1 What is the formula of calcium nitrate(V)?

A $CaNO_3$ ⬭

B $Ca(NO_3)_2$ ⬭

C Ca_2NO_2 ⬭

D $Ca(NO_2)_2$ ⬭

(Total 1 mark)

2 Some airbags in cars contain sodium azide (NaN_3).

(a) Sodium azide is made by reacting dinitrogen monoxide gas with sodium amide ($NaNH_2$) as shown by the equation.

$$2NaNH_2 + N_2O \longrightarrow NaN_3 + NaOH + NH_3$$

Calculate the mass of sodium amide needed to obtain 550 g of sodium azide, assuming there is a 95.0% yield of sodium azide.
Give your answer to 3 significant figures.

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(5)

(b) If a car is involved in a serious collision, the sodium azide decomposes to form sodium and nitrogen as shown in the equation.

$$2NaN_3(s) \longrightarrow 2Na(s) + 3N_2(g)$$

The nitrogen produced then inflates the airbag to a volume of 7.50×10^{-2} m^3 at a pressure of 150 kPa and temperature of 35 °C.

Calculate the minimum mass of sodium azide that must decompose.
(The gas constant R = 8.31 J K^{-1} mol^{-1})

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(6)

(c) Sodium azide is toxic. It can be destroyed by reaction with an acidified solution of nitrous acid (HNO_2) as shown in the equation.

$$2NaN_3 + 2HNO_2 + 2HCl \longrightarrow 3N_2 + 2NO + 2NaCl + 2H_2O$$

(i) A 500 cm^3 volume of the nitrous acid solution was used to destroy completely 150 g of the sodium azide.

Calculate the concentration, in mol dm^{-3}, of the nitrous acid used.

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(3)

(ii) Nitrous acid decomposes on heating.

Balance the following equation for this reaction.

$$.....HNO_2 \longrightarrow .....HNO_3 + ...NO + ...H_2O$$

(1)

(d) Sodium azide has a high melting point.

Predict the type of bonding in a crystal of sodium azide.
Suggest why its melting point is high.

Type of bonding .....

Reason for high melting point .....

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(3)

(e) The azide ion has the formula N_3^-

(i) The azide ion can be represented as $N \equiv N - N^-$
One of these bonds is a co−ordinate bond.

On the following diagram, draw an arrowhead on one of the bonds to represent the direction of donation of the lone pair in the co−ordinate bond.

(1)

(ii) Give the formula of a molecule that has the same number of electrons as the azide ion.

.....

(1)

(iii) Which is the correct formula of magnesium azide?

Tick (✓) **one** box.

Mg_3N ☐

MgN ☐

MgN_6 ☐

Mg_3N_2 ☐

(1)
(Total 21 marks)

3 Zinc forms many different salts including zinc sulfate, zinc chloride and zinc fluoride.

(a) People who have a zinc deficiency can take hydrated zinc sulfate ($ZnSO_4.xH_2O$) as a dietary supplement.

A student heated 4.38 g of hydrated zinc sulfate and obtained 2.46 g of anhydrous zinc sulfate.

Use these data to calculate the value of the integer x in $ZnSO_4.xH_2O$
Show your working.

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(3)

(b) Zinc chloride can be prepared in the laboratory by the reaction between zinc oxide and hydrochloric acid.
The equation for the reaction is

$$ZnO + 2HCl \longrightarrow ZnCl_2 + H_2O$$

A 0.0830 mol sample of pure zinc oxide was added to 100 cm^3 of 1.20 mol dm^{-3} hydrochloric acid.

Calculate the maximum mass of anhydrous zinc chloride that could be obtained from the products of this reaction.

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(4)

(c) Zinc chloride can also be prepared in the laboratory by the reaction between zinc and hydrogen chloride gas.

$$Zn + 2HCl \longrightarrow ZnCl_2 + H_2$$

An impure sample of zinc powder with a mass of 5.68 g was reacted with hydrogen chloride gas until the reaction was complete. The zinc chloride produced had a mass of 10.7 g.

Calculate the percentage purity of the zinc metal.
Give your answer to 3 significant figures.

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(4)

(d) Predict the type of crystal structure in solid zinc fluoride and explain why its melting point is high.

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(3)
(Total 14 marks)

4 The table below shows the boiling points of some hydrogen compounds formed by Group 6 elements.

	H_2O	H_2S	H_2Se	H_2Te
Boiling point / K	373	212	232	271

(a) State the strongest type of intermolecular force in water and in hydrogen sulfide (H_2S).

Water .....

Hydrogen sulfide .....

.....

(2)

(b) Draw a diagram to show how two molecules of water are attracted to each other by the type of intermolecular force you stated in part (a). Include partial charges and all lone pairs of electrons in your diagram.

(3)

(c) Explain why the boiling point of water is much higher than the boiling point of hydrogen sulfide.

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(1)

(d) Explain why the boiling points increase from H_2S to H_2Te

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(2)

(e) When H^+ ions react with H_2O molecules, H_3O^+ ions are formed.

Name the type of bond formed when H^+ ions react with H_2O molecules.
Explain how this type of bond is formed in the H_3O^+ ion.

Type of bond .....

Explanation .....

.....

(2)

(f) Sodium sulfide (Na_2S) has a melting point of 1223 K.
Predict the type of bonding in sodium sulfide and explain why its melting point is high.

Type of bonding .....

Explanation .....

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(3)
(Total 13 marks)

5 (a) (i) Define the term *relative atomic mass* (A_r) of an element.

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(2)

(ii) A sample of the metal silver has the relative atomic mass of 107.9 and exists as two isotopes. In this sample, 54.0% of the silver atoms are one isotope with a relative mass of 107.1

Calculate the relative mass of the other silver isotope.

State why the isotopes of silver have identical chemical properties.

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(4)

(b) The isotopes of silver, when vaporised, can be separated in a mass spectrometer.

Name the **three** processes that occur in a mass spectrometer before the vaporised isotopes can be detected.

State how each process is achieved.

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(6)

(c) State the type of bonding involved in silver.

Draw a diagram to show how the particles are arranged in a silver lattice and show the charges on the particles.

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(3)

(d) Silver reacts with fluorine to form silver fluoride (AgF).

Silver fluoride has a high melting point and has a structure similar to that of sodium chloride.

State the type of bonding involved in silver fluoride.

Draw a diagram to show how the particles are arranged in a silver fluoride lattice and show the charges on the particles.

Explain why the melting point of silver fluoride is high.

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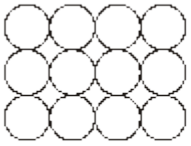
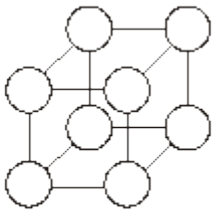
(5)
(Total 20 marks)

6 At room temperature, both sodium metal and sodium chloride are crystalline solids which contain ions.

(a) On the diagrams for sodium metal and sodium chloride below, mark the charge for each ion.



Sodium metal



Sodium chloride

(2)

(b) (i) Explain how the ions are held together in solid sodium metal.

.....

.....

(ii) Explain how the ions are held together in solid sodium chloride.

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.....

(iii) The melting point of sodium chloride is much higher than that of sodium metal. What can be deduced from this information?

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(3)

(c) Compare the electrical conductivity of solid sodium metal with that of solid sodium chloride. Explain your answer.

Comparison .....

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Explanation .....

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(3)

(d) Explain why sodium metal is malleable (can be hammered into shape).

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(1)

(e) Sodium chlorate(V), $NaClO_3$, contains 21.6% by mass of sodium, 33.3% by mass of chlorine and 45.1% by mass of oxygen.

(i) Use the above data to show that the empirical formula of sodium chlorate(V) is $NaClO_3$

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(ii) Sodium chlorate(V) may be prepared by passing chlorine into hot aqueous sodium hydroxide. Balance the equation for this reaction below.

..... Cl_2 + ... NaOH → ..... NaCl + $NaClO_3$ + $3H_2O$

(3)

(Total 12 marks)

7 (a) Complete the following table.

Particle	Relative charge	Relative mass
Proton		
Neutron		
Electron		

(3)

(b) An atom of element **Z** has two more protons and two more neutrons than an atom of $^{34}_{16}S$. Give the symbol, including mass number and atomic number, for this atom of **Z.**

.....

(2)

(c) Complete the electronic configurations for the sulphur atom, S, and the sulphide ion, S^{2-}.

S $1s^2$ .....

S^{2-} $1s^2$ .....

(2)

(d) State the block in the Periodic Table in which sulphur is placed and explain your answer.

Block .....

Explanation .....

(2)

(e) Sodium sulphide, Na_2S, is a high melting point solid which conducts electricity when molten. Carbon disulphide, CS_2, is a liquid which does not conduct electricity.

(i) Deduce the type of bonding present in Na_2S and that present in CS_2

Bonding in Na_2S .....

Bonding in CS_2.....

(ii) By reference to all the atoms involved explain, in terms of electrons, how Na_2S is formed from its atoms.

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(iii) Draw a diagram, including all the outer electrons, to represent the bonding present in CS_2

(iv) When heated with steam, CS_2 reacts to form hydrogen sulphide, H_2S, and carbon dioxide.
Write an equation for this reaction.

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(7)
(Total 16 narks)

8 Ammonia reacts with aluminium chloride as shown by the equation:

$$NH_3 + AlCl_3 \longrightarrow H_3NAlCl_3$$

(a) Draw diagrams to illustrate the shapes of NH_3 molecules and of $AlCl_3$ molecules.

Include in your diagrams any lone pairs of electrons that influence the shape.

Indicate the values of the bond angles.

(3)

(b) Name the type of bond formed between N and Al in H_3NAlCl_3 and explain how this bond is formed.

Type of bond .....

Explanation .....

.....

.....

.....

(2)

(c) Explain how the value of the Cl-Al-Cl bond angle in $AlCl_3$ changes, if at all, on formation of the compound H_3NAlCl_3

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(2)

(Total 7 marks)

9 Which type of bond is formed between N and B when a molecule of NH_3 reacts with a molecule of BF_3?

A Ionic. ⬭

B Covalent. ⬭

C Co-ordinate. ⬭

D Van der Waals. ⬭

(Total 1 mark)

10 (a) Ammonia gas readily condenses to form a liquid when cooled.

(i) Name the strongest attractive force between two ammonia molecules.

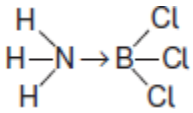
.....

(1)

(ii) Draw a diagram to show how two ammonia molecules interact with each other in the liquid phase.
Include all partial charges and all lone pairs of electrons in your diagram.

(3)

(b) Ammonia reacts with boron trichloride to form a molecule with the following structure.



State how the bond between ammonia and boron trichloride is formed.

