**Q1.**          (a)     A small sample of barium metal was added to water in a flask. When the reaction had ceased, the contents of the flask were treated with a small amount of dilute aqueous sodium sulphate.

Describe all that you would observe and write equations, with state symbols, for the reactions that occur.

**(8)**

(b)     Dilute sodium hydroxide solution was added dropwise until in excess to separate dilute aqueous solutions of beryllium chloride, magnesium chloride and barium chloride.

Describe what you would observe in each case and account for your observations.

**(8)**

(c)     (i)      A naturally occurring compound of calcium contains by mass 23.29% of calcium,18.64% of sulphur and 2.32% of hydrogen, the remainder being oxygen.

Determine the empirical formula of this compound.

(ii)     For any compound, what is the relationship between empirical and molecular formula? What additional information is required to determine a molecular formula from an empirical formula?

**(5)**

**(Total 21 marks)**

**Q2.**          (a)     Explain why certain elements in the Periodic Table are classified as p-block elements. Illustrate your answer with an example of a p-block element and give its electronic configuration.

**(3)**

(b)     Explain the meaning of the term *periodicity* as applied to the properties of rows of elements in the Periodic Table. Describe and explain the trends in atomic radius, in electronegativity and in conductivity for the elements sodium to argon.

**(13)**

**(Total 16 marks)**

**Q3.**          (a)     State the trend in atomic radius down Group II from Be to Ba and give a reason for this trend.

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

*Reason .*........................................................................................................

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

**(2)**

(b)     State and explain the trend in melting points of the elements down Group II from Be to Ba.

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

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

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

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

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

**(3)**

(c)     State the trend in reactivity with water of the elements down Group II from Be to Ba.  
Write an equation for the reaction of magnesium with steam and an equation for the reaction of strontium with water.

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

*Equation for magnesium ….*..........................................................................

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

*Equation for strontium* ...................................................................................

**(3)**

(d)     Sulphates of the Group II elements from Be to Ba have different solubilities. Give the formula of the least soluble of these sulphates and state **one** use that depends upon the insolubility of this sulphate.

*Formula* .......................................................................................................

*Use* ..............................................................................................................

**(2)**

(e)     A solution contains ions of a Group II element, **M**. When aqueous sodium hydroxide is added a white precipitate forms. This precipitate dissolves in an excess of aqueous sodium hydroxide. Identify **M** and write ionic equations for the two reactions.

*Identity of* **M** .................................................................................................

*Equation 1 ....................................................................................................*

*Equation 2 ....................................................................................................*

**(3)**

(f)      With the exception of beryllium chloride, Group II chlorides are classed as ionic.  
Explain why beryllium chloride is different by considering how a beryllium ion would interact with a chloride ion.

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

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

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

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

**(3)**

**(Total 16 marks)**

**Q4.**          (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.**

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

**(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.

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

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

(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.

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

**(7)**

**(Total 16 narks)**

**Q5.**          (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)**

**Q6.**          (a)     (i)      Complete the electronic configuration of aluminium.

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

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

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

**(2)**

(b)     Describe the bonding in metals.

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

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

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

**(2)**

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

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

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

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

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

**(3)**

(d)     Explain how metals conduct electricity.

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

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

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

**(2)**

**(Total 9 marks)**

**Q7.**          (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)**

**Q8.**          Compound **A** is an oxide of sulphur. At 415 K, a gaseous sample of **A**, of mass 0.304 g, occupied a volume of 127 cm3 at a pressure of 103 kPa.

State the ideal gas equation and use it to calculate the number of moles of **A** in the sample, and hence calculate the relative molecular mass of **A**.  
(The gas constant *R* = 8.31 J K–1 mol–1)

*Ideal gas equation* ................................................................................................

*Calculation* ............................................................................................................

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

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

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

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

**(Total 5 marks)**

**Q9.**          Define the term *electronegativity* and explain why the electronegativity values of the Group II elements Be–Ba decrease down the group.

**(Total 4 marks)**

**Q10.**          (a)     There is a trend in the reactivity of the Group II metals, Be–Ba, with water. State this trend and give the conditions under which magnesium reacts rapidly with water.  
Write an equation to represent this reaction.

*Trend Be to Ba* .............................................................................................

*Conditions .*...............................….................................................................

*Equation* .......................................................................................................

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

**(3)**

(b)     Describe what you would observe when a few drops of aqueous sodium hydroxide are added to aqueous beryllium chloride, followed by a large excess of aqueous sodium hydroxide. Write equations for the two reactions which occur.

*Observation when a few drops are added* ....................................................

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

*Equation ………*............................................................................................

*Observation with excess* ..............................................................................

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

*Equation .*......................................................................................................

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

**(4)**

**(Total 7 marks)**

**Q11.**          (i)      For the elements Mg–Ba, state how the solubilities of the hydroxides and the solubilities of the sulphates change down Group II.

(ii)      Describe a test to show the presence of sulphate ions in an aqueous solution. Give the results of this test when performed on separate aqueous solutions of magnesium chloride and magnesium sulphate. Write equations for any reactions occurring.

(iii)     State the trend in the reactivity of the Group II elements Mg–Ba with water.

Write an equation for the reaction of barium with water.

**(Total 11 marks)**

**Q12.**          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)**

**Q13.**          (a)     When aluminium is added to an aqueous solution of copper(II) chloride, CuCl2, copper metal and aluminium chloride, AlCl3, are formed. Write an equation to represent this reaction.

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

**(1)**

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

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

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

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

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

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

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

**(4)**

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

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

**(1)**

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

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

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

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

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

**(3)**

**(Total 9 marks)**

**Q14.**          (a)     State the meaning of the term *first ionisation energy* of an atom.

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

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

**(2)**

(b)     Complete the electron arrangement for the Mg2+ ion.

