1 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 .....

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(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)

2

(a) Write an equation, including state symbols, for the reaction with enthalpy change equal to the standard enthalpy of formation for $CF_4(g)$.

.....

(1)

(b) Explain why CF_4 has a bond angle of 109.5°.

.....

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(2)

(c) **Table 1** gives some values of standard enthalpies of formation ($\Delta_f H^\ominus$).

Table 1

Substance	$F_2(g)$	$CF_4(g)$	HF(g)
$\Delta_f H^\ominus$ / kJ mol^{-1}	0	−680	−269

The enthalpy change for the following reaction is −2889 kJ mol^{-1}.

$$C_2H_6(g) + 7F_2(g) \longrightarrow 2CF_4(g) + 6HF(g)$$

Use this value and the standard enthalpies of formation in **Table 1** to calculate the standard enthalpy of formation of $C_2H_6(g)$.

Standard enthalpy of formation of $C_2H_6(g)$ = ... kJ mol^{-1}

(3)

(d) Methane reacts violently with fluorine according to the following equation.

$$CH_4(g) + 4F_2(g) \longrightarrow CF_4(g) + 4HF(g) \quad \Delta H = -1904 \text{ kJ mol}^{-1}$$

Some mean bond enthalpies are given in **Table 2**.

Table 2

Bond	C−H	C−F	H−F
Mean bond enthalpy / kJ mol^{-1}	412	484	562

A student suggested that one reason for the high reactivity of fluorine is a weak F−F bond.

Is the student correct? Justify your answer with a calculation using these data.

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(4)
(Total 10 marks)

3 Which of these species has a trigonal planar structure?

A PH_3 ⬭

B BCl_3 ⬭

C H_3O^+ ⬭

D CH_3^- ⬭

(Total 1 mark)

4 (a) Explain how the electron pair repulsion theory can be used to deduce the shape of, and the bond angle in, PF_3

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(6)

(b) State the full electron configuration of a cobalt(II) ion.

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(1)

(c) Suggest **one** reason why electron pair repulsion theory **cannot** be used to predict the shape of the $[CoCl_4]^{2-}$ ion.

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.....

(1)

(d) Predict the shape of, and the bond angle in, the complex rhodium ion $[RhCl_4]^{2-}$.

Shape .....

Bond angle .....

(2)

(Total 10 marks)

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

(a) State the element in Period 3 that has the highest melting point.
Explain your answer.

Element .....

Explanation .....

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(3)

(b) State the element in Period 3 that has the highest first ionisation energy.
Explain your answer.

Element .....

Explanation .....

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(3)

(c) Suggest the element in Period 3 that has the highest electronegativity value.

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(1)

(d) Chlorine is a Period 3 element.
Chlorine forms the molecules ClF_3 and CCl_2

(i) Use your understanding of electron pair repulsion to draw the shape of ClF_3 and the shape of CCl_2
Include any lone pairs of electrons that influence the shape.

Shape of ClF_3 Shape of CCl_2

(2)

(ii) Name the shape of CCl_2

.....

(1)

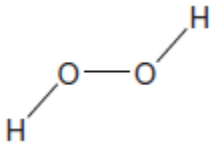
(iii) Write an equation to show the formation of one mole of ClF_3 from its elements.

.....

(1)

(Total 11 marks)

6 A hydrogen peroxide molecule can be represented by the structure shown.



(a) Suggest a value for the H−O−O bond angle.

.....

(1)

(b) Hydrogen peroxide dissolves in water.

(i) State the strongest type of interaction that occurs between molecules of hydrogen peroxide and water.

.....

(1)

(ii) Draw a diagram to show how one molecule of hydrogen peroxide interacts with one molecule of water.
Include all lone pairs and partial charges in your diagram.

(3)

(c) Explain, in terms of electronegativity, why the boiling point of H_2S_2 is lower than H_2O_2.

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(2)
(Total 7 marks)

7 Thallium is in Group 3 of the Periodic Table.
Thallium reacts with halogens to form many compounds and ions.

(a) Draw the shape of the $TlBr_3^{2-}$ ion and the shape of the $TlCl_4^{3-}$ ion.
Include any lone pairs of electrons that influence the shapes.

Name the shape made by the atoms in $TlBr_3^{2-}$ and suggest a value for the bond angle.

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(4)

(b) Thallium(I) bromide (TlBr) is a crystalline solid with a melting point of 480 °C.

Suggest the type of bonding present in thallium(I) bromide and state why the melting point is high.

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(3)

(c) Write an equation to show the formation of thallium(I) bromide from its elements.

.....

(1)

(Total 8 marks)

8 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.

.....

(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)

9 Chlorine can form molecules and ions that contain only chlorine, or that contain chlorine combined with another element.

(a) Use your understanding of the electron pair repulsion theory to draw the shape of the $AsCl_3$ molecule and the shape of the Cl_3^+ ion.
Include any lone pairs of electrons that influence the shape.

Name the shape made by the atoms in the $AsCl_3$ molecule and in the Cl_3^+ ion.

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(Extra space) .....

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(4)

(b) Explain why the $AsCl_4^+$ ion has a bond angle of 109.5°.

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(Extra space).....

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(2)
(Total 6 marks)

10 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.

.....

(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)

11 (a) Boron trichloride (BCl_3) can be prepared as shown by the following equation.

$$B_2O_3(s) + 3C(s) + 3Cl_2(g) \longrightarrow 2BCl_3(g) + 3CO(g)$$

A sample of boron oxide (B_2O_3) was reacted completely with carbon and chlorine.

The two gases produced occupied a total volume of 5000 cm^3 at a pressure of 100 kPa and a temperature of 298 K.

Calculate the mass of boron oxide that reacted.
Give your answer to 3 significant figures.