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(1)

(c) The following table shows the electronegativity values of some elements.

	H	**Li**	**B**	**C**	**O**	**F**
Electronegativity	2.1	1.0	2.0	2.5	3.5	4.0

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

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(2)

(ii) Suggest the formula of an ionic compound that is formed by the chemical combination of two different elements from the table.

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(1)

(iii) Suggest the formula of the compound that has the least polar bond and is formed by chemical combination of two of the elements from the table.

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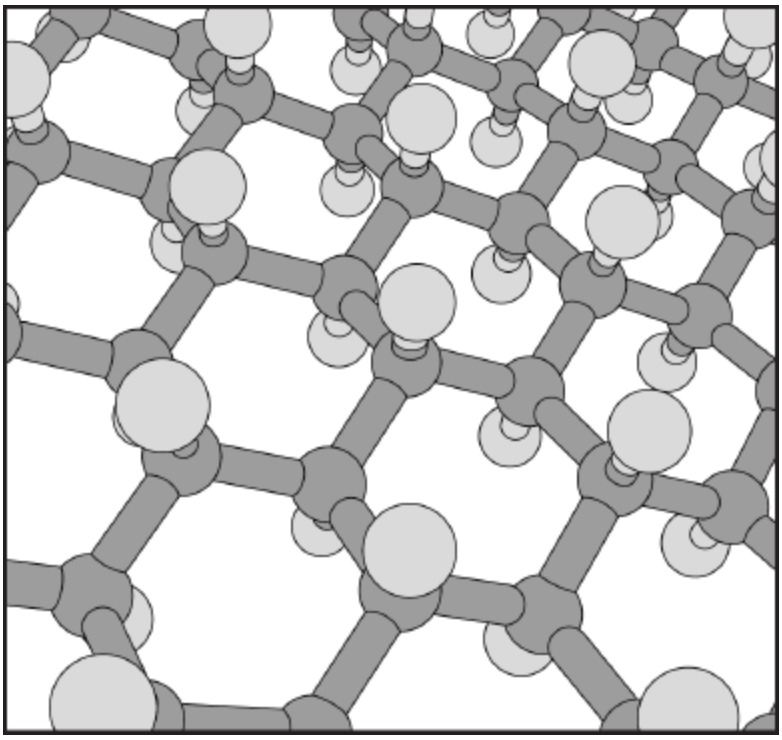
(1)

(Total 9 marks)

11 In 2009 a new material called graphane was discovered. The diagram shows part of a model of the structure of graphane. Each carbon atom is bonded to three other carbon atoms and to one hydrogen atom.



(a) Deduce the type of crystal structure shown by graphane.

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(1)

(b) State how two carbon atoms form a carbon–carbon bond in graphane.

.....

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(1)

(c) Suggest why graphane does **not** conduct electricity.

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(1)

(d) Deduce the empirical formula of graphane.

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(1)
(Total 4 marks)

12 Aluminium and thallium are elements in Group 3 of the Periodic Table.
Both elements form compounds and ions containing chlorine and bromine.

(a) Write an equation for the formation of aluminium chloride from its elements.

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(1)

(b) An aluminium chloride molecule reacts with a chloride ion to form the $AlCl_4^-$ ion.

Name the type of bond formed in this reaction. Explain how this type of bond is formed in the $AlCl_4^-$ ion.

Type of bond .....

Explanation .....

.....

.....

(2)

(c) Aluminium chloride has a relative molecular mass of 267 in the gas phase.

Deduce the formula of the aluminium compound that has a relative molecular mass of 267

.....

(1)

(d) Deduce the name or formula of a compound that has the same number of atoms, the same number of electrons and the same shape as the $AlCl_4^-$ ion.

.....

(1)

(e) Draw and name the shape of the $TlBr_5^{2-}$ ion.

Shape of the $TlBr_5^{2-}$ ion.

Name of shape .....

(2)

(f) (i) Draw the shape of the $TlCl_2^+$ ion.

(1)

(ii) Explain why the $TlCl_2^+$ ion has the shape that you have drawn in part (f)(i).

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(1)

(g) Which **one** of the first, second or third ionisations of thallium produces an ion with the electron configuration [Xe] $5d^{10}6s^1$?

Tick (✓) one box.

First ☐

Second ☐

Third ☐

(1)

(Total 10 marks)

13 The following equation shows the reaction of a phosphine molecule (PH_3) with an H^+ ion.

$$PH_3 + H^+ \longrightarrow PH_4^+$$

(a) Draw the shape of the PH_3 molecule. Include any lone pairs of electrons that influence the shape.

(1)

(b) State the type of bond that is formed between the PH_3 molecule and the H^+ ion. Explain how this bond is formed.

Name of bond .....

How bond is formed .....

.....

(2)

(c) Predict the bond angle in the PH_4^+ ion.

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(1)

(d) Although phosphine molecules contain hydrogen atoms, there is no hydrogen bonding between phosphine molecules.
Suggest an explanation for this.

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(1)
(Total 5 marks)

14 Fluorine forms compounds with many other elements.

(a) Fluorine reacts with bromine to form liquid bromine trifluoride (BrF_3).
State the type of bond between Br and F in BrF_3 and state how this bond is formed.

Type of bond .....

How bond is formed .....

.....

(2)

(b) Two molecules of BrF_3 react to form ions as shown by the following equation.

$$2BrF_3 \longrightarrow BrF_2^+ + BrF_4^-$$

(i) Draw the shape of BrF_3 and predict its bond angle.
Include any lone pairs of electrons that influence the shape.

Shape of BrF_3

Bond angle .....

(2)

(ii) Draw the shape of BrF_4^- and predict its bond angle.
Include any lone pairs of electrons that influence the shape.

Shape of BrF_4^-

Bond angle .....

(2)

(c) BrF_4^- ions are also formed when potassium fluoride dissolves in liquid BrF_3 to form $KBrF_4$
Explain, in terms of bonding, why $KBrF_4$ has a high melting point.

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(Extra space) .....

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(3)

(d) Fluorine reacts with hydrogen to form hydrogen fluoride (HF).

(i) State the strongest type of intermolecular force between hydrogen fluoride molecules.

.....

(1)

(ii) Draw a diagram to show how two molecules of hydrogen fluoride are attracted to each other by the type of intermolecular force that you stated in part (d)(i). Include all partial charges and all lone pairs of electrons in your diagram.

(3)

(e) The boiling points of fluorine and hydrogen fluoride are –188 °C and 19.5 °C respectively. Explain, in terms of bonding, why the boiling point of fluorine is very low.

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(Extra space) .....

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(2)
(Total 15 marks)

15 Fluorine and iodine are elements in Group 7 of the Periodic Table.

(a) Explain why iodine has a higher melting point than fluorine.

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(Extra space).....

.....

(2)

(b) (i) Draw the shape of the NHF_2 molecule and the shape of the BF_3 molecule.

Include any lone pairs of electrons that influence the shape. In each case name the shape.

Shape of NHF_2 Shape of BF_3

Name of shape of NHF_2 .....

Name of shape of BF_3 .....

(4)

(ii) Suggest a value for the F—N—F bond angle in NH_2I

.....

(1)

(c) State the strongest type of intermolecular force in a sample of NHF_2

.....

(1)

(d) A molecule of NHF_2 reacts with a molecule of BF_3 as shown in the following equation.

$$NHF_2 + BF_3 \longrightarrow F_2HNBF_3$$

State the type of bond formed between the N atom and the B atom in F_2HNBF_3.

Explain how this bond is formed.

Name of type of bond .....

How bond is formed .....

.....

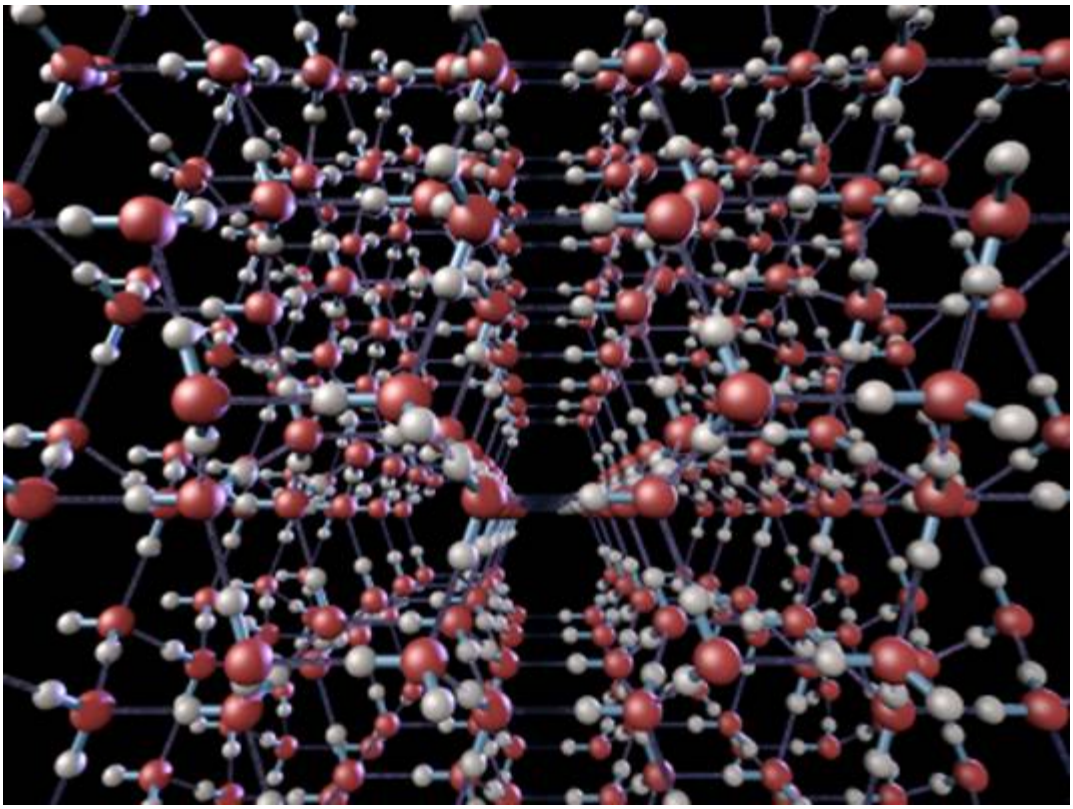
.....

(2)

(Total 10 marks)

16 Water can be found as ice, water and steam.

(a) The following diagram shows the arrangement of some of the water molecules in a crystal of ice.



With reference to the structure shown above give **one** reason why ice is less dense than water.

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(1)

(b) Water and methane have similar relative molecular masses and both contain the element hydrogen.
The table below gives some information about water and methane.