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

**(1)**

(c)     Identify the block in the Periodic Table to which magnesium belongs.

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

**(1)**

(d)     Write an equation to illustrate the process occurring when the **second** ionisation energy of magnesium is measured.

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

**(1)**

(e)     The Ne atom and the Mg2+ ion have the same number of electrons. Give **two** reasons why the first ionisation energy of neon is lower than the third ionisation energy of magnesium.

*Reason 1* .....................................................................................................

*Reason 2* .....................................................................................................

**(2)**

(f)      There is a general trend in the first ionisation energies of the Period 3 elements, Na – Ar

(i)      State and explain this general trend.

*Trend ………..*.....................................................................................

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

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

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

(ii)     Explain why the first ionisation energy of sulphur is lower than would be predicted from the general trend.

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

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

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

**(5)**

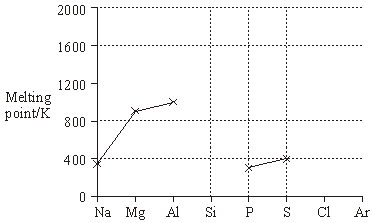
**(Total 12 marks)**

**Q15.**          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)**

**Q16.**          (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.

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

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

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

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

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

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

**(8)**

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

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

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

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

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

**(3)**

**(Total 11 marks)**

**Q17.**          The elements phosphorus, sulfur, chlorine and argon are in the p block of the Periodic Table.

(a)     State why these elements are classified as p block elements.

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

**(1)**

(b)     State the trend in atomic radius from phosphorus to chlorine and explain the trend.

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

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

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

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

**(3)**

(c)     In terms of structure and bonding, explain why sulfur has a higher melting point than phosphorus.

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

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

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

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

**(3)**

(d)     In terms of atomic structure, explain why the van der Waals’ forces in liquid argon are very weak.

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

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

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

**(2)**

**(Total 9 marks)**

**Q18.**          This question is about the elements in Period 3 from Na to P

(a)     (i)      Explain the meaning of the term *first ionisation energy*.

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

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

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

**(2)**

(ii)     State and explain the general trend in first ionisation energies for the elements   
Na to P

Trend ...................................................................................................

Explanation .........................................................................................

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

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

**(3)**

(iii)     State which one of the elements from Na to P deviates from this general trend and explain why this occurs.

Trend ..................................................................................................

Explanation .........................................................................................

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

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

**(3)**

(b)     State which one of the elements from Na to P has the highest melting point and explain your answer.

Element .......................................................................................................

Explanation ..................................................................................................

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

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

**(3)**

**(Total 11 marks)**

**Q19.**          (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.

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

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

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

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

**(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.

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

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

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

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

**(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)**

**Q20.**          Ionisation energies provide evidence for the arrangement of electrons in atoms.

(a)     Complete the electron configuration of the Mg+ ion.

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

**(1)**

(b)     (i)      State the meaning of the term *first ionisation energy*.

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

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

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

**(2)**

(ii)     Write an equation, including state symbols, to show the reaction that occurs when the **second** ionisation energy of magnesium is measured.

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

**(1)**

(iii)     Explain why the second ionisation energy of magnesium is greater than the first ionisation energy of magnesium.

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

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

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

**(1)**

(iv)    Use your understanding of electron arrangement to complete the table by suggesting a value for the third ionisation energy of magnesium.

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
|  | First | Second | Third | Fourth | Fifth |
| Ionisation energies of magnesium / kJ mol–1 | 736 | 1450 |  | 10 500 | 13 629 |
|  |  |  |  |  |  |

**(1)**

(c)     State and explain the general trend in the first ionisation energies of the Period 3 elements sodium to chlorine.

Trend ...........................................................................................................

Explanation ..................................................................................................

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

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

**(3)**

(d)     State how the element sulfur deviates from the general trend in first ionisation energies across Period 3. Explain your answer.

How sulfur deviates from the trend ..............................................................

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

Explanation ..................................................................................................

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

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

**(3)**

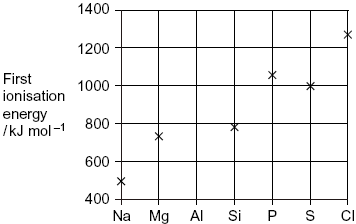
(e)     A general trend exists in the first ionisation energies of the Period 2 elements lithium to fluorine. Identify **one** element which deviates from this general trend.

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

**(1)**

**(Total 13 marks)**

**Q21.**          The following diagram shows the first ionisation energies of some Period 3 elements.



(a)     Draw a cross on the diagram to show the first ionisation energy of aluminium.

**(1)**

(b)     Write an equation to show the process that occurs when the first ionisation energy of aluminium is measured.

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

**(2)**

(c)     State which of the first, second or third ionisations of aluminium would produce an ion with the electron configuration 1s2 2s2 2p6 3s1

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

**(1)**

(d)     Explain why the value of the first ionisation energy of sulfur is less than the value of the first ionisation energy of phosphorus.

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

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

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

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

**(2)**

(e)     Identify the element in Period 2 that has the highest first ionisation energy and give its electron configuration.

Element .......................................................................................................

Electron configuration ..................................................................................

**(2)**

(f)      State the trend in first ionisation energies in Group 2 from beryllium to barium.  
Explain your answer in terms of a suitable model of atomic structure.

Trend …........................................................................................................

Explanation ..................................................................................................

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

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

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

**(3)**

**(Total 11 marks)**

**Q22.**         The following table gives the melting points of some elements in Period 3.

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Element | Na | Al | Si | P | S |
| Melting point / K | 371 | 933 | 1680 | 317 | 392 |

(a)     State the type of structure shown by a crystal of silicon.  
Explain why the melting point of silicon is very high.