(The gas constant R = 8.31 J K^{-1} mol^{-1})

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(Extra space) .....

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(5)

(b) Boron trichloride can also be prepared from its elements.

Write an equation for this reaction.
Explain why boron trichloride has a trigonal planar shape with equal bond angles.

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(Extra space) .....

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(3)

(c) (i) Boron trichloride is easily hydrolysed to form two different acids as shown in the following equation.

$$BCl_3(g) + 3H_2O(l) \longrightarrow H_3BO_3(aq) + 3HCl(aq)$$

Calculate the concentration, in mol dm^{-3}, of hydrochloric acid produced when 43.2 g of boron trichloride are added to water to form 500 cm^3 of solution.
Give your answer to 3 significant figures.

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(Extra space) .....

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(4)

(ii) Boric acid (H_3BO_3) can react with sodium hydroxide to form sodium borate and water. Write an equation for this reaction.

.....

(1)

(d) Boron trichloride can be reduced by using hydrogen to form pure boron.

$$BCl_3(g) + 1\frac{1}{2} H_2(g) \longrightarrow B(s) + 3HCl(g)$$

Calculate the percentage atom economy for the formation of boron in this reaction.

Apart from changing the reaction conditions, suggest **one** way a company producing pure boron could increase its profits from this reaction.

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(Extra space) .....

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(3)

(e) A different compound of boron and chlorine has a relative molecular mass of 163.6 and contains 13.2% of boron by mass.

Calculate the molecular formula of this compound.
Show your working.

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(Extra space) .....

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(4)
(Total 20 marks)

12 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)

13 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 .....

.....

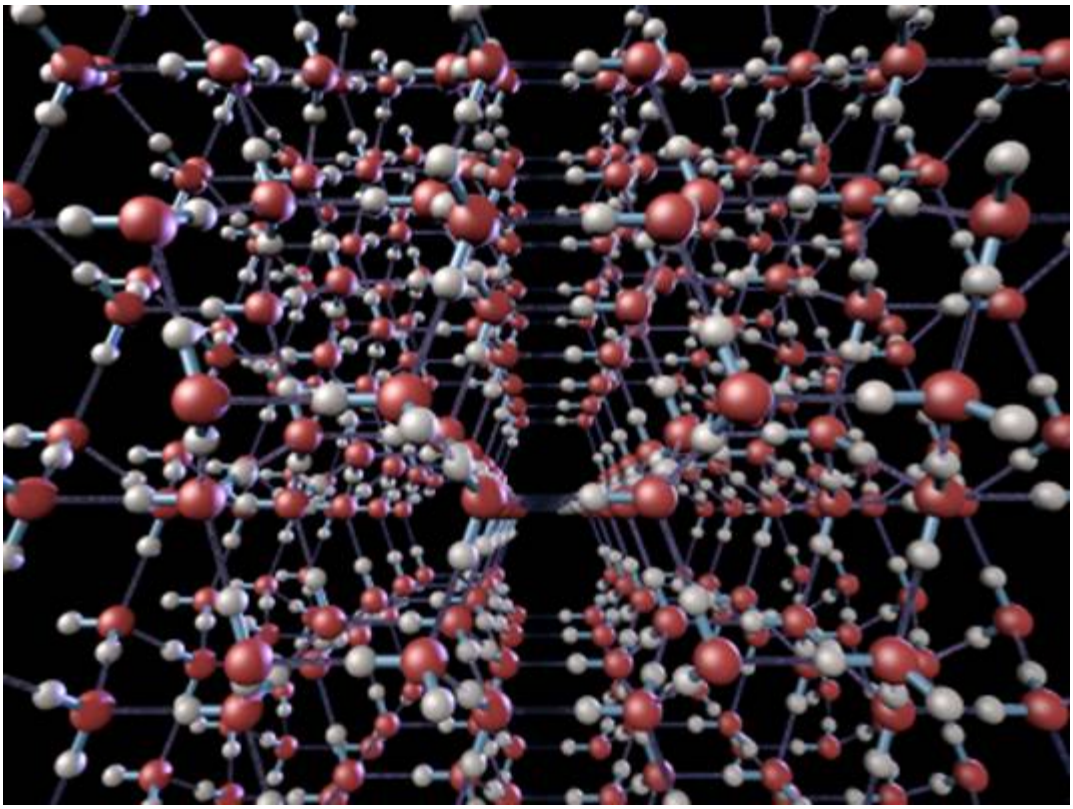
.....

(2)

(Total 10 marks)

14 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.

.....

.....

.....

(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)

15 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.

.....

.....

(2)
(Total 11 marks)

16 A molecule of ClF_3 reacts with a molecule of AsF_5 as shown in the following equation.

$$ClF_3 + AsF_5 \rightarrow ClF_2^+ + AsF_6^-$$

Use your understanding of electron pair repulsion to draw the shape of the AsF_5 molecule and the shape of the ClF_2^+ ion. Include any lone pairs of electrons.

Name the shape made by the atoms in the AsF_5 molecule and in the ClF_2^+ ion.

Predict the bond angle in the ClF_2^+ ion.

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(Total 5 marks)

17 (a) Complete the electronic configuration for the sodium ion, Na^+

$1s^2$ .....

(1)

(b) (i) Write an equation, including state symbols, to represent the process for which the energy change is the second ionisation energy of sodium.

.....

(2)

(ii) Explain why the second ionisation energy of sodium is greater than the second ionisation energy of magnesium.

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(3)

(iii) An element **X** in Period 3 of the Periodic Table has the following successive ionisation energies.

	First	Second	Third	Fourth
Ionisation energies / kJ mol^{-1}	577	1820	2740	11600

Deduce the identity of element **X**.

.....