	H_2O	CH_4
M_r	18.0	16.0
Melting point / K	273	91

(i) State the strongest type of intermolecular force holding the water molecules together in the ice crystal.

.....

(1)

(ii) State the strongest type of intermolecular force in methane.

.....

(1)

(iii) Give **one** reason why the melting point of ice is higher than the melting point of methane.

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(1)

(c) A molecule of H_2O can react with an H^+ ion to form an H_3O^+ ion.

(i) Draw and name the shape of the H_3O^+ ion. Include any lone pairs of electrons.

Shape of the H_3O^+ ion

Name of shape .....

(2)

(ii) Suggest a value for the bond angle in the H_3O^+ ion.

.....

(1)

(iii) Identify **one** molecule with the same number of atoms, the same number of electrons and the same shape as the H_3O^+ ion.

.....

(1)

(d) Water can also form the hydroxide ion.
State the number of lone pairs of electrons in the hydroxide ion.

.....

(1)
(Total 9 marks)

17 Fluorine forms many compounds that contain covalent bonds.

(a) (i) State the meaning of the term *covalent bond*.

.....

.....

(1)

(ii) Write an equation to show the formation of one molecule of ClF_3 from chlorine and fluorine molecules.

.....

(1)

(b) Draw the shape of a dichlorodifluoromethane molecule (CCl_2F_2) and the shape of a chlorine trifluoride molecule (ClF_3). Include any lone pairs of electrons that influence the shape.

Shape of CCl_2F_2 Shape of ClF_3

(2)

(c) Suggest the strongest type of intermolecular force between CCl_2F_2 molecules.

.....

(1)

(d) BF_3 is a covalent molecule that reacts with an F^- ion to form a BF_4^- ion.

(i) Name the type of bond formed when a molecule of BF_3 reacts with an F^- ion. Explain how this bond is formed.

Type of bond .....

Explanation .....

.....

.....

.....

(3)

(ii) State the bond angle in the BF_4^- ion

.....

(1)

(e) An ultrasound imaging agent has the formula C_4F_{10}
It can be made by the reaction of butane and fluorine as shown in the following equation.

$$C_4H_{10} + 10F_2 \rightarrow C_4F_{10} + 10HF$$

Calculate the percentage atom economy for the formation of C_4F_{10} in this reaction.
Give your answer to three significant figures.

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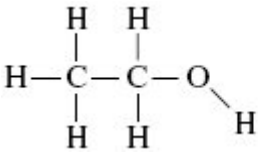
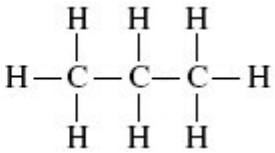
(2)
(Total 11 marks)

18 (a) Two organic compounds with similar relative molecular masses are shown below.



Ethanol



Propane

(i) State the type of bond present between the C and H atoms in both of these molecules. Explain how this type of bond is formed.

Type of bond .....

Explanation .....

(2)

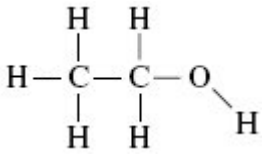
(ii) State the strongest type of intermolecular force present in each compound.

Liquid ethanol .....

Liquid propane .....

(2)

(b) Ethanol dissolves in water. Draw a diagram to show how one molecule of ethanol interacts with one molecule of water in the solution. Include partial charges and all lone pairs. The ethanol molecule has been drawn for you.



(3)

(c) Ethanol was the fuel used in the first mass-produced car, the Model T Ford.

(i) Write an equation which shows how ethanol burns completely in air to form carbon dioxide and water as the only products.

.....

(1)

(ii) Suggest **one** environmental problem caused by incomplete combustion of ethanol in a car engine.

.....

.....

(1)

(iii) Suggest **one** economic problem for the car user caused by incomplete combustion of ethanol in the car engine.

.....

.....

(1)

(d) Propane is also used as a fuel, although sometimes it can be contaminated with sulfur-containing impurities. When this propane burns, these impurities form sulfur dioxide.

(i) State how the sulfur dioxide can be removed from the waste gases produced when this propane is burned on a large scale in industry. Suggest a reason why the method you have stated may not be 100% efficient.

How removed .....

.....

Reason for less than 100% efficiency .....

.....

(2)

(ii) Although propane has a boiling point of –42 °C, it is usually supplied as a liquid for use in camping stoves. Suggest why it is supplied as a liquid.

.....

.....

(1)
(Total 13 marks)

19 The table below shows the electronegativity values of some elements.

	H	C	N	O
Electronegativity	2.1	2.5	3.0	3.5

(a) State the meaning of the term *electronegativity*.

.....

.....

.....

(2)

(b) State the strongest type of intermolecular force in the following compounds.

Methane (CH_4) .....

Ammonia (NH_3) .....

(2)

(c) Use the values in the table to explain how the strongest type of intermolecular force arises between two molecules of ammonia.

.....

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.....

(3)

(d) Phosphorus is in the same group of the Periodic Table as nitrogen.

A molecule of PH_3 reacts with an H^+ ion to form a PH_4^+ ion.

Name the type of bond formed when PH_3 reacts with H^+ and explain how this bond is formed.

Type of bond .....

Explanation .....

.....

.....

(3)

(e) Arsenic is in the same group as nitrogen. It forms the compound AsH_3

Draw the shape of an AsH_3 molecule, including any lone pairs of electrons. Name the shape made by its atoms.

Shape

Name of shape .....

(2)

(f) The boiling point of AsH_3 is –62.5 °C and the boiling point of NH_3 is –33.0 °C.

Suggest why the boiling point of AsH_3 is lower than that of NH_3

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(1)

(g) Balance the following equation which shows how AsH_3 can be made.

..... $AsCl_3$ + ... $NaBH_4$ → ..... AsH_3 + ... NaCl + ... BCl_3

(1)

(Total 14 marks)

20 The equation below shows the reaction between boron trifluoride and a fluoride ion.

$$BF_3 + F^- \rightarrow BF_4^-$$

(i) Draw diagrams to show the shape of the BF_3 molecule and the shape of the BF_4^- ion. In each case, name the shape. Account for the shape of the BF_4^- ion and state the bond angle present.

(ii) In terms of the electrons involved, explain how the bond between the BF_3 molecule and the F^- ion is formed. Name the type of bond formed in this reaction.

(Total 9 marks)

21 Phosphorus and nitrogen are in Group V of the Periodic Table and both elements form hydrides. Phosphine, PH_3, reacts to form phosphonium ions, PH_4^+, in a similar way to that by which ammonia, NH_3, forms ammonium ions, NH_4^+

(a) Give the name of the type of bond formed when phosphine reacts with an H^+ ion. Explain how this bond is formed.

Type of bond .....

Explanation .....

.....

.....

(3)

(b) Draw the shapes, including any lone pairs of electrons, of a phosphine molecule and of a phosphonium ion.
Give the name of the shape of the phosphine molecule and state the bond angle found in the phosphonium ion.

PH_3 PH_4^+

Shape of PH_3 ..... *Bond angle in PH_4^+* .....

(4)
(Total 7 marks)

22 Lithium hydride, LiH, is an ionic compound containing the hydride ion, H^-
The reaction between LiH and aluminium chloride, $AlCl_3$, produces the ionic compound $LiAlH_4$

(a) Balance the equation below which represents the reaction between LiH and $AlCl_3$

$LiH + AlCl_3 \rightarrow LiAlH_4 + LiCl$

(1)

(b) Give the electronic configuration of the hydride ion, H^-

.....

(1)

(c) Predict the shape of the AlH_4^- ion. Explain why it has this shape.

Shape .....

Explanation .....

.....

.....

(3)

(d) A bond in AlH_4^- can be represented by H → Al

Name this type of bond and explain how it is formed.

Type of bond .....

Explanation .....

.....

.....

(3)
(Total 8 marks)

23 (a) Both HF and HCl are molecules having a polar covalent bond. Their boiling points are 293 K and 188 K respectively.

(i) State which property of the atoms involved causes a bond to be polar.

.....

.....

(ii) Explain, in terms of the intermolecular forces present in each compound, why HF has a higher boiling point than HCl.

.....

.....

.....

.....

.....

(4)

(b) When aluminium chloride reacts with chloride ions, as shown by the equation below, a co-ordinate bond is formed.

$$AlCl_3 + Cl^- \rightarrow AlCl_4^-$$

Explain how this co-ordinate bond is formed.

.....

.....

.....

(2)

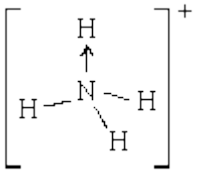
(c) Draw the shape of the PCl_5 molecule and of the PCl_4^+ ion. State the value(s) of the bond angles.

PCl_5 PCl_4^+

Bond angle(s) ..... *Bond angle(s)* .....

(4)
(Total 10 marks)

24 (a) An ammonium ion, made by the reaction between an ammonia molecule and a hydrogen ion, can be represented as shown in the diagram below.



(i) Name the type of bond represented in the diagram by N—H

.....

(ii) Name the type of bond represented in the diagram by N→H

.....

(iii) In terms of electrons, explain why an arrow is used to represent this N→H bond.

.....

.....

(iv) In terms of electron pairs, explain why the bond angles in the NH_4^+ ion are all 109° 28'

.....

.....

.....

.....

(7)

(b) Define the term *electronegativity*.

.....

.....

(2)

(c) A bond between nitrogen and hydrogen can be represented as $\overset{\delta-}{N}—\overset{\delta+}{H}$

(i) In this representation, what is the meaning of the symbol δ+ ?

.....

(ii) From this bond representation, what can be deduced about the electronegativity of hydrogen relative to that of nitrogen?

.....

.....

(2)

(Total 11 marks)

25 (a) Nickel is a metal with a high melting point.

(i) State the block in the Periodic Table that contains nickel.

.....

(1)

(ii) Explain, in terms of its structure and bonding, why nickel has a high melting point.

.....

.....

.....

.....

.....

(2)

(iii) Draw a labelled diagram to show the arrangement of particles in a crystal of nickel.
In your answer, include at least six particles of each type.

(2)

(iv) Explain why nickel is ductile (can be stretched into wires).

.....

.....

.....

(1)

(b) Nickel forms the compound nickel(II) chloride ($NiCl_2$).

(i) Give the full electron configuration of the Ni^{2+} ion.

.....

(1)

(ii) Balance the following equation to show how anhydrous nickel(II) chloride can be obtained from the hydrated salt using $SOCl_2$
Identify **one** substance that could react with both gaseous products.

.....$NiCl_2.6H_2O(s)$ + ... $SOCl_2(g)$ ⟶ .....$NiCl_2(s)$ + ...$SO_2(g)$ + ...$HCl(g)$

Substance .....