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

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

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

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

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

**(3)**

(b)     State the type of structure shown by crystals of sulfur and phosphorus.  
Explain why the melting point of sulfur is higher than the melting point of phosphorus.

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

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

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

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

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

**(3)**

(c)     Draw a diagram to show how the particles are arranged in aluminium and explain why aluminium is malleable.  
(You should show a minimum of six aluminium particles arranged in two dimensions.)

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

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

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

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

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

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

**(3)**

(d)     Explain why the melting point of aluminium is higher than the melting point of sodium.

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

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

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

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

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

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

**(3)**

**(Total 12 marks)**

**Q23.**          Indium is in Group 3 in the Periodic Table and exists as a mixture of the isotopes 113In and 115In.

(a)     Use your understanding of the Periodic Table to complete the electron configuration of indium.

1s2 2s2 2p6 3s2 3p6 4s2 3d10 4p6 ........................................................................

**(1)**

(b)     A sample of indium must be ionised before it can be analysed in a mass spectrometer.

(i)      State what is used to ionise a sample of indium in a mass spectrometer.

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

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

**(1)**

(ii)     Write an equation, including state symbols, for the ionisation of indium that requires the minimum energy.

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

**(1)**

(iii)     State why more than the minimum energy is **not** used to ionise the sample of indium.

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

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

**(1)**

(iv)    Give two reasons why the sample of indium must be ionised.

Reason 1 ............................................................................................

Reason 2 ............................................................................................

**(2)**

(c)     A mass spectrum of a sample of indium showed two peaks at *m/z* = 113 and *m/z*= 115. The relative atomic mass of this sample of indium is 114.5

(i)      Give the meaning of the term *relative atomic mass*.

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

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

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

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

**(2)**

(ii)     Use these data to calculate the ratio of the relative abundances of the two isotopes.

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

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

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

**(2)**

(d)     State and explain the difference, if any, between the chemical properties of the isotopes 113In and 115In

Difference in chemical properties ................................................................

Explanation ..................................................................................................

**(2)**

(e)     Indium forms a compound **X** with hydrogen and oxygen. Compound **X** contains 69.2% indium and 1.8% hydrogen by mass.  
Calculate the empirical formula of compound **X**.

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

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

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

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

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

**(3)**

**(Total 15 marks)**

**Q24.**Trends in physical properties occur across all Periods in the Periodic Table.  
This question is about trends in the Period 2 elements from lithium to nitrogen.

(a)     Identify, from the Period 2 elements lithium to nitrogen, the element that has the largest atomic radius.

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

**(1)**

(b)     (i)      State the general trend in first ionisation energies for the Period 2 elements lithium to nitrogen.

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

**(1)**

(ii)      Identify the element that deviates from this general trend, from lithium to nitrogen, and explain your answer.

Element ................................................................................................

Explanation ...........................................................................................

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

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

*(Extra space)* ........................................................................................

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

**(3)**

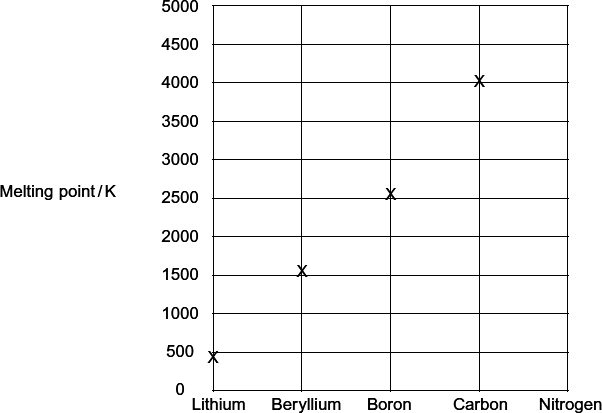
(c)     Identify the Period 2 element that has the following successive ionisation energies.

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
|  | First | Second | Third | Fourth | Fifth | Sixth |
| Ionisation energy / kJ mol–1 | 1090 | 2350 | 4610 | 6220 | 37 800 | 47 000 |

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

**(1)**

(d)     Draw a cross on the diagram to show the melting point of nitrogen.



**(1)**

(e)     Explain, in terms of structure and bonding, why the melting point of carbon is high.

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

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

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

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

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

*(Extra space)* .................................................................................................

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

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

**(3)**

**(Total 10 marks)**

**Q25.**There are many uses for compounds of barium.

(a)     (i)      Write an equation for the reaction of barium with water.

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

**(1)**

(ii)     State the trend in reactivity with water of the Group 2 metals from Mg to Ba

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

**(1)**

(b)     Give the formula of the **least** soluble hydroxide of the Group 2 metals from Mg to Ba

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

**(1)**

(c)     State how barium sulfate is used in medicine.  
Explain why this use is possible, given that solutions containing barium ions are poisonous.

Use .................................................................................................................

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

Explanation ....................................................................................................

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

*(Extra space)* .................................................................................................

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

**(2)**

**(Total 5 marks)**

**Q26.**          (a)     Boron trichloride (BCl3) can be prepared as shown by the following equation.

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| B2O3(s) | + | 3C(s) | + | 3Cl2(g) |  | 2BCl3(g) | + | 3CO(g) |

A sample of boron oxide (B2O3) was reacted completely with carbon and chlorine.  
The two gases produced occupied a total volume of 5000 cm3 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)

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

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

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

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

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

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

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

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

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

*(Extra space)* .................................................................................................

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

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

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

**(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.

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

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

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

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

*(Extra space)* .................................................................................................

