**BONDING**

**Q1.**          (a)     (i)      Describe the bonding in a metal.

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

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**(4)**

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

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**(3)**

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

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**(1)**

(d)     Why is graphite soft?

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**(2)**

**(Total 10 marks)**

**Q2.**          (a)     State the meaning of the term *electronegativity*.

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**(2)**

(b)     State and explain the trend in electronegativity values across Period 3 from sodium to chlorine.

*Trend* ...........................................................................................................

*Explanation* ..................................................................................................

**(3)**

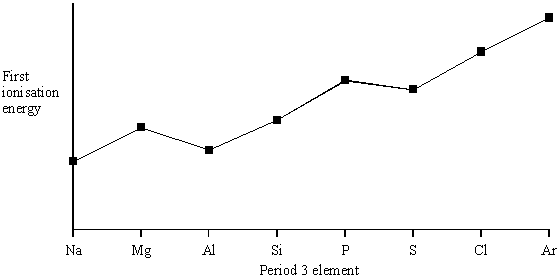
(c)     What is meant by the term *first ionisation energy*?

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**(2)**

(d)     The diagram below shows the variation in first ionisation energy across Period 3.



(i)      What is the maximum number of electrons that can be accommodated in an s sub-level?

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(ii)     What evidence from the diagram supports your answer to part (d)(i)?

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(iii)     What evidence from the diagram supports the fact that the 3p sub-level is higher in energy than the 3s?

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(iv)    What evidence from the diagram supports the fact that no more than three unpaired electrons can be accommodated in the 3p sub-level?

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**(5)**

**(Total 12 marks)**

**Q3.**          (a)     The shape of the molecule BCl3 and that of the unstable molecule CCl2 are shown below.



(i)      Why is each bond angle exactly 120° in BCl3?

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(ii)     Predict the bond angle in CCl2 and explain why this angle is different from that in BCl3

*Predicted bond angle* .........................................................................

*Explanation* .........................................................................................

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**(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 XeF4 molecule is shown below.



(i)      State the bond angle in XeF4

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

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

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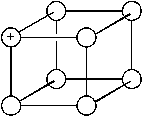
**(4)**

(d)     Draw a sketch of the NF3 molecule. Indicate in your sketch any lone pairs of electrons on nitrogen.

**(2)**

**(Total 13 marks)**

**Q4.**          (a)     The diagram below represents a part of the structure of sodium chloride. The ionic charge is shown on the centre of only one of the ions.



(i)      On the diagram, mark the charges on the four negative ions.

(ii)     What change occurs to the motion of the ions in sodium chloride when it is heated from room temperature to a temperature below its melting point?

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**(2)**

(b)     Sodium chloride can be formed by reacting sodium with chlorine.

(i)      Write an equation for this reaction.

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(ii)     A chloride ion has one more electron than a chlorine atom. In the formation of sodium chloride, from where does this electron come?

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**(2)**

(c)     In some ionic compounds the chloride ions are polarised.

(i)      What is a polarised chloride ion?

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(ii)     What feature of a cation causes a chloride ion to become polarised?

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**(2)**

(d)     (i)      What is a covalent bond?

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(ii)     What property of the atoms joined by a covalent bond causes the bond to be polar?

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**(3)**

**(Total 9 marks)**

**Q5.**         The table below shows some values of melting points and some heat energies needed for melting.

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Substance | I2 | NaCl | HF | HCl | HI |
| Melting point/K | 387 | 1074 | 190 | 158 | 222 |
| Heat energy for melting /kJ mol–1 | 7.9 | 28.9 | 3.9 | 2.0 | 2.9 |

(a)     Name **three** types of intermolecular force.

*Force 1 .*.......................................................................................................

*Force 2 …*.....................................................................................................

*Force 3 …*.....................................................................................................

**(3)**

(b)     (i)      Describe the bonding in a crystal of iodine.

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(ii)     Name the crystal type which describes an iodine crystal.

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(iii)     Explain why heat energy is required to melt an iodine crystal.

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**(4)**

(c)     In terms of the intermolecular forces involved, suggest why

(i)      hydrogen fluoride requires more heat energy for melting than does hydrogen chloride,

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(ii)     hydrogen iodide requires more heat energy for melting than does hydrogen chloride.

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**(5)**

(d)     (i)      Explain why the heat energy required to melt sodium chloride is large.

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(ii)     The heat energy needed to vaporise one mole of sodium chloride (171 kJ mol–1) is much greater than the heat energy required to melt one mole of sodium chloride. Explain why this is so.

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**(3)**

(e)     In terms of its structure and bonding, suggest why graphite has a very high melting point.

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**(2)**

**(Total 17 marks)**

**Q6.**          (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

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

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

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(iv)    In terms of electron pairs, explain why the bond angles in the NH4+ ion are all 109° 28’

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**(7)**

(b)     Define the term *electronegativity*.

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**(2)**

(c)     A bond between nitrogen and hydrogen can be represented as —

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

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

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**(2)**

**(Total 11 marks)**

**Q7.**          (a)     Predict the shapes of the SF6 molecule and the  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)**

**Q8.**          (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 . Give the symbol, including mass number and atomic number, for this atom of **Z.**

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**(2)**

(c)     Complete the electronic configurations for the sulphur atom, S, and the sulphide ion, S2–.

*S*       1s2 .......................................................................................................

*S2–*     1s2 .......................................................................................................

**(2)**

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

*Block* ...........................................................................................................

*Explanation* ..................................................................................................

**(2)**

(e)     Sodium sulphide, Na2S, is a high melting point solid which conducts electricity when molten. Carbon disulphide, CS2, is a liquid which does not conduct electricity.

(i)      Deduce the type of bonding present in Na2S and that present in CS2

*Bonding in Na2S* ..................................................................................

*Bonding in CS2*.....................................................................................

(ii)     By reference to all the atoms involved explain, in terms of electrons, how Na2S is formed from its atoms.

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(iii)     Draw a diagram, including all the outer electrons, to represent the bonding present in CS2

(iv)    When heated with steam, CS2 reacts to form hydrogen sulphide, H2S, and carbon dioxide.  
Write an equation for this reaction.

