SECTION A

Answer **all** *questions in the spaces provided.*

1. Complete the table below by putting a tick (✓) in the boxes that correctly describe graphite. [1]

Conducts electricity		*Melting temperature*		*Bonding*	
Yes	No	High	Low	Covalent	Ionic

2. (i) Give the equation for the reaction of barium metal with water. [1]

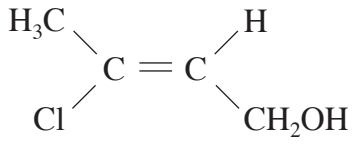
.....

(ii) The solution obtained in (i) contains barium ions.
State a reagent that would be added to this solution to show the presence of barium ions, giving the result of the test.

Reagent ..... [1]

Observation ..... [1]

3. (i) Explain why Compound **T** has E-Z (trans-cis) isomers. [1]



Compound **T**

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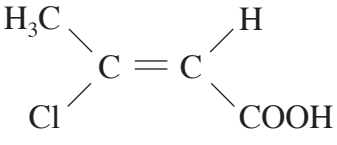
(ii) State a reagent, used in acid solution, that reacts with Compound **T** to give Compound **Y**.[1]



Compound **Y**

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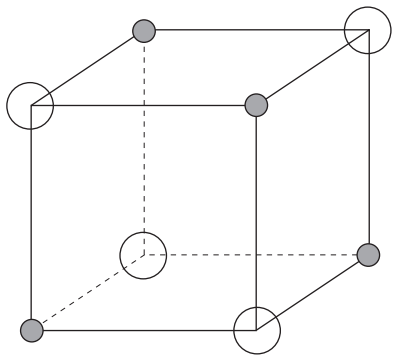
Examiner only

6. *(a)* The following diagram shows the crystal structure of sodium chloride.



(i) Write the formula of the species represented as

● ..... , ○ ..... . [1]

(ii) State the crystal co-ordination numbers for sodium chloride. ..... [1]

(iii) State the crystal co-ordination numbers for caesium chloride and explain why these are different from those of sodium chloride. [2]

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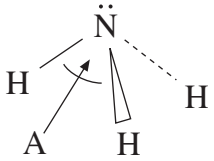
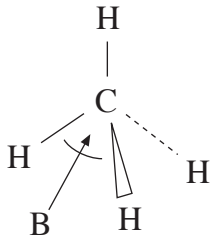
9. *(a)* (i) Explain why angle **A** in an ammonia molecule is less than angle **B** in a methane molecule. [1]





.....

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(ii) A student wrote that *'the bonds in an ammonia molecule are not purely covalent'*. Explain why this statement is correct. [2]

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.....

(b) The d-block element, nickel, has a number of important uses.

(i) Nickel is used as the catalyst in the hydrogenation of alkenes.
Using an alkene of your choice, write an equation, using displayed formulae, for this hydrogenation, naming your product. [2]

(ii) In recent years, nickel-containing 'smart alloys' have been developed.
A particular smart alloy changes shape when a force is applied but returns to its original shape when the force is removed.
Suggest a use for this type of smart alloy. [1]

.....

(iii) Nickel is purified using nickel tetracarbonyl, $Ni(CO)_4$.
This is a tetrahedral molecule with the same shape as methane.

State the bond angle in such tetrahedral molecules. ..... [1]

Examiner only

10. The electronegativities and melting temperatures of some of the elements in Groups 1-7 of the Periodic Table are shown in the table below.
Some values have been omitted.

		Group						
		1	2	3	4	5	6	7
Period 2	Element	Li	Be	B	C graphite	N	O	F
	Electronegativity	1.0	1.5	2.0	2.5	3.0	3.5	4.0
	Melting temperature / K	453	1550	2600	3730	63	54	53
Period 3	Element	Na	Mg	Al	Si	P	S	Cl
	Electronegativity	0.9	1.2	1.5	1.8	2.1	2.5	3.0
	Melting temperature / K	371	923		1680	317	392	172
Period 4	Element	K						Br
	Electronegativity	0.8						2.8
	Melting temperature / K	337						266

(a) (i) Explain the meaning of the term ***electronegativity***. [1]

.....

.....

(ii) State the trend shown in electronegativity across a period. [1]

.....

(iii) Explain this trend. [2]

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Examiner only

(b) (i) State the trends shown in melting temperature across Period 2. [2]

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.....