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

**(3)**

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

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| BCl3(g) | + | 3H2O(I) |  | H3BO3(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 cm3 of solution.  
Give your answer to 3 significant figures.

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

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

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

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

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

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

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

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

*(Extra space)* ........................................................................................

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

**(4)**

(ii)     Boric acid (H3BO3) 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.

BCl3(g) + 1H2(g)  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.

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

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

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

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

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

*(Extra space)* .................................................................................................

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

**(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.

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

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

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

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

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

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

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

*(Extra space)* .................................................................................................

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

**(4)**

**(Total 20 marks)**

**Q27.**The elements in Period 2 show periodic trends.

(a)     Identify the Period 2 element, from carbon to fluorine, that has the largest atomic radius. Explain your answer.

Element .........................................................................................................

Explanation ....................................................................................................

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

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

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

**(3)**

(b)     State the general trend in first ionisation energies from carbon to neon.  
Deduce the element that deviates from this trend and explain why this element deviates from the trend.

Trend .............................................................................................................

Element that deviates ....................................................................................

Explanation ....................................................................................................

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

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

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

**(4)**

(c)     Write an equation, including state symbols, for the reaction that occurs when the first ionisation energy of carbon is measured.

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

**(1)**

(d)     Explain why the second ionisation energy of carbon is higher than the first ionisation energy of carbon.

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

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

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

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

**(1)**

(e)     Deduce the element in Period 2, from lithium to neon, that has the highest second ionisation energy.

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

**(1)**

**(Total 10 marks)**

**M1.**          (a)     Barium dissolves **(1)**                (or forms solution)  
Gas evolved **(1)**                        (or hydrogen evolved) or  
bubbles     gets hot **(1)**

*do not allow evolution of wrong gas*

Ba(s) + 2H2O(l) → Ba2+(aq) + 2OH–(aq)    (or Ba(OH)2(aq) + H2(g)  
Species all correct **(1)**State symbols correct **(1)** (provided species are correct)  
Balanced equation **(1)**

White precipitate with sodium sulphate **(1)**(or white solid or suspension or white cloudy or milky)  
Ba2+(aq) + SO42–(aq) → BaSO4(s)  
(or Ba(OH)2(aq) + Na2SO4(aq) → BaSO4(s) + 2NaOH(aq)  
State symbols **(1)**Balanced equation **(1)**

*(mark obs. of ppts independently (and in (b))*

**8**

(b)     with BeCl2 and NaOH get a white precipitate **(1)** (or solid etc)  
because Be(OH)2 is insoluble **(1)**      (or white ppt is Be(OH)2)  
ppt is soluble in excess of the reagent **(1)**Because Be(OH)2 is amphoteric (or beryllium forms complex ion  
(Be(OH)42–)) **(1)***(This is the quality of language mark so the terms must be used in  
a sentence)*

With MgCl2 get white ppt **(1)**Because Mg(OH)2 is sparingly soluble (or insoluble) **(1)** (or white ppt is  
Mg(OH)2)

With BaCl2 no ppt formed **(1)** (or no reaction) (or remains in solution)  
Because Ba(OH)2 is soluble **(1)** (or all species are soluble)  
Solubility of hydroxides increases down Group **(1)**

*Note can take marks for Be(OH)2(s), Mg(OH)2 (s), Ba(OH)2(aq)  
from equations  
Wrong formula for M(OH)2 loses mark*

**max 8**

(c)     (i)      %O = 55.75% **(1)**Ca : S : O : H =  **(1)**

*Allow 40, 32*

*= 1:    1:         6:      4:*

*therefore formula: CaSO6H4* ***(1)***

*if Oxygen omitted can score 2nd mark only*

**2**

(ii)      = an integer **(1) (or a number)**

*Allow correct definitions as an alternative for the mark  
emp. form. The simplest ratio of atoms of each element in a compound molec. form. The actual number of atoms of  
each element in a molecule*

         Mr **(1)** (or molar mass or RFM NOT molecular mass)

**5**

**[21]**

**M2.**          (a)     Elements in the p block have their outer electron(s) in  
p orbital(s) or levels or sub-shells **(1)**example of element **(1)**correct electronic configuration **(1)**

**3**

(b)     Pattern in the change in the properties of a row of elements **(1)**

*OR Trend in the properties of elements across a period*

          Repeated in the next row **(1)**

*OR element underneath (or in same group) has similar properties*

**atomic radius**decreases across the row **(1)**

*CE if trend is wrong*

number of protons increases **(1)** (or nuclear charge increases)  
more attraction for electrons in the same shell **(1)**

**electronegativity**increases across the row **(1)**number of protons increases **(1)** (or nuclear charge)  
atomic radius decreases **(1)** (or shielding remains the same or electrons  
in the same shell) more attraction for bonding or shared electrons **(1)**

**conductivity**decreases row **(1)**

*OR significant drop from Al to Si*

          Na–Al metals **(1)**

*OR metallic bonding or description of metallic bonding*

          Two of Si - Ar non metals **(1)**

*OR molecular or covalent*

EITHER electrons free to move (or delocalised) in metals  
OR electrons unable to move in non-metals **(1)**

**13**

**[16]**

**M3.**          (a)     *Trend*: increases **(1)**

*Wrong trend CE=0 and in (b)*

*Reason*: More electron shells **(1)**

*OR implies more shell / sub-shells / levels*

**2**

(b)     *Trend*: decreases **(1)**

*Explanation*: Metallic bonds weaker **(1)**

*OR weaker attraction between ions (or nuclei) & delocalised electrons*

          Atoms (ions) larger **(1)**

*This mark is only scored if previous mark given*

*CE if mention molecules, intermolecular forces ionic bonding*

**3**

(c)     *Trend*: increases **(1)**

*Equation for magnesium*: Mg + H2O → MgO + H2 **(1)**

*Equation for strontium*: Sr +2 H2O → Sr(OH)2 + H2 **(1)***Ignore state symbols.*