(1)

(c) State and explain the trend in atomic radius of the Period 3 elements from sodium to chlorine.

Trend .....

Explanation .....

.....

.....

(3)

(d) Explain why sodium has a lower melting point than magnesium.

.....

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.....

(3)

(e) Sodium reacts with ammonia to form the compound $NaNH_2$ which contains the NH_2^- ion.

Draw the shape of the NH_2^- ion, including any lone pairs of electrons.

Name the shape made by the three atoms in the NH_2^- ion.

Shape of NH_2^-

Name of shape .....

(2)

(f) In terms of its electronic configuration, give **one** reason why neon does not form compounds with sodium.

.....

(1)

(Total 16 marks)

18 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)

19 (a) Describe the bonding in, and the structure of, sodium chloride and ice. In each case draw a diagram showing how each structure can be represented. Explain, by reference to the types of bonding present, why the melting point of these two compounds is very different.

(12)

(b) Explain how the concept of bonding and non-bonding electron pairs can be used to predict the shape of, and bond angles in, a molecule of sulfur tetrafluoride, SF_4.
Illustrate your answer with a diagram of the structure.

(8)
(Total 20 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 In which one of the following species is the shape influenced by the presence of one or more lone pairs of electrons?

A NH_2^-

B NH_4^+

C $[CH_3NH_3]^+$

D $[Co(NH_3)_6]^{2+}$

(Total 1 mark)

22 (a) Complete the following table.

	Relative mass	Relative charge
Neutron		
Electron		

(2)

(b) An atom has twice as many protons as, and four more neutrons than, an atom of ^9Be. Deduce the symbol, including the mass number, of this atom.

.....

(2)

(c) Draw the shape of a molecule of $BeCl_2$ and the shape of a molecule of Cl_2O. Show any lone pairs of electrons on the central atom. Name the shape of each molecule.

$BeCl_2$ *Cl_2O*

Name of shape ..... *Name of shape* .....

(4)

(d) The equation for the reaction between magnesium hydroxide and hydrochloric acid is shown below.

$$Mg(OH)_2(s) + 2HCl(aq) \rightarrow MgCl_2(aq) + 2H_2O(l)$$

Calculate the volume, in cm^3, of 1.00 mol dm^{-3} hydrochloric acid required to react completely with 1.00 g of magnesium hydroxide.

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(4)
(Total 12 marks)

23 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)

24 Which one of the following molecules is **not** planar?

A BF_3

B NCl_3

C C_2H_4

D HCHO

(Total 1 mark)

25 (a) Ammonia, NH_3, reacts with sodium to form sodium amide, $NaNH_2$, and hydrogen.

(i) Write an equation for the reaction between ammonia and sodium.

.....

(ii) Draw the shape of an ammonia molecule and that of an amide ion, NH_2^-

In each case show any lone pairs of electrons.

NH_3 NH_2^-

(iii) State the bond angle found in an ammonia molecule.

.....

(iv) Explain why the bond angle in an amide ion is smaller than that in an ammonia molecule.

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(6)

(b) A salt, **X**, contains 16.2% by mass of magnesium, 18.9% by mass of nitrogen and 64.9% by mass of oxygen.

(i) State what is meant by the term *empirical formula*.

.....

.....

(ii) Determine the empirical formula of **X**.

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(3)
(Total 9 marks)

26 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)

27 (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.

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(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)

28 (a) Predict the shapes of the SF_6 molecule and the $AlCl_4^-$ ion. Draw diagrams of these species to show their three-dimensional shapes. Name the shapes and suggest values for the bond angles. Explain your reasoning.

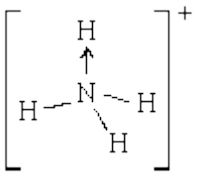
(8)

(b) Perfume is a mixture of fragrant compounds dissolved in a volatile solvent.

When applied to the skin the solvent evaporates, causing the skin to cool for a short time. After a while, the fragrance may be detected some distance away. Explain these observations.

(4)
(Total 12 marks)

29 (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?

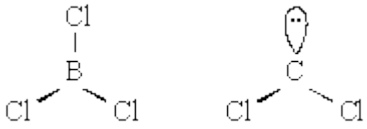
.....

.....

(2)

(Total 11 marks)

30 (a) The shape of the molecule BCl_3 and that of the unstable molecule CCl_2 are shown below.



(i) Why is each bond angle exactly 120° in BCl_3?

.....

.....

(ii) Predict the bond angle in CCl_2 and explain why this angle is different from that in BCl_3

Predicted bond angle .....

Explanation .....

.....

(5)

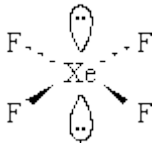
(b) Give the name which describes the shape of molecules having bond angles of 109° 28'. Give an example of one such molecule.

Name of shape .....

Example .....

(2)

(c) The shape of the XeF_4 molecule is shown below.



(i) State the bond angle in XeF_4

.....

(ii) Suggest why the lone pairs of electrons are opposite each other in this molecule.

.....

.....

(iii) Name the shape of this molecule, given that the shape describes the positions of the Xe and F atoms only.

.....

(4)

(d) Draw a sketch of the NF_3 molecule. Indicate in your sketch any lone pairs of electrons on nitrogen.