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**(7)**

**(Total 16 narks)**

**Q9.**          (a)     The table below gives the melting point for each of the Period 3 elements Na – Ar.

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Element | Na | Mg | Al | Si | P | S | Cl | Ar |
| Melting point / K | 371 | 923 | 933 | 1680 | 317 | 392 | 172 | 84 |

In terms of structure and bonding, explain why silicon has a high melting point, and why the melting point of sulphur is higher than that of phosphorus.

**(7)**

(b)     Draw a diagram to show the structure of sodium chloride. Explain, in terms of bonding, why sodium chloride has a high melting point.

**(4)**

(c)     Give the conditions under which, if at all, beryllium and magnesium react with water. For any reaction that occurs, state **one** observation you would make and write an equation.

**(4)**

**(Total 15 marks)**

**Q10.**          (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.

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(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.

AlCl3   +   Cl–   →   AlCl4–

Explain how this co-ordinate bond is formed.

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**(2)**

(c)     Draw the shape of the PCl5 molecule and of the PCl4+ ion. State the value(s) of the bond angles.

PCl5                                                PCl4+

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

**(4)**

**(Total 10 marks)**

**Q11.**          (a)     (i)      Complete the electronic configuration of aluminium.

1s2 .......................................................................................................

(ii)     State the block in the Periodic Table to which aluminium belongs.

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**(2)**

(b)     Describe the bonding in metals.

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**(2)**

(c)     Explain why the melting point of magnesium is higher than that of sodium.

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**(3)**

(d)     Explain how metals conduct electricity.

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**(2)**

**(Total 9 marks)**

**Q12.**          (a)     Iodine and graphite crystals both contain covalent bonds and yet the physical properties of their crystals are very different.  
For iodine and graphite, state and explain the differences in their melting points and in their electrical conductivities.

**(9)**

(b)     Draw the shape of the BeCl2 molecule and explain why it has this shape.  
State and explain the effect that an isolated Be2+ ion would have on an isolated Cl– ion and explain how this effect would lead to the formation of a covalent bond.  
Give one chemical property of Be(OH)2 which is atypical of the chemistry of Group II hydroxides.

**(6)**

**(Total 15 marks)**

**Q13.**          (a)     Name the strongest type of intermolecular force between hydrogen fluoride molecules and draw a diagram to illustrate how two molecules of HF are attracted to each other.  
In your diagram show all lone pairs of electrons and any partial charges. Explain the origin of these charges.  
Suggest why this strong intermolecular force is not present between HI molecules.

**(7)**

(b)     Crystals of sodium chloride and of diamond both have giant structures. Their melting points are 1074 K and 3827 K, respectively. State the type of structure present in each case and explain why the melting point of diamond is so high.

**(4)**

**(Total 11 marks)**

**Q14.**          Define the term *electronegativity* and explain why the electronegativity values of the Group II elements Be–Ba decrease down the group.

**(Total 4 marks)**

**Q15.**          Lithium hydride, LiH, is an ionic compound containing the hydride ion, H–The reaction between LiH and aluminium chloride, AlCl3, produces the ionic compound LiAlH4

(a)     Balance the equation below which represents the reaction between LiH and AlCl3

LiH +    AlCl3  →      LiAlH4   +     LiCl

**(1)**

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

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**(1)**

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

*Shape* ..........................................................................................................

*Explanation* ..................................................................................................

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**(3)**

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

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

*Type of bond* ................................................................................................

*Explanation* ..................................................................................................

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**(3)**

**(Total 8 marks)**

**Q16.**          Iodine and diamond are both crystalline solids at room temperature. Identify one similarity in the bonding, and one difference in the structures, of these two solids.  
Explain why these two solids have very different melting points.

**(Total 6 marks)**

**Q17.**          (a)     Ammonia, NH3, reacts with sodium to form sodium amide, NaNH2, and hydrogen.

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

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(ii)     Draw the shape of an ammonia molecule and that of an amide ion, NH

In each case show any lone pairs of electrons.

NH3                                                  NH

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

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(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*.

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

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**(3)**

**(Total 9 marks)**

**Q18.**          (a)     Magnesium and chlorine react together to form the ionic compound magnesium chloride, MgCl2.

(i)      Explain how each of the ions in this compound is formed.

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(ii)     Explain why compounds with ionic bonding tend to have high melting points.

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**(4)**

(b)     (i)      Define the term *electronegativity*.

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(ii)     Explain why electronegativity increases across a period in the Periodic Table.

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**(4)**

(c)     Chloride ions are polarised more by aluminium ions than they are by magnesium ions.

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

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(ii)     Why is a chloride ion polarised more by an aluminium ion than by a magnesium ion?

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(iii)     Predict the type of bonding in aluminium chloride.

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**(5)**

**(Total 13 marks)**

**Q19.**          This question concerns the chemistry of the Group II metals Mg to Ba.  
An aqueous solution of a Group II metal chloride, **X**Cl2, forms a white precipitate when dilute aqueous sodium hydroxide is added. A separate sample of the solution of **X**Cl2 does **not** form a precipitate when dilute aqueous sodium sulphate is added.

An aqueous solution of a different Group II metal chloride, **Y**Cl2, does **not** form a precipitate when dilute aqueous sodium hydroxide is added. A separate sample of the solution of **Y**Cl2 forms a white precipitate when dilute aqueous sodium sulphate is added.

Suggest identities for the Group II metals **X** and **Y**. Write equations, including state symbols, for the reactions which occur.

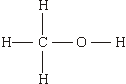
**(Total 6 marks)**

**Q20.**          Diamond and graphite are both forms of carbon.  
Diamond is able to scratch almost all other substances, whereas graphite may be used as a lubricant. Diamond and graphite both have high melting points.

Explain each of these properties of diamond and graphite in terms of structure and bonding. Give **one** other difference in the properties of diamond and graphite.

**(Total 9 marks)**

**Q21.**          (a)     Methanol has the structure



Explain why the O–H bond in a methanol molecule is polar.

