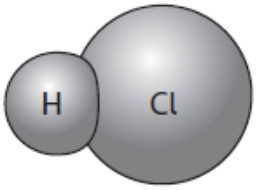
**Answer the question with a cross in the box you think is correct ☒. If you change your mind about an answer, put a line through the box ☒ and then mark your new answer with a cross ☒.**

Which diagram best represents the electron density in a molecule of hydrogen chloride?

☒ **A** 


☒ **B** 


☒ **C** 


☒ **D** 

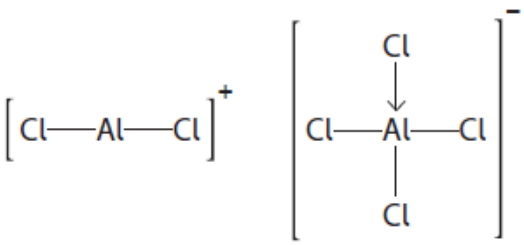

**(Total for question = 1 mark)**

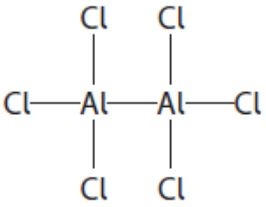
Q30.

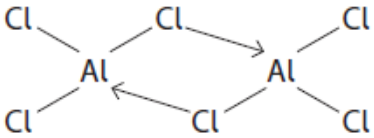
**Answer the question with a cross in the box you think is correct ☒. If you change your mind about an answer, put a line through the box ☒ and then mark your new answer with a cross ☒.**

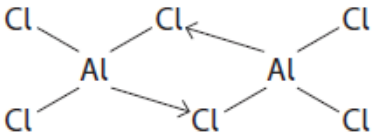
At 180°C, aluminium chloride exists as $Al_2Cl_6$.

What is the structure of $Al_2Cl_6$?

☒ **A** 

☒ **B** 

☒ **C** 

☒ **D** 

**Use this space for any rough working. Anything you write in this space will gain no credit.**

**(Total for question = 1 mark)**

Q31.

**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 substance has a giant lattice of atoms?

☒ **A** diamond

☒ **B** ice

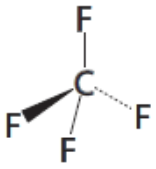
☒ **C** poly(ethene)

☒ **D** sodium chloride

**(Total for question = 1 mark)**

Q32.

Which is correct for tetrafluoromethane ($CF_4$)?




| | Bonds | Molecule |
|---|---|---|
| ☐ **A** | polar | polar |
| ☐ **B** | non-polar | polar |
| ☐ **C** | polar | non-polar |
| ☐ **D** | non-polar | non-polar |

**(Total for question = 1 mark)**

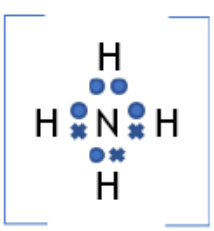
## Mark Scheme

Q1.

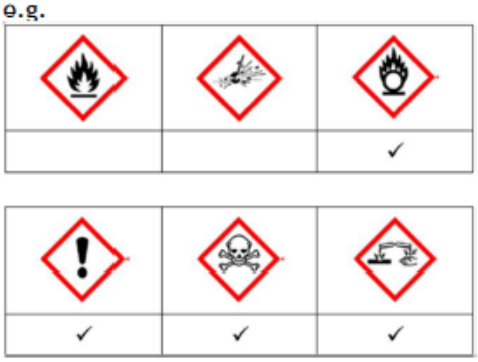
| Question Number | Answer | Additional guidance | Mark |
|---|---|---|---|
| (a)(i) | • $(NH_4)_2Cr_2O_7 \rightarrow N_2 + 4H_2O + Cr_2O_3$ | 1 mark for $Cr_2O_3$<br>1 mark for all the rest being correct<br><br>Allow multiples<br><br>Marks are standalone | (2) |

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

| Question Number | Answer | Additional guidance | Mark |
|---|---|---|---|
| (b) | • conversion of units for *P* and *V* (1)<br>• substitution in equation and rearrange (1)<br>• answer in K (1)<br>• convert to °C (1) | Example of calculation:<br>$P = 101000 / 1.01 \times 10^5$ Pa<br>$V = 0.0000252 / 2.52 \times 10^{-5}$ m$^3$<br>Allow incorrect use standard form e.g. $10.1 \times 10^4$ Pa<br>$T = \frac{101000 \times 0.0000252}{0.001 \times 8.31}$<br>$T$ = 306.28 (K)<br>$T$ = 33.3(°C) (33.1°C if 273.15 is used for conversion of kelvin to Celsius)<br>Ignore SF except 1 SF on final answer<br>TE throughout but only award for MP4 if final answer in °C is between 0 and 50°C<br>Units if given must be correct<br>*Comment:*<br>*Correct answer with no working scores 4*<br>*306.28(K) scores 3*<br>*30.85 °C scores 3*<br>*33.7 °C scores 3 as they have used R as 8.3*<br>*33.55 °C scores 3 using 8.3 and 273.15*<br>*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:<br>• four pairs of electrons and 4 hydrogen atoms around nitrogen (1)<br>• one dative covalent bond **and** plus sign (1) | <br>Allow answers without brackets<br>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)<br>Ignore placement of positive sign | (2) |

| Question Number | Answer | Additional guidance | Mark |
|---|---|---|---|
| (c)(ii) | An explanation that makes reference to:<br>• tetrahedral / tetrahedron (1)<br>• (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)<br>Allow phonetic spelling<br>Allow equal repulsion of electron-pairs<br>Allow reference to bonding pairs<br>Ignore reference to bonds<br>Ignore all bond angles<br>Do not award references to lone pairs<br>Marks are standalone | (2) |

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

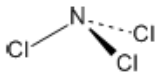
| Question Number | Answer | Additional guidance | Mark |
|---|---|---|---|
| (d)(ii) | An answer containing an appropriate suggestion:<br>• dichromate/oxidising agents promote(s) combustion/burning of alkanes/fuels<br>OR<br>alkanes are flammable/combustible **and** dichromate is an oxidising agent |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

Q2.

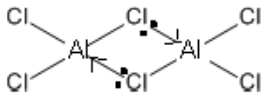
| Question number | Answer | Additional guidance | Mark |
|---|---|---|---|
| 24(a) | An explanation that makes reference to the following points:<br><br>• (I) is incorrect because the solutions are aqueous<br>**or**<br>ions are (in the) aqueous (state)<br>the state symbols should be (aq) instead of (I)<br><br>• silver ions should have one positive charge / $Ag^+$<br>**or**<br>silver chloride is AgCl | Allow silver nitrate and sodium chloride are aqueous<br><br>Do not award if incorrect state symbol for one of the species in the equation e.g. Ag is (s) / AgCl is (aq)<br><br>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)**<br><br>• calculation of empirical formula **(1)**<br><br>• calculation of molecular formula **(1)** | Example of calculation:<br>C : H : Cl<br>mol $\frac{3.09}{12} : \frac{0.26}{1} : \frac{9.15}{35.5}$<br>= 0.2575 : 0.26 : 0.2577<br>(ratio 1 : 1 : 1)<br>Empirical formula is CHCl<br><br>molar mass CHCl = 12 + 1 + 35.5 = 48.5<br><br>$\frac{\text{molar mass } (CHCl)_n}{\text{molar mass CHCl}} = \frac{97}{48.5} = 2$<br><br>Molecular formula is $C_2H_2Cl_2$<br><br>Allow symbols in any order<br><br>Do not award 2CHCl<br><br>Ignore SF in mol and ratio<br><br>Correct molecular formula with some working scores (3)<br><br>**Alternative method** scores (3)<br>no. C atoms = $\frac{3.09 \times 97}{12.5 \times 12} = 2 / 1.9982$<br><br>no. H atoms = $\frac{0.26 \times 97}{12.5 \times 1} = 2(.0176)$<br><br>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<br>• all 4 (corresponding) *m* / *z* values | Example of answer:<br>ions *m* / *z*<br>$N(^{35}Cl)_3^+$ 119<br>$N(^{35}Cl)_2{}^{37}Cl^+$ 121<br>$N^{35}Cl(^{37}Cl)_2^+$ 123<br>$N(^{37}Cl)_3^+$ 125<br><br>Allow any other unambiguous way of representing the formulae e.g. in words<br><br>Allow (1) for any two *m* / *z* values with corresponding ion formulae<br><br>Ignore missing /<br><br>incorrect charge on ion<br><br>Ignore mass number on N<br><br>Ignore bonds or + between Cl atoms / order of atoms<br>e.g. $N\text{-}^{35}Cl\text{-}^{35}Cl\text{-}^{35}Cl$ | (2) |

