

Questions are for both separate science and combined science students unless indicated in the question

Q1.

This question is about carbon and its compounds.

Fullerenes are molecules of carbon atoms.

The first fullerene to be discovered was Buckminsterfullerene (C_{60}).

(a) What shape is a Buckminsterfullerene molecule?

Spherical (1)

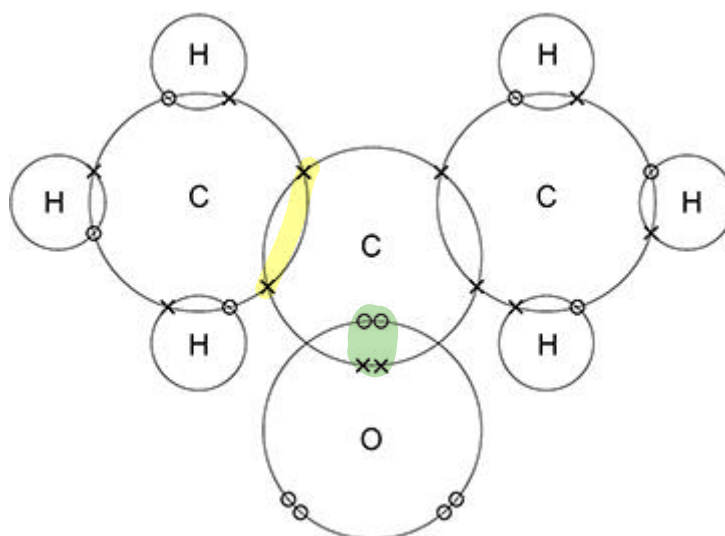
(b) Give **one** use of a fullerene.

Drug delivery - transport around the body (1)

Propanone is a compound of carbon, hydrogen and oxygen.

Figure 1 shows the dot and cross for a propanone molecule.

Figure 1



(c) Complete **Figure 2** to show a propanone molecule.

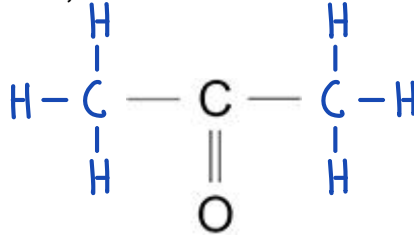
Use a line to represent each single bond.

Use **Figure 1**.

Figure 2

Single covalent bonds:
Share a pair of e^-

Double covalent bonds:
Share two pairs of e^-



W! C atoms = 3 (1)
 H " = 6
 O " = 1

(d) Determine the molecular formula of propanone.

Use **Figure 1**.

Molecular formula = $\frac{C_3H_6O}{CH_3COCH_3}$ (1)

(e) Propanone is a liquid with a **low boiling point**.

Why does propanone have a low boiling point?

Tick (✓) **one** box.

← If intermolecular bonds are weak, don't need much energy to break, releasing molecules to vapour (aka boiling)

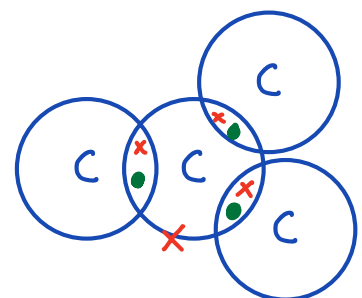
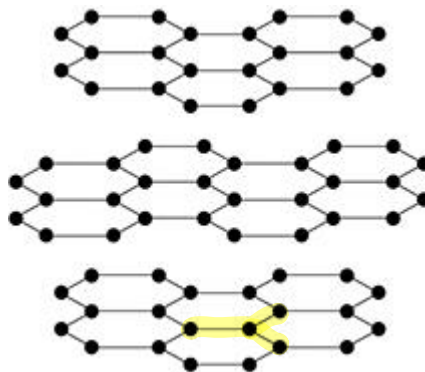
Boiling:
 Covalent bonds are not being broken.
 Intermolecular ones are!

- The covalent bonds are strong.
- The covalent bonds are weak.
- The **intermolecular forces** are strong.
- The **intermolecular forces** are weak.

(1)

(f) **Figure 3** represents the structure of graphite.