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**(2)**

(b)     The boiling point of methanol is +65 °C; the boiling point of oxygen is –183 °C. Methanol and oxygen each have an *M*r value of 32. Explain, in terms of the intermolecular forces present in each case, why the boiling point of methanol is much higher than that of oxygen.

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**(3)**

**(Total 5 marks)**

**Q22.**          Phosphorus and nitrogen are in Group V of the Periodic Table and both elements form hydrides. Phosphine, PH3, reacts to form phosphonium ions, , in a similar way to that by which ammonia, NH3, forms ammonium ions, 

(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 ..................................................................................................*

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**(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.

PH3                                                                                           

*Shape of PH3* ...........................              *Bond angle in * ...........................

**(4)**

**(Total 7 marks)**

**Q23.**          Phosphorus exists in several different forms, two of which are white phosphorus and red phosphorus. White phosphorus consists of P4 molecules, and melts at 44°C. Red phosphorus is macromolecular, and has a melting point above 550°C.

Explain what is meant by the term *macromolecular*. By considering the structure and bonding present in these two forms of phosphorus, explain why their melting points are so different.

**(Total 5 marks)**

**Q24.**          The table below shows the electronegativity values of some elements.

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
|  | Fluorine | Chlorine | Bromine | Iodine | Carbon | Hydrogen |
| Electronegativity | 4.0 | 3.0 | 2.8 | 2.5 | 2.5 | 2.1 |

(a)     Define the term *electronegativity*.

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**(2)**

(b)     The table below shows the boiling points of fluorine, fluoromethane (CH3F ) and hydrogen fluoride.

|  |  |  |  |
| --- | --- | --- | --- |
|  | F–F |  | H–F |
| Boiling point/K | 85 | 194 | 293 |

(i)      Name the strongest type of intermolecular force present in:

Liquid F2 ..............................................................................................

Liquid CH3F ........................................................................................

Liquid HF ............................................................................................

(ii)     Explain how the strongest type of intermolecular force in liquid HF arises.

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**(6)**

(c)     The table below shows the boiling points of some other hydrogen halides.

|  |  |  |  |
| --- | --- | --- | --- |
|  | HCl | HBr | HI |
| Boiling point / K | 188 | 206 | 238 |

(i)      Explain the trend in the boiling points of the hydrogen halides from HCl to HI.

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(ii)     Give **one** reason why the boiling point of HF is higher than that of all the other hydrogen halides.

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**(3)**

**(Total 11 marks)**

**Q25.**          (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.

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**(2)**

(c)     Draw the shape of a molecule of BeCl2 and the shape of a molecule of Cl2O. Show any lone pairs of electrons on the central atom. Name the shape of each molecule.

*BeCl2 Cl2O*

*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) → MgCl2(aq) + 2H2O(l)

Calculate the volume, in cm3, 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)**

**Q26.**          The equation below shows the reaction between boron trifluoride and a fluoride ion.

BF3 + F– → BF

(i)      Draw diagrams to show the shape of the BF3 molecule and the shape of the BF ion. In each case, name the shape. Account for the shape of the BF ion and state the bond angle present.

(ii)      In terms of the electrons involved, explain how the bond between the BF3 molecule and the F– ion is formed. Name the type of bond formed in this reaction.

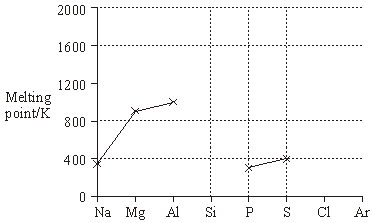
**(Total 9 marks)**

**Q27.**          State the trends in solubility of the hydroxides and of the sulphates of the Group II elements Mg–Ba.

Describe a chemical test you could perform to distinguish between separate aqueous solutions of sodium sulphate and sodium nitrate. State the observation you would make with each solution. Write an equation for any reaction which occurs.

**(Total 6 marks)**

**Q28.**          (a)     The diagram below shows the melting points of some of the elements in Period 3.



(i)      On the diagram, use crosses to mark the approximate positions of the melting points for the elements silicon, chlorine and argon. Complete the diagram by joining the crosses.

(ii)     By referring to its structure and bonding, explain your choice of position for the melting point of silicon.

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(iii)     Explain why the melting point of sulphur, S8, is higher than that of phosphorus, P4

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**(8)**

(b)     State and explain the trend in melting point of the Group II elements Ca–Ba.

*Trend* ...........................................................................................................

*Explanation* ..................................................................................................

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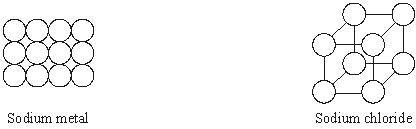
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**(3)**

**(Total 11 marks)**

**Q29.**          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.



**(2)**

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

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(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), NaClO3, 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 NaClO3

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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.

....... Cl2 + ....... NaOH → ....... NaCl + NaClO3 + 3H2O

**(3)**

**(Total 12 marks)**

**Q30.**          A student studying GCSE science is puzzled by data which indicate that a sodium atom is larger than a chlorine atom and that a sodium ion is smaller than a chloride ion. How should an A–level Chemistry student explain this apparently conflicting information.

**(Total 6 marks)**

**Q31.**          (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, SF4.  
Illustrate your answer with a diagram of the structure.

**(8)**

**(Total 20 marks)**

**Q32.**          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*.

......................................................................................................................

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**(2)**

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

Methane (CH4) .............................................................................................

Ammonia (NH3) ............................................................................................

**(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 PH3 reacts with an H+ ion to form a PH4+ ion.  
Name the type of bond formed when PH3 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 AsH3Draw the shape of an AsH3 molecule, including any lone pairs of electrons. Name the shape made by its atoms.

Shape

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

**(2)**

(f)      The boiling point of AsH3 is –62.5 °C and the boiling point of NH3 is –33.0 °C.  
Suggest why the boiling point of AsH3 is lower than that of NH3

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**(1)**

(g)     Balance the following equation which shows how AsH3 can be made.

          ...... AsCl3   +   ...... NaBH4   →   ...... AsH3   +   ...... NaCl   +   ...... BCl3

**(1)**

**(Total 14 marks)**

**Q33.**          (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)**

**Q34.**          (a)     Complete the electronic configuration for the sodium ion, Na+

ls2 .................................................................................................................