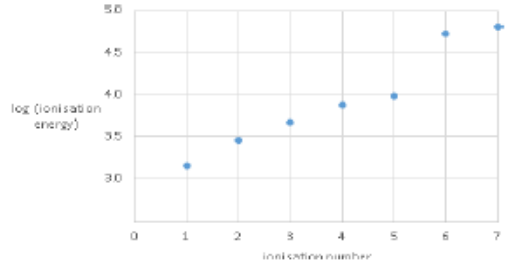
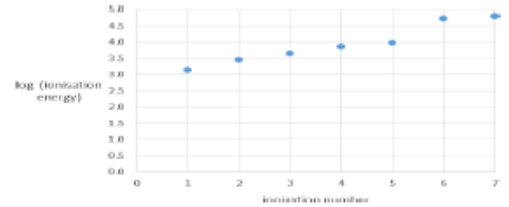
| Question number | Answer | Additional guidance | Mark |
|---|---|---|---|
| (c)(ii) | • number of bonding pairs<br>**and**<br>number of lone pairs<br><br>• shape<br><br>• bond angle | Example of table:<br>Number of bonding pairs of electrons on nitrogen: 3<br>Number of lone pairs on electrons on nitrogen: 1<br>Shape of molecule: trigonal pyramidal<br>Bond angle: 107°<br><br>**Shape:**<br>Allow 3-dimensional drawing e.g.<br><br><br>There must be at least 1 dotted/dashed line or wedge for 3-d<br>Allow just 'pyramidal'<br>Allow pyramid for pyramidal<br>Do not award tetrahedral<br><br>**Bond angle:**<br>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:<br><br>**Polarisation route**<br>• an aluminium ion / cation is (very) small **and** highly charged<br>**or**<br>$Al^{3+}$ has a small ionic radius / is small<br><br>• so it polarises / distorts the chloride ion / $Cl^-$ / anion<br><br>**Allow Electronegativity route**<br><br>• there is a (relatively) small difference in electronegativity between aluminium and chlorine<br><br>• so the electrons are (partially) shared | Marks must come from the same route<br>– maximum 1 mark if one point from one route and one point from the other route<br><br>Allow the aluminium ion has a high charge density<br><br>Allow a description of<br><br>polarisation Allow<br><br>chlorine anion / ion<br><br>Ignore the aluminium chloride is polarised<br><br>Ignore size of chloride ion | (2) |

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

Q3.

| Question number | Answer | Additional guidance | Mark |
|---|---|---|---|
| (a)(i) | • two correct values | <table><tr><td>(6)</td><td>(53 268)</td><td>4.73</td></tr><tr><td>(7)</td><td>(64 362)</td><td>4.81</td></tr></table><br>Both numbers correct and must be to 2 d.p. | (1) |

| Question number | Answer | Additional guidance | Mark |
|---|---|---|---|
| (a)(ii) | • axes correct way round **and** linear scale points covering at least half the grid horizontally **(1)**<br>• both axes labelled **(1)**<br>• points plotted correctly **(1)** | Example of graph:<br><br><br>Allow<br><br><br>**Labels**:<br>Allow log(IE / kJ mol$^{-1}$)<br>Do not award log(IE) / kJ mol$^{-1}$<br>**Points**:<br>TE on values in table for 6$^{th}$ and 7$^{th}$ log(IE)<br>Allow ±1 small square<br>Allow points joined by lines / bar chart<br>Ignore lines drawn from x axis to each point<br>Do not award a best fit straight line<br>Do not award lines joined to the origin | **(3)** |

| Question number | Answer | Additional guidance | Mark |
|---|---|---|---|
| (a)(iii) | An answer that makes reference to the following:<br>• the range of numbers / 1402 to 64362 is too large (to fit on a graph / axis)<br>**or**<br>logarithms make it easier to plot the numbers | Allow:<br>A (very) long y axis would be needed<br>The difference between the ionisation energies is too large<br>So the numbers will fit on the graph<br>Allow logs give smaller (range of) numbers | **(1)** |

| Question number | Answer | Additional guidance | Mark |
|---|---|---|---|
| (a)(iv) | An explanation that makes reference to the following points:<br><br>• the (large) jump (between ionisations 5 and 6) shows the start of a new (quantum) shell **(1)**<br><br>• there are two electrons that are harder to remove and they are closer to the nucleus **(1)**<br><br>• there are five electrons that are easier to remove and they are further from the nucleus **(1)** | Penalise use of orbitals instead of shells once only<br><br>Allow any answer relating the jump / large increase to two (quantum) shells<br>Allow jump linked to **1s** and **2s** sub-shells<br>Do not award jump between incorrect numbers<br><br>Allow there are two electrons in the inner (quantum) shell<br><br>Allow there are five electrons in the outer (quantum) shell / five valence electrons | **(3)** |

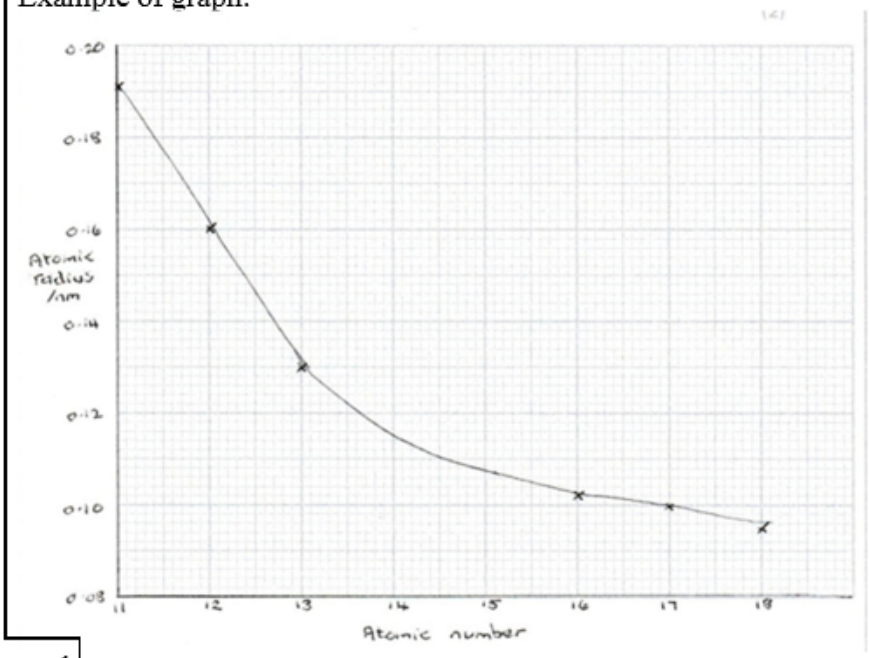
| Question number | Answer | Additional guidance | Mark |
|---|---|---|---|
| (a)(v) | An explanation that makes reference to the following points:<br><br>**Oxygen**<br>• oxygen (atom) loses a paired electron (from a 2p orbital / 2p sub-shell)<br>**or**<br>electron is lost from a full (2p) orbital<br>**(1)**<br><br>**Nitrogen**<br>• nitrogen (atom) loses an electron from a singly-occupied orbital<br>**or**<br>loses an electron from a half-filled subshell<br>**(1)**<br><br>**Repulsion**<br>• there is (more) repulsion between **paired** electrons (than between electrons in different orbitals so less energy is required to remove the electron in oxygen) **(1)** | Penalise mention of incorrect orbital e.g. 3p once only<br><br>Ignore any reference to nuclear charge / numbers of protons / shielding / atomic radius<br><br>Allow M1 and M2 from diagrams showing electrons in boxes<br><br>Allow oxygen has a pair of electrons in a (2)p orbital<br>**or**<br>there is spin pairing in oxygen in a (2)p orbital<br><br>Allow nitrogen has no paired electrons in the (2)p sub-shell / (2)p orbitals<br>**or**<br>nitrogen only has 1 electron in each (2)p orbital / has 3 unpaired (2)p electrons / has a half-filled (2)p sub-shell / has half-filled (2)p orbitals<br><br>Do not award just 'nitrogen has a half-filled p orbital' | **(3)** |