Figure 3



Explain why graphite is:

- a **good electrical conductor**
- **soft and slippery**.

You should answer in terms of **structure** and **bonding**.

Carbon atoms in the graphite layers are covalently bonded to three other carbon atoms to form a giant molecular structure. As carbon (Group 4) has four valence electrons, three are used in bonding to other carbon atoms and the fourth electron is left over. It is delocalised and free to move through the structure, carrying electrical charge. Thus graphite conducts electricity.

Graphite is a layered structure of interlocking hexagonal rings with weak intermolecular forces between the layers, so they slide over each other easily, hence use as a lubricant.

(6)

(Total 11 marks)

Q2.

This question is about Group 1 elements.

- (a) Give **two** observations you could make when a small piece of potassium is added to water.

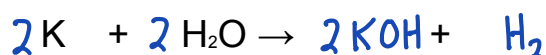
1 Observe effervescence, bubbles

2 Observe a lilac flame

(2)

- (b) Complete the equation for the reaction of potassium with water.

You should balance the equation.



(2)

- (c) Explain why the reactivity of elements changes going down Group 1.

Reactivity increases going down the group.

Because the outer electron (shell) is further from the nucleus

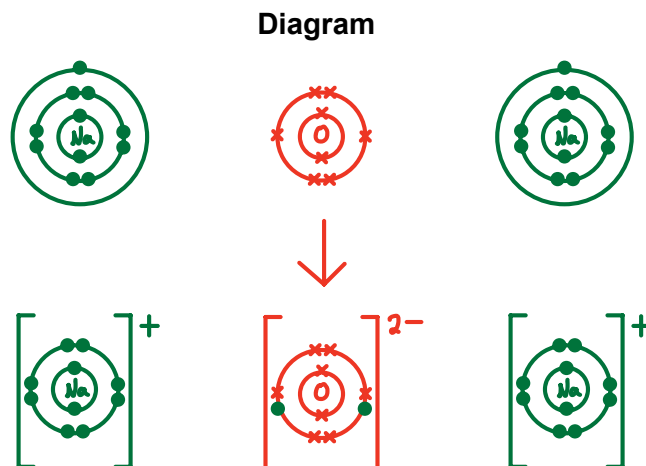
So there is less attraction between the nucleus and the outer electron. So the atom loses an electron more easily.

(4)

Sodium reacts with oxygen to produce the ionic compound sodium oxide.

Oxygen is a Group 6 element.

- (d) Draw a dot and cross diagram to show what happens when atoms of sodium and oxygen react to produce sodium oxide.



(4)

- (e) Why is oxygen described as being reduced in the reaction between sodium and oxygen?

Because it gains electrons

OILRIG

(1)

- (f) Explain why sodium oxide has a high melting point.

Na_2O is a giant structure (ionic lattice) with strong electrostatic forces of attraction between oppositely charged ions.

So large amounts of energy are needed to overcome these and break the bonds.

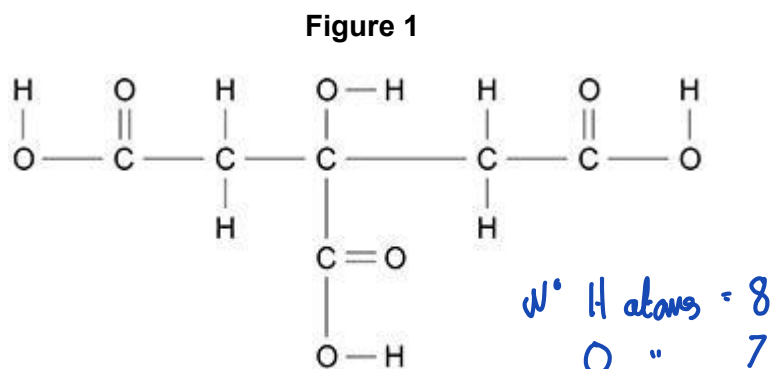
(3)

(Total 16 marks)

Q3.

This question is about citric acid.

Figure 1 represents one molecule of citric acid.



(a) Complete the molecular formula of citric acid.

Use **Figure 1**.



(1)

(b) What type of bonding is shown in **Figure 1**?