**3**

(d)     *Formula*: BaSO4 **(1)**

*Use*: Test for sulphate ion **(1)**

*OR Pigment, for x-rays, barium meal, paint*

**2**

(e)     *Identity of* **M**: Be **(1)**

*Allow Be2+*

*Equation 1*: Be2+ + 2 OH– → Be(OH)2 **(1)**

*Allow + 2 NaOH → +2Na+*

*Equation 2*: Be(OH)2 + 2 OH– → [Be(OH)4]2– **(1)**

*Allow + 2 NaOH → +2Na+*

**3**

(f)      Be2+ ion has high charge density, (charge / size ratio) **(1)**

*OR Be2+ ion is very small*

*Penalise Be*

          polarises Cl– **(1)**

*Can score from diagram*

          causes covalency **(1)**

*OR sharing of electrons*

*Do not allow if BeCl2 is ionic*

**3**

**[16]**

**M4.**         (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**

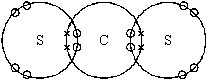
(e)     (i)      *Bonding in Na2S*: ionic **(1)***Bonding in CS2*:  covalent **(1)**

*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]**

**M5.**          (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*

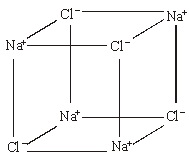
          P4 **or** Mr = 124 **(1)** S8 **or** Mr = 256 **(1)**

*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]**

**M6.**          (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]**

**M7.**          (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]**

**M8.**          *Ideal gas equation*: pV = nRT **(1)**

*Calculation*: n = pV/RT =  **(1)**

*mark for volume conversion fully correct*

                                             = 3.79 × 10–3 (mol) **(1)**

*range 3.79 × 10–3 to 3.8 × 10–3*

          Mr = m/n = .304/3.79 × 10–3 = 80.1 **(1)**

*range 80 – 80.3  
min 2 s.f. conseq*

*If ‘V’ wrong lose M2; ‘p’ wrong lose M3; ‘inverted’ lose M3 and M4*

**[5]**

**M9.**          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]**

**M10.**          (a)     Increases

**1**

Heat or steam or gas phase or H temp (>100°) *(NOT ‘hot’)*

**1**

Mg + H2O → MgO + H2

*(Ignore state symbols – even if they are wrong)*

**1**

(b)     White precipitate/solid/suspension    (Not ‘cloudy / milky’)  
BeCl2 + 2NaOH → Be(OH)2 + 2NaCl

**1**

Or Be2+ + 2OH– → Be(OH)2

*(Accept BeCl2 + 2OH– → Be(OH)2 + 2Cl–)*

**1**

          Ppt (re)dissolves        or solution goes clear

*(Allow ‘ppt disappears’)*

*(NOT ‘solution forms’)*

**1**

          Be(OH)2 + 2OH– → 

*[NOT ]*

          Or     Be(OH)2 + 2NaOH → Na2Be(OH)4

**1**

**[7]**

**M11.**          (i)      Hydroxide        solubility increases            *(need trend)*

**1**

Sulphate          solubility decreases         *(need trend)*

*(If both Mg/Ba salts correctly compared - but no trend- allow 1 max)*

**1**

Add acid           name/correct formula       HCl

**1**

(ii)      *(accept HNO3/CH3COOH)              [NOT hydrogen chloride]*

*[If acid added is H2SO4 = CE – allow only M2]*

          Add Ba2+ salt   name/correct formula BaCl2

*(accept Ba(NO3)2 / Ba(CH3COO)2)*

*[If reagent added is BaSO4 /Ba/Ba(OH)2 = CE – allow only M1]*

**1**

          MgCl2 No change / no ppt / no reaction

**1**

MgSO4         White ppt / solid / suspension *[NOT chalky, milky]*

*Both observations tied to Ba2+ ions being added*

**1**

          MgSO4 + BaCl2 → BaSO4 + MgCl2

*Accept ionic equation*

**1**

          (Reagent mark (M2) can be awarded from full equation)

**1**

          [Treat incorrect equation for MgCl2 as contradiction of correct equation]

*(Ignore carbonate equations)            (Ignore state symbols)*

**1**

(iii)     Reactivity   increases (down group)         *[NOT solubility increases]*

**1**

          Ba + 2H2O → Ba(OH)2 + H2

**1**

**[11]**

**M12.**          **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]**

**M13.**          (a)     2Al + 3CuCl2  →  2AlCl3 + 3Cu;

*(accept multiples/fractions)*

OR

2Al+ 3Cu2+ → 2Al3+ + 3Cu;

**1**

(b)     (i)      increases;

**1**

(ii)     lower than expected / lower than Mg /

**1**

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

**1**

*(‘e*– *removed’ may be implied)*

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

**1**

(c)     Al+(g) → Al2+(g) + e–;

**1**

(d)     trend:  increases;

**1**

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

**1**

OR

stronger metallic bonding;

**1**

**[9]**

**M14.**          (a)     enthalpy/energy change/required when an electron is removed/  
knocked out / displaced/ to form a uni-positive ion

*(ignore ‘minimum’ energy)*

**1**

from a gaseous atom

*(could get M2 from a correct equation here)  
(accept ‘Enthalpy/energy change for the process...’  
followed by an appropriate equation, for both marks)  
(accept molar definitions)*