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(ii) Suggest a value for the melting temperature of aluminium. [1]

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(iii) Explain why the melting temperature of magnesium is higher than that of sodium. [2]

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(iv) Explain why the melting temperatures of the Group 7 elements increase down the group. [2]

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(c) Explain, in terms of bonding and structure, why graphite has a very high melting temperature. [2]

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Total [13]

Examiner only

(b) Edmund wants to prepare aqueous sodium chloride using the same method as in *(a)*(ii) opposite. Explain why he should not use this method and state what reagents he could use to obtain aqueous sodium chloride. [2]

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(c) For both calcium chloride and calcium metal:

- state the conditions necessary for each to conduct electricity;
- explain, in terms of bonding and structure, how this process occurs. [4]

QWC [2]

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Total [19]

Section B Total [70]

Examiner only

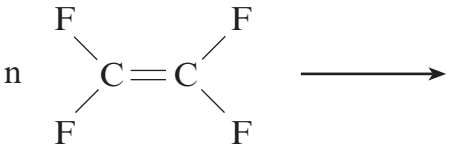
(b) Sodium fluoride is a white, ionic solid that has the same crystal structure as sodium chloride.
Give the formula of each ion present and its crystal co-ordination number. [2]

Sodium ion ..... *Crystal co-ordination number* .....

Fluoride ion ..... *Crystal co-ordination number* .....

(c) Tetrafluoroethene, C_2F_4, can be polymerised to give poly(tetrafluoroethene), PTFE, in a similar way to the polymerisation of ethene.

(i) Complete and balance the equation below, showing a repeating section of the structural formula of poly(tetrafluoroethene). [1]



(ii) A stretched form of PTFE is marketed under the name 'Goretex'. This is used to make waterproof materials that can 'breathe'. Gaseous water molecules can escape from tiny 'holes' in the fabric but larger liquid water droplets cannot enter. These liquid water droplets contain water molecules that are hydrogen bonded to each other.

Draw a diagram to show hydrogen bonding between water molecules. [3]

Total [14]

Examiner only

(b) A solution, giving an apple-green colour to a flame, was suspected to be aqueous barium hydroxide.

Describe **two** simple tests to confirm this conclusion, giving the result of each test. [2]

1. .....

.....

2. .....

.....

(c) Both solid strontium metal and solid graphite are conductors of electricity.
Describe the structures of these two materials and explain how they are both able to conduct electricity. You may use diagrams in your answer. [5]

QWC [1]

Strontium

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Graphite

.....

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(d) There is much interest in carbon nanotubes as drug delivery agents.
Describe how the structure of carbon nanotubes is related to the structure of graphite. [2]

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Total [15]

Examiner only

10. *(a)* Bromine is produced commercially from bromide ions in sea water by reaction with chlorine.

(i) Give the equation for this reaction. [1]

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(ii) Although both bromine and chlorine are oxidising agents, this reaction proceeds because chlorine is a stronger oxidising agent than bromine.

I. Explain what is meant by the term *oxidising agent*. [1]

.....

.....

II. Explain why chlorine is the stronger oxidising agent. [2]

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(iii) Air is then blown through the bromine-containing mixture to remove bromine as its vapour.
Iodine can be produced in a similar way from the iodide ions present in sea water but it is more difficult to produce iodine vapour from its solution because iodine is less volatile than bromine.
Explain, in terms of bonding, why iodine is less volatile than bromine. [2]

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(b) One important use of a bromine compound is as a very concentrated aqueous solution of calcium bromide, in the oil industry.

(i) The concentration of a calcium bromide solution is 1200 g dm^{-3}.
Calculate the concentration of this solution in mol dm^{-3}. [2]

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.....

(ii) Many of the metals present in compounds of Group 2 can be identified by a flame test.
Complete the table below showing the flame colours (if any) obtained using magnesium bromide and calcium bromide. [2]

Compound	Flame colour (if any)
magnesium bromide	
calcium bromide	

Examiner only

9. Calcium oxide is one of the most widely used industrial materials in the world, with worldwide production being in the region of 283 million tonnes every year.

(a) Most calcium oxide is produced from calcium carbonate by thermal decomposition. The chemical reaction occurring is:

$$CaCO_3 \longrightarrow CaO + CO_2$$

Calculate the atom economy of this process. [2]

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.....

(b) Draw a dot and cross diagram to show the formation of calcium oxide from atoms of calcium and oxygen. [2]

(c) Calcium oxide has the same crystal structure as sodium chloride.