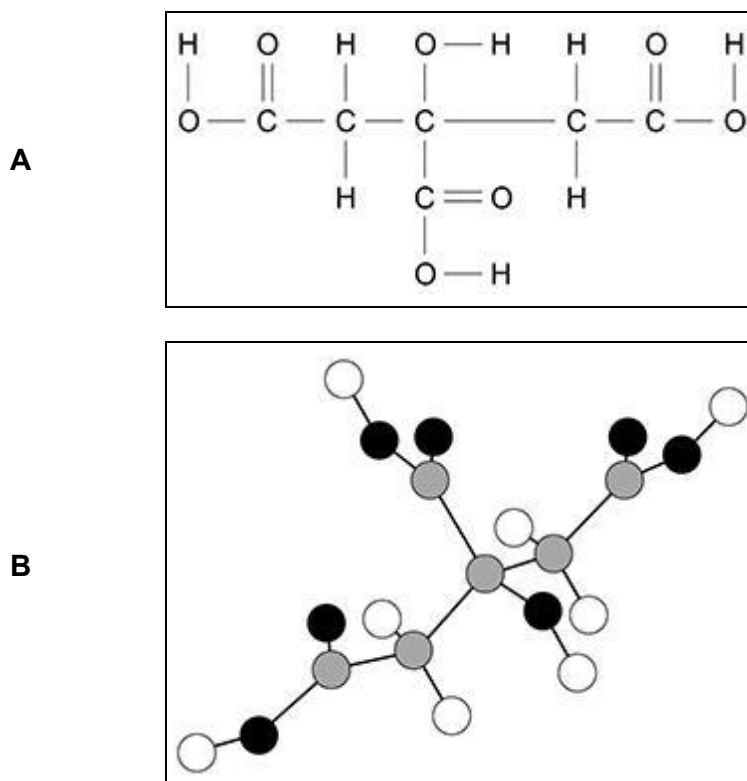
Tick (✓) **one** box.

- | | |
|----------|-------------------------------------|
| Covalent | <input checked="" type="checkbox"/> |
| Ionic | <input type="checkbox"/> |
| Metallic | <input type="checkbox"/> |

(1)

(c) **Figure 2** shows two representations of one molecule of citric acid, **A** and **B**.

Figure 2



Give **two** advantages of representation **A** compared with representation **B**.

Advantages of **A**:

- 1 Shows single and double covalent bonds
- 2 Shows which atoms are which element

(2)

A student investigated the temperature change during the reaction between citric acid and sodium hydrogencarbonate solution.

Citric acid is a solid.

This is the method used.

1. Pour 25 cm³ of sodium hydrogencarbonate solution into a polystyrene cup.
2. Measure the temperature of the sodium hydrogencarbonate solution.
3. Add 0.25 g of citric acid to the cup.
4. Stir the solution.
5. Measure the temperature of the solution.
6. Repeat steps 3 to 5 until a total of 2.00 g of citric acid has been added.

The table below shows some of the student's results.

Mass of citric acid added in g	Temperature of solution in °C
0.00	22.6
0.25	22.2
0.50	21.8
0.75	21.4
1.00	21.0
1.25	20.6

(d) How do the results in table above show that the reaction is endothermic?

Temperature decreases during the reaction

(1)