(2)
(Total 13 marks)

31 Which one of the following ions has three lone pairs of electrons around the central atom?

A BF_2^-

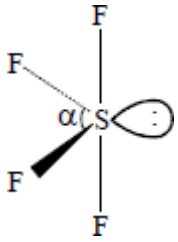
B NH_2^-

C ClF_2^-

D PF_6^-

(Total 1 mark)

32 Which one of the following is the most likely value for the bond angle α shown in the diagram of SF_4 below?



A 118°

B 101°

C 90°

D 88°

(Total 1 mark)

33 Which one of the following molecules or ions is pyramidal in shape?

A BF_3

B CH_3^+

C CH_3^-

D SF_3^-

(Total 1 mark)

34 Which one of the following has a shape which is **not** influenced by a lone pair of electrons?

A CH_3OH

B H_2F^+

C BF_3

D NF_3

(Total 1 mark)

1

(a) Correct diagram of NH_3 including LP on N

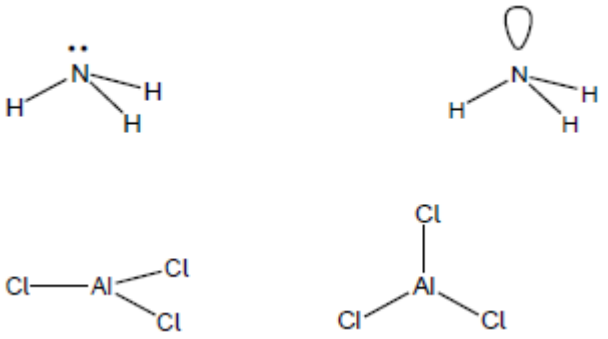
1

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]

2

(a) $C(s) + 2F_2(g) \longrightarrow CF_4(g)$

State symbols essential

1

(b) Around carbon there are 4 bonding pairs of electrons (and no lone pairs)

1

Therefore, these repel equally and spread as far apart as possible

1

(c) $\Delta H = \Sigma\ \Delta_f H$ products $- \Sigma\ \Delta_f H$ reactants or a correct cycle

1

Hence = $(2 \times -680) + (6 \times -269) - (x) = -2889$

1

$x = 2889 - 1360 - 1614 = -85$ (kJ mol^{-1})

1

Score 1 mark only for +85 (kJ mol^{-1})

(d) Bonds broken = 4(C–H) + 4(F–F) = 4 × 412 + 4 × F–F

Bonds formed = 4(C–F) + 4(H–F) = 4 × 484 + 4 × 562

Both required

1

–1904 = [4 × 412 + 4(F–F)] – [4 × 484 + 4 × 562]

4(F–F) = –1904 – 4 × 412 + [4 × 484 + 4 × 562] = 632

1

F–F = 632 / 4 = 158 (kJ mol^{-1})

1

The student is correct because the F–F bond energy is much less than the C–H or other covalent bonds, therefore the F–F bond is weak / easily broken

Relevant comment comparing to other bonds

(Low activation energy needed to break the F–F bond)

1

[10]

3 B

[1]

4 (a) This question is marked using levels of response. Refer to the Mark Scheme Instructions for Examiners for guidance on how to mark this question.

All stages are covered and the explanation of each stage is generally correct and virtually complete.

Answer is communicated coherently and shows a logical progression from stage 1 to stage 2 then stage 3.

Level 3
5 – 6 marks

All stages are covered but the explanation of each stage may be incomplete or may contain inaccuracies OR two stages are covered and the explanations are generally correct and virtually complete.

Answer is mainly coherent and shows progression from stage 1 to stage 3.

Level 2
3 – 4 marks

Two stages are covered but the explanation of each stage may be incomplete or may contain inaccuracies, OR only one stage is covered but the explanation is generally correct and virtually complete

Answer includes isolated statements but these are not presented in a logical order or show confused reasoning.

Level 1
1 – 2 marks

Insufficient correct chemistry to gain a mark.

Level 0
0 marks

Indicative chemistry content

Stage 1: Electrons round P
- P has 5 electrons in the outside shell
- With 3 electrons from 3 fluorine, there are a total of 8 electrons in outside shell
- so 3 bond pairs, 1 non-bond pair

Stage 2: Electron pair repulsion theory
- Electron pairs repel as far as possible
- Lone pair repels more than bonding pairs

Stage 3: Conclusions
- Therefore, tetrahedral / trigonal pyramidal shape
- With angle of 109(.5)° decreased to 107°

6

(b) $1s^2 2s^2 2p^6 3s^2 3p^6 3d^7$

Allow correct numbers that are not superscripted

1

(c) Too many electrons in d sub-shell / orbitals

1

(d) Tetrahedral (shape)

1

109.5°

Allow 109°

1

[10]

5

(a) Silicon / Si

If not silicon then CE = 0 / 3

1

<u>covalent</u> (bonds)

M3 dependent on correct M2

1

Strong or many of the (covalent) bonds need to be <u>broken</u> / needs a lot of energy to <u>break</u> the (covalent) bonds

Ignore hard to break

1

(b) Argon / Ar

If not argon then CE = 0 / 3. But if Kr chosen, lose M1 and allow M2+M3

1

Large(st) number of protons / large(st) nuclear charge

Ignore smallest atomic radius

1

Same amount of shielding / same number of shells / same number of energy levels

Allow similar shielding

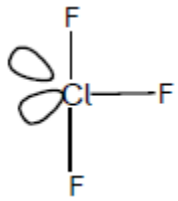
1

(c) Chlorine / Cl

*Not Cl_2, Not C**L**, Not Cl^2*

1

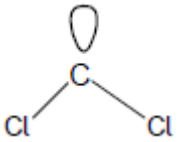
(d) (i)



Or any structure with 3 bonds and 2 lone pairs

Ignore any angles shown

1



Or a structure with 2 bonds and 1 lone pair

1

(ii) Bent / v shape

Ignore non-linear, angular and triangular

Apply list principle

1

(iii) $\frac{1}{2}Cl_2 + \frac{3}{2}F_2 \longrightarrow ClF_3$

No multiples

Ignore state symbols

1

[11]