(i) Draw the arrangement of ions in the structure of calcium oxide. [2]

(ii) Explain why calcium chloride cannot have the same crystal structure as sodium chloride and calcium oxide. [1]

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.....

Examiner only

(b) Graphite, aluminium and caesium chloride are three substances whose structures allow them to conduct electricity under appropriate conditions.

Briefly describe the structure and bonding adopted by **each** and explain how these lead to their ability to conduct electricity. Your answer should include:

- A **brief** description of the structures found in **each** of the three materials;
- An indication of the conditions required for electrical conduction in **each**;
- An explanation of how **each** material conducts electricity. [6]

QWC [2]

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(c) Carbon nanotubes have similar conducting abilities to graphite. Suggest a use for carbon nanotubes that relies on this property. [1]

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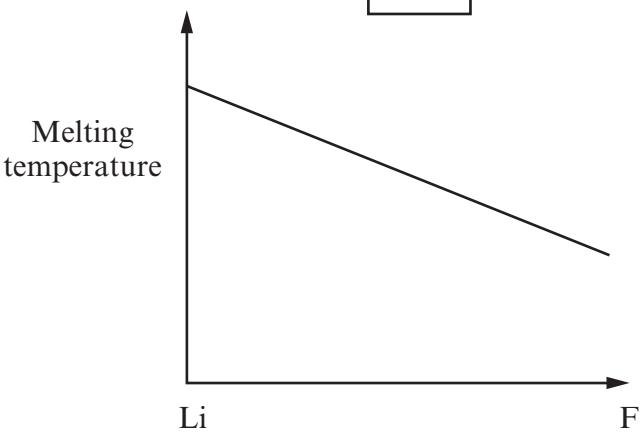
Total [13]

Total Section B [70]

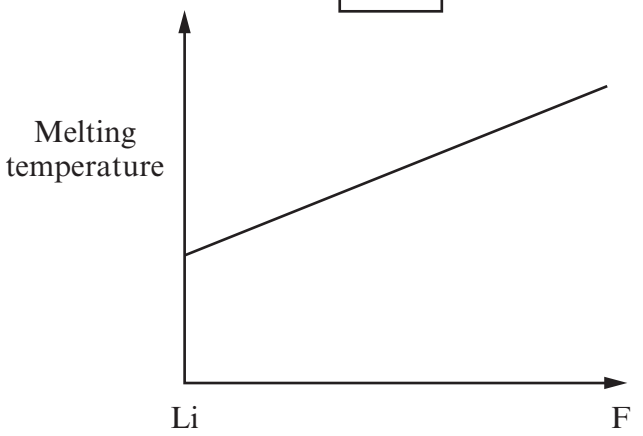
Examiner only

4. State which one of the following graphs best shows how melting temperature changes across period 2 in the Periodic Table. [1]