| Question number | Answer | Additional guidance | Mark |
|---|---|---|---|
| (b)(i) | • dot-and-cross diagram | Example of dot-and-cross diagram:<br><br>Allow overlapping circles Allow all dots / all crosses<br><br>Allow dots and crosses in any order in the triple bond<br><br>Allow the dots and crosses side-by-side in the triple bond e.g.<br>x o<br>x o<br>x o<br><br>Allow the non-bonded electrons on each N shown separately<br><br>Ignore inner shell electrons, even if incorrect<br><br>Ignore lines as bonds e.g.<br><br>x x x<br>o o o | (1) |

| Question number | Answer | Additional guidance | Mark |
|---|---|---|---|
| (b)(ii) | • calculation of moles of nitrogen atoms<br><br>• calculation of number of nitrogen atoms | Example of calculation:<br><br>mol $N_2 = \frac{5.60}{28} = 0.20$<br>**and**<br>mol N atoms = 0.20 x 2 = 0.40<br><br>**or**<br>$\frac{5.60}{14} = 0.40$<br><br>number of N atoms = $0.40 \times 6.02 \times 10^{23}$<br>$= 2.408 \times 10^{23}$ / $2.41 \times 10^{23}$ / $2.4 \times 10^{23}$<br><br>TE on moles of nitrogen<br><br>Ignore SF except 1SF<br><br>Correct answer with no working scores (2) | (2) |

| Question number | Answer | Additional guidance | Mark |
|---|---|---|---|
| (b)(iii) | • conversion of volume to $m^3$ **(1)**<br>• conversion of temperature to K **(1)**<br>• rearrangement of ideal gas equation **(1)**<br>• evaluation to give n **(1)** | Example of calculation:<br>volume of $N_2 = \frac{108}{1 \times 10^6} = 1.08 \times 10^{-4}$ $m^3$<br>temperature = 25 + 273<br>= 298 K $n = \frac{pV}{RT}$<br>**or**<br>$n = \frac{1.36 \times 10^5 \times 1.08 \times 10^{-4}}{8.31 \times 298}$<br>TE on volume and temperature<br>$n = 5.9312 \times 10^{-3}$ / 0.0059312 (mol)<br>Conditional on correctly rearranged equation in M3 Ignore SF except 1SF<br>Correct answer with no working scores full marks | **(4)** |

Q4.

| Q | Answer | Additional guidance | Mark |
|---|---|---|---|
| (a)(i) | | Example of graph:<br><br> | **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<br>Ignore symbols on x axis<br>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<br><br>Accept graph with or without line drawn<br><br>**Comment**<br>If atomic radius is plotted on the x axis, allow (1) for correct graph | |

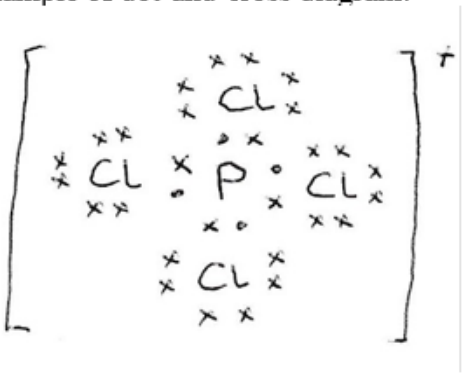
| Q | Answer | Additional guidance | Mark |
|---|---|---|---|
| (a)(ii) | • value in allowed range | Allow 0.112 to 0.118 (nm)<br>Allow value written in table<br><br>Ignore any value given for phosphorus | **1** |

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

| Q | Answer | Additional guidance | Mark |
|---|---|---|---|
| (b) | • giant for structure of sodium chloride **(1)**<br>• metallic bonding for sodium **(1)**<br>• ionic bonding for sodium chloride **(1)**<br>• intermolecular (forces) for chlorine **(1)**<br>• $Na^+$ **and** electrons / cations **and** electrons (particles in sodium) **(1)**<br>• $Na^+$ **and** $Cl^-$ /cations **and** anions (particles in sodium chloride) **(1)** | Allow giant ionic / (giant) lattice<br>Ignore metal<br>Ignore ion(s)<br>Ignore electrostatic attractions in M2 and M3<br>Accept London / dispersion (forces)<br>Allow van der Waals' (forces)<br>Ignore weak (forces)<br>Allow positive ions **and** electrons<br>Allow sodium atoms / ions **and** electrons<br>Allow positive (sodium) ion and negative (chloride / chlorine) ion<br>Ignore just sodium ions and chloride ions<br>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:<br><br>Allow any combination of dots and crosses, including all dots or all crosses<br><br>Allow overlapping circles<br><br>Allow electrons in bonds along the axis of the bond<br><br>Ignore missing bracket and charge<br><br>Ignore lines representing covalent bonds<br>e.g. x | 1 |

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

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Q5.

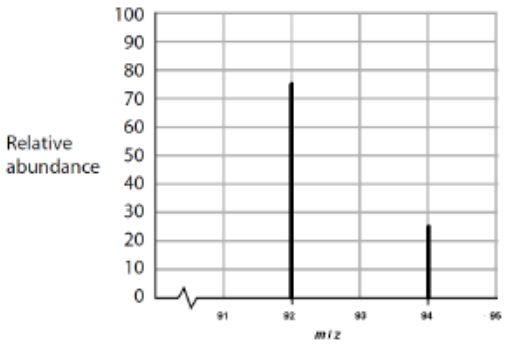
| Question number | Answer | Additional guidance | Mark |
|---|---|---|---|
| (a)(i) | • 17 protons (1)<br>• 18 neutrons (1) | Any reference to electrons scores (1) for an answer that includes 17 protons **and** 18 neutrons | (2) |

| Question number | Answer | Additional guidance | Mark |
|---|---|---|---|
| (a)(ii) | • $(1s^2)2s^22p^63s^23p^6$ | Allow $2p_x^2 2p_y^2 2p_z^2$ and/or $3p_x^2 3p_y^2 3p_z^2$<br><br>Allow numbers of electrons written as subscripts or large numbers<br><br>Ignore repeated $1s^2$ | (1) |

| Question number | Answer | Additional guidance | Mark |
|---|---|---|---|
| (a)(iii) | • correct working (1)<br><br>• answer given to 2 dp (1) | Example of calculation:<br><br>$\frac{(35 \times 75.53) + (37 \times 24.47)}{100}$ (= 35.4894)<br>or<br>(35 x 0.7553) + (37 x 0.2447) (= 35.4894)<br><br>35.49<br>TE on working involving two different species<br><br>Correct answer to 2 dp with no working scores (2)<br><br>35.50 with no working scores (0)<br><br>Ignore units, even if incorrect | (2) |

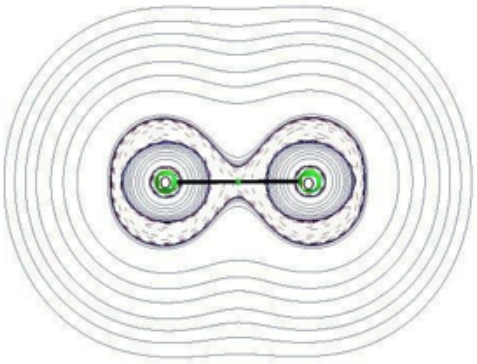
| Question number | Answer | Additional guidance | Mark |
|---|---|---|---|
| (b)(i) | • dot-and-cross diagram showing three pairs of electrons between one Cl and three F atoms (1)<br><br>• rest of diagram correct conditional on M1 (1) | Example of dot-and-cross diagram:<br><br><br><br><br>Allow overlapping circles<br><br>Allow all dots / all crosses<br><br>Allow 4 non-bonded electrons on Cl shown as:<br>2 lone pairs together or<br>2 lone pairs between any two of the bonded pairs or<br>1 lone pair and 2 unpaired electrons or<br>3 electrons and 1 electron<br><br>Ignore inner shell electrons / lines for bonds<br><br>Penalise a charged species in M2 only | (2) |

| Question number | Answer | Additional guidance | Mark |
|---|---|---|---|
| (b)(ii) | • there are 10 electrons / 5 pairs of electrons in the outer / valence shell of chlorine | Allow there are more than 8 electrons in the outer / valence shell of chlorine<br><br>Allow there are 3 bond pairs and 2 lone pairs (in the outer shell of chlorine)<br><br>Allow chlorine has expanded its octet<br><br>Allow chlorine does not have a noble gas electronic structure / does not have 8 electrons in the outer / valence shell<br><br>Allow just 'chlorine has 10 electrons' / 'more than 8 electrons'<br><br>Ignore chlorine is the central atom<br><br>Ignore just 'chlorine has 2 lone pairs'<br><br>Do not award incorrect numbers of electrons / orbitals | (1) |