6 (a) 94−105.5°

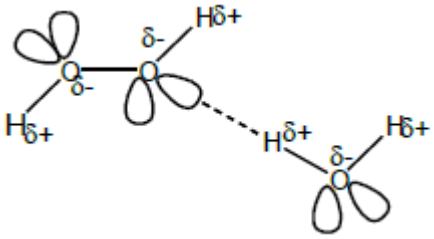
1

(b) (i) Hydrogen bond(ing) / H bonding / H bonds

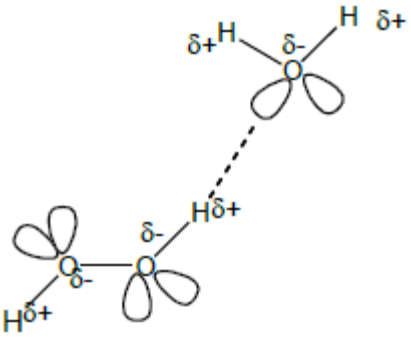
Not just hydrogen

1

(ii)



OR



1 mark for all lone pairs

1 mark for partial charges on the O and the H that are involved in H bonding

1 mark for the H-bond, from Hδ+ on one molecule to lone pair on O of other molecule

3

(c) Electronegativity of S lower than O or electronegativity difference between H and S is lower

Mark independently

1

No hydrogen bonding between H_2S_2 molecules

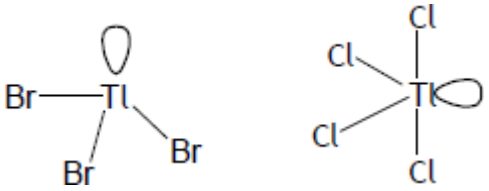
Or only van der Waals / only dipole-dipole forces between H_2S_2 molecules

If breaking covalent bonds CE = 0

1

[7]

7 (a)



Mark is for correct number of bonds and lone pair in each case.

Ignore charges if shown.

2

Pyramidal / trigonal pyramid

Allow tetrahedral.

1

107°

Allow 107 to 107.5°.

1

(b) M1 Ionic

CE = 0 / 3 if not ionic.

1

M2 Oppositely charged ions / Tl^+ and Br^- ions

If molecules / intermolecular forces / metallic bonding, CE=0.

1

M3 <u>Strong attraction</u> between ions

M3 dependent on M2.

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

1

(c) $Tl + \frac{1}{2}Br_2 \longrightarrow TlBr$

Allow multiples.

Ignore state symbols even if incorrect.

1

[8]

8 (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

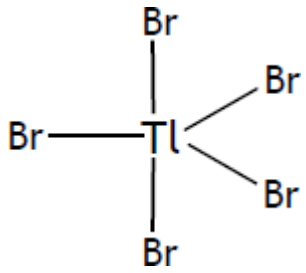
Accept silicon(4) chloride or silicon(IV) chloride.

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.

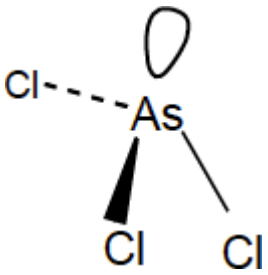
1

(g) Second

1

[10]

9 (a)



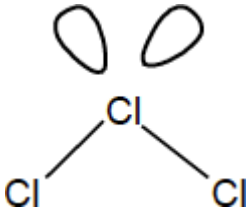
Mark is for 3 As-Cl bonds and 1 lone pair

1

(Trigonal) pyramid(al) / tetrahedral

Allow triangular pyramid

1



Mark is for 2 Cl-Cl bonds and 2 lone pairs
Do not penalise if + not shown

1

Bent / V-shaped / triangular

Not trigonal

1

(b) There are 4 bonds or 4 pairs of electrons (around As)

Can show in a diagram. If lone pair included in shape, CE = 0 / 2

1

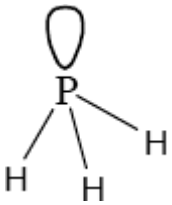
(Electron pairs / bonds) repel equally

QoL

1

[6]

10 (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]

11 (a) P = 100 000 (Pa) and V = 5.00 x 10^{-3} (m^3)

M1 is for correctly converting P and V in any expression or list Allow 100 (kPa) and 5 (dm^3) for M1.

1

$$n = \frac{PV}{RT} = \frac{100\ 000 \times 5.00 \times 10^{-3}}{8.31 \times 298}$$

M2 is correct rearrangement of PV = nRT

1

= 0.202 moles (of gas produced)

This would score M1 and M2.

Therefore $\frac{0.202}{5}$ = 0.0404 moles B_2O_3

M3 is for their answer divided by 5

1

Mass of B_2O_3 = 0.0404 x 69.6

M4 is for their answer to M3 x 69.6

1

= 2.81 (g)

M5 is for their answer to 3 sig figures.

2.81 (g) gets 5 marks.

1

(b) B + 1.5 Cl_2 → BCl_3

Accept multiples.

1

3 bonds

1

Pairs repel equally/ by the same amount

Do not allow any lone pairs if a diagram is shown.

1

(c) (i) 43.2/117.3 (= 0.368 moles BCl_3)

1

0.368 x 3 (= 1.105 moles HCl)

Allow their BCl_3 moles x 3

1

Conc HCl = $\frac{1.105 \times 1000}{500}$

Allow moles of HCl × 1000 / 500

1

= 2.20 to 2.22 mol dm^{-3}

Allow 2.2

Allow 2 significant figures or more

1

(ii) $H_3BO_3 + 3NaOH \rightarrow Na_3BO_3 + 3H_2O$

Allow alternative balanced equations to form acid salts.

Allow $H_3BO_3 + NaOH \rightarrow NaBO_2 + 2H_2O$

1

(d) $\frac{10.8}{120.3}(\times 100)$

Mark is for both M_r values correctly as numerator and denominator.