(2)
(Total 9 marks)

26 This question is about some Period 3 elements and their oxides.

(a) Describe what you would observe when, in the absence of air, magnesium is heated strongly with water vapour at temperatures above 373 K.
Write an equation for the reaction that occurs.

Observations .....

.....

.....

.....

.....

Equation .....

(3)

(b) Explain why magnesium has a higher melting point than sodium.

.....

.....

.....

.....

(Extra space) .....

.....

(2)

(c) State the structure of, and bonding in, silicon dioxide.
Other than a high melting point, give **two** physical properties of silicon dioxide that are characteristic of its structure and bonding.

Structure .....

Bonding.....

Physical property 1.....

Physical property 2.....

(4)

(d) Give the formula of the species in a sample of solid phosphorus(V) oxide.
State the structure of, and describe fully the bonding in, this oxide.

Formula .....

Structure .....

Bonding.....

.....

.....

.....

(4)

(e) Sulfur(IV) oxide reacts with water to form a solution containing ions.

Write an equation for this reaction.

.....

(1)

(f) Write an equation for the reaction between the acidic oxide, phosphorus(V) oxide, and the basic oxide, magnesium oxide.

.....

(1)

(Total 15 marks)

27 Group 2 metals and their compounds are used commercially in a variety of processes.

(a) Strontium is extracted from strontium oxide (SrO) by heating a mixture of powdered strontium oxide and powdered aluminium.

Consider these standard enthalpies of formation.

	SrO(s)	$Al_2O_3(s)$
$\Delta H_f^{\ominus}$ / kJ mol^{-1}	– 590	– 1669

$$3SrO(s) + 2Al(s) \longrightarrow 3Sr(s) + Al_2O_3(s)$$

Use these data and the equation to calculate the standard enthalpy change for this extraction of strontium.

The use of powdered strontium oxide and powdered aluminium increases the surface area of the reactants.
Suggest **one** reason why this increases the reaction rate.

Suggest **one** major reason why this method of extracting strontium is expensive.

.....

.....

.....

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.....

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.....

.....

(5)

(b) Explain why calcium has a higher melting point than strontium.

.....

.....

.....

.....

.....

.....

.....

(2)

(c) Magnesium is used in fireworks. It reacts rapidly with oxygen, burning with a bright white light. Magnesium reacts slowly with cold water.

Write an equation for the reaction of magnesium with oxygen.

Write an equation for the reaction of magnesium with cold water.

Give a medical use for the magnesium compound formed in the reaction of magnesium with cold water.

.....

.....

.....

.....

.....

.....

.....

.....

(3)
(Total 10 marks)

28 Group 2 elements and their compounds have a wide range of uses.

(a) For parts (a)(i) to (a)(iii), draw a ring around the correct answer to complete each sentence.

(i) From $Mg(OH)_2$ to $Ba(OH)_2$, the solubility in water

decreases.
increases.
stays the same.

(1)

(ii) From Mg to Ba, the first ionisation energy

decreases.

increases.

stays the same.

(1)

(iii) From Mg to Ba, the atomic radius

decreases.

increases.

stays the same.

(1)

(b) Explain why calcium has a higher melting point than strontium.

.....

.....

.....

.....

.....

(Extra space) .....

.....

(2)

(c) Acidified barium chloride solution is used as a reagent to test for sulfate ions.

(i) State why sulfuric acid should **not** be used to acidify the barium chloride.

.....

.....

.....

(1)

(ii) Write the **simplest ionic** equation for the reaction that occurs when acidified barium chloride solution is added to a solution containing sulfate ions.

.....

(1)

(Total 7 marks)

29 There are several types of crystal structure and bonding shown by elements and compounds.

(a) (i) Name the type of bonding in the element sodium.

.....

(1)

(ii) Use your knowledge of structure and bonding to draw a diagram that shows how the particles are arranged in a crystal of sodium.
You should identify the particles and show a minimum of six particles in a two-dimensional diagram.

(2)

(b) Sodium reacts with chlorine to form sodium chloride.

(i) Name the type of bonding in sodium chloride.

.....

(1)

(ii) Explain why the melting point of sodium chloride is high.

.....

.....

.....

.....

(Extra space) .....

.....

(2)

(c) The table below shows the melting points of some sodium halides.

	NaCl	NaBr	NaI
Melting point /K	1074	1020	920

Suggest why the melting point of sodium iodide is lower than the melting point of sodium bromide.

.....

.....

(1)
(Total 7 marks)

30 Group 2 metals and their compounds are used commercially in a variety of processes and applications.

(a) State a use of magnesium hydroxide in medicine.

.....

(1)

(b) Calcium carbonate is an insoluble solid that can be used in a reaction to lower the acidity of the water in a lake.

Explain why the rate of this reaction decreases when the temperature of the water in the lake falls.

.....

.....

.....

.....

.....

(3)

(c) Strontium metal is used in the manufacture of alloys.

(i) Explain why strontium has a higher melting point than barium.

.....

.....

.....

.....

(2)

(ii) Write an equation for the reaction of strontium with water.

.....

(1)

(d) Magnesium can be used in the extraction of titanium.

(i) Write an equation for the reaction of magnesium with titanium(IV) chloride.

.....

(1)

(ii) The excess of magnesium used in this extraction can be removed by reacting it with dilute sulfuric acid to form magnesium sulfate.

Use your knowledge of Group 2 sulfates to explain why the magnesium sulfate formed is easy to separate from the titanium.

.....

.....

.....

(1)
(Total 9 marks)

31 (a) When aluminium is added to an aqueous solution of copper(II) chloride, $CuCl_2$, copper metal and aluminium chloride, $AlCl_3$, are formed. Write an equation to represent this reaction.

.....

(1)

(b) (i) State the general trend in the first ionisation energy of the Period 3 elements from Na to Ar.

.....

(ii) State how, and explain why, the first ionisation energy of aluminium does not follow this general trend.

.....

.....

.....

.....

(4)

(c) Give the equation, including state symbols, for the process which represents the second ionisation energy of aluminium.

.....

(1)

(d) State and explain the trend in the melting points of the Period 3 metals Na, Mg and Al.

Trend .....

Explanation .....

.....

.....

(3)
(Total 9 marks)

32 (a) (i) Describe the bonding in a metal.

.....

.....

.....

(ii) Explain why magnesium has a higher melting point than sodium.

.....

.....

.....

(4)

(b) Why do diamond and graphite both have high melting points?

.....

.....

.....

.....

(3)

(c) Why is graphite a good conductor of electricity?

.....

(1)

(d) Why is graphite soft?

.....

.....

.....

(2)
(Total 10 marks)

33 Which one of the following does **not** contain any delocalised electrons?

A poly(propene)

B benzene

C graphite

D sodium

(Total 1 mark)

Mark schemes

1 B

[1]

2 (a) M1 $550 \times \frac{100}{95} = 579$ g would be 100% mass

Allow alternative methods.

There are 4 process marks:

1

M2 So $\frac{579}{65} = 8.91$ moles NaN_3

or

M1 $\frac{550}{65} = 8.46$ moles NaN_3 (this is 95%)

M2 So 100% would be $8.46 \times \frac{100}{95} = 8.91$ moles NaN_3

1: mass ÷ 65

2: mass or moles × 100 / 95 or × 1.05

3: moles NaN_3 × 2

4: moles $NaNH_2$ × 39

1

Then M3 Moles $NaNH_2$ = 8.91 × 2 = (17.8(2) moles)

1

M4 mass $NaNH_2$ = 17.8(2) × 39

1

M5 693 or 694 or 695 (g)

If 693, 694 or 695 seen to 3 sig figs award 5 marks

1

(b) M1 308 K and 150 000 Pa

1

M2 $n = \frac{PV}{RT}$ or $\frac{150\ 000 \times 7.5 \times 10^{-2}}{8.31 \times 308}$

1

M3 = 4.4(0) or 4.395 moles N_2

Allow only this answer but allow to more than 3 sig figs

1

M4 Moles NaN_3 = 4.395 × $\frac{2}{3}$ (= 2.93)

M4 is for M3 × $\frac{2}{3}$

1

M5 Mass NaN_3 = (2.93) × 65

M5 is for moles M4 × 65

1

M6 = 191 g

Allow 190 to 191 g allow answers to 2 sig figs or more

1

(c) (i) 150 / 65 = 2.31 moles NaN_3 or 2.31 moles nitrous acid

1

Conc = 2.31 × $\frac{1000}{500}$

M2 is for M1 × 1000 / 500

1

4.6(1) or 4.6(2) (mol dm^{-3})

Only this answer

1

(ii) $3HNO_2 \longrightarrow HNO_3 + 2NO + H_2O$

Can allow multiples

1

(d) Ionic

If not ionic then CE = 0 / 3

1

Oppositely charged ions / Na^+ and N_3^- ions

Penalise incorrect ions here but can allow M3

1

Strong attraction between (oppositely charged) ions / lots of energy needed to overcome (strong) attractions (between ions)

M3 dependent on M2

1

(e) (i) $N \equiv N \longrightarrow N^-$

Only

1

(ii) CO_2 / N_2O / BeF_2 / HN_3

Allow other correct molecules

1

(iii) MgN_6

Only

1

[21]

3 (a)

Method 1	Method 2
Mass of H_2O = 4.38−2.46 (= 1.92 g)	Percentage of H_2O = 44%

If there is an AE in M1 then can score M2 and M3

If M_r incorrect can only score M1

1

$ZnSO_4$	H_2O	ZnSO4	H2O
2.46	1.92	56	44
161.5	18	161.5	18

1

(0.0152	0.107)	(0.347	2.444)
(1	: 7)	(1	: 7)

x = 7 x = 7

If x = 7 with working then award 3 marks.

Allow alternative methods.

If M1 incorrect due to AE, M3 must be an integer.

1

(b) Moles HCl = 0.12(0)

1

mol $ZnCl_2$ = 0.06(0) ***OR*** 0.12 / 2

1

If M2 incorrect then CE and cannot score M2, M3 and M4.

mass $ZnCl_2$ = 0.06 × 136.4

Allow 65.4 + (2 × 35.5) for 136.4

1

= 8.18(4) (g) ***OR*** 8.2 (g)

Must be to 2 significant figures or more.

Ignore units.

1

(c) Moles $ZnCl_2 = \frac{10.7}{136.4}$ (= 0.0784)

1

OR moles Zn = 0.0784

Mass Zn reacting = 0.0784 × 65.4 = (5.13 g)

M2 is for their M1 × 65.4

1

$$\%\text{ purity of Zn} = \frac{5.13}{5.68} \times 100$$

M3 is M2 × 100 / 5.68 provided M2 is < 5.68

1

= 90.2% ***OR*** 90.3%

Allow alternative methods.