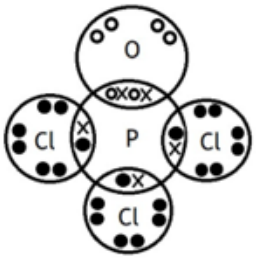
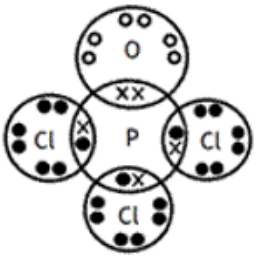
| Question number | Answer | Additional guidance | Mark |
|---|---|---|---|
| (b)(iii) | • a peak at *m/z* = 92 (1)<br><br>• a peak at *m/z* = 94 (1)<br><br>• peaks at 92 and 94 are in the ratio 3:1 approximately (1) | Example of mass spectrum:<br><br><br><br><br>Allow any 3:1 ratio for the peaks<br>e.g. 100:33, 30:10<br><br>Ignore any labels on the peaks<br><br>M3 is a stand alone mark for peaks at 92 and 94 only | (3) |

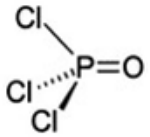
| Question number | Answer | Additional guidance | Mark |
|---|---|---|---|
| (b)(iv) | • conversion of temperature to K (1)<br><br>• rearrangement of Ideal Gas Equation (1)<br><br>• evaluation to give volume (1)<br><br>• conversion of volume to $cm^3$ **and** answer given to 2 or 3 SF (1) | Example of calculation:<br><br>temperature = 60 + 273 = 333 K<br><br>$V = \frac{nRT}{P}$<br>or<br>$V = \frac{0.0200 \times 8.31 \times 333}{1.28 \times 10^5}$<br><br>V = $4.3238 \times 10^{-4}$ ($m^3$)<br>TE on temperature<br><br>volume = $4.3238 \times 10^{-4} \times 1 \times 10^6$<br>= (432.38)<br>= 432 / 430 / $4.32 \times 10^2$ / $4.3 \times 10^2$ ($cm^3$)<br>TE on volume in M3<br><br>Penalise rounding to 1SF once only in M1, M2 and M3<br><br>Correct answer with no working scores full marks | (4) |

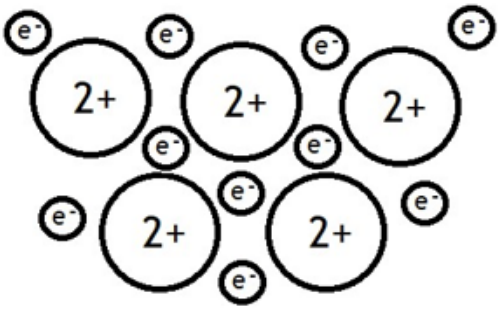
Q6.

| Question Number | Answer | Additional guidance | Mark |
|---|---|---|---|
| **(a)** | A sketch showing:<br>• two atoms with high electron density and a symmetrical cloud around both | e.g.<br><br>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<br><br>is the minimum<br>Allow nuclei shown as + signs<br>Allow dashed contour lines | **(1)** |

| Question Number | Answer | Additional guidance | Mark |
|---|---|---|---|
| **(b)** | A diagram that includes:<br><br>• shape of $H_2O$ **(1)**<br><br>• bond angle **(1)** | CHECK THE ANSWER LINE ON BOTTOM RIGHT CORNER!<br>(as well as angles on diagram)<br><br><br><br><br>Allow dot-cross diagrams if in the correct shape<br><br>Allow 3D representations showing lone pairs Ignore the presence of lone/bonding pairs of electrons Ignore charges or partial charges even if incorrect<br><br>Do not award double bonds<br><br>Accept bond angle from 104° to 105 °<br>Allow bond angle labelled <u>correctly</u> on diagram<br><br>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:<br>• phosphorus singly covalently bonded to three chlorine atoms and three lone pairs on each chlorine **(1)**<br>• phosphorus doubly bonded to an oxygen atom and two lone pairs on the oxygen<br>or<br>a dative covalent bond from the phosphorus and three lone pairs on the oxygen<br>**(1)** | <br><br>OR<br><br><br>Penalise absence of lone pairs once only<br>Allow lone pairs to appear as separate electrons<br>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:<br><br>• (based on) tetrahedron / tetrahedral (arrangement) **(1)**<br><br>• four regions of bonding electrons **(1)**<br><br>• adopt the positions of minimum repulsion **(1)** | MP1 can be given for a 3-D diagram<br><br><br>Accept 5 bonding pairs, where two (in double bond) behave as one. Allow 4 bonding pairs<br>Allow phosphorous bonds to 4 other atoms<br><br>Accept repel to maximum separation Allow maximise the distance between the bonding pairs<br>Allow to achieve lowest (potential) energy state<br>Ignore to become most stable<br>Do not award maximum repulsion<br><br>Ignore bond angles throughout<br>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<br>Accept close packed ions<br>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"<br>Allow "e" or "–" to represent electrons<br>Ignore "electron cloud" | |

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

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

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

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

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

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

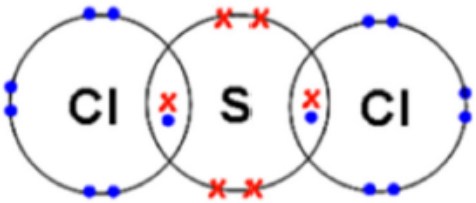
Q7.

| 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.**<br>Allow **electrostatic forces** as an alternative to **attraction**<br>Allow **attraction** between metal ions and **delocalised** electrons<br>Allow **attraction** between (positive) nuclei and **delocalised** electrons<br><br>Ignore just 'ions'<br>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<br>• M1 Mg has more **delocalised** electrons **(1)**<br>• M2 **$Mg^{2+}$** is smaller (than $Na^+$) **(1)**<br>• M3 **$Mg^{2+}$** has a higher charge (than $Na^+$) **(1)**<br>• 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<br>Ignore free moving electrons<br><br>Allow Mg ion is smaller (than $Na^+$)<br>Allow Mg smaller ionic radius<br>Do not award atomic radius<br><br>Allow Mg ion has a higher charge (than $Na^+$)<br>Ignore the number of protons<br><br>Just $Mg^{2+}$ 'has a greater charge density' scores (1) for M2 & M3<br><br>Allow greater attraction between the delocalised electrons and Mg<br>Ignore attraction to the protons<br>Ignore outer shell electrons<br><br>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:<br>• phosphorus (P) simple molecular (1)<br>• silicon (Si) giant (covalent/molecular) structure (1)<br>• 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<br>Allow lattice instead of giant<br>Ignore macromolecular<br>Do not award giant metallic/ionic<br>Allow / dispersion /van der Waals forces/ instantaneous dipole-induced dipole/intermolecular forces<br>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:<br>• dot-and-cross diagram showing two shared pairs of electrons between S and Cls (1)<br>• rest of diagram correct (1) | Example of dot-and-cross diagram<br><br><br>Allow all dots/all crosses/dots crosses the wrong way round<br>Allow the non-bonded pairs of electrons on S and Cl anywhere and allow non-bonding electrons unpaired.<br>Ignore inner shells<br>Charged species/ions scores 0 | (2) |

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

Q8.

| Question number | Answer | Mark |
|---|---|---|
| | **The only correct answer is B** (covalent and dative covalent bonding)<br><br>*A is incorrect because there is a dative bond between the nitrogen atom and $H^+$ ion*<br>*C is incorrect because dative bonding is missing and ionic bonding is between ions, not within an ion*<br>*D is incorrect because ionic bonding is between ions, not within an ion* | (1) |

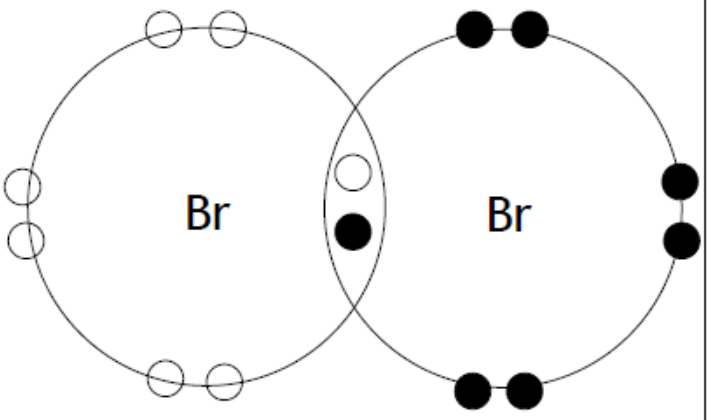
Q9.