1

8.98(%)

Allow 9(%).

1

Sell the HCl

1

(e) Alternative method

Cl = 86.8%

Cl = 142 g

1

$\frac{13.2}{10.8}$ $\frac{86.8}{35.5}$

B *Cl*

$\frac{21.6}{10.8}$ $\frac{142}{35.5}$

1

1.22 2.45 or ratio 1:2 or BCl_2

2:4 ratio

1

BCl_2 has M_r of 81.8 so
81.8 x 2 = 163.6
Formula = B_2Cl_4

B_2Cl_4

Allow 4 marks for correct answer with working shown.

Do not allow $(BCl_2)_2$

1

[20]

12 (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

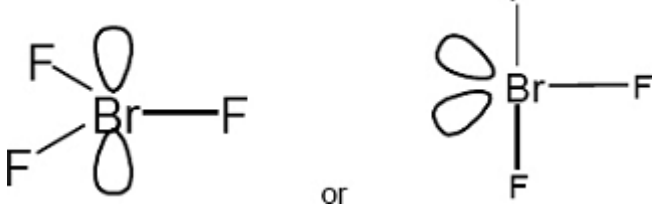
Shared <u>pair</u>(s) of electrons / one electron from Br and one electron from F

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°

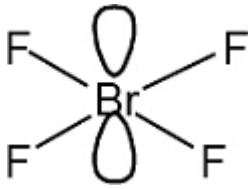
Allow 84 – 90° or 120° and ignore 180°

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

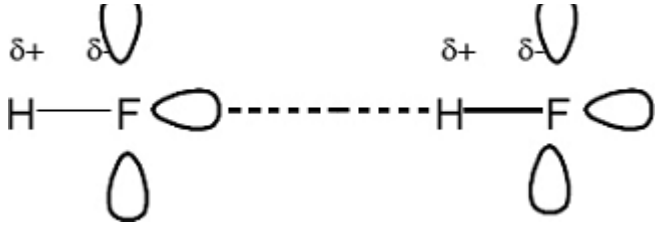
1

(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 lone pair to the Hδ+

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]

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

1

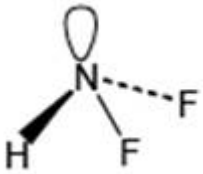
Stronger / more van der Waals forces / vdw / London / temporarily induced dipole / dispersion forces between molecules

1

Stronger VdW intermolecular forces = M2

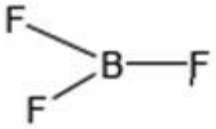
If stated VdW between atoms lose M2

(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 - trigonal planar

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 on $N(HF_2)$ donated (to BF_3)

Direction of donation needed here

1

[10]

14

(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]

15 (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

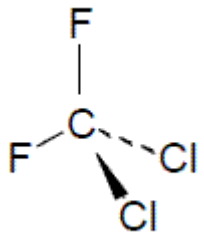
1

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

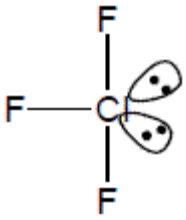
1

Only
Ignore state symbols even if wrong

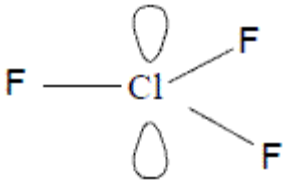
(b)



1



OR

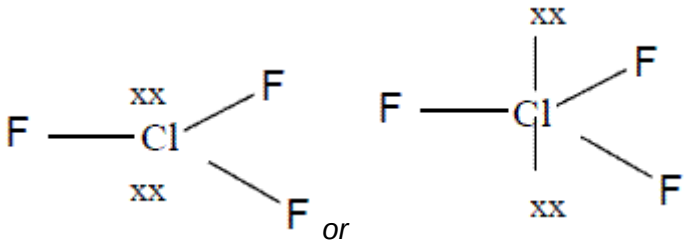


Allow any structure with 4 bp

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

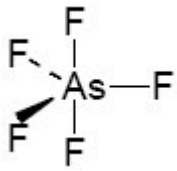
= 54.3%

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

1

[11]

16



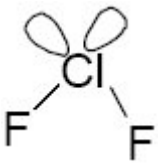
Mark M1 – M5 independently
M1 for 5 bond pairs around As
Do not penalise A for As or Fl for F

1

trigonal/triangular bipyramid(al)

Allow trigonal dipyramid

1



M3 for 2 bond pairs to F and 2 lone pairs
Lone pairs can be shown as lobes with or without electrons or as xx
or
x
x

1

Bent/V shape/non-linear/triangular/angular

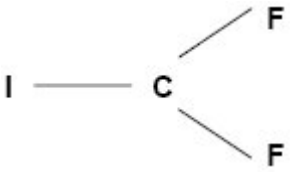
Bent-linear = contradiction
Do not allow trigonal

1

104° – 106°

1

(For candidates who thought this was ClF_2^+ which contained iodine allow



Trigonal/triangular <u>planar</u>

Not just triangular

120°

[5]

17 (a) $2s^2\ 2p^6$;

If ignored the $1s^2$ given and written $1s^2 2s^2 2p^6$ mark as correct
Allow capitals and subscripts

1

(b) (i) $Na^+(g) \rightarrow Na^{2+}(g) + e^{(-)}$;

One mark for equation and one mark for state symbols

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

M2 dependent on M1
Allow $Na^+(g) - e^{(-)} \rightarrow Na(g)$
Allow $X^+(g) \rightarrow X^{2+}(g) + e$ = 1 mark

2

(ii) $Na^{(2+)}$ requires loss of e^- from a 2(p) orbital or 2nd energy level or 2nd shell and $Mg^{(2+)}$ requires loss of e^- from a 3(s) orbital or 3rd energy level or 3rd shell / $Na^{(2+)}$ loses e from a lower (energy) orbital/ or vice versa;

Not from 3p

1

Less shielding (in Na);

Or vice versa for Mg

1

$e^{(-)}$ closer to nucleus/ more attraction (of electron to nucleus) (in Na);

M3 needs to be comparative

1

(iii) Aluminium /Al;

1

(c) Decreases;

If not decreases CE = 0
If blank, mark on

1

Increasing nuclear charge/ increasing number of protons;

1

Electrons in same shell or level/ same shielding/ similar shielding;

1

(d) Answer refers to Na;

Allow converse answers relating to Mg.