M1 = Moles $ZnCl_2$ = $\frac{10.7}{136.4}$ (= 0.0784)

M2 = Theoretical moles Zn = $\frac{5.68}{65.4}$ (= 0.0869)

M3 = M1 × 100 / M2 = (0.0784 × 100 / 0.0869)

*M4 = 90.2% **OR** 90.3%*

1

(d) Ionic

If not ionic CE = 0/3

1

Strong (electrostatic) attraction (between ions)

1

between oppositely charged ions / + and − ions / F^- and Zn^{2+} ions

If IMF, molecules, metallic bonding implied CE = 0/3

1

[14]

4 (a) Hydrogen/H bonds

Not just hydrogen

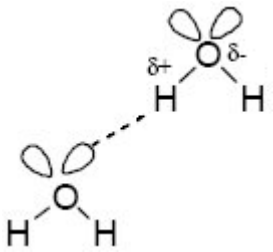
1

van der Waals/vdw/dipole-dipole/London/temporarily induced dipole/dispersion forces

Not just dipole

1

(b)



M1 for partial charges as indicated in diagram (correct minimum)
M2 for all four lone pairs
M3 for H bond from the lp to the H (δ+) on the other molecule
Lone pair on hydrogen CE = 0
OHO CE = 0
If only one molecule of water shown
CE = 0

3

(c) Hydrogen bonds/IMF (in water) stronger

OR

IMF/VDW/dipole-dipole forces (in H_2S) are weaker

OR

H bonding is the strongest IMF

Ignore energy references
Comparison must be stated or implied

1

(d) Atoms/molecules get larger/more shells/more electrons/more surface area

Not heavier/greater Mr

1

therefore increased <u>Van der Waals/IMF</u> forces

Ignore references to dipole-dipole forces

1

(e) Dative (covalent)/coordinate

If not dative/coordinate CE = 0/2
If covalent or blank read on

1

(Lone) pair/both electrons/two electrons on O(H_2) donated (to H^+)
OR pair/both electrons come from O(H_2)

Explanation of a coordinate bond specific to oxygen or water required
Not just H+ attracted to lone pair since that is nearer to a H bond

1

(f) ionic

1

if not ionic CE = 0

oppositely charged ions/+ and – ions or particles

atoms or molecules loses M2 and M3

1

ions attract strongly OR strong/many (ionic) bonds must be broken

S^- loses M2
Reference to IMF loses M2 and M3

1

[13]

5 (a) (i) Average/mean mass of 1 atom (of an element);

Average mass of 1 atom × 12.

1

Mass 1/12 atom of ^{12}C;

Mass 1 atom of ^{12}C.
QWC.

1

(ii) Other isotope = 46.0%;

1

$$107.9 = \frac{(54 \times 107.1) + (46 \times ?)}{100};$$

M2 whole expression.

1

108.8;

Answer 108.8 (3 marks).
Answer min 1 d.p..

1

Same electronic configuration/ same number of electrons (in outer shell)/ both have 47 electrons;

Ignore protons and neutrons unless incorrect.
Not just electrons determine chemical properties.

1

(b) Ionisation;

1

high energy electrons fired at sample;

Allow electron gun /blasted with electrons.

1

Acceleration;

1

With electric field/accelerating potential/potential difference;

Allow by negative plate.

1

Deflection;

1

With electromagnet/ magnet/ magnetic field;

M2 dependent on M1.
M4 dependent on M3.
M6 dependent on M5.

1

(c) (Silver) metallic (bonding);

Vdw/molecules CE=0.

1

Regular arrangement of same sized particles;

1

+ charge in each ion;

Ignore multiple positive charges.
Candidates do not need to show delocalised electrons.

1

(d) Ionic (bonds);

1

Minimum 4 ions shown in 2D square arrangement placed Correctly;

Do not allow multiple charges on ions.

1

Further 3 ions shown correctly in a cubic lattice;

1

Strong (electrostatic) forces/bonds;

If vdw/molecules/covalent mentioned CE = 0 for M4 and M5.

1

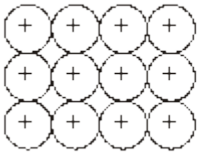
Between + and – ions;

Accept between oppositely charged ions.

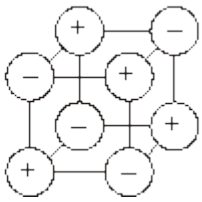
1

[20]

6 (a)



(1)



(1)

[Diagrams must be complete and accurate]

2

(b) (i) Attraction /electrostatic forces/bonds/attractions between (positive) ions/lattice and delocalised/free electrons/sea of electrons.

[Not metallic bonding]

[Not just 'forces']

1

(ii) Electrostatic attractions/forces between ions or attractions between (oppositely charged) ions/ Na^+ & Cl^-

[Not ionic bonding]

1

(iii) (Here) the ionic bonding in NaCl is stronger/requires more energy to break than the metallic bonding in Na

QoL Accept 'bonding/forces of attraction in NaCl is strong er than in Na'

[If IMF/molecules/van der Waals'/dipole–dipole mentioned in parts(i) or (ii), then CE = 0 for parts (i) and/or(ii) and CE = 0 for part(iii)]

1

(c) Comparison:
Sodium conducts **and** sodium chloride does NOT conduct

Allow 'only Na conducts'

Accept 'Na conducts, NaCl only conducts when molten'

[Do not accept sodium conducts better than sodium chloride etc.]

1

Explanation:
(Delocalised) electrons flow though the metal

1

Allow e^- move/carry current/are charge carriers/transfer charge.

[Not 'electrons carry electricity']

[Not 'NaCl has no free charged particles']

Ions can't move in solid salt

1

(d) Layers can slide over each other – idea that ions/atoms/particles move

[Not molecules]

[Not layers separate]

1

(e) (i)

Na	Cl	O
$\frac{21.6}{23}$	$\frac{33.3}{35.5}$	$\frac{45.1}{16}$

1

0.9(39)	0.9(38)	2.8(2)
Hence: 1	1	3

Accept backwards calculation, i.e. from formula to % composition, and also accept route via M_r to 23; 35.5; 48, and then to 1:1:3

[If % values incorrectly copied, allow M1 only]

[If any wrong A_r values/atomic numbers used = CE = 0]

1

(ii) $3Cl_2 + 6NaOH \rightarrow 5NaCl + NaClO_3 + 3H_2O$

1

[12]

7 (a)

Particle	Relative charge	Relative mass	
Proton	+1 **or** 1+	1	**(1)**
Neutron	0 **or** no charge/neutral/zero	1 (not – 1)	**(1)**
Electron	–1 or 1–	1/1800 to 1/2000	**(1)**

or negligible
or zero
or 5.0×10^{-4} to 5.6×10^{-4}

if 'g' in mass column - wrong
penalise once

3

(b) $^{38}_{18}Ar$ **(1)(1)**

Allow numbers before or after Ar

2

(c) *S*: $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^4$ **(1)**

Allow upper case letters

S^{2-}: $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6$ **(1)**

If use subscript penalise once

2

(d) *Block*: p **(1)**
Explanation: Highest energy or outer orbital is (3) p

OR outer electron, valency electron in (3) p
NOT 2p etc.

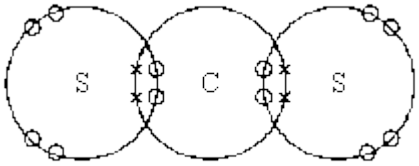
2

(e) (i) *Bonding in* Na_2S: ionic **(1)**
Bonding in CS_2: covalent **(1)**

ignore other words such as dative / polar / co-ordinate

(ii) Clear indication of electron transfer from Na to S **(1)**
1 e^- from each (of 2) Na atoms or 2 e^- from 2 Na atoms **(1)**

QoL correct English

(iii) 

Correct covalent bonds **(1)**
All correct including lone pairs **(1)**

Allow all •s or all ×s

M2 tied to M1

NOT separate e⁻s in S•- 2 l p

(iv) $CS_2 + 2H_2O \rightarrow CO_2 + 2H_2S$ **(1)**

Ignore state symbols even if wrong

7

[16]

8

(a) Correct diagram of NH_3 including LP on N

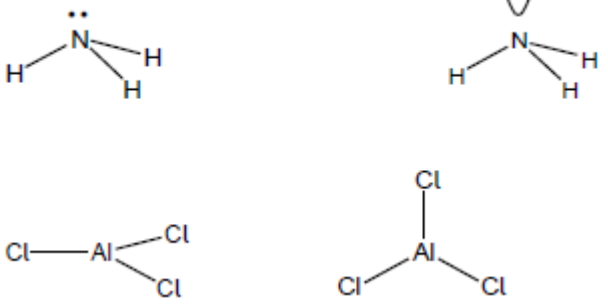
1

Correct diagram of $AlCl_3$

1

Bond angles in range 106-108° and bond angle of 120°

1



Ignore shape names

(b) Dative (covalent) /co-ordinate bond

Wrong bond CE=0 but mark on if covalent quoted

1

Shared pair of / both electrons come from the $N(H_3)$

1

(c) Aluminium is now surrounded by 4 electron pairs/bonds or is tetrahedral

Independent

1

Therefore Cl-Al-Cl bond angle decreases / changes
(from 120° in $AlCl_3$) to allow range 107-111° in H_3NAlCl_3

1

[7]

9 C

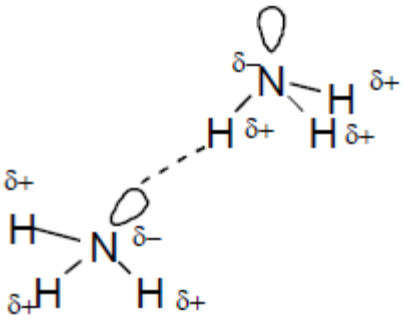
[1]

10 (a) (i) Hydrogen bonds / H bonds

Not just hydrogen.

1

(ii)



M1 – lone pair on each N.

M2 – correct partial charges must be shown on the N and H of a bond in each molecule.

M3 – for the H bond from lone pair on N to the Hδ⁺ on the other NH_3 molecule.

If not ammonia molecules, CE = 0 / 3.

3

(b) Lone pair / both electrons / 2 electrons / electron pair on N(H_3) is donated to B(Cl_3)

Allow both electrons in the bond come from N(H_3).

1

(c) (i) The power of an <u>atom</u> or <u>nucleus</u> to withdraw or attract electrons or electron density or a pair of electrons (towards itself)

1

in a <u>covalent</u> bond

1

(ii) LiF **OR** Li_2O **OR** LiH

Allow Li_2O_2, allow correct lithium carbide formula.

1

(iii) BH_3 / H_3B

Allow B_2H_6 / H_6B_2

Do not allow lower case letters.