**1**

(b)     *1s2* 2s22p6

*(accept capitals and subscripts)*

**1**

(c)     ‘s’ block

*(not a specific ‘s’ orbital – e.g. 2s)*

**1**

(d)     Mg+(g) → Mg2+(g) + e– or

Mg+(g) + e– → Mg2+(g) + 2e– or

Mg+(g) – e– → Mg2+(g)

**1**

(e)     Mg2+ ion smaller than Ne atom / Mg2+ e– closer to nucleus

*(Not ‘atomic’ radius fo Mg2+)*

**1**

Mg2+ has more protons than Ne / higher nuclear charge or   
e– is removed from a charged Mg2+ion / neutral neon atom

*(accept converse arguments)*

*(If used ‘It’ or Mg/magnesium/Mg3+ etc. & 2 correct reasons, allow* ***(1)****)*

**1**

(f)      (i)      trend: increases

*(if ‘decreases’, CE = 0/3)*

**1**

Expln: more protons / increased proton number /  
increased nuclear charge

*(NOT increased atomic number)*

**1**

same shell / same shielding / smaller size

**1**

(ii)     QoL reference to the e– pair in the 3p sub-level

*(penalise if wrong shell, e.g. ‘2p’, quoted)*

**1**

repulsion between the e–in this e–pair

*(if not stated, ‘e– pair’ must be clearly implied)*

*(mark M4 and M5 separately)*

**1**

**[12]**

**M15.**          *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**

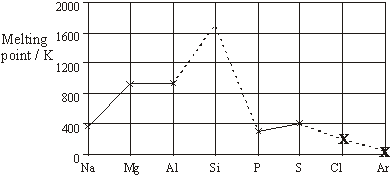
          BaCl2 + Na2SO4 → BaSO4 + 2NaCl

*Accept ionic equation*

**1**

**[6]**

**M16.**          (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]**

**M17.**          (a)     Outer electrons are in p orbitals

**1**

(b)     decreases

**1**

Number of protons increases

**1**

Attracting outer electrons in the same shell (or similar shielding)

**1**

(c)     Sulfur molecules (S8) are larger than phosphorus (P4)

**1**

Therefore van der Waals’ forces between molecules are stronger

**1**

Therefore more energy needed to loosen forces between molecules

**1**

(d)     Argon particles are single atoms with electrons closer to nucleus

**1**

Cannot easily be polarised (or electron cloud not easily distorted)

**1**

**[9]**

**M18.**          (a)     (i)      Energy/enthalpy (change)/∆*H/* needed to remove  
1 mole of electrons;

*Allow 1 electron  
Not heat alone*

**1**

         From 1 mol of gaseous atoms;

*From 1 gaseous atom  
Not mix and match moles and one electron.  
Allow 1 for balanced eq with ss*

**1**

(ii)     Increase;

*If blank mark on  
If incorrect CE = 0*

**1**

         Increasing nuclear charge/ increasing number of protons;

*Not increasing atomic number*

**1**

         Same or similar shielding /same number of shells or energy  
levels/ (atomic) radius decreases/electron closer to nucleus;

*Not same distance from nucleus.*

**1**

(iii)     Aluminium/Al;

*If incorrect CE = 0*

**1**

         Electron in higher energy /p or 3p orbital;

*Not 2p  
Ignore shielding*

**1**

Less energy needed to lose electron/ electron more easily  
lost/ ionisation energy less;

**1**

(b)     Silicon/Si;

*If incorrect CE = 0  
If silicone, silica Si8, Si4 mark on.*

**1**

          Macromolecular/ Giant molecular or atomic or covalent;

*If IMFor ionic or metallic in Silicon then CE = 0 for explanation*

**1**

Many or strong covalent bonds need to be broken/  
lots of energy needed to break the covalent bonds;

*Not loosened bonds*

**1**

**[11]**

**M19.**          (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]**

**M20.**          (a)     2s22p63s1

*1s2 can be rewritten  
Allow 2s22px22py22pz23s1Allow subscripts and capitals*

**1**

(b)     (i)      Energy/enthalpy (needed) to remove one mole of electrons  
from one mole of atoms/compounds/molecules/elements

**1**

***OR***

Energy to form one mole of positive ions from one mole of atoms

OR

Energy/enthalpy to remove one electron from one atom

In the gaseous state (to form 1 mol of gaseous ions)

*Energy given out loses M1*

*M2 is dependent on a reasonable attempt at M1*

*Energy needed for this change  
X(g) → X+(g) + e(–) = 2 marks  
This equation alone scores one mark*

**1**

(ii)     Mg+(g) → Mg2+(g) + e(–)Mg+(g) + e(–) → Mg2+(g) + 2e(–)Mg+(g) – e(–) → Mg2+(g)

*Do not penalise MG  
Not equation with X*

**1**

(iii)     Electron being removed from a positive ion (therefore need more  
energy)/electron being removed is closer to the nucleus/Mg+smaller (than Mg)/Mg+ more positive than Mg

*Allow from a + particle/species  
Not electron from a higher energy level/or higher sub-level  
More protons = 0*

**1**

(iv)    Range from 5000 to 9000 kJ mol–1

**1**

(c)     Increase

*If decrease CE = 0/3  
If blank mark on*

**1**

Bigger nuclear charge (from Na to Cl)/more protons

*QWC*

**1**

electron (taken) from same (sub)shell/similar or same shielding/  
electron closer to the nucleus/smaller atomic radius

*If no shielding = 0  
Smaller ionic radius = 0*

**1**

(d)     Lower

*If not lower CE = 0/3  
If blank mark on  
Allow does not increase*

**1**

Two/pair of electrons in (3)p orbital or implied

*Not 2p*

**1**

repel (each other)