Na fewer protons/smaller nuclear charge/ fewer delocalised electrons;

Allow Mg is 2+ and Na is +.
If vdw CE = 0.

1

Na is a bigger ion/ atom;

1

Smaller attraction between nucleus and delocalised electrons;

If mentioned that charge density of Mg^{2+} is greater then allow first 2 marks.
(ie charge / size / attraction).
M3 allow weaker metallic bonding.

1

(e) (Bent) shape showing 2 lone pairs + 2N−H bond pairs;

Atoms must be labelled.
Lone pairs can be with or without lobes.

1

Bent / v shape/ triangular;

Not tetrahedral.
Allow non-linear.
Bent-linear = contradiction.

1

(f) Ne has full sub-levels/ can't get any more electrons in the sub-levels/ Ne has full shells;

Not $2s^2\ 2p^6$ alone.
Not stable electron configuration.

1

[16]

18 (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]

19 (a) NaCl is ionic

1

cubic lattice

1

ions placed correctly

1

electrostatic attraction between ions

1

Covalent bonds between atoms in water

1

Hydrogen bonding between water molecules

1

Tetrahedral representation showing two covalent and two hydrogen bonds

1

2 hydrogen bonds per molecule

1

Attraction between ions in sodium chloride is very strong

1

Covalent bonds in ice are very strong

1

Hydrogen bonds between water molecules in ice are much weaker

1

Consequently, less energy is required to break the hydrogen bonds in ice to form separate water molecules than to break the ionic bonds in sodium chloride and make separate ions

1

(b)

Mark Range	The marking scheme for this part of the question includes an overall assessment for the Quality of Written Communication (QWC). There are no discrete marks for the assessment of QWC but the candidates' QWC in this answer will be one of the criteria used to assign a level and award the marks for this part of the question **Descriptor** an answer will be expected to meet most of the criteria in the level descriptor
3	– claims supported by an appropriate range of evidence – good use of information or ideas about chemistry, going beyond those given in the question – argument well structured with minimal repetition or irrelevant points – accurate and clear expression of ideas with only minor errors of grammar, punctuation and spelling
2	– claims partially supported by evidence – good use of information or ideas about chemistry given in the question but limited beyond this – the argument shows some attempt at structure – the ideas are expressed with reasonable clarity but with a few errors of grammar, punctuation and spelling
0-1	– valid points but not clearly linked to an argument structure – limited use of information or ideas about chemistry – unstructured – errors in spelling, punctuation and grammar or lack of fluency

4 bonding electron pairs

1

and one lone pair

1

repel as far apart as possible QWC

1

lone pair - bond pair repulsion > bp—bp QWC

1

pushes S-F bonds closer together

1

shape is trigonal bipyramidal with lone pair either axial or equatorial QWC

1

angles <90

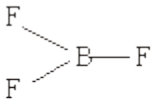
1

and < 120

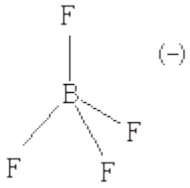
1

[20]

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

[1]

22 *(penalty for sig fig error =1 mark per question)*

(a) neutron: relative mass = 1 relative charge = 0

(not 'neutral')

1

electron: relative mass = 1/1800 → 0/negligible *or*

5.56 × 10–4 → 0 relative charge = –1

1

(b) $^{17}O/O^{17}$ mass number (*Do not accept 17.0*)

1

oxygen symbol 'O'

(if 'oxygen' + — 'mass number = 17'(1))

(if 'oxygen'+ — 'mass number = 17'(0))

(if at N^0 given but ≠ 8, treat as 'con' for M2)

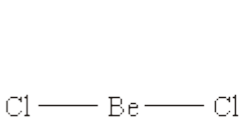
(if lp on Be, diagram = 0)

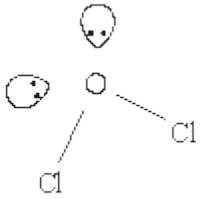
(ignore bond angles)

(not dot and cross diagrams)

1

(c)





2

QoL Linear **(1)** bent / V-shaped / angular **(1)**

(mark name and shape independently)

(accept (distorted) tetrahedral)

(if balls instead of symbols, lose M1 – can award M2)

(penalise missing 'Cl' once only)

(not 'non-linear')

2

(d) M_r ($Mg(NO_3)_2$ = 58(.3) *(if At N ^{0} used, lose M1 and M2)*

1

moles $Mg(OH)_2$ = 0.0172 (conseq on wrong M2) (answer to 3+ s.f.)