**(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 ..................................................................................................

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**(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 NaNH2 which contains the NH2– ion. Draw the shape of the NH2– ion, including any lone pairs of electrons.  
Name the shape made by the three atoms in the NH2– ion.

Shape of NH2–

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)**

**Q35.**          (a)     Complete the electronic configuration for the sodium ion, Na+

ls2 .................................................................................................................

**(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.

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**(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 ..................................................................................................

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**(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 NaNH2 which contains the NH2– ion. Draw the shape of the NH2– ion, including any lone pairs of electrons.  
Name the shape made by the three atoms in the NH2– ion.

Shape of NH2–

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)**

**M1.**          (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 Mg2+ 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]**

**M2.**          (a)     Ability (or power) of an atom to attract electron density  
(or electrons or ‑ve charge) **(1)**in a covalent bond **(1)**

*or shared pair  
If remove an electron lose first mark*

**2**

(b)     *Trend:* increases **(1)***Explanation:* nuclear charge (number of protons) increases **(1)**electrons in same shell **(1)**

*OR similar shielding  
OR atoms similar size or smaller  
OR 1 mol of e-*

**3**

(c)     Heat / enthalpy / energy for removal of one electron **(1)**from a gaseous atom **(1)**can score in an equation

*must have first mark to score the second*

**2**

(d)     (i)      2 **(1)**

(ii)     Two elements (or Na / Mg) before the drop (in energy) to Al **(1)**

(iii)     ionisation energy of Al < that for Mg **(1)**

(iv)    fall in energy from P to S **(1)**

*or discontinuity in trend*

From Al to P there are 3 additional electrons **(1)**

*or three elements*

*For second mark idea of block of 3 elements*

**5**

**[12]**

**M3.**          (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  < 118°  
but C.E. = 0 if   120°*

**5**

(b)     *Name of shape:* Tetrahedral **(1)***Example:* CH4 etc **(1)**

*Allow correct ion*

**2**

(c)     (i)      90° **(1)**

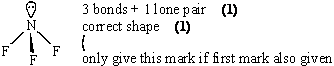
(ii)     lone pairs (or they) repel more than bonding pairs (or most) **(1)**(so are) as far apart as possible **(1)**

*Mark independently*

(iii)     square planar **(1)**

*allow square*

**4**

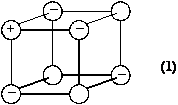
(d)     

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

**2**

**[13]**

**M4.**          (a)     (i)



(ii)     vibrate faster **(1)**

*Or bigger amplitude or more  
NOT start to vibrate or other type of motion esp. translation  
Ignore rotation*

**2**

(b)     (i)      Na + ½ Cl2 → NaCl **(1)** or Na+Cl–

*or 2 Na + Cl2 → 2 NaCl  
If NA penalise once  
ignore s.s. even if wrong*

(ii)     from sodium **(1)**

*Allow from sodium ion, also from metal*

**2**

(c)     (i)      not spherical (or charge uneven or distorted) **(1)**

*OR diagram  
Do NOT allow if describe Cl– (or Cl–6) in a polarised covalent compound)*

(ii)     high charge / size ratio **(1)**

*allow also high charge density  
OR high charge  
OR small size*

**2**

(d)     (i)      shared **(1)** electron pair **(1)**

(ii)     difference in electronegativity **(1)**

**3**

**[9]**

**M5.**          (a)     *Force 1:* Van der Waals’ **(1)**

*Force 2:* dipole - dipole **(1)**

*Force 3:* hydrogen bonding **(1)**

*OR London, Dispersion, temporary dipole*

**3**

(b)     (i)      covalent between atoms **(1)**

*OR within molecule*

         Van der Waals’ between molecules **(1)**

(ii)     molecular **(1)**

(iii)     Bonds (or forces) between molecules must be broken or loosened **(1)**

*OR V.dW forces*

*OR intermolecular forces*

*Mention of ions CE=0*

**4**

(c)     (i)      H-Bonding in HF **(1)**

         (dipole-) dipole in HCl **(1)**

*OR V.dW*

         H-bonding is stronger than dipole-dipole or V.dW **(1)**

*OR H-bonding is a strongest intermolecular force for 3rd mark*

(ii)     HI bigger molecule than HCl **(1)**

*OR Heavier, more e’s, more electron shells, bigger Mr, more polarisable*

         Therefore the forces between HI molecules are stronger **(1)**

*QL mark (Look for unambiguous statements using correct terminology)*

**5**

(d)     (i)      ionic **(1)**

Strong forces between ions **(1)**

*OR lots of energy required to break bonds*

(ii)     All bonds must be broken **(1)**

*mention of molecules etc CE=0*

**3**

(e)     macromolecular **(1)**

*OR giant molecule / lattice or correct diagram*

          Strong covalent bonds **(1)**

*OR lots of energy required to break bonds*

**2**

**[17]**

**M6.**          (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]**

**M7.**          (a)     SF6 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*

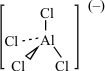
**

*Wrong symbols ‑ no diagram mark*

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

AlCl4– 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]**

**M8.**         (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)      **(1)(1)**

*Allow numbers before or after Ar*

**2**

(c)     *S*: 1s2 2s2 2p6 3s2 3p4 **(1)**

*Allow upper case letters*

*S2–:* 1s2 2s2 2p6 3s2 3p6 **(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**

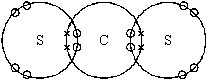
(e)     (i)      *Bonding in Na2S*: ionic **(1)***Bonding in CS2*:  covalent **(1)**

*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)    CS2 + 2H2O → CO2 + 2H2S **(1)**

*Ignore state symbols even if wrong*

**7**

**[16]**

**M9.**          (a)     Macromolecular **or** giant structure **(1)**

*Accept diamond shaped lattice*

*Intermolecular forces / molecular lattice / comparison to graphite structure, = ‘con’*