*M3 dependent upon a reasonable attempt at M2*

**1**

(e)     Boron/B or oxygen/O/O2

**1**

**[13]**

**M21.**          (a)     Cross between the Na cross and the Mg cross

**1**

(b)     Al(g) → Al+(g) + e–  
Al(g) – e– → Al+(g)  
Al(g) + e– → Al+(g) + 2e–

*One mark for state symbols consequential on getting equation correct.  
Electron does not have to have the – sign on it  
Ignore (g) if put as state symbol with e– but penalise state symbol mark if other state symbols on* *e–*

**2**

(c)     2nd/second/2/II

*Only*

**1**

(d)     Paired electrons in (3)p orbital

*Penalise wrong number  
If paired electrons repel allow M2*

**1**

repel

**1**

(e)     Neon/Ne

*No consequential marking from wrong element*

**1**

1s22s22p6/[He}2s22p6

*Allow capital s and p  
Allow subscript numbers*

**1**

(f)      Decreases

*CE if wrong*

**1**

Atomic radius increases/electron removed further from nucleus  
or nuclear charge/electron in higher energy level/Atoms  
get larger/more shells

*Accept more repulsion between more electrons for M2  
Mark is for distance from nucleus  
Must be comparative answers from M2 and M3  
CE M2 and M3 if mention molecules  
Not more sub-shells*

**1**

As group is descended more shielding

**1**

**[11]**

**M22.**          (a)     Macromolecular/giant covalent/giant molecular/giant atomic

*If IMF/H-bonds/Ionic/metallic CE = 0/3*

*covalent bond between molecules CE = 0/3*

*If giant unqualified M1 = 0 but mark on*

**1**

Many/strong covalent bonds

*M2 and M3 can only be scored if covalent mentioned in answer*

*Ignore metalloid and carbon*

*Ignore bp*

**1**

Bonds must be broken/overcome

*Ignore numbers of bonds and references to energy*

**1**

(b)     (Simple) molecular

*QoL*

*Do not allow simple covalent for M1*

*Giant covalent/ionic/metallic, CE = 0*

*If breaking covalent bonds CE= 0/3*

**1**

S bigger molecule (than P) or S8 and P4 references

*QoL*

*Allow more electrons in sulfur molecule or S8*

*Do not allow S is bigger then P*

*Allow S molecule has a bigger Mr*

*Do not allow contradictions*

**1**

So more/stronger van der Waals’ forces (to be broken or overcome)

*Not just more energy to break*

**1**

(c)     Regular arrangement of minimum of 6 particles in  
minimum of 2 rows

*Ignore e–*

*Do not allow ring arrangements OR structures bonded with electrons*

**1**

+ charge in each one (of 6)

*Allow +, (1+, 2+ or 3+) in ions/or in words*

**1**

Rows/planes/sheets/layers (of atoms/ions) can slide (owtte)  
over one another

*M3 independent*

*If ionic bonding/molecules/IMF/vdw/covalent, penalise M3*

*Ignore layers of electrons sliding*

**1**

(d)     Bigger charge (3+ compared to 1+)

*CE = 0 if molecules, ionic, covalent, IMF*

*(Allow Al2+)*

***OR*** smaller atom/ion in Al/more protons/bigger nuclear charge

**1**

More free/delocalised electrons (in Al)/bigger sea of electrons in Al

*Accept 2 or 3 delocalised electrons compared to 1 in Na*

**1**

Stronger metallic bonding/stronger (electrostatic) attraction  
between the (+) ions or nuclei and the (delocalised) electrons  
(or implied)

*Must be implied that the electrons are the delocalised ones not the electrons in the shells.*

*Accept converse arguments*

**1**

**[12]**

**M23.**          (a)     4d10 5s2 5p1 in any order

*Allow subscripts for numbers*

*Allow capitals*

**1**

(b)     (i)      Using an electron gun/(beam of) high energy/fast  
moving electrons

*Ignore ‘knocks out an electron’*

**1**

(ii)     In(g) + e– → In+(g) + 2e–

***OR***

In(g) → In+(g) + e–

In(g) – e– → In+(g)

*The state symbols need not be present for the electron - but if they are they must be (g)*

*No need to show charge on electron*

*If I CE = 0*

*Ignore any equations using M*

**1**

(iii)     So no more than 1 electron is knocked out/so only one electron  
is knocked out/prevent further ionisation

*Allow stop 2+ and 3+/other ions being formed*

*Not to get wrong m/z*

**1**

(iv)    Any two processes from

•        Accelerate (owtte)

•        Deflect (owtte)

•        Detect (owtte)

*Ignore wrong causes of process*

**2 max**

(c)     (i)      Average/mean mass of (1) atom(s) (of an element)

**1**

1/12 mass of one atom of 12C

**1**

***OR***

(Average) mass of one mole of atoms

1/12 mass of one mole of 12C

***OR***

(Weighted) average mass of all the isotopes

1/12 mass of one atom of 12C

***OR***

Average mass of an atom/isotope compared to C-12 on a  
scale in which an atom of C-12 has a mass of 12

*Not average mass of 1 molecule*

*Allow the wording Average mass of 1 atom of an element compared to 1/12 mass atom of 12C (or mass 1/12 atom of 12C)*

*Allow if moles of atoms on both lines*

*Accept answer in words*

*Can have top line × 12 instead of bottom line ÷12*

*If atoms/moles mixed, max = 1*

(ii)     

*Allow idea that there are 4 × 0.5 divisions between 113 and 115*

**1**

ratio (113:115) = 1:3 **OR** 25:75 **OR** 0.5:1.5 etc

*Correct answer scores M1 and M2*

*If 1:3 for In(115):In(113), max = 1*

**1**

(d)     None

**1**

Same no of electrons (in the outer shell)/same electron configuration)