1

[9]

11 (a) Giant covalent / giant molecular / macromolecular

Not giant alone.

Not covalent alone.

1

(b) Shared pair of electrons / one electron from each C atom

1

(c) No delocalised / free / mobile electrons

Allow all (outer) electrons involved in (covalent) bonds.

Ignore ions.

1

(d) CH

Allow HC

C and H must be capital letters.

1

[4]

12 (a) $Al + 1.5Cl_2 \rightarrow AlCl_3$

Accept multiples.

Also $2Al + 3Cl_2 \rightarrow Al_2Cl_6$

Ignore state symbols.

1

(b) Coordinate / dative (covalent)

If wrong CE=0/2 if covalent mark on.

1

Electron pair on Cl^- donated to Al(Cl_3)

QoL

Lone pair from Cl^- *not just Cl*

Penalise wrong species.

1

(c) Al_2Cl_6 or $AlBr_3$

Allow Br_3Al *or* Cl_6Al_2

Upper and lower case letters must be as shown.

Not $2AlCl_3$

1

(d) $SiCl_4$ / silicon tetrachloride

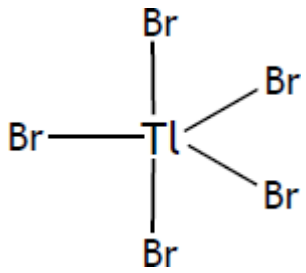
Accept silicon(4) chloride or silicon(IV) chloride.

Upper and lower case letters must be as shown.

Not silicon chloride.

1

(e)



Accept shape containing 5 bonds and no lone pairs from Tl to each of 5 Br atoms.

Ignore charge.

1

Trigonal bipyramid(al)

1

(f) (i) Cl — Tl — C

Accept this linear structure only with no lone pair on Tl

1

(ii) (Two) bonds (pairs of electrons) repel equally / (electrons in) the bonds repel to be as far apart as possible

Dependent on linear structure in (f)(i).

Do not allow electrons / electron pairs repel alone.

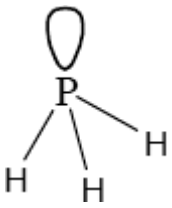
1

(g) Second

1

[10]

13 (a)



Need to see 3 P–H bonds and one lone pair (ignore shape).

1

(b) Coordinate / dative

If not coordinate / dative then chemical error CE=0 unless blank or covalent then M1 = 0 and mark on.

1

Pair of electrons on P(H_3) donated (to H+)

Do not allow a generic description of a coordinate bond.

1

(c) 109.5° / 109½ / 109° 28'

Allow answers in range between 109° to 109.5°

1

(d) Difference in electronegativity between P and H is too small

Allow P not very electronegative / P not as electronegative as N, O and F / P not electronegative enough / P not one of the 3 most electronegative elements.

Do not allow phosphine is not very electronegative.

1

[5]

14 (a) Covalent

If not covalent CE = 0/2

If dative covalent CE = 0/2

If blank mark on

Ignore polar

If number of pairs of electrons specified, must be 3

1

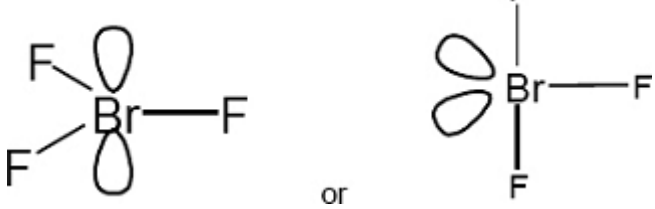
Shared pair(s) of electrons / one electron from Br and one electron from F

Not 2 electrons from 1 atom

Not shared pair between ions/molecules

1

(b) (i)



BrF_3 should have 3 bp and 2 lp and correct atoms for the mark

Penalise Fl

1

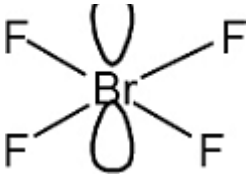
BrF_3 if trigonal planar shown = 120°

Allow 84 – 90° or 120° and ignore 180°

or if T shape shown 84 – 90°

Irrespective of shape drawn

1

(ii) 

BrF_4^- should have 4 bp and 2 lp and all atoms for the mark (ignore sign)

Allow Fl

1

BrF_4^- 90°

Only

Ignore 180°

1

(c) Ionic or (forces of) attraction between ions / bonds between ions

If molecules, IMF, metallic, CE =0

If covalent bonds mentioned, 0/3, unless specified <u>within</u> the BrF_4^- ion and not broken

Ignore atoms

1

Strong (electrostatic) attraction / strong bonds / lots of energy needed to break bonds

1

Between K^+ and BrF_4^- ions/oppositely charged ions / + and – ions

If ions mentioned they must be correct

Strong bonds between + and – ions =3/3

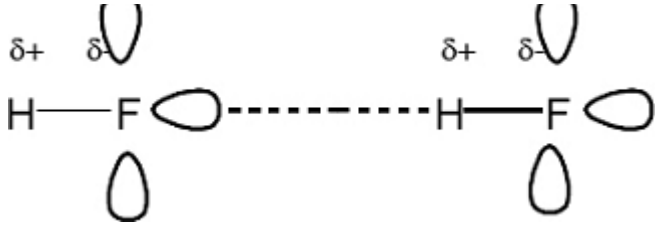
1

(d) (i) Hydrogen <u>bonds</u>/hydrogen <u>bonding</u>/H <u>bonds</u>/H <u>bonding</u>

Not just hydrogen

1

(ii)



One mark for 4 partial charges

One mark for 6 lone pairs

One mark for H bond from the <u>lone pair to the Hδ+</u>

Allow Fl

If more than 2 molecules are shown they must all be correct. Treat any errors as contradictions within each marking point.

CE = 0/3 if incorrect molecules shown.

3

(e) vdw / van der Waals forces between molecules

QoL

Not vdw between HF molecules, CE = 0/2

vdw between atoms, CE = 0/2

If covalent, ionic, metallic, CE=0/2

1

IMF are weak / need little energy to break IMF / easy to overcome IMF

1

[15]

15 (a) Iodine has more electrons / iodine is bigger (atom or molecule) / iodine has bigger M_r / bigger surface area

1

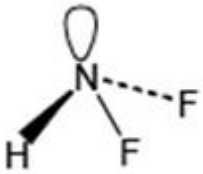
<u>Stronger</u> / <u>more</u> van der Waals forces / vdw / London / temporarily induced dipole / dispersion forces <u>between molecules</u>

1

Stronger VdW intermolecular forces = M2

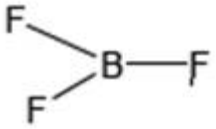
If stated VdW between atoms lose M2

(b) (i)



Mark is for 3 bp and 1 lp attached to N (irrespective of shape)

1



Mark is for 3 bp and 0 lp attached to B (irrespective of shape)

1

NHF_2 shape - pyramidal / trigonal pyramid

Accept tetrahedral / triangular pyramid

1

BF_3 shape - <u>trigonal planar</u>

Not triangular or triangular planar

1

(ii) 107°

Allow 106-108°

1

(c) Hydrogen bonds

Allow H-Bonds

Not just Hydrogen

Apply list principle eg Hydrogen bonding and dipole-dipole = 0

1

(d) Coordinate / dative covalent / dative

If covalent mark on

If ionic / metallic CE = 0

1

Lone pair / both electrons/ 2 electrons <u>on N(HF_2)</u> donated (to BF_3)

Direction of donation needed here

1

[10]

16 (a) Water or H_2O or molecules (in ice) are held further apart (than in liquid water)/(more) space/gaps/holes in structure/Water or H_2O or molecules (in ice) are more spread out

Allow water (liquid) is more compact/less space/gaps/holes

CE if holes filled with air, O_2 etc

CE if macromolecule

CE if atoms further apart (since ambiguous)

Ignore spaces filled with H_2O

Ignore reference to H bonds

Allow better tessellation in liquid water

1

(b) (i) Hydrogen bonding

Allow H bonds

Do not allow 'hydrogen' only but mark on

1

(ii) Van der Waals'/VdW

Allow London forces, dispersion forces, temporary induced dipole forces

1

(iii) Hydrogen bonding is stronger (than van der Waals forces)/IMF in ice stronger (than IMF in methane)/H bonds take more energy to break

Not H Bonds are strong (needs comparison)

If (b)(i) OR (ii) is incorrect, cannot award (b)(iii)

If (b)(i) and/or (ii) is blank, can score (b)(iii)

1

(c) (i) Structure showing 3 bonds to H and 1 lone pair

1

(trigonal) pyramid(al)/(distorted) tetrahedral

do not insist on the + sign

Allow triangular pyramid

Not square pyramid

Ignore bond angles in structure

M2 independent of M1

1

(ii) 107°

Allow range 106 – 108°

Ignore °(C)

1

(iii) NH_3/ammonia

Contradictions (eg NH_4 ammonia) CE = 0

1

(d) 3

Allow three/III/3 lone pairs/3lp/3 lone pairs of electrons

1

[9]

17 (a) (i) shared <u>pair of electrons</u>

Can have one electron from each atom contributes to the bond
Not both electrons from one atom

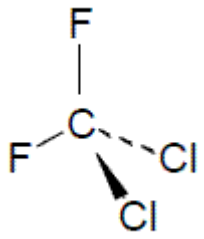
1

(ii) $\frac{1}{2}Cl_2 + \frac{3}{2}F_2 \rightarrow ClF_3$

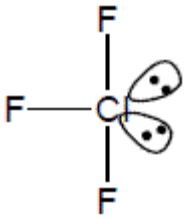
1

Only
Ignore state symbols even if wrong

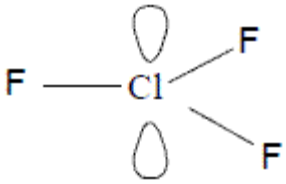
(b)



1



OR

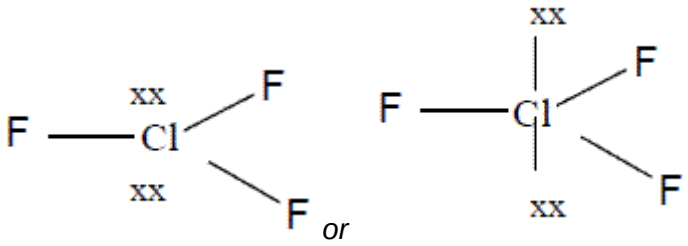


Allow any structure with 4 bp

In $CClF_2$, watch for Cl in centre- it must be C

Ignore wrong bond angles

Representations of lone pairs allowed are the two examples shown with or without the electrons in the lobe.
Also they can show the lone pair for either structure by two crosses/dots or a line with two crosses/dots on it e.g.