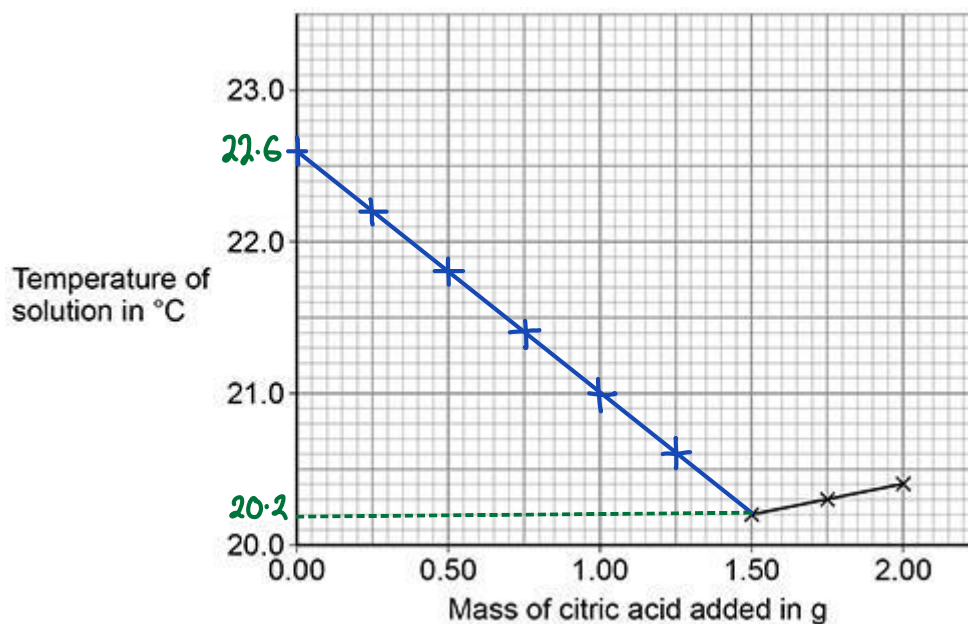
(e) Three of the student's results are plotted on the graph below.

A line of best fit for these points is drawn.

Complete the graph below.

You should:

- plot the data from table above on the graph below
- draw a line of best fit through the points you have plotted
- extend your line of best fit to meet the line of best fit already drawn on the graph below.



(4)

- (f) Determine the overall temperature change for the reaction.

Use the graph above.

$$22.6 - 20.2 = 2.4$$

Overall temperature change = 2.4 °C

(2)

- (g) What is the dependent variable in this investigation?

Tick (✓) **one** box.

Mass of citric acid

Temperature of solution

Volume of solution

(1)

(Total 12 marks)

Q4.

This question is about structure and bonding.

- (a) Which **two** substances have intermolecular forces between particles?

Tick (✓) **two** boxes.

Diamond

Magnesium

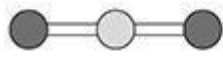
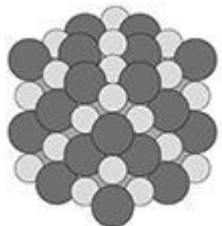
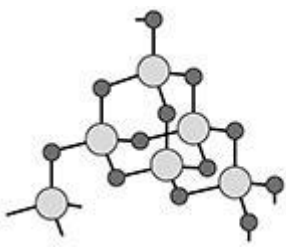
Poly(ethene)

Sodium chloride

Water

(2)

- (b) The table below shows the structures of three compounds.

Compound	Structure
Carbon dioxide CO_2	 <p>Key</p> <ul style="list-style-type: none"> ● O ○ C
Magnesium oxide MgO	 <p>Key</p> <ul style="list-style-type: none"> ● O^{2-} ○ Mg^{2+}
Silicon dioxide SiO_2	 <p>Key</p> <ul style="list-style-type: none"> ● O ○ Si

Compare the **structure** and **bonding** of the three compounds:

- carbon dioxide
- magnesium oxide
- silicon dioxide.

N.B. NOT b.p. or m.p.!

CO_2 and SiO_2 are made up of atoms, MgO from ions
 SiO_2 and MgO are giant structures.

CO_2 is small molecules with weak intermolecular forces
 All three compounds have strong bonds.

CO_2 & SiO_2 formed from two non-metals

\therefore covalent bonds where electron pairs shared between atoms

MgO bonding is ionic - electrons transferred from
 Mg to O . ($Mg \rightarrow Mg^{2+} + 2e^-$ $O + 2e^- \rightarrow O^{2-}$)

SiO_2 bonds are single, Si forms 4 bonds, O: 2 bonds

In CO_2 , bonds are double bonds,

where C forms 2 double bonds and

O forms 1 double bond.

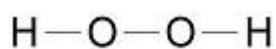
(6)

(Total 8 marks)

Q5.

This question is about compounds of oxygen and hydrogen.

Figure 1 represents the structure of hydrogen peroxide.

Figure 1

- (a) What is the correct formula of hydrogen peroxide?

Tick (✓) **one** box.