*Ignore electrons determine chemical properties/ignore protons*

*M2 dependent on M1 being correct*

**1**

(e)     29.0%/29% O

*If no O calculated, allow M2 if In and H divided by the correct Ar*

**1**

****

**1**

or

0.603      1.8      1.81

   1            3          3

EF = In H3O3

*Allow In(OH)3*

*Do not allow last mark just for ratio 1:3:3*

*If InO3H3 given with no working then allow 3 marks*

*If I not In, lose M3*

**1**

**[15]**

**M24.**(a)    Lithium / Li

*Penalise obvious capital I (second letter).*

**1**

(b)     (i)     Increase / gets bigger

*Ignore exceptions to trend here even if wrong*

**1**

(ii)     Boron / B

*If not Boron, CE = 0/3*

**1**

Electron removed from (2)p orbital /sub-shell / (2)p electrons removed

*If p orbital specified it must be 2p*

**1**

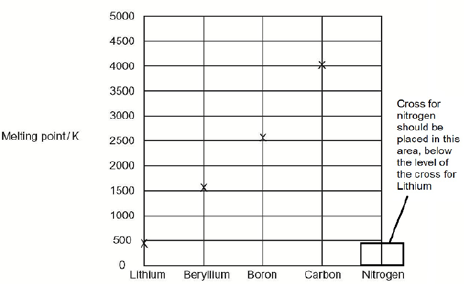
Which is higher in energy (so more easily lost) / more shielded (so more  
easily lost) / further from nucleus

**1**

(c)     C / carbon

**1**

(d)     Below Li



*The cross should be placed on the diagram, on the column for nitrogen, below the level of the cross printed on the diagram for Lithium.*

**1**

(e)     Macromolecular / giant molecular / giant atomic

*Allow giant covalent (molecule) = 2*

**1**

Covalent bonds in the structure

**1**

Strong (covalent) bonds must be broken or overcome / (covalent) bonds need  
a lot of energy to break

*Ignore weakening / loosening bonds*

*If ionic / metallic/molecular/ dipole dipole/ H bonds/ bonds between molecules, CE = 0/3*

*Ignore van der Waals forces*

*Ignore hard to break*

**1**

**[10]**

**M25.**         (a)      (i)     Ba + **2**H2O   Ba(OH)2 + H2

*Ignore state symbols*

*Credit multiples and correct ionic equations*

**1**

(ii)     (Reactivity with water) increase(s) / increasing / increased (down the Group /  
from Mg to Ba)

*Accept “greater” or “gets more” or similar words to that effect.*

*Ignore reference to “increase in solubility / gets more soluble”*

**1**

(b)     Mg(OH)2

*Accept Mg2+(OH–)2 / Mg(HO)2*

*Insist on brackets and correct case*

**1**

(c)     **M1**    Barium meal / barium swallow / barium enema or (internal) X-ray or to  
          block X-rays

**M2**    BaSO4 / barium sulfate is insoluble (and therefore not toxic)

*Accept a correct reference to* ***M1*** *written in the explanation in* ***M2****, unless contradictory*

*For* ***M2*** *NOT barium ions*

*NOT barium*

*NOT barium meal and NOT “It”*

*Ignore radio-tracing*

**2**

**[5]**

**M26.**          (a)     P = 100 000 (Pa) and V = 5.00 x 10–3 (m3)

*M1 is for correctly converting P and V in any expression or list Allow 100 (kPa) and 5 (dm3) for M1.*

**1**

****

*M2 is correct rearrangement of PV = nRT*

**1**

= 0.202 moles (of gas produced)

*This would score M1 and M2.*

Therefore  = 0.0404 moles B2O3

*M3 is for their answer divided by 5*

**1**

Mass of B2O3 = 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 Cl2 → BCl3

*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 BCl3)

**1**

0.368 x 3 (= 1.105 moles HCl)

*Allow their BCl3 moles x 3*

**1**

Conc HCl = 

*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)     H3BO3 + 3NaOH → Na3BO3 + 3H2O

*Allow alternative balanced equations to form acid salts.*

*Allow H3BO3 + NaOH → NaBO2 + 2H2O*

**1**

(d)     

*Mark is for both Mr 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**

  B                 Cl  
           

*B                 Cl  
           *

**1**

1.22           2.45 or ratio 1:2 or BCl2

*2:4 ratio*

**1**

BCl2 has *Mr* of 81.8 so  
81.8 x 2 = 163.6  
Formula = B2Cl4

*B2Cl4*

*Allow 4 marks for correct answer with working shown.*

*Do not allow (BCl2)2*

**1**

**[20]**

**M27.**(a)    Carbon / C

*If M1 incorrect, CE = 0 / 3*

**1**

Fewest protons / smallest nuclear charge / least attraction between protons (in the nucleus) and electrons / weakest nuclear attraction to electrons

*Allow comparative answers.*

*Allow converse answers for M2*

**1**

Similar shielding

*Allow same shielding.*

**1**

(b)     Increase

**1**

Oxygen / O

*If not oxygen, then cannot score M2, M3 and M4*

**1**

Paired electrons in a (2)p orbital

*If paired electrons in incorrect p orbital, lose M3 but can award M4*

**1**

(Paired electrons in a p orbital) repel

**1**

(c)     C(g) → C+(g) + e(−)

***OR***

C(g) + e (−) → C+(g) + 2e (−)

***OR***

C(g) − e (−) → C+(g)

*Ignore state symbols for electron.*

**1**

(d)     (More energy to) remove an electron from a (more) positive ion / cation

*Allow electron closer to the nucleus in the positive ion.*

**1**

(e)     Lithium / lithium / Li

If formula given, upper and lower case letters must be as shown.

**1**

**[10]**