| Question number | Answer | Mark |
|---|---|---|
| | B covalent and dative covalent bonding only | 1 |

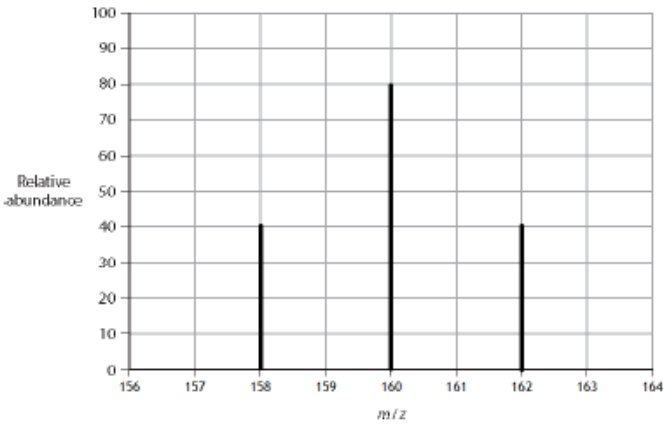
Q10.

| Question number | Answer | Additional guidance | Mark |
|---|---|---|---|
| (a) | An answer that makes reference to<br>• (atoms with the) same atomic number and different mass numbers | Accept<br>proton number for atomic number<br>or<br>same number of protons but different numbers of neutrons<br>Allow<br>bromine-79 has 35 protons & 44 neutrons<br>**and**<br>bromine-81 has 35 protons & 46 neutrons<br><br>Allow "an atom" or "element"<br>Do not award molecule<br>Ignore same number of electrons | 1 |

| Question number | Answer | Additional guidance | Mark |
|---|---|---|---|
| (b) | An answer that makes reference to:<br>• all subatomic particles correct for bromine-79 (1)<br>• all subatomic particles correct for bromine-81 (1) | <table><tr><th>Protons</th><th>Neutrons</th><th>Electrons</th></tr><tr><td>35</td><td>44</td><td>35</td></tr><tr><td>35</td><td>46</td><td>35</td></tr></table><br>Any four correct scores 1 | 2 |

| Question number | Answer | Additional guidance | Mark |
|---|---|---|---|
| (c)(i) | A diagram showing:<br>• one shared pair of electrons (1)<br>• six non-bonding electrons on **both** atoms in the molecule (1) | Example of diagram:<br><br>Accept shared electrons on circles between the atoms<br>Accept omission of circles or chemical symbols<br>Allow any symbols for the electrons or elements (even if incorrect)<br>Allow non-bonding electrons to be unpaired<br>Allow horizontal sharing of bond pair<br>Ignore horizontal line representing the bond | 2 |

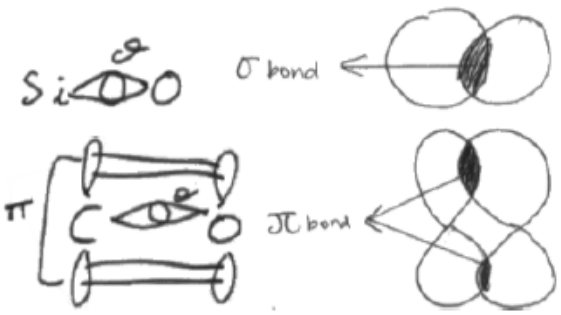
| Question number | Answer | Additional guidance | Mark |
|---|---|---|---|
| (c)(ii) | An answer that makes reference to:<br><br>• (a beam of) high energy electrons striking the (gaseous) bromine (molecule) (1)<br><br>• equation for the formation of the molecular ion (1) | Both marks may be scored with a correct equation and any indication the **bombarding** electrons are high energy<br><br>Allow 'high speed electrons'<br>Allow electron gun<br>Allow "fast moving"<br>Allow bromine atoms<br><br>$Br_2 + e^{(-)} \rightarrow Br_2^+ + 2e^{(-)}$<br>Allow<br>$Br_2 \rightarrow Br_2^+ + e^{(-)}$<br>$Br_2 - e^{(-)} \rightarrow Br_2^+$<br><br>Allow $^{81}Br^{81}Br$ (etc) instead of $Br_2$ on either side of the equation<br><br>Ignore state symbols even if incorrect<br><br>Do not award $Br_2 \rightarrow 2Br^+ + 2e^{(-)}$ or $\frac{1}{2}Br_2 \rightarrow Br^+ + e^{(-)}$ | 2 |

| Question number | Answer | Additional guidance | Mark |
|---|---|---|---|
| (c)(iii) | An answer on the grid showing:<br><br>• three peaks: at *m/z* = 158, *m/z* = 160 and *m/z* = 162 (1)<br><br>• peak heights in the ratio 1:2:1 (for 158: 160: 162) (1) | Example of grid:<br><br><br><br>Allow bars or "X" at the top of any lines<br>Allow bars shown around the m/z values<br>Do not award if a line is drawn from peak to peak<br><br>Do not award if more than three peaks<br><br>Allow any abundance values<br><br>No TE on incorrect *m/z* values | 2 |

| Question number | Answer | Additional guidance | Mark |
|---|---|---|---|
| (d) | • weighted mean mass expression (1)<br>• evaluation of relative atomic mass for Br (1)<br>• calculation of relative molecular mass for $Br_2$ corrected to 2 d.p. (1) | Example of calculation:<br>$A_r = \frac{79 \times 56.38 + 81 \times 43.62}{100}$<br>= 79.87<br>2 x 79.87 = 159.74 = 159.74<br>Allow TE to M2 for values between 79 and 81<br>Allow TE for M3 of double M2 value<br>Ignore units even if incorrect<br>Penalise rounding errors once only<br>Correct answer to 2 d.p. scores (3)<br>A **final** answer of 79.9 or 79.872 only scores 1 mark | **3** |

Q11.

| Question number | Answer | Additional guidance | Mark |
|---|---|---|---|
| (a)(i) | An answer that makes reference to the following points:<br><br>• the (strong electrostatic) **attraction** between the **shared** pair of **electrons** of the covalent bond (1)<br><br>• and the nuclei (of the silicon atom and the oxygen atom) (1) | Allow attraction between 2 shared electrons<br>Ignore plurals<br>Ignore bonding pair of electrons<br><br>Allow "silicone" in place of silicon<br>Allow references to protons instead of nuclei<br>Do not award M2 for carbon atoms<br><br>Ignore numbers of bonds<br><br>Ignore references to giant/simple, double bonds, polar bonds, sigma bonds or orbital overlap<br><br>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:<br><br>Similarities:<br>• both molecules contain a σ-bond (1)<br><br>• description of end-on overlap (1)<br><br>Difference:<br>• 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.<br><br><br>Allow any indication that the σ overlap is between the atoms and the π overlap is above and below the plane of the atoms<br>e.g. "end-on", "horizontal", "head on" for axial<br>"sideways" or "parallel" for lateral | 3 |

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

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

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

| Question number | Answer | Additional guidance | Mark |
|---|---|---|---|
| (c)(i) | An answer that makes reference to the following:<br><br>• each silicon atom has four silicon atoms in a **tetrahedral** arrangement as nearest silicon atom neighbours<br><br>or<br><br>each silicon is bonded to four oxygen atoms in a **tetrahedral** arrangement<br><br>or<br><br>each carbon is bonded to 4 carbon atoms in a **tetrahedral** arrangement (in diamond) | Allow "giant tetrahedral structure(s)"<br><br>Do not award each silicon is tetrahedrally bonded to four other silicon atoms<br><br>Ignore just "the silicon atoms are in a diamond structure"<br>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:<br><br>• There are fewer bonds (per atom) in the structure of silicon dioxide | Allow reverse argument<br>Allow oxygen only forms two bonds<br>Allow bond strength is an average<br>Allow oxygen has lone pairs of electrons<br>Ignore silicon-oxygen bond is polar<br>Ignore references to sizes of atoms<br><br>Do not award reference to intermolecular forces | 1 |

Q12.

| Question Number | Answer | Mark |
|---|---|---|
| | **The only correct answer is D** (two nuclei and a shared pair of electrons)<br><br>**A** *is not correct because this describes ionic bonding*<br>**B** *is not correct because this describes metallic bonding*<br>**C** *is not correct because electrons do not attract one another* | **(1)** |

Q13.