H₂O₂HO₂H²O²H₂O₂

*no 1-1 atoms = 2
no 0 atoms = 2
written as sub-script.*

(1)

- (b) Which type of bonding is shown in **Figure 1**?

Tick (✓) **one** box.

Covalent

Ionic

Metallic

(1)

- (c) Hydrogen peroxide decomposes in the presence of a catalyst.

Which elements are often used as catalysts?

Tick (✓) **one** box. **(separate only)**

- Alkali metals
- Halogens
- Transition metals

(1)

Figure 2 shows the reaction profile for the decomposition of hydrogen peroxide.

The word equation for this reaction is:

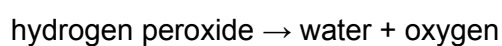
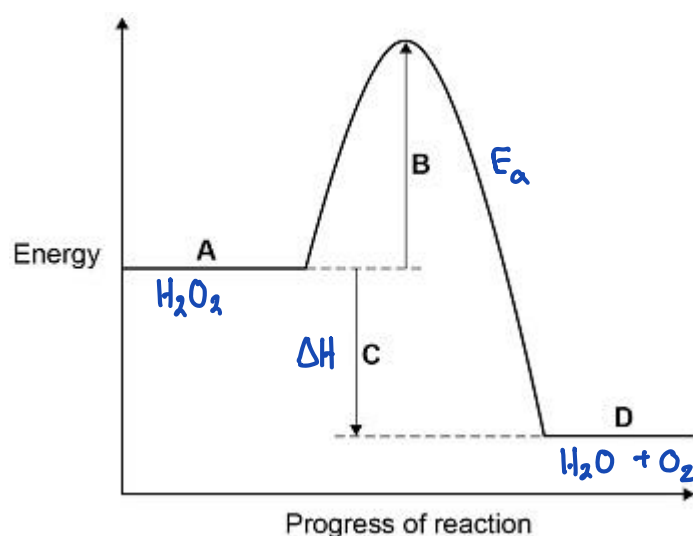


Figure 2



E_a = Activation Energy
ΔH = Enthalpy change of reaction

Labels **A**, **B**, **C** and **D** each represent a different part of the reaction profile.

Use **Figure 2** to answer parts (d) and (e).

(d) Which label shows the activation energy?

Tick (✓) **one** box.

- A** **B** **C** **D**

(1)

(e) Which label shows the energy of hydrogen peroxide?

Tick (✓) **one** box.

A B C D

(1)

- (f) The decomposition of hydrogen peroxide gives out energy to the surroundings.

What type of reaction is this?

Tick (✓) **one** box.

Displacement

Endothermic

Exothermic

Neutralisation



(1)

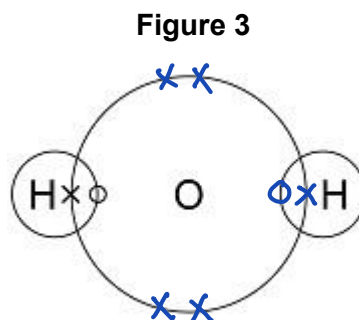
- (g) Hydrogen and oxygen form water.

A hydrogen atom contains one electron.

An oxygen atom contains six electrons in the outer shell.

Complete **Figure 3** to show a dot and cross diagram for a water molecule.

Show the outer electrons only.



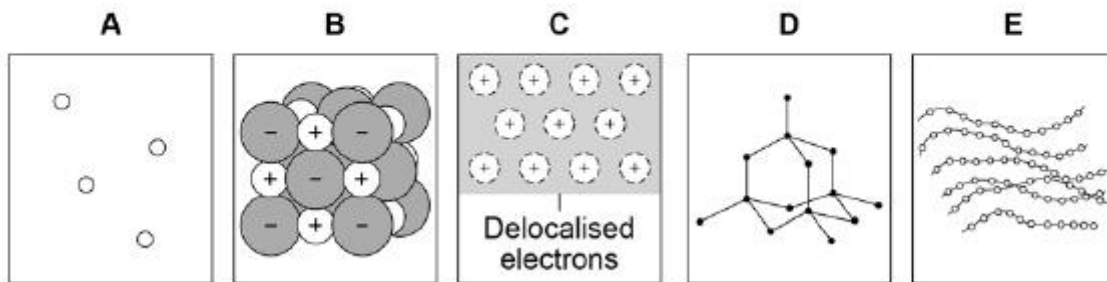
(2)

(Total 8 marks)

Q6.