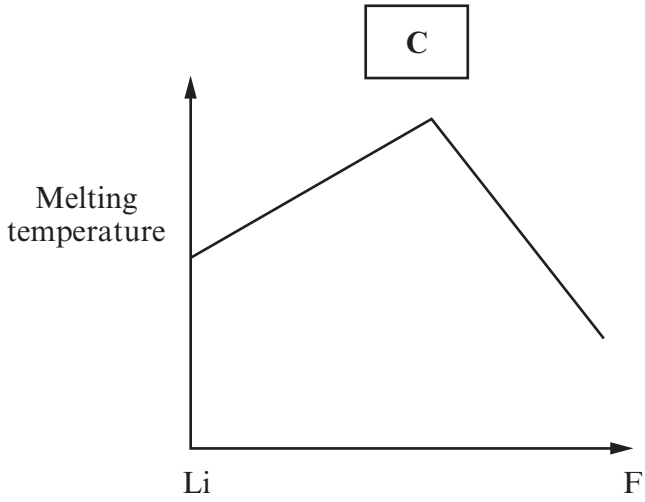
A



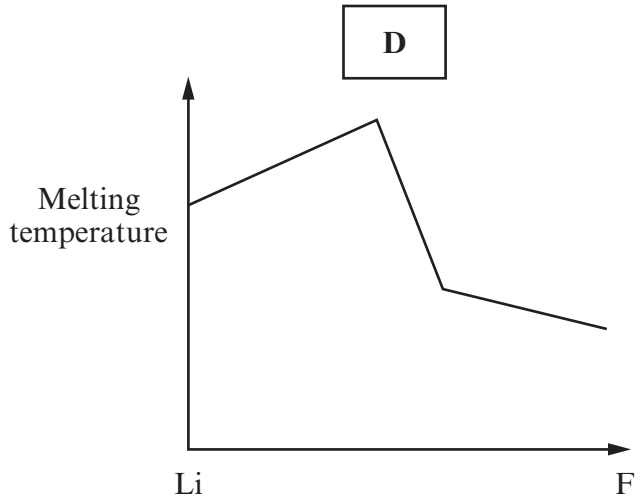
B



C



D



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5. In recent years scientists have developed a range of materials known as smart materials. State what is meant by a *smart material*. [1]

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Examiner only

(c) In the final experiment, Dr Ballard heats a piece of sodium and puts it in a gas jar containing chlorine to form sodium chloride.

(i) Apart from wearing safety goggles, give **one** precaution that Dr Ballard should take when using chlorine. [1]

.....

(ii) Sodium chloride is a solid with a melting temperature of 801°C.

I State the crystal co-ordination numbers for sodium chloride. [1]

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II Explain in terms of bonding why its melting temperature is high. [2]

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.....

.....

Total [14]

Section B Total [70]

Examiner only

SECTION A

Answer **all** *questions in the spaces provided.*

1. 'Smart' alloys have an increasing importance in many applications.
State how 'smart' alloys differ from other alloys in the way in which they act when used for a particular purpose. [2]

.....

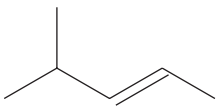
.....

2. A small piece of sodium metal is added to water.
Give the equation for this reaction and suggest a pH value for the resulting solution. [2]

Equation .....

pH of solution .....

3. The skeletal formula of a hydrocarbon is shown below.



Give the **systematic name** of this hydrocarbon. [1]

.....

4. Police use a breathalyser to test motorists for the presence of alcohol.

(a) An early type of breathalyser required the motorist to breathe into a tube that contained acidified potassium dichromate. The alcohol in their breath was oxidised to ethanal and ethanoic acid. State the colour change that occurred if the test was positive. [1]

..... to .....

(b) Modern breathalysers use infrared spectroscopy to detect and measure the concentration of alcohol in breath. An absorption frequency at 2940 cm^{-1} is used rather than the frequency caused by the O—H bond, as this is also present in water.

(i) Use the Data Sheet to identify the bond that causes the absorption at 2940 cm^{-1}. [1]

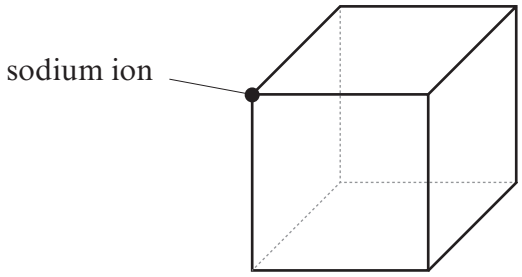
.....

Examiner only

SECTION B

Answer **all** *questions in the spaces provided.*

6. *(a)* A section of the crystal structure of sodium chloride is shown below.



(i) Indicate, with a cross, the position of any chloride ion on this diagram. [1]

(ii) State the crystal co-ordination number of a **chloride** ion in the structure of sodium chloride. [1]

.....

(b) 'Rock salt', used on roads in winter, consists mainly of crystalline sodium chloride that is contaminated by a small quantity of insoluble mudstone.
Gwen added powdered rock salt to water and filtered out the insoluble material. She then evaporated the filtrate to dryness to produce pure white crystals of sodium chloride.
State **two** steps that she should have carried out to ensure that she obtained the **maximum** amount of sodium chloride from her rock salt crystals. [2]

.....

.....

(c) The minerals 'rock salt', NaCl, and kainite, $KCl.MgSO_4.3H_2O$, both contain chloride ions.

(i) Give a chemical test that produces the same result for both of these compounds. You should state the reagent(s) used and the result of the test. [2]

.....

.....

(ii) Give a chemical test, other than a flame test, that will show that these two compounds are different. You should assume that they are present as aqueous solutions.
Give the reagent(s) used and the result of the test for each compound. [2]

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Examiner only

(b) Dolomite, $MgCO_3.CaCO_3$, is a mineral found in Italy. State the colour given by dolomite in a flame test, giving a reason for your choice. [2]

.....

.....