1

moles HCl = 2 × 0.0172 = 0.0344 *or* 0.0343 (mol) *(process mark)*

1

vol HCl = $\frac{0.0343 \times 1000}{1}$ = 34.3 – 34.5 (cm^3) *(unless wrong unit)*

*(if candidate **used** 0.017 or 0.0171 lose M2)*

(just answer with no working, if in range = (4).
if, say, 34 then =(2))

(if not 2:1 ratio, lose M3 and M4)

(if work on HCl, CE = 0/4)

1

[12]

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

1

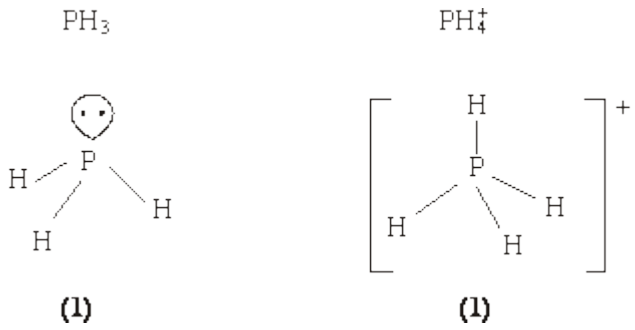
Lone/non-bonding pair / both electrons;

1

(donated) from P to H^+;

1

(b)



(1) (1)

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

(accept tetrahedral)

4

[7]

24 B

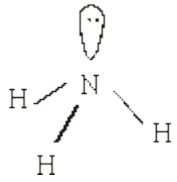
[1]

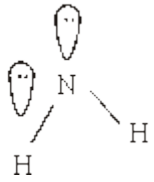
25 (a) (i) $2Na + 2NH_3 \rightarrow 2NaNH_2 + H_2$

(or multiples)

1

(ii) (Missing 'H' penalise once only) [NOT dot-and-cross diagrams]





1

[NOT 90° / 180° angles] (need 2 lp & 'bent' shape)

1

(iii) 107°

1

(iv) More lone pairs on NH_2^-, than on NH_3

1

Lone pairs repel more than bonding pairs

Must be comparison

(Mark separately)

[NOT repulsion between atoms or between bonds]

1

(b) (i) Simplest ratio of atoms of each element in a compound / substance / species / entity / molecule

1

(ii)

	Mg	N	O
$\frac{16.2}{(24)}$	$\frac{16.2}{24.3}$	$\frac{18.9}{14}$	$\frac{64.9}{16}$
(0.675)	0.667	1.37	4.06
	1	2	6

MgN_2O_6

1

(Mark M1 first. If any wrong A_r used = CE = 0)

(Accept $Mg(NO_3)_2$ for M3 if above working shown)

1

[9]

26 (a) **4**LiH + $AlCl_3 \rightarrow LiAlH_4$ + **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]

27 (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

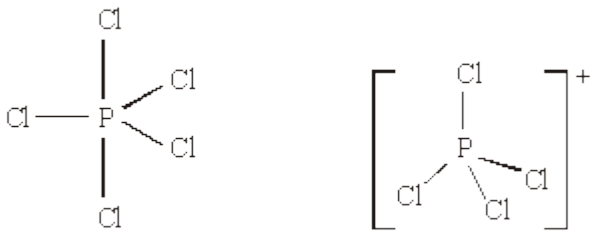
Ignore missing charge

2

(c)

4

PCl_5 PCl_4^+



(1) **(1)**

PCl_5 shown as trigonal bipyramid [Look for: ONE solid linear Cl-P-Cl bond]

PCl_4^+ shown as tetrahedral NO solid linear Cl-P-Cl bonds]

Bond Angle(s) 90° and 120° **(1)**

Bond angle(s) 109 or 109.5° **(1)**

[10]

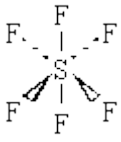
28

(a) SF_6 shown as octahedral / square based bipyramid **(1)**

Bond angle: 90° **or** 180° and 90° **(1)**

Shape = octahedral **(1)**

If lone pair shown then C.E. = 0 / 4

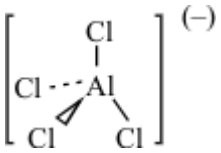


Wrong symbols - no diagram mark

Equal repulsion between 6 bonding **or** shared electron pairs **QoL (1)**

$AlCl_4^-$ shape shown as tetrahedral **(1)**
Bond angle = 109° to 109.5° **(1)**
Shape = tetrahedral **(1)**

If lone pair shown then C.E = 0/4



(Equal repulsion between) 4 bonding pairs **or** shared electron pairs **(1)**

QoL may be awarded here also
Mark all points independently

8

(b) Solvent has low bp or weak intermolecular forces **or** evaporates quickly **(1)**

(Solvent) needs energy to evaporate **(to overcome intermolecular forces) or** valid reference to latent heat of vaporisation **(or evaporation is endothermic) (1)**

OR higher energy or faster molecules more likely to escape so mean energy (and hence temperature) falls

Energy taken from the skin (and so it cools) **(1)**

Fragrance or perfume (molecules) slowly spreads (through the room) **(1)**

By random movement **or** diffusion (of the perfume / fragrance) **(1)**

4

[12]

29

(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]

30 (a) (i) 3 (bonding) pairs of electrons **(1)**

allow 3 bonds

repel equally **(1)** *(or as much as possible)*

Or get as far apart as possible

(ii) *Predicted bond angle:* 118° *(allow 117 - 119°)* **(1)**
Explanation: lone pair **(1)**
repels more than bonding pair **(1)**

Allow EXP if $\angle$ *< 118°*
but C.E. = 0 if $\angle \geq 120°$

5

(b) *Name of shape:* Tetrahedral **(1)**
Example: CH_4 etc **(1)**

Allow correct ion

2

(c) (i) 90° **(1)**

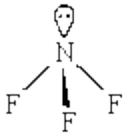
(ii) lone pairs (or they) repel more than bonding pairs (or most) **(1)**
(so are) as far apart as possible **(1)**

Mark independently

(iii) square planar **(1)**

allow square

4



3 bonds + 1 lone pair **(1)**
correct shape **(1)**
(
only give this mark if first mark also given

Penalise sticks (i.e. N-) once but N must be shown

2

[13]

31 C

[1]

32 A

[1]

33 C

[1]

34 C

[1]