          Held together by covalent bonds **(1)**

*‘Giant covalent structure’ earns both M1 and M2*

(Much) energy needed to break bonds         **Or** many bonds  
to be broken **(1)**Mark tied to earning ‘covalent’ M2       If explanation is  
clearly of ionic bonding = CE

Vand der Waal / temporary induced dipole-dipole / London /  
disperse forces **(1)**

Forces increase with size **or** with number of electrons  
**or** with surface area etc. **(1)**

*Description must be of the molecules of P and S*

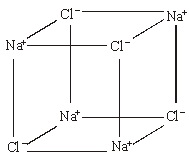
          P4 **or** Mr = 124 **(1)** S8 **or** Mr = 256 **(1)**

*If M6 (i.e. P4) and M7 (i.e. S8) are not attempted, allow S molecule bigger /more surface area than P molecule for 1 mark*

**7**

(b)     Diagram NaCl = cubic **(1)**

*Allow if 3 full faces shown correctly*

**

          Ions identified and placed properly **(1)**

*If diagram shows ‘+’ and ‘–’ signs rather than symbols for ions, identification of the ions could be from the text*

          (Bonding) identified in writing as being ionic **(1)**

*Not ionic molecule*

Due to strong electrostatic attractions **or** similar description  
about attraction between oppositely charged ions.**(1)   QoL**

***Not just:*** *‘ionic bonds are strong’ / ‘need much energy to break bonding’*

**4**

(c)     Be – no reaction with water or steam **(1)**

***Not****: Be does not dissolve*

Mg reacts **with steam**      **or** reacts slowly with cold/hot water **(1)**

White solid **(not precipitate)** formed        Bubbles **(1)**

**or** Mg glows or burns (with bright white light)  Not ‘fizzes’ or ‘gas evolved’

Mg + H2O → MgO + H2   Mg + 2H2O → Mg(OH)2 + H2 **(1)**

*Condition, equation and observation marks are tied. Candidate can’t mix-and-match but, when both conditions quoted, select the higher scoring option*

**4**

**[15]**

**M10.**          (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** AlCl3 **(1)**

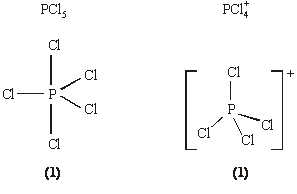
*M1 can be earned by a general explanation of coordinate bonding, even if the electron pair is said to come from Al. The second mark, M2, is for this specific bond*

*Ignore missing charge*

**2**

(c)

**4**



PCl5 shown as trigonal bipyramid    PCl4+ 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]**

**M11.**          (a)     (i)      *1s2* 2s2 2p6 3s2 3p1 **(1)**

*Allow subscripted electron numbers*

(ii)     p (block) **(1)**

*Allow upper or lower case ‘s’ and ‘p’ in (a)(i) and (a)(ii)*

**2**

(b)     Lattice of metal / +ve ions/ cations / atoms **(1)**

*Not +ve nuclei/centres*

*Accept regular array/close packed/tightly packed/uniformly arranged*

          (Surrounded by) delocalised electrons **(1)**

*Note: Description as a ‘giant ionic lattice’ = CE*

**2**

(c)     Greater nuclear or ionic charge or more protons **(1)**

          Smaller atoms / ions **(1)**

*Accept greater charge density for either M1 or M2*

          More delocalised electrons / e– in sea of e– / free e– **(1)**

          Stronger attraction between ions and delocalised / free electrons etc. **(1)**

*Max 3*

*Note: ‘intermolecular attraction/ forces’ or covalent molecules = CE*

*Accept stronger ‘electrostatic attraction’ if phrase prescribed elsewhere  
Ignore references to m/z values  
If Mg or Na compared to Al, rather than to each other, then:* ***Max 2****Treat description that is effectively one for Ionisation Energy as a ‘****contradiction****’*

**3**

(d)     (Delocalised) electrons **(1)**

          Move / flow in a given direction (idea of moving non-randomly)  
**or** under the influence applied pd   *QoL mark*   **(1)**

*Allow ‘flow through metal’*

*Not: ‘Carry the charge’; ‘along the layers’; ‘move through the metal’*

**2**

**[9]**

**M12.**          (a)     I2 sublimes when heated / has low melting point AND   
graphite has (very) high melting point **(1)**

          I2 is (simple) molecular / I2 / I-I **(1)**

*CE = 0 if ‘ionic’  
loses M2, M3, M4  
Max 1 if I-I bond broken*

          Van der Waals forces / induced or temporary dipole-dipole / London forces **(1)**

          Whch are weak or easily overcome (so low melting point) **(1)**

Graphite is macromolecular / giant covalent / giant molecular / giant atomic / **(1)**Diagram

*min 3 correctly fused rings – ignore diagram unless no description offered*

*CE = 0 if ‘ionic’ or ‘metallic’    loses M5, M6, M7*

          (Many) covalent bonds need to be broken **(1)**

*covalent may be inferred from structure*

          Which takes much energy / bonds are strong **(1)**

          Only graphite conducts **(1)**

*NOT just graphite is a better conductor*

          As it has delocalised / free / mobile electrons **(1)**

All e– in iodine are used in bonding and lone pairs   
OR as it has no delocalised / free / mobile e– **(1)**

*M9 and M10 tied to correct statements about graphite = conductor and iodine = non-conductor*

**Max 9**

(b)     Diagram Cl–Be–Cl (clearly linear) **(1)**

*CE = 0 if lone pair(s) on Be, loses M1 and M2*

          (Equal) repulsion between 2 bonding pairs / bonds **(1)**

*‘2’ may be inferred from a correct diag*

*NOT repulsion between Cl atoms*

Cl– ion polarised by Be2+ / distorts e– cloud (must be ions) /  
diag with correct charges **(1)**

          Because of high charge density on Be2+ OR high charge / size ratio **(1)**

*NOT just Be2+ is smaller. Treat higher m/z value as a contradiction*

Electrons / electron cloud from Cl– ion forms covalent bond (with Be) /  
electrons in new bond are from Cl– ion (wtte) **(1)**