(c) A solution of calcium hydroxide is reacted with aqueous sulfuric acid. A faint white precipitate is seen, as the calcium ions react with the sulfate ions. Give the **ionic** equation for this reaction. [1]

.....

(d) The hard mineral fluorapatite, $CaF_2.3Ca_3(PO_4)_2$, is found in tooth enamel.
One weakness with this material is that there are tiny holes between each 'molecule' of fluorapatite and these may be a cause of sensitive teeth.
Recently a manufacturer has suggested that nano-sized fluorapatite particles in a toothpaste may help solve this problem by filling the holes. Suggest what should be done before this nano-sized material is licensed for use. [1]

.....

.....

(e) Fluorapatite occurs naturally as a rock and can be used to make the fertiliser 'superphosphate'. 5.0 tonnes of fluorapatite give a maximum yield of 8.6 tonnes of superphosphate.
Calculate the mass of superphosphate made from 5000 tonnes of fluorapatite if the percentage yield is 93%. [2]

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(f) Radium and calcium are elements in Group 2. Explain why radium carbonate, $RaCO_3$, has a similar formula to calcium carbonate, $CaCO_3$. [1]

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Total [14]

Examiner only

(b) A primary alcohol was oxidised to a carboxylic acid. The mass spectrum of the acid showed a molecular ion at m/z 88.
Use the information provided to write a displayed formula for the acid. [3]

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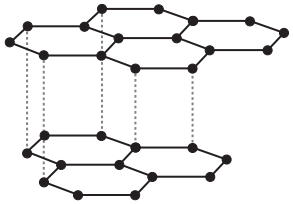
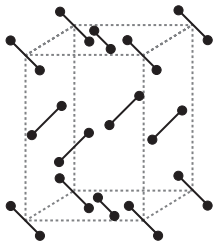
(c) Both carbon and iodine are non-metallic elements. The crystalline structures of graphite and iodine are shown below.



graphite



iodine

Solid iodine exists as a molecular crystal, I_2.

Explain why graphite is able to conduct electricity but iodine is a non-conductor.
Your answer should focus on the bonding present in each solid element. [5]
QWC [2]

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Total [15]

Section B Total [70]

Examiner only

6. When the temperature is increased, both solid iodine and diamond change directly into their gaseous state – they sublime.

(a) In each case, name the force or bond that is being overcome when the solid changes into a gas. [2]

Iodine .....

Diamond .....

(b) State, with a reason, which solid would have the higher sublimation temperature. [1]

.....

.....

Total Section A [10]

Examiner only

(c) Describe how the structures of sodium chloride and caesium chloride are similar and how they are different. Give a reason for any difference.
You may include a diagram if you consider it helpful. [3]

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(d) When hydrogen bromide, HBr, is added to propene, C_3H_6, two different products are possible. In practice, however, more of one of the products is formed.
Explain why more of one product is formed.

You should:

- state the type of reaction involved
- identify the two possible products
- state which of the two products predominates
- give the reason why more of this product is formed. [4]

QWC [1]

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Total [16]

Examiner only

6. The gas oxygen, O_2, is converted into ozone, O_3, in the upper atmosphere. The equation for this process is:

$$3O_2 \longrightarrow 2O_3$$

Use oxidation states to explain why this is not a redox reaction. [2]

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7. Recent advances in chemistry have produced a range of smart materials.

Give the meaning of the term *smart material*. [1]

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Total Section A [10]

Examiner only

11. *(a)* Both sodium chloride and caesium chloride have giant ionic structures.

(i) Draw a labelled diagram to show the arrangement of ions in a crystal of caesium chloride. [2]

(ii) Give a reason why sodium chloride has a different structure from caesium chloride. [1]

.....

.....

Examiner only

(b) Both diamond and graphite have giant covalent structures.

(i) Describe the structure and bonding in graphite. [3]
QWC [1]

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(ii) Explain why graphite can conduct electricity whilst diamond cannot. [2]

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(iii) Iodine, I_2, also contains covalent bonds. Explain why solid iodine can be converted into a vapour at a much lower temperature than diamond. [3]

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Total [12]

Examiner only

4. Classify the following species as electrophile, nucleophile or radical by completing the table below. [2]

Species	Cl•	NH_3
Classification		

5. Nanoscience involves the study of very small particles. Nano-sized silver particles have antibacterial and antifungal properties. Give **one** use of nano-sized silver particles. [1]

.....

.....