Or a structure with 3 bp and 2 lp

1

(c) Dipole – dipole

Allow van der Waals/vdw/London/dispersion/temporary dipole – induced dipole
Not dipole alone

1

(d) (i) Coordinate/dative (covalent)

If wrong CE = 0/3 but if 'covalent' or left top line blank, mark on.

1

(Lone) pair of electrons/both electrons (on F^-)

CE if lone pair is from B

1

Donated from F^-/fluoride or donated to the BF_3

Must have the – sign on the F ie F^-

Ignore Fl^-
M3 dependent on M2

1

(ii) 109° to 109.5°

1

(e) $\frac{238 \times 100}{438}$

For 1 mark allow 238 as numerator and 438 as denominator or correct strings

1

= 54.3%

2 marks if correct answer to 3 sig figs.
54% or greater than 3 sig figs = 1 mark

1

[11]

18

(a) (i) Covalent;

If not covalent CE = 0.
If blank, mark on.

1

Shared pair of electrons (one from each atom);

Not shared electrons.

1

(ii) Hydrogen bonds / H bonds;

Not just hydrogen.

1

Van der Waals/London/dispersion forces/temporary induced dipole;

1

(b) Showing all the lone pairs on both molecules;

Allow showing both lone pairs on the O involved in the H-bond.

1

Showing the partial charges on O and H on both molecules;

Allow showing both partial charges on the O and H of the other molecule involved in the H bond.

1

Showing the Hydrogen bond from the lone pair on O of one molecule to the delta + on the H of the other molecule;

1

(c) (i) $C_2H_5OH + 3O_2 \rightarrow 2CO_2 + 3H_2O$;

Accept multiples.
Allow C_2H_6O.

1

(ii) CO is (produced which is) toxic/ poisonous/C (may be produced) which is toxic/ C is a respiratory irritant/ C (particles) exacerbate asthma/C causes global dimming/ smog;

Must relate to C or CO.
Any mention of SO_2 NO_2 or other pollutants CE = 0.

1

(iii) More fuel needed (which costs more)/Wastes fuel/ less fuel burnt (so need more to buy more)/engine gets sooty so need to pay for engine to be cleaned/Have to fit catalytic converter;

Not just costs more.
Not engine gets sooty unless qualified.

1

(d) (i) (React) with CaO/ calcium oxide/quicklime/lime;

Accept $CaCO_3$/ calcium carbonate/limestone.
Not chalk.

1

All the sulfur dioxide may not react with the CaO or $CaCO_3$ / may not have time to react/ incomplete reaction;

Accept incomplete reaction.

1

(ii) Occupies a (much) smaller volume;

Not easier to store or transport.

1

[13]

19 (a) Ability/power of an atom/element/nucleus to withdraw electron density or electron cloud or a pair of electrons (towards itself);

Not withdraw an electron
If ref to ionic, metallic , imf etc then CE = 0

1

From a covalent bond or from a shared pair of electrons;

Not distort
Not remove electrons

1

(b) Van der Waals/ vdw/London/ temporary (induced) dipole/ dispersion forces;

1

Hydrogen bonds/H bonds;

Not just hydrogen

1

(c) (Large) electronegativity difference between N + H/ difference of 0.9/ N very electronegative;

Insufficient to say N= 3.1 and H = 2.1

1

Forms N δ– / H δ+ or dipole explained in words;

Not N becomes (fully) negative or vice versa

1

Lone pair on N attracts/forms weak bonds with H (δ+);

QWC
Can score M2 and 3 from a diagram

1

(d) Co-ordinate/dative;

If not correct then CE = 0. If covalent/blank mark on.

1

Both electrons/ lone pair (on P/PH_3)

Not lone pair on hydrogen

1

Shares/donated from $P(H_3)$/ to H(δ+);

1

(e) 3 bonds and 1 lp attached to As;

Must label H and As atoms
Accept distorted tetrahedral not bent tetrahedral

1

Pyramidal/tetrahedral/ trigonal pyramidal;

Not bipyramidal/triangular

1

(f) (Only) weak Van der Waals forces between molecules /AsH_3 has weaker IMF /ammonia has hydrogen bonding/ more energy needed to break IMF's in ammonia/ Van der Waals weaker than H bonds;

Accept has no H bonds.
Ignore dp-dp in AsH_3 provided ammonia has stronger IMF.
If between atoms mentioned CE=0
Break bonds CE = 0

1

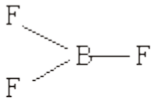
(g) $4AsCl_3 + 3NaBH_4 \rightarrow 4AsH_3 + 3NaCl + 3BCl_3$;

Accept multiples

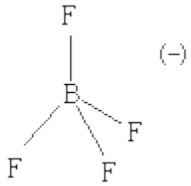
1

[14]

20 (i)



(1)



(1)

[Do not allow shapes which show a lone pair]

2

BF_3 Trigonal planar/planar triangular

[Not plane triangle]

1

BF_4^- Tetrahedral

[Not distorted tetrahedral]

1

Equal repulsion between (4) bonding pairs/bonds/bonding electrons

1

109(½)°

1

(ii) Lone pair donated / both electrons supplied by one atom

1

from F^- (to B)

[ignore missing charge or fluorine or 'atom']

1

dative/dative covalent/coordinate bonding

1

[9]

21 (a) dative / coordinate (covalent) bond;

1

Lone/non-bonding pair / both electrons;

1

(donated) from P to H^+;

1

(b)

PH_3 PH_4^+

(1) (1)

pyramidal *OR* trigonal pyramid 109(1/2)°;

(accept tetrahedral)

4

[7]

22 (a) **4**LiH + $AlCl_3$ → $LiAlH_4$ + **3**LiCl

1

(b) H^- = $1s^2$ **or** $1s_2$

1

(c) Tetrahedral or diagram

(Not distorted tetrahedral)

1

(Equal) repulsion

1

between four bonding pairs / bonds

(Not repulsion between H atoms loses M2 and M3)

(Not 'separate as far as possible')

('4' may be inferred from a correct diagram)

1

(d) Dative (covalent) or coordinate

1

Lone pair **or** non-bonding pair of electron **or** both e^-

1

QoL Donated from H^- to Al **or** shared between H and Al

(tied to M2)

(Not 'from H atom') (Not 'to Al ion') (Not 'e⁻s transferred')

1

[8]

23

(a) (i) Electronegativity (difference) or suitable description **(1)**

Accept F and Cl are highly electronegative
Not both atoms are highly electronegative

(ii) HF = hydrogen bonding **(1)**
HCl = (permanent) dipole-dipole bonding **or** even van de Waals' **(1)**
Hydrogen bonding stronger / is the strongest IMF **(1)**

Accept a statement that HF must have the stronger IMF, even if no IMFs identified

*The explanation **must** be based on **intermolecular** forces/attractions*

Note: if the explanation is clearly intramolecular = CE

4

(b) Electron pair **or** lone pair donated **(1)**

Do not accept 'donation of electrons'

From chloride ion to Al **or** $AlCl_3$ **(1)**

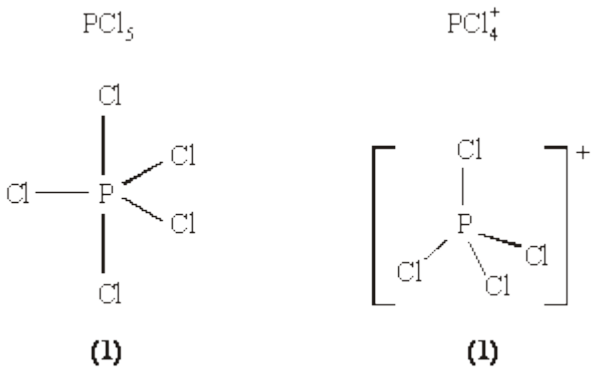
M1 can be earned by a general explanation of coordinate bonding, even if the electron pair is said to come from Al. The second mark, M2, is for this specific bond

Ignore missing charge

2

(c)

4



(1) (1)

PCl_5 shown as trigonal bipyramid PCl_4^+ shown as tetrahedral

[Look for: ONE solid linear Cl-P-Cl bond] NO solid linear Cl-P-Cl bonds]

Bond Angle(s) 90° and 120° **(1)** *Bond angle(s)* 109 or 109.5° **(1)**

[10]

24 (a) (i) Covalent **(1)**

(ii) Co-ordinate **(1)** (or dative)

(iii) Both / two / pair electrons come from nitrogen **(1)**

(iv) 4 bonding / electron pairs **(1)**

repel equally **(1)**

OR are identical

as far apart as possible **(1)**

OR to position of minimum repulsion

tetrahedron **(1)**

7

(b) Power (or ability) of an element / atom to attract electron pair**/**electrons/ an electron/electron density **(1)**

in a covalent bond **(1)**

Allow attract from, withdraw in, do not allow remove from, withdraw from.

2

(c) (i) Electron deficient **(1)**

Or small, slight, partial positive charge

(ii) H < N **(1)**

2

[11]

25 (a) (i) d (block) **OR** D (block)

Ignore transition metals / series.

Do not allow any numbers in the answer.

1

(ii) Contains positive (metal) ions or protons or nuclei and <u>delocalised / mobile / free / sea of</u> electrons

Ignore atoms.

1

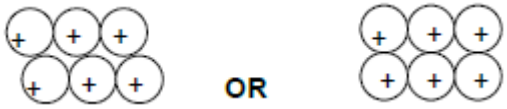
<u>Strong attraction</u> between them or <u>strong metallic</u> bonds

Allow 'needs a lot of energy to break / overcome' instead of 'strong'.

If strong attraction between incorrect particles, then CE = 0 / 2.

If molecules / intermolecular forces / covalent bonding / ionic bonding mentioned then CE=0.

1

(iii)  **OR**

M1 is for regular arrangement of atoms / ions (min 6 metal particles).

M2 for + sign in each metal atom / ion.

Allow 2^+ sign.

2

(iv) <u>Layers / planes / sheets of atoms or ions</u> can slide over one another

QoL.

1

(b) (i) $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 3d^8\ (4s^0)$

Only.

1

(ii) $NiCl_2.6H_2O$ + **6** $SOCl_2$ $\longrightarrow$ $NiCl_2$ + **6** SO_2 + **12** HCl

Allow multiples.

1

$NaOH$ / NH_3 / $CaCO_3$ / CaO

Allow any name or formula of alkali or base.

Allow water.