*Accept a correct dot-and-cross diagram*

*Penalise missing charges or ions once only for M3, M4 and M5*

          Be(OH)2 is amphoteric / description / dissolves in base **(1)**

*NOT Beryllium is amphoteric*

**6**

**[15]**

**M13.**          (a)     Hydrogen bonding *(full name)*

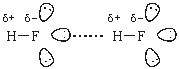
**1**

Diagram shows at least one δ+H **and** at least one δ–F

*(If full charges shown, M2 = 0)*

**1**

3 lone pairs shown on at least one fluorine atom  
H-bond indicated, between H and a lone pair on F



*(If atoms not identified, zero for diag)*

*(‘Fl’ for fluorine - mark to Max 2)*

*(Max 1 if only one HF molecule shown,* ***or*** *HCl shown)*

**1**

          Dipole results from electronegativity difference **or** values quoted

*(‘difference’ may be inferred)*

*(Allow explanation – e.g. F attracts bonding electrons more strongly than H)*

**1**

**QoL**  Fluorine more/very electronegative **or** iodine less electronegative  
**or** electronegativity difference too small in HI  
**Comparison required, may be implied**.

**1**

          HI dipole weaker or bonding e– more equally shared  -  wtte

**1**

(b)     NaCl is ionic (lattice)

*(Treat atoms/molecules as a contradiction)*

*(Accept ‘cubic lattice’)*

**1**

          Diamond is macromolecular/giant covalent/giant atomic/giant molecular

*(NOT molecular or tetrahedral)*

*(Ionic/van der Waals’ = CE = 0)*

**1**

          (Many) covalent/C-C bonds need to be broken / overcome

*(NOT just ‘weakened’ etc.)*

*(‘Covalent’ may be inferred from diagram)*

*(Treat diagram of graphite (without one of diamond) as a  
contradiction – lose M2 but allow M3/M4])*

**2**

          Which takes much energy **or** covalent bonds are strong

*(References to van Der Waals’ bonds breaking lose M3/M4)*

**1**

**[11]**

**M14.**          Tendency **or** strength **or** ability **or** power of an atom/element/nucleus to  
attract/withdraw electrons / e– density / bonding pair / shared pair

**1**

          In a covalent bond

*(tied to M1 – unless silly slip in M1)*

*(If molecule/ion then = CE = 0) (NOT electron (singular) for M1)****Mark as 2 + 2***

**1**

Increase in size **or** number of shells **or** increased shielding **or** bonding  
electrons further from nucleus

*[NOT ‘increase in number of electrons’]*

**1**

          Decreased attraction for (bonding) electrons

*(****tied to M3****)*

*(If ‘ion’ here, lose M3 and M4) (NOT ‘attraction of covalent bond’)*

*(Ignore reference to proton number or effective nuclear charge)*

**1**

**[4]**

**M15.**          (a)     **4**LiH + AlCl3 → LiAlH4 + **3**LiCl

**1**

(b)     H – = 1s2 **or** 1s2

**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]**

**M16.**          **QoL**       Bonding      Both covalent

*(linked statement)*

**1**

         Structure     Iodine  = molecular /I2 *(stated or in diagram)*

*[treat incorrect diagram as contradiction]*

**1**

                        Diamond = giant molecular/macromolecular/giant  
           covalent / giant atomic (stated only)

*Reference to van der Waals’ /dipole-dipole = contradiction*

**1**

**QoL** Iodine         Weak van der Waals’ forces / induced dipole-induced  
               dipole

**1**

Diamond    Covalent bonds would need to be broken

**1**

          Many / strong covalent bonds **OR** much energy needed  
                   *Tied to M5                     or near miss*

*[If ionic/metallic structure suggested then CE for that substance]  
[If hydrogen bonding suggested, for I2 lose M2 & M4; for diamond lose M3,M5&M6]*

**1**

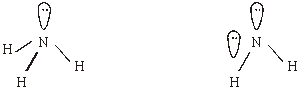
**[6]**

**M17.**          (a)     (i)      2Na   +   2NH3   →   2NaNH2   +   H2

*(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 NH2–, than on NH3

**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

**1**

*(0.675)*            0.667          1.37              4.06

                                      1               2                 6              MgN2O6

*(Mark M1 first. If any wrong Ar used = CE = 0)  
(Accept Mg(NO3)2 for M3 if above working shown)*

**1**

**[9]**

**M18.**          (a)     (i)      Electron transfers from Mg to Cl/Mg loses e– and Cl gains e–

**1**

Mg loses 2e–, each Cl gains 1e–

*(Marks can be awarded from diagrams/equations)*

**1**

(ii)     Electrostatic attractions / attractions between  
oppositely charged ions

*(molecules = CE = 0)*

**1**

         Are strong or require much energy to overcome

*Tied to M1*

*‘Ionic bonds are strong’ score 1 mark*

**1**

(b)     (i)      Tendency / strength / ability / power of an  
atom/ element / nucleus to

**1**

attract / withdraw electrons / e– density / bonding pair / shared pair  
In a covalent bond

*(tied to M1 - unless silly slip in M1)*

*(If molecule/ion then = CE = 0)  
(NOT electron (singular) for M1)*

**1**

(ii)     Increasing proton number / nuclear charge  
*(NOT atomic number)*

**1**

Decreasing size / same shielding / same shells

**1**

(c)     (i)      Electron cloud/distribution (around anion)

**1**

Is distorted or is unequally distributed

*Marks may be awarded from diagrams   
‘Chloride ion is distorted’ scores 1 mark   
(Reference to dipoles or polarised bond = CE)*

**1**

(ii)     Smaller size

*(Ignore m/z references)*

**1**

Higher charge     **or**      3+/2+ specified

*(‘Higher charge density’ scores 1 mark if neither mark awarded above)*

**1**

(iii)     Covalent / covalent character / polar covalent / coordinate / dative

*[NOT ionic with covalent character]*

**1**

**[13]**

**M19.**          X = Mg;

*(accept Be,Ca)*

**1**

          Y = Ba;

*(accept Sr)*

**1**

          MgCl2(aq) *+* 2NaOH(aq) → Mg(OH)2(s) + 2NaCl(aq)

Species;