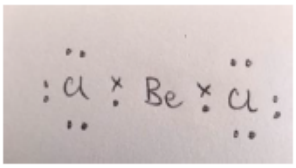
| Question Number | Correct Answer | Mark |
|---|---|---|
| | **The only correct answer is D** ($CH_2Cl_2$)<br><br>*A is incorrect because* $C_5H_{12}$ *is non-polar*<br>*B is incorrect because although* $CCl_4$ *has polar bonds it does not have a dipole moment*<br>*C is incorrect because although* $BCl_3$ *has polar bonds it does not have a dipole moment* | 1 |

Q14.

| Question number | Answer | Mark |
|---|---|---|
| | **The only correct answer is C** (Hg(l))<br>***A*** *is incorrect because simple molecules do not conduct electricity*<br>***B*** *is incorrect because simple molecules do not conduct electricity*<br>***D*** *is incorrect because ionic compounds do not conduct electricity as solids* | **1** |

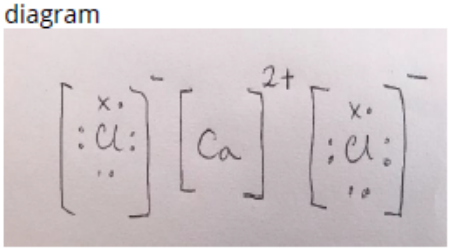
Q15.

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

| Question Number | Answer | Additional Guidance | Mark |
|---|---|---|---|
| **(b)** | Answer that shows .....<br>• 2 single covalent bonds **(1)**<br>• 6 non-bonding electrons shown on chlorine **(1)** | Example of correct dot-and-cross diagram:<br><br>Allow non-bonding electrons unpaired<br>Allow all dots or all crosses<br>Allow shared electrons on the axis of the bond<br>If Ca in place of Be Max 1<br>Ignore line showing covalent bond<br>Ignore overlapping circles<br>Ionic bond scores 0 overall<br>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)**<br><br>• 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.<br><br>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)**<br><br>• bond angle in $BeCl_2$(s)/polymeric is 109.5° **(1)**<br><br>• electron pairs/bonds repel each other to minimise repulsion **(1)**<br><br>• 4 electron pairs/bonds in solid **or** 2 bonding pairs/2 bonds (no lone pairs) in gas | Ignore references to shape<br><br>ALLOW any bond angle between 110 ° and 95 °.<br>[98° actual value]<br>Ignore references to shape<br><br>Allow to a maximum separation<br>Do not award repulsion between atoms/elements or between lone pairs<br><br>Ignore references to lp-lp/lp-bp repulsion | **(4)** |

| Question Number | Answer | Additional Guidance | Mark |
|---|---|---|---|
| (e) | • correct charges shown and two chloride ions **(1)**<br><br>• electronic configuration of all ions **(1)** | Example of correct dot-and-cross diagram<br><br>Accept Ca with 8 electrons<br>Allow all dots or all crosses or any combination<br>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)**<br><br>• Beryllium ion/ $Be^{2+}$ is more polarising (than calcium /ion $Ca^{2+}$) OR calcium loses (outer) electrons more easily (than beryllium) **(1)**<br>OR<br>difference in electronegativity between calcium and chlorine is greater (than between beryllium and chlorine) **(1)**<br><br>• beryllium-chlorine bond has a higher degree of covalency (than calcium-chlorine bond) | Allow beryllium is more polarising than calcium<br><br>Accept bonding in beryllium chloride is (more) covalent/ bonding in calcium chloride is (more) ionic.<br>M3 is dependent on either M1 or M2 being scored<br>Allow reverse arguments throughout | **(3)** |

Q16.

| Question number | Answer | Mark |
|---|---|---|
| | **The only correct answer is A** ($C_{60}$ fullerene)<br>***B*** *is incorrect because the structure of diamond is formed by a giant lattice of carbon atoms*<br>***C*** *is incorrect because the structure of graphene is formed by a giant lattice of carbon atoms*<br>***D*** *is incorrect because the structure of graphite is formed by a giant lattice of carbon atoms* | **1** |

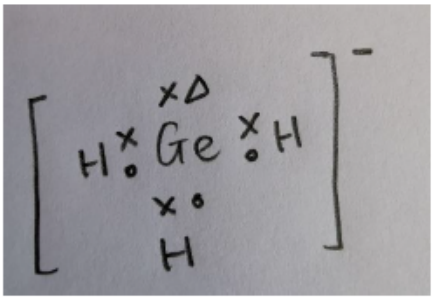
Q17.

| Question Number | Acceptable Answers | Additional Guidance | Mark |
|---|---|---|---|
| (a) | An explanation that makes reference to the following points:<br><br>• **atoms** (of the same element) with the same number of protons / **atoms** with same atomic number / **atoms** with same proton number (1)<br><br>• 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<br><br>e.g. 'elements with same number of protons but different number of neutrons' scores 1 mark<br><br>e.g. 'isotopes have the same atomic number and different mass number' scores 1 mark<br><br>Ignore references to same number of electrons<br>Ignore references to relative atomic mass | 2 |

| Question Number | Acceptable Answers | Additional Guidance | Mark |
|---|---|---|---|
| (b) | • numerator of weighted mean expression (1)<br>• calculation of relative atomic mass (1) | Example of calculation<br><br>$(70 \times 20.6) + (72 \times 27.4) + (73 \times 7.7) + (74 \times 36.7) + (76 \times 7.6)$<br><br>$\frac{(70 \times 20.6) + (72 \times 27.4) + (73 \times 7.7) + (74 \times 36.7) + (76 \times 7.6)}{100}$<br>= 72.703 / 72.70 / 72.7<br>TE on one transcription error<br>Final answer must be to at least 1 decimal place<br>Correct answer with no working scores 2<br>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] $3d^{10} 4s^2 4p^2$<br>Allow $4s^2$ immediately before $3d^{10}$<br>Allow $3p_x^2 3p_y^2 3p_z^2$<br>Allow numbers of electrons not shown as superscripts<br>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)<br><br>• calculation of atom economy as a percentage (1) | Example of calculation<br><br>46+72.6 +48+23+10.8+4+18 = 222.4<br>/ 72.6+4+80+23+10.8+32) = 222.4<br><br>(76.6 ÷ 222.4) × 100 = 34.442%<br>Allow TE in M2 from M1 provided atom economy is less than 100%<br>Allow use of $A_r$ = 72.7 for Ge calculated in (b) which gives the answer 34.472%<br><br>Ignore SF except 1 SF | 2 |

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

| Question Number | Acceptable Answers | Additional Guidance | Mark |
|---|---|---|---|
| (d)(iii) | An answer that makes reference to the following points:<br><br>• trigonal pyramid(al) (1)<br><br>• angle between 106 and 108° (1) | Allow pyramidal<br><br>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)**<br>• conversion of mass from mg to g **(1)**<br>• calculation of moles of germane **(1)**<br>• calculation of maximum number of germane molecules in laboratory **(1)**<br>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<br>$0.640 \times 231 = 147.84$ (mg)<br>$147.84 \div 1000 = 0.14784$ (g)<br>Allow TE from M1 to M2<br>$= 0.14784 \div 76.6 = 1.9300 \times 10^{-3}$ (mol)<br>Allow TE from M2 to M3<br>$1.9300 \times 10^{-3} \times 6.02 \times 10^{23} = 1.1619 \times 10^{21}$ (molecules)<br>Allow TE from M3 to M4<br>Allow use of 76.7 for 76.6 giving $1.1604 \times 10^{21}$<br>Correct answer with no working scores 4 marks<br>Ignore SF except 1 SF | 4 |

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

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

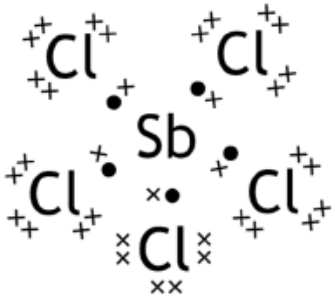
| Question Number | Acceptable Answers | Additional Guidance | Mark | |
|---|---|---|---|---|
| (e)(iii) | • answer to (ii) ÷ 4 | $(0.027958 \div 4)$<br>$= 0.0069896 / 6.9896 \times 10^{-3}$ (mol)<br>Ignore SF except 1 SF<br>Allow TE from (ii) | 1 | |

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

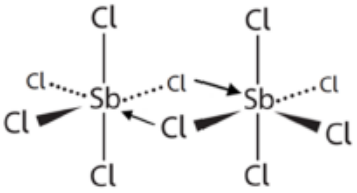
Q18.