6. State and explain which two of the following elements combine to form the **most** ionic bond. [2]

chlorine magnesium potassium sulfur

.....

.....

Total Section A [10]

Examiner only

(e) Covalent compounds like methane and butane are gases at room temperature, however metals are generally solids with high melting temperatures.

(i) State, giving a reason, whether you would expect butane to have a higher or lower boiling temperature than methane. [1]

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(ii) Describe briefly the nature of metallic bonding and use this to explain why metals are malleable (can be hammered into shape) and conduct electricity. [4]
QWC [1]

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Total [13]

Examiner only

11. Jennifer and Marged carry out some experiments with Group 2 metals.

(a) In the first experiment, Jennifer reacts calcium with oxygen to form calcium oxide.

(i) Write an equation for the reaction. [1]

.....

(ii) Using outer electrons only, draw a dot and cross diagram to show the transfer of electrons involved in the formation of calcium oxide. Show the charges on the ions formed. [2]

(b) Jennifer then adds water to the calcium oxide. Some of it reacts to form a solution of calcium hydroxide.

(i) Write the formula of calcium hydroxide. [1]

.....

(ii) Suggest the pH of this solution. [1]

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(c) Jennifer reacts the solution of calcium hydroxide with an aqueous solution of sodium carbonate and a white precipitate is seen. Write the **ionic** equation for this reaction. Include the relevant state symbols in the equation. [1]

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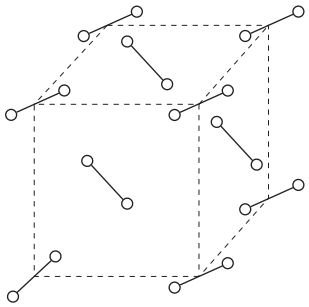
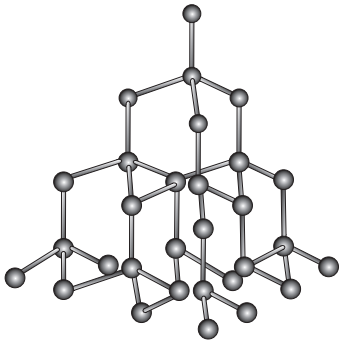
Examiner only

11. *(a)* The structures of solid iodine and diamond are shown below.



Iodine



Diamond

Use these diagrams to help you explain why

- iodine vapourises easily but diamond does not vapourise until about 3550 °C
- neither iodine nor diamond conduct electricity

[4]

QWC [1]

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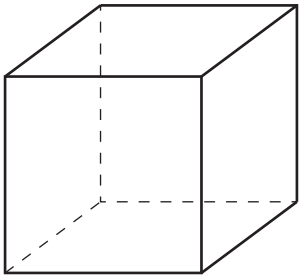
Examiner only

(b) Potassium iodide has the same cubic structure as sodium chloride. Use the diagram below to identify and show the positions of the species involved. [2]



(c) You are given an aqueous solution containing 0.05 mol of barium chloride and a supply of potassium sulfate solution.

Devise a method to obtain the maximum amount of pure dry barium sulfate.
You should assume that a risk assessment has been carried out. [4]
QWC [1]

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Total [12]

Examiner only

9. Haematite is an ore of iron that contains Fe_2O_3. Iron is extracted from this ore in a blast furnace.

(a) Balance the equation for the extraction of iron from Fe_2O_3. [1]

..... Fe_2O_3 + ... CO ⟶ ..... Fe + ... CO_2

(b) Use oxidation states to show that the reaction in *(a)* is a redox reaction. [2]

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(c) A different oxide of iron is iron(II) oxide, FeO. The ions in this compound adopt an arrangement similar to that of sodium chloride.

(i) Give the crystal co-ordination numbers for the ions in FeO. [1]

.....

(ii) Draw the arrangement of oxide ions around each iron ion. [1]

(d) Iron can be extracted from FeO according to the equation below.

$$FeO + CO \longrightarrow Fe + CO_2$$

Calculate the mass of iron that could be extracted from 20.0 kg of iron(II) oxide, FeO. [3]

Mass of iron = ... kg

Examiner only

(e) Carbon monoxide contains two covalent bonds and one co-ordinate bond. Explain what is meant by the terms *covalent bond* and *co-ordinate bond*, indicating the difference between them. [2]

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(f) Iron is a typical metal. Describe the bonding present in iron. Explain how it can conduct electricity and why it has a high melting temperature. [4]

QWC [1]

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Total [15]