**1**

State symbols & balance;

**1**

          BaCl2(aq) + Na2SO4(aq) → BaSO4(s) + 2NaCl(aq);

Species;

**1**

State symbols & balance;

*(accept ionic equations)*

**1**

**[6]**

**M20.**          Structure and hardness

M1

Q of L   both macromolecular/giant atomic/giant covalent/giant molecular;

**1**

M2

C atoms in diamond joined to 4 other C atoms / diagram with min 5 C  
atoms i.e. shows tetrahedral shape / coordination number = 4;

**1**

M3

C atoms in graphite joined to 3 other C atoms diagram with clear  
extended hexagonal plane/pattern i.e. shows trigonal planar shape /  
coordination number = 3;

**1**

M4

diamond hard / crystal strong;

*(not diamond stronger than graphite)*

**1**

M5

because of 3-D structure / rigid structure / not layered;

**1**

M6

graphite (soft) as layer can slide over each other;

**1**

M7

Q of L   as only (weak) van der Waals’ forces between layers;

**1**

Melting point (for either allotrope)

M8  
covalent bonds must be broken / overcome;

**1**

M9  
which are strong / many / hard to break;

*(M9 tied to M8)*

**1**

          Other difference

M10  
diamond is non-conductor of electricity, graphite is conductor  
*OR* appropriate difference in appearance;

**1**

**[9]**

**M21.**          (a)     Oxygen more/very/highly electronegative (than hydrogen)  
*OR* oxygen has stronger attraction for bonding electrons / bonding  
electrons drawn towards oxygen;

**1**

causes higher e– density round oxygen atom / causes Hδ+Oδ–;

**1**

(b)     van der Waals’ forces between oxygen molecules;

**1**

Hydrogen bonding between methanol molecules;

**1**

H-B stronger than van der Waals’ *OR* stronger IMF in methanol;

*(if dipole-dipole forces in O2 or methanol, allow comparison,   
hence max 2)*

*(if ionic/covalent etc. max 1)*

*(mention of bond break = CE = 0)*

**1**

**[5]**

**M22.**          (a)     dative / coordinate (covalent) bond;

**1**

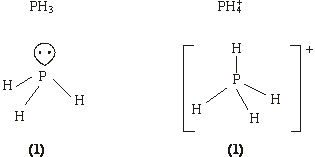
Lone/non-bonding pair / both electrons;

**1**

(donated) from P to H+;

**1**

(b)



pyramidal *OR* trigonal pyramid 109()°;

*(accept tetrahedral)*

**4**

**[7]**

**M23.**          **M1** macromolecule = a giant/massive/huge molecule/lattice/structure  
                               with covalent bonding

*(in words, not diagram)*

*(not just ‘very large’)*

*(not ‘molecules bonded together’/reference to ions)*

**1**

**M2**    **White**: IMF = van der Waals’

**1**

**M3**    which are weak

*(tied to ‘IMF’ or van der Waals’ in M2)*

*(if H-bonding or dipole-dipole, treat as CE, M2 = M3 = 0)*

**1**

**M4**    **Red**: (covalent) bonds must be broken/overcome

*(not weakened / loosened)*

**1**

**M5**    (covalent) bonds are strong                     [tied to M4]  
**Or**  there are many (covalent) bonds  
**Or**  much energy is required to.

**1**

•        If wrong bonding quoted, e.g. ionic bonding in white phosphorus  
or an IMF in red phosphorus, award no marks for that allotrope.

•        In order for marks to be awarded for red phosphorus, the bonding  
must be stated to be covalent. One reference to covalent bonding  
is sufficient; the rest may be inferred as shown above. Thus, failure  
to refer to covalent bonding anywhere would result in the loss of M1,  
M4 and M5,

•        Mark M1 independently. Allow the criteria for this mark to be earned  
elsewhere, but do not treat errors in the red allotrope description as contradictions of M1.

**[5]**

**M24.**          (a)     tendency / strength / ability / power of an atom / element / nucleus  
to attract / pull / withdraw electrons / e - density / bonding  
pair / shared pair

**1**

in a covalent bond

**1**

(b)     (i)      F2       =       van der Waals’ / induced/temporary dipole-dipole /  
                   dispersion / London forces

**1**

CH3F           dipole-dipole

*(not just ‘dipole’)*

**1**

HF     =       hydrogen bonding

*(not just ‘H’ / ‘hydrogen’)*

**1**

(ii)     large difference in electronegativity between H and F / F  
most/very/much more electronegative / values ‘4’ & ‘2.1’ quoted

*(not just ‘higher’)*

**1**

δ+H-Fδ- dipole created or dipole clearly implied

*(accept arguments such as ‘uneven charge in bond’/  
’polar bond’ F slightly negative / H slightly positive)*

**1**

attraction/bond formed between δ+H and lone pair on F

*(M2 / M3 may be scored from a diagram)*

*(CE if full charges shown - lose M2 and M3)*

**1**

(c)     (i)      van der Waals’ / induced/temporary dipole-dipole / dispersion /  
London forces / attractions

*(ignore references to dipole-dipole)*

**1**

increase with the increasing Mr / size / mass / N 0 of e- / size   
of e- cloud (in the hydrogen halides)

*(if ionic, or if ‘covalent bonds broken’ = CE = 0)*

*(mark M1 and M2 separately)*

**1**

(ii)     hydrogen bonding stronger than van der Waals’ attraction/forces

*(accept hydrogen bonding is very strong / strongest)*

*(accept arguments such as ‘HF has H-bonds, others only have van der Waals’)*

*(not just ‘HF has H-bonding’)*

**1**

**[11]**

**M25.**          *(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)     17O/O17 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)*

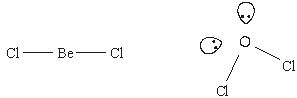
*(if lp on Be, diagram = 0)*

*(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(NO3)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 = = 34.3 – 34.5 (cm3) *(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))*

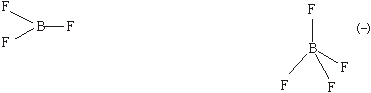
*(if not 2:1 ratio, lose M3 and M4)*

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

**1**

**[12]**

**M26.**          (i)



(1)                                                                (1)