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

| Question Number | Answer | Additional guidance | Mark |
|---|---|---|---|
| (b)(i) | An explanation that makes reference to the following points:<br>• strong(er) (electrostatic) attraction between ions (in $PCl_5$) (1)<br>• (than) weak intermolecular forces (in $SbCl_5$) (1) | **Mark M1 and M2 independently**<br>Ignore reference to solid/liquid<br><br>Allow strong ionic bonds / strong ionic lattice<br>Allow strong attraction between positive and negative charges<br>Allow strong attraction between cations and anions / $PCl_4^+$ and $PCl_6^-$<br>Ignore just $PCl_5$ is (giant) ionic<br>Do not award reference to $PCl_5$ molecules/ intermolecular forces<br>Do not award reference to breaking of covalent bonds<br><br>Accept just London/van der Waals/dispersion/ temporary-induced dipole/instantaneous-induced dipole forces<br>Ignore just $SbCl_5$ is (simple) molecular<br>Do not award reference to breaking of covalent/ionic bonds<br><br>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:<br>• central Sb with five bond pairs and no lone pairs (1)<br>• five Cl atoms each with one bond pair and three lone pairs (1) | **Mark M1 and M2 independently**<br><br>Example of dot-and-cross diagram:<br><br><br><br>TE on M1 for three or four Cl atoms<br><br>Allow any combination of crosses and dots<br><br>Allow circles to indicate outer shells<br>Ignore inner shells<br>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:<br>i) a pair of / two electrons are involved<br>ii) these electrons are shared/bonding<br>iii) these electrons come from the same atom<br><br>eg shared electrons in which both electrons come from the same atom<br><br>eg lone pair/full orbital from one atom overlaps with empty orbital of another<br><br>Allow element for atom<br>Allow just both electrons in the bond come from the same element<br>Allow one element donates/gives/shares both electrons to the bond<br>Allow one atom shares both electrons<br><br>Do not award just one atom donates/gives both electrons (or any reference to ions being formed)<br>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 | <br><br>Ignore lone pairs shown on Cl<br>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:<br><br>• no 2d orbitals<br>**or**<br>(nitrogen) cannot expand its octet<br><br>**or**<br><br>• (nitrogen is) too small (to bond to 5 atoms)<br><br>**or**<br><br>• repulsion between electron **pairs** would be too great | Accept reverse arguments<br><br>Allow no d orbitals as only two (quantum) shells<br>Allow no d orbitals (accessible)<br>Allow (nitrogen) cannot have more than eight electrons in its outer shell<br>Ignore just cannot expand its outer/valence shell<br>Ignore just nitrogen obeys the octet rule<br><br>Ignore just (nitrogen has a) very small/smallest atomic radius<br>Ignore Cl atoms too large<br>Ignore nitrogen has fewest/only two shells<br><br>Ignore just repulsion between electron pairs<br>Ignore repulsion between Cl atoms<br>Ignore not enough room for 5 electron pairs | 1 |

Q19.

| Question Number | Answer | Mark |
|---|---|---|
| | **The only correct answer is A** ($CO_2$)<br><br>**B** *is not correct because HCl is a polar molecule*<br><br>**C** *is not correct because $H_2O$ is a polar molecule*<br><br>**D** *is not correct because $NH_3$ is a polar molecule* | (1) |

Q20.

| Question Number | Answer | Mark |
|---|---|---|
| | **The only correct answer is B** (polar, non-polar)<br><br>***A*** *is incorrect because the $SF_6$ molecule is non-polar*<br><br>***C*** *is incorrect because the S-F bond is polar and the $SF_6$ molecule is non-polar*<br><br>***D*** *is incorrect because the S-F bond is polar* | **(1)** |

Q21.

| Q | Answer | Mark |
|---|---|---|
| | **The only correct answer is A** ($H_2O$)<br><br>***B*** *is incorrect because the greatest electronegativity difference is between hydrogen and oxygen*<br><br>***C*** *is incorrect because the greatest electronegativity difference is between hydrogen and oxygen*<br><br>***D*** *is incorrect because the greatest electronegativity difference is between hydrogen and oxygen* | **1** |

Q22.

| Question Number | Answer | Mark |
|---|---|---|
| | **The only correct answer is B** (H–F)<br><br>**A** *is not correct because the molecule is not polar*<br>**C** *is not correct because chlorine is less electronegative than fluorine*<br>**D** *is not correct because bromine is less electronegative than fluorine* | **(1)** |

Q23.

| Question number | Answer | Mark |
|---|---|---|
| | **The only correct answer is A** (HF)<br>**B** *is incorrect because there is a relatively small difference in electronegativity between oxygen and fluorine*<br>**C** *is incorrect because $BF_3$ is a non-polar molecule*<br>**D** *is incorrect because $CF_4$ is a non-polar molecule* | 1 |

Q24.

| Question number | Answer | Mark |
|---|---|---|
| | **The only correct answer is C** (polar bond, non-polar molecule)<br>**A** *is incorrect because the Al-Cl bond is polar*<br>**B** *is incorrect because the Al-Cl bond is polar and the molecule is symmetrical so the bond polarities cancel*<br>**D** *is incorrect because the molecule is symmetrical so the bond polarities cancel* | (1) |

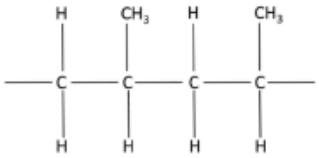
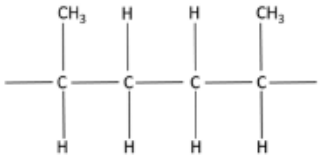
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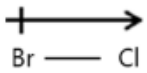
| Question number | Answer | Mark |
|---|---|---|
| | D C-Cl bond polar, $CCl_4$ molecule non-polar | 1 |

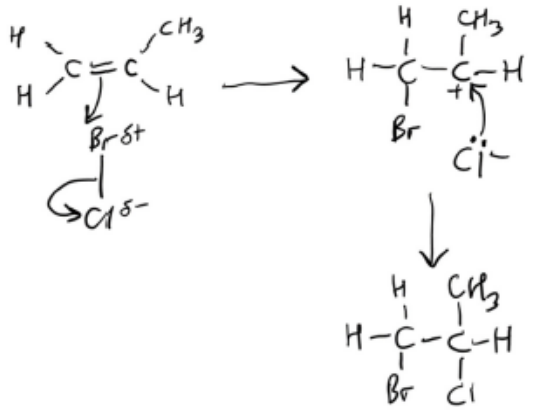
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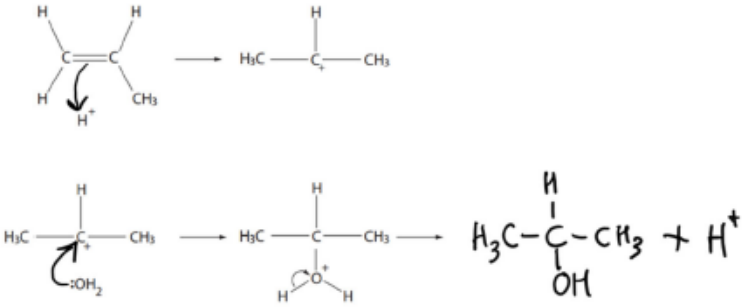
| Question Number | Answer | Additional guidance | Mark |
|---|---|---|---|
| (a) | • balanced equation with **1 mol** $C_3H_6$ and correct products (1)<br>• state symbols (1) | Example of equation:<br>$C_3H_6(g) + 3O_2(g) \rightarrow CO_2(g) + CO(g) + C(s) + 3H_2O(l)$<br>Allow structural, displayed or skeletal formulae<br>Allow $H_2O(g)$<br>Do not award $H_2O(aq)$<br>M2 dependent on correct species for the incomplete combustion of any $C_nH_{2n}$ / $C_nH_{2n+2}$ hydrocarbon forming $CO_2(g)$, $CO(g)$, $C(s)$ and $H_2O(l)/(g)$<br>If no other mark awarded, a correctly balanced equation, with correct state symbols, for the incomplete combustion of propene scores (1)<br>eg $C_3H_6(g) + 3O_2(g) \rightarrow 3CO(g) + 3H_2O(l)/(g)$<br>eg $2C_3H_6(g) + 7O_2(g) \rightarrow 2CO_2(g) + 4CO(g) + 6H_2O(l)/(g)$ | **2** |