1

[9]

26

(a) White powder / solid / ash / smoke

Ignore ppt / fumes

1

Bright / white light / flame

Allow glows white / glows bright

1

$Mg + H_2O \rightarrow MgO + H_2$

Ignore state symbols

Ignore reference to effervescence or gas produced

1

(b) Mg^{2+} / magnesium ion has higher charge than Na^+

Allow Mg^{2+} ions smaller / greater charge density than Na^+ ions

Allow Mg atoms smaller than Na (atoms)

Allow magnesium has more delocalised electrons

Must be a comparison

Ignore reference to nuclear charge

1

Attracts delocalised / free / sea of electrons more strongly / metal–metal bonding stronger / metallic bonding stronger

Wrong type of bonding (vdW, imf), mention of molecules CE = 0

1

(c) **Structure:** Macromolecular / giant molecule / giant covalent

Mark independently

1

Bonding: Covalent / giant covalent

1

Physical Properties:

Any **two** from: Hard/
Brittle / not malleable
Insoluble
Non conductor

Ignore correct chemical properties

Ignore strong, high boiling point, rigid

2

(d) **Formula:** P_4O_{10}

Mention of ionic or metallic, can score M1 only

1

Structure: Molecular

If macromolecular, can score M1 & M3 only

1

Bonding: Covalent / shared electron pair

1

van der Waals' / dipole–dipole forces <u>between molecules</u>

Allow vdW, imf and dipole–dipole imf but do not allow imf alone

1

(e) $SO_2 + H_2O \rightarrow H^+ + HSO_3^-$

Products must be ions

Allow $SO_2 + H_2O \rightarrow 2H^+ + SO_3^{2-}$

Allow two equations showing intermediate formation of H_2SO_3 *that ends up as ions*

Ignore state symbols

Allow multiples

1

(f) $P_4O_{10} + 6MgO \rightarrow 2Mg_3(PO_4)_2$

OR $P_4O_{10} + 6MgO \rightarrow 6Mg^{2+} + {}_4PO_4^{3-}$

OR $P_2O_5 + 3MgO \rightarrow Mg_3(PO_4)_2$ etc

Ignore state symbols

Allow multiples

1

[15]

27 (a) **M1 (could be scored by a correct mathematical expression**

*Correct answer to the calculation gains all of **M1**, **M2** and **M3***

M1 $\Delta H = \Sigma \Delta H_f$ (**products**) − $\Sigma \Delta H_f$ (**reactants**)

Credit 1 mark for − 101 (kJ mol^{-1})

OR a correct cycle of balanced equations

M2 = − 1669 − 3(− 590)
= − 1669 + 1770
(This also scores M1)

M3 = **+ 101** (kJ mol^{-1})

Award 1 mark ONLY for − 101

For other incorrect or incomplete answers, proceed as follows

- *check for an arithmetic error (AE), which is either a transposition error or an incorrect multiplication; this would score 2 marks (**M1** and **M2**)*
- *If no AE, check for a correct method; this requires either a correct cycle with 3Sr and 2Al OR a clear statement of **M1** which could be in words and scores **only M1***

M4 - Using powders
Any **one** from

- To increase collision frequency / collisions in a given time / rate of collisions
- To increase the surface contact / contact between the solids / contact between (exposed) particles

Ignore dividing final answer by 3

*Penalise **M4** for reference to molecules.*

5

M5 Major reason for expense of extraction
Any **one** from

- Aluminium is extracted by electrolysis ***OR*** aluminium extraction uses (large amounts of) electricity
- Reaction / process / It / the mixture requires heat
- It is endothermic

(b) Calcium has a higher melting point than strontium, because

Ignore general Group 2 statements.

Correct reference to size of cations / proximity of electrons

M1 (For Ca) delocalised <u>electrons closer to cations / positive ions / atoms / nucleus</u>
OR <u>cations / positive ions / atoms are smaller</u>
OR <u>cation / positive ion / atom or it has fewer (electron) shells / levels</u>

*Penalise **M1** if either of Ca or Sr is said to have <u>more or less</u> delocalised electrons OR the same nuclear charge.*

Ignore reference to shielding.

Relative strength of metallic bonding

M2 (Ca) has <u>stronger</u> attraction between the <u>cations / positive ions / atoms / nucleus</u> and the <u>delocalised electrons</u>
OR
<u>stronger metallic</u> bonding

(assume argument refers to Ca but credit converse argument for Sr)

***CE= 0** for reference to molecules or Van der Waals forces or intermolecular forces or covalent bonds.*

2

(c) **M1** $\mathbf{2}Mg + O_2 \longrightarrow \mathbf{2}MgO$

M2 $Mg + \mathbf{2}H_2O \longrightarrow Mg(OH)_2 + H_2$

Credit multiples of the equations.

M3 Magnesium hydroxide is used as an antacid / relieve indigestion (heartburn) / neutralise (stomach) acidity / laxative

*Not simply "milk of magnesia" in **M3***

3

[10]

28 (a) (i) Increases

1

(ii) Decreases

1

(iii) Increases

1

(b) Calcium has a higher melting point than strontium, because

CE = 0 for reference to molecules or intermolecular forces or covalent bonds

Correct reference to size of cations/proximity of electrons

M1 (For Ca) delocalised <u>electron(s) closer to cations / positive ions / nucleus</u>

Ignore "Van der Waals forces (between atoms)" but penalise if between "molecules"

OR <u>cations / positive ions / atoms are smaller</u>

OR <u>cation / positive ion / atom or it has fewer (electron) shells / levels</u>

Ignore general Group 2 statements

Answers must be specific

Relative strength of metallic bonding

M2 (For Ca) has <u>stronger</u> attraction between the <u>cations / positive ions / nucleus</u> and the <u>delocalised electron(s)</u>

Penalise M1 if Ca or Sr is said to have <u>more or less</u> delocalised electrons

OR

<u>stronger metallic bonding</u>

(assume argument refers to Ca but accept converse argument for Sr)

Ignore reference to shielding

2

(c) (i) Sulfuric acid / it contains <u>sulfate ions / SO_4^{2-}</u>

OR

Do not penalise an <u>additional</u> but incorrect formula for sulfate ion.

<u>Sulfuric acid</u> would form a (white) <u>precipitate</u>

If only the formula of the sulfate ion is given, it must be correct

1

(ii) $Ba^{2+} + SO_4^{2-} \longrightarrow BaSO_4$ ONLY

Ignore state symbols

No multiples

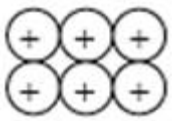
1

[7]

29 (a) (i) Metallic

Allow body centred cubic

1

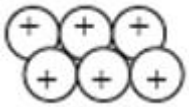
(ii) 

One mark for regular arrangement of particles. Can have a space between them

Do not allow hexagonal arrangement

1

OR



Na^+ Na^+ Na^+

Na^+ Na^+ Na^+

One mark for + in each

Ignore electrons

If it looks like ionic bonding then CE = 0/2

1

(b) (i) <u>Ionic</u>

CE = 0 for (b)(i) and (b)(ii) if not ionic

1

(ii) Strong (electrostatic) attraction

Any mention of IMF or molecules / metallic / covalent in (b)(ii) then CE 0/2

1

Between <u>oppositely</u> charged ions / particles

Or + and – ions

1

(c) Iodide / I^- bigger (ion) (so less attraction to the Na+ ion)

Need comparison

Do not allow iodine is a bigger atom

Ignore I^- has one more c– shell

CE = 0 if IMF / covalent / metallic mentioned

1

[7]

30 (a) Antacid

OR

to neutralise acidity

OR

eases indigestion

Credit suitable reference to indigestion or to laxative or to relief of constipation

1

(b) **M1** Decrease in T decreases the <u>energy</u> of the <u>particles/ions/H^+/molecules</u>

M2 (also scores M1) Decrease in the number of/less particles/ions/ H^+/molecules with $E \geq E_{Act}$ or E ≥ minimum energy to react

*In **M1** and **M2,** credit "atoms" but ignore "calcium carbonate", ignore "calcium", ignore any ion formula except H^+*

M3 Few(er)/Less effective/productive/successful collisions

QoL

3

(c) (i) Strontium has a higher melting point than barium, because

Correct reference to size of cations/proximity of electrons
M1 (For Sr) delocalised <u>electrons closer to cations/positive ions/atoms/nucleus</u>

OR

cations/positive ions/atoms are smaller

OR

cation/positive ion/atom or it has fewer (electron) shells/levels

Ignore general Group 2 statements

Penalise M1 if Sr or Ba is said to have <u>more or less</u> delocalised electrons

Ignore reference to shielding

***CE = 0** for reference to molecules or intermolecular forces or covalent bonds*

Relative strength of metallic bonding
M2 (Sr) has <u>stronger</u> attraction between the <u>cations/positive ions/ atoms/nucleus</u> and the delocalised <u>electrons</u>

OR

<u>stronger metallic</u> bonding
(assume argument refers to Sr but accept converse argument for Ba) 2

Ignore "Van der Waals forces (between atoms)" but penalise if "between molecules"

(ii) $Sr + \mathbf{2}H_2O \rightarrow Sr(OH)_2 + H_2$

Or multiples

1

(d) $\mathbf{2}Mg + TiCl_4 \rightarrow \mathbf{2}MgCl_2 + Ti$

Or multiples

1

[9]

31 (a) $2Al + 3CuCl_2 \rightarrow 2AlCl_3 + 3Cu$;

(accept multiples/fractions)

OR

$2Al + 3Cu^{2+} \rightarrow 2Al^{3+} + 3Cu$;

1

(b) (i) increases;

1

(ii) lower than expected / lower than Mg /

1

less energy needed to ionise; e^- removed from (3)p sub-level;

1

('e^- removed' may be implied)

of higher energy / further away from nucleus / shielded by 3s e^-s;

1

(c) $Al^+(g) \rightarrow Al^{2+}(g) + e^-$;

1

(d) trend: increases;

1

more protons / higher charge on cation / more delocalised e^- / smaller atomic/ionic radius;
stronger attraction between (cat)ions and delocalised/free/mobile e^-

1

OR

stronger metallic bonding;

1

[9]

32 (a) (i) positive ions **(1)**
(attract) delocalised electrons **(1)** *(or sea of or free or mobile)* **(1)**

Confusion with -ve ions
or ionic lattice C.E. = 0

(ii) more protons **(1)** (or Mg^{2+} more charge than Na^+)
attracts delocalised (or bonding) electrons more strongly **(1)**
Delocalised: can be brought forward from (a) (i)

OR more delocalised electrons (1)
Attacks positive ions more (1)
Metallic bonding is stronger scores one mark, only given if no other marks awarded

4

(b) macromolecular **(1)** *(or giant molecule etc)*
covalent **(1)**
strong covalent bonds **(1)**

or bonds require much energy to break

3

(c) delocalised *(OR free or sea of or mobile)* electrons **(1)**

1

(d) Planes **(1)**
weak (bonds) forces between planes **(1)**

2

or v.dw forces between planes

[10]

33 A

[1]