*[Do not allow shapes which show a lone pair]*

**2**

          BF3             Trigonal planar/planar triangular

*[Not plane triangle]*

**1**

          BF           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]**

**M27.**          *Hydroxide:           solubility increases*

**1**

*Sulphate:             solubility decreases               [BOTH inc/dec allow 1/2]*

[Allow correct solubilities of top (Mg) and bottom (Ba) cpds]

**1**

Add:                     BaCl2(aq) / Ba(NO3)2(aq) / Ba(OH)2(aq)

*[Not solid added]*

*[Not Ba2+ / Ba / Ba + HCl / Pb(NO3)2(aq)]*

**[If BaSO4 / H2SO4 used, M3 to M6 = CE = 0]**

*[Allow any sensible nitrate test as an alternative to the sulphate test]*

**1**

**[Note: If M3 not awarded but test would work, allow correct observations  
and equations]**

*Na2SO4 white precipitate / solid / suspension*

*[not cloudy/milky]*

**1**

*NaNO3                 no change*

**1**

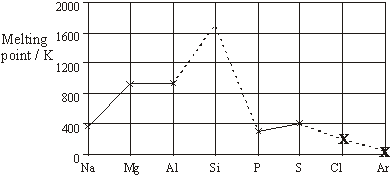
          BaCl2 + Na2SO4 → BaSO4 + 2NaCl

*Accept ionic equation*

**1**

**[6]**

**M28.**          (a)     (i)



**M1**    Si:          cross ≥ 1200

**1**

**M2**    Cl:          cross below S

**1**

**M3**    Ar:          cross below Cl

*[allow, even if M2 wrong)*

*[If Cl cross missing and Ar below S, allow M3]*

**1**

(ii)     Si is macromolecular/giant molecular/giant covalent/ giant atomic

**1**

Covalent bonds need to be broken/accept ‘overcome’

*[Not loosened/weakened]*

**1**

Covalent bonds are strong / many covalent bonds involved/  
requires much energy/hard to break

*[Tied to ‘break’ or near miss in M2]   [Not ‘structure’ is broken]*

*[Must mention ‘covalent’ somewhere in part (a)(ii) to earn M2/M3]*

*[If van der Waals’/IMF mentioned M2/M3 = CE = 0.*

*[If ions mentioned M1/M2/M3 = CE = 0]*

**1**

(iii)     Intermolecular force = van der Waals’/induced   
dipole–dipole/dispersion forces

**1**

**QoL**  Sulphur has greater *M*r / size / surface area/more electrons/more  
atoms **so** stronger intermolecular forces (comparison)

*[Mark separately] [Not ‘more shells’]*

**1**

(b)     Trend:      Decreases

*[If trend wrong = CE = 0]*

**1**

Increase in size of ion/atom / more shells / decrease in charge density /decrease in charge size ratio

**1**

Weaker attraction for delocalised/free/sea of electrons / weaker   
metallic bonding

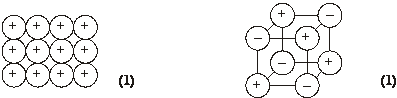
*[Ignore shielding]*

*[van der Waals’ etc. = CE = 0 for M2 and M3]*

**1**

**[11]**

**M29.**          (a)



*[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 stronger 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

**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 Arvalues/atomic numbers used = CE = 0]*

**1**

(ii)     3Cl2 + 6NaOH → 5NaCl + NaClO3 + 3H2O

**1**

**[12]**

**M30.**          A chlorine atom has more protons in its nucleus than has a  
sodium atom

**1**

          Both have three shells of electrons

**1**

Electrons more strongly attracted by chlorine nucleus  
so size smaller than Na

**1**

          An electron shell is lost when a sodium ion is formed from a sodium atom

**1**

          Inner electrons more strongly attracted so ion smaller than atom

**1**

          An electron is added to the outer shell when a chloride ion is formed

**1**

Greater repulsion between shells so size of chloride ion  
greater than Cl atom

**1**

**MAX 6**

**QWC**

**[6]**

**M31.**          (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]**

**M32.**          (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/PH3)

*Not lone pair on hydrogen*

**1**

          Shares/donated from P(H3)/ 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 /AsH3has 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 AsH3 provided ammonia has stronger IMF.  
If between atoms mentioned CE=0  
Break bonds CE = 0*

**1**

(g)     4AsCl3 + 3NaBH4 → 4AsH3 + 3NaCl + 3BCl3;

*Accept multiples*

**1**

**[14]**

**M33.**          (a)     (i)      Average/mean mass of 1 atom (of an element);

*Average mass of 1 atom × 12.*

**1**

         Mass 1/12 atom of 12C;

*Mass 1 atom of 12C.  
QWC.*

**1**

(ii)     Other isotope = 46.0%;

**1**

         107.9 = ;

*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]**

**M34.**          (a)     2s2 2p6;

*If ignored the 1s2 given and written 1s22s22p6 mark as correct  
Allow capitals and subscripts*

**1**

(b)     (i)      Na+(g) → Na2+ (g) + e(–);

*One mark for equation and one mark for state symbols*

         Na+(g) + e(–) → Na2+ (g) + 2e(–);

*M2 dependent on M1  
Allow Na+(g) – e(–) → Na(g)  
Allow X+(g) → X2+ (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 3rdenergy 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 Mg2+ 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 2s2 2p6 alone.  
Not stable electron configuration.*

**1**

**[16]**

**M35.**          (a)     2s2 2p6;

*If ignored the 1s2 given and written 1s22s22p6 mark as correct  
Allow capitals and subscripts*

**1**

(b)     (i)      Na+(g) → Na2+ (g) + e(–);

*One mark for equation and one mark for state symbols*

         Na+(g) + e(–) → Na2+ (g) + 2e(–);

*M2 dependent on M1  
Allow Na+(g) – e(–) → Na(g)  
Allow X+(g) → X2+ (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 3rdenergy 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 Mg2+ 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 2s2 2p6 alone.  
Not stable electron configuration.*

**1**

**[16]**