| Question Number | Answer | Additional guidance | Mark |
|---|---|---|---|
| (b) | • both solutions decolourise / turn colourless (1)<br>• from purple with (potassium) manganate((VII))/$KMnO_4$/$MnO_4^-$ **and** from orange with (aqueous) bromine/$Br_2$ (1) | Ignore any reference to breaking of the C=C bond / type of reaction<br>Ignore any reference to layers / effervescence<br>Ignore any reference to reaction products / formation of solids<br>Ignore turn clear / change colour<br>Allow pink for purple or any combination of purple/pink<br>Allow yellow or brown for orange or any combination of orange/yellow/brown<br>Do not award any mention of red (eg red-brown)<br>If neither M1 nor M2 awarded, either of the following scores (1):<br>(potassium) manganate((VII))/$KMnO_4$/$MnO_4^-$ decolourises from purple/pink<br>or<br>bromine decolourises from orange/yellow/brown | **2** |

| Question Number | Answer | Additional guidance | Mark |
|---|---|---|---|
| (c) | • poly(propene) structure containing two repeat units with extension bonds | Example of diagram:<br><br>Accept $CH_3$ groups on same or opposite sides<br><br>Allow head-to-head and tail-to-tail configurations eg<br><br><br>Allow displayed, structural, skeletal formulae or any combination of these<br><br>Ignore connectivity of vertical C–$CH_3$ bond<br><br>Ignore brackets and 'n' | 1 |

| Question Number | Answer | Additional guidance | Mark |
|---|---|---|---|
| (d)(i) | • correct dipole | Example of correct diagram:<br>$\delta+$ $\delta-$<br>Br — Cl<br><br>Allow correct indication of net dipole moment:<br><br>Br — Cl<br><br>Ignore horizontal arrow from Br to Cl, on or above the bond<br>Ignore bond pair electrons on diagram<br>Ignore lone pairs on Br/Cl<br>Ignore electron density map<br>Ignore double-headed curly arrow from bond to Cl<br>Do not award full charges | 1 |

| Question Number | Answer | Additional guidance | Mark |
|---|---|---|---|
| (d)(ii) | A mechanism showing: | Example of mechanism:<br><br>Allow displayed, structural, skeletal formulae or any combination of these | 3 |
| | • curly arrow from C=C bond to (δ+)halogen<br>**and**<br>curly arrow from Br–Cl bond to (δ–)halogen or just beyond<br>(1) | Penalise incorrect propene structure once only<br><br>Penalise half-headed curly arrows once only | |
| | • secondary carbocation<br>(1) | Allow primary carbocation for mechanism involving ethene only | |
| | • curly arrow from lone pair on halide ion to $C^{(+)}$<br>**and**<br>correct product<br>(1) | Allow curly arrow from lone pair to positive charge<br>Do not award δ– on halide ion | |

| Question Number | Answer | Additional guidance | Mark |
|---|---|---|---|
| (e) | A mechanism showing:<br><br>• curly arrow from C=C bond to $H^+$ (1)<br>• curly arrow from lone pair on water to $C^+$ (1)<br><br>• correct structure for propan-2-ol **and** $H^+$ (catalyst regenerated) (1) | Example of correct mechanism:<br><br><br>Do not award any additional curly arrows from/to/on propene/$H^+$<br><br>Allow curly arrow from lone pair to positive charge<br>Do not award any additional curly arrows shown in this step<br><br>Allow any combination of displayed/structural/skeletal formulae<br>Ignore atom connectivity except displayed C–H–O<br>Ignore any additional curly arrows added to the central intermediate | 3 |

Q27.

| Question Number | Answer | Additional Guidance | Mark |
|---|---|---|---|
| (a)(i) | • expression for calculation of RAM of silicon (1)<br><br>• answer to two decimal places (1) | Example of calculation:<br>$\frac{(28\times92.17)+(29\times4.71)+(30\times3.12)}{100}$<br>=28.1095<br>=28.11<br>Allow units g $mol^{-1}$/a.m.u only<br>Correct answer scores 2<br>Allow TE from incorrect expression if answer lies between 28 and 30. | (2) |

| Question Number | Answer | Additional Guidance | Mark |
|---|---|---|---|
| (a)(ii) | Some silicon atoms (of mass 28) lose two electrons/have a charge of 2+ | Allow (formation of ) $Si^{2+}$<br>Do not award "atoms of mass 14" | (1) |

| Question Number | Answer | Additional Guidance | Mark |
|---|---|---|---|
| (a)(iii) | $^{28}Si$ 14 14<br>$^{29}Si$ 14 15<br>$^{30}Si$ 14 16 | | (1) |

| Question Number | Answer | Additional Guidance | Mark |
|---|---|---|---|
| (b) | • **all** atoms are joined together by covalent bonds/giant covalent(structure) (1)<br>• these are strong / take a lot of energy to break (so melting temperature is very high) (1)<br>• no electrons are free (to move)/ mobile/delocalised/ (so charge cannot be carried) (1) | Allow correct description of covalent bond<br>Do not award intermolecular forces/ ionic bonds/ double covalent bonds. Ignore stoichiometry even if incorrect.<br>Ignore high boiling temperature<br>Ignore no free moving ions | (3) |

| Question Number | Answer | Additional Guidance | Mark |
|---|---|---|---|
| (c) | • calculation of number of moles (1)<br>• calculation of whole number mole ratio (1)<br>• empirical formula | Example of calculation<br>$\frac{12}{40.1}$ $\frac{8.43}{28.1}$ $\frac{14.47}{16}$<br>OR 0.299 : 0.30 : 0.904<br>1 : 1 : 3<br>$CaSiO_3$<br>Correct formula with no working scores 1 mark only<br>TE on use of atomic numbers<br>Incorrect symbol(s) in formula loses M3 | (3) |

| Question Number | Answer | Additional Guidance | Mark |
|---|---|---|---|
| (d) | • calculation of moles carbon dioxide (1)<br>• conversion of temperature to K (1)<br>• rearrangement of expression (1)<br>• evaluation of answer in $cm^3$ | Example of calculation:<br>3÷44 = 0.06818<br>273 + 5 = 278<br>$V=\frac{0.06818 \times 8.31 \times 278}{1.3 \times 10^5}$<br>($=1.2116 \times 10^{-3} m^3$)<br>=1211.6/1212/1210/1200 ($cm^3$)<br>TE throughout but do not award M4 for negative volume<br>Ignore SF except 1 SF<br>Correct answer with no working scores 4 marks | (4) |

Q28.

| Question Number | Answer | Mark |
|---|---|---|
| (a) | **The only correct answer is C** (392.0)<br><br>***A*** *is incorrect because the brackets have been ignored*<br><br>***B*** *is incorrect because the mass of water has been omitted*<br><br>***D*** *is incorrect because the iron has been doubled* | **(1)** |

| Question Number | Answer | Mark |
|---|---|---|
| (b) | **The only correct answer is D** (ionic, covalent and dative covalent)<br><br>***A*** *is incorrect because there are both dative covalent and covalent bonds within the ions*<br><br>***B*** *is incorrect because there are dative covalent bonds within the ions*<br><br>***C*** *is incorrect because there are covalent bonds within the ions* | **(1)** |

| Question Number | Answer | Mark |
|---|---|---|
| (c) | **The only correct answer is C** ($3.01 \times 10^{23}$)<br><br>***A*** *is incorrect because only one ammonium, one iron and one sulfate ion have been included*<br><br>***B*** *is incorrect because the iron ions have not been included*<br><br>***D*** *is incorrect because the water molecules have been included* | **(1)** |

Q29.

| Question number | Answer | Mark |
|---|---|---|
| | **The only correct answer is D** (  )<br><br>*A is incorrect because the bonding is not ionic*<br>*B is incorrect because the electron density would not form this shape*<br>*C is incorrect because the molecule is not symmetrical* | **(1)** |

Q30.

| Question number | Answer | Mark |
|---|---|---|
| | **The only correct answer is C**   <br>***A*** *is not correct because* $Al_2Cl_6$ *is not ionic*<br>***B*** *is not correct because the structure does not have a covalent bond between the aluminium atoms*<br>***D*** *is not correct because the aluminium atoms have no lone pairs to donate in a dative bond* | 1 |

Q31.

| Q | Answer | Mark |
|---|---|---|
| | **The only correct answer is A** (diamond)<br>***B*** *is incorrect because ice consists of* $H_2O$ *molecules*<br>***C*** *is incorrect because poly(ethene) consists of long chain molecules*<br>***D*** *is incorrect because sodium chloride consists of a giant lattice of ions* | 1 |

Q32.

| Question Number | Answer | Mark |
|---|---|---|
| | **The only correct answer is C** (bonds are polar, molecule is non-polar)<br>**A** *is not correct because the molecule is non-polar*<br>**B** *is not correct because the C–F bonds are polar and the molecule is non-polar*<br>**D** *is not correct because the C–F bonds are polar* | **(1)** |