Figure 1 shows the structure of five substances.

Figure 1



(a) Which diagram shows a gas?

Tick (✓) **one** box.

A B C D E

(1)

(b) Which diagram shows the structure of diamond?

Tick (✓) **one** box.

A B C D E

(1)

(c) Which diagram shows a metallic structure?

Tick (✓) **one** box.

A B C D E

(1)

(d) Which diagram shows a polymer?

Tick (✓) **one** box.

A B C D E

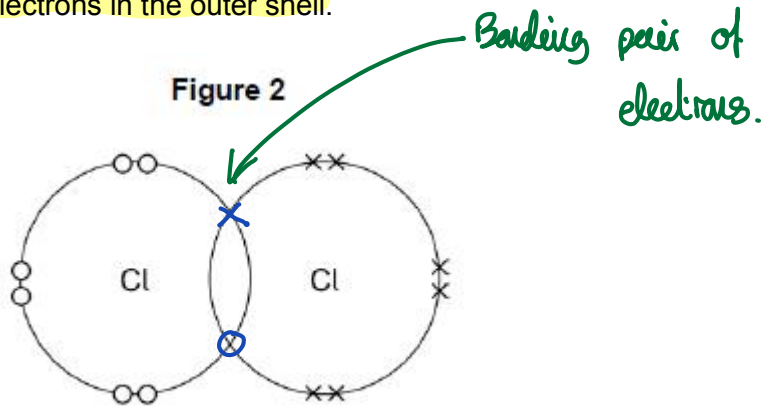
(1)

(e) A chlorine atom has 7 electrons in the outer shell.

Two chlorine atoms covalently bond to form a chlorine molecule, Cl₂

Figure 2 is a dot and cross diagram showing the outer shells and some electrons in a chlorine molecule.

Complete the dot and cross diagram.
 Show only the **electrons in the outer shell**.



(1)

(f) What is the reason for chlorine's **low** boiling point?

Tick (✓) **one** box.

Strong covalent bonds

Strong forces between molecules

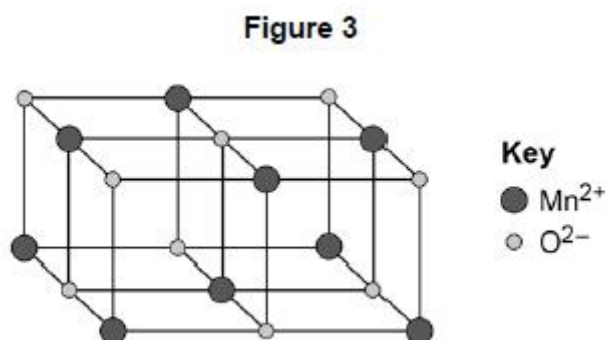
Weak covalent bonds ✗

Weak forces between molecules

(1)

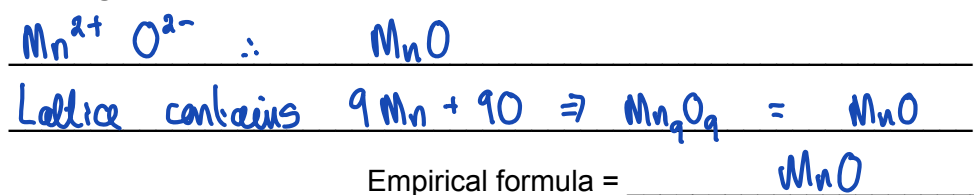
Figure 3 represents the structure of manganese oxide.

Manganese oxide is an ionic compound.



(g) Determine the **empirical formula** of manganese oxide.

Use Figure 3.



(1)

- (h) Why does **manganese oxide** conduct electricity as a liquid?

Tick (✓) **one** box.

Atoms move around in the liquid

Electrons move around in the liquid

Ions move around in the liquid

Molecules move around in the liquid

(1)

(Total 8 marks)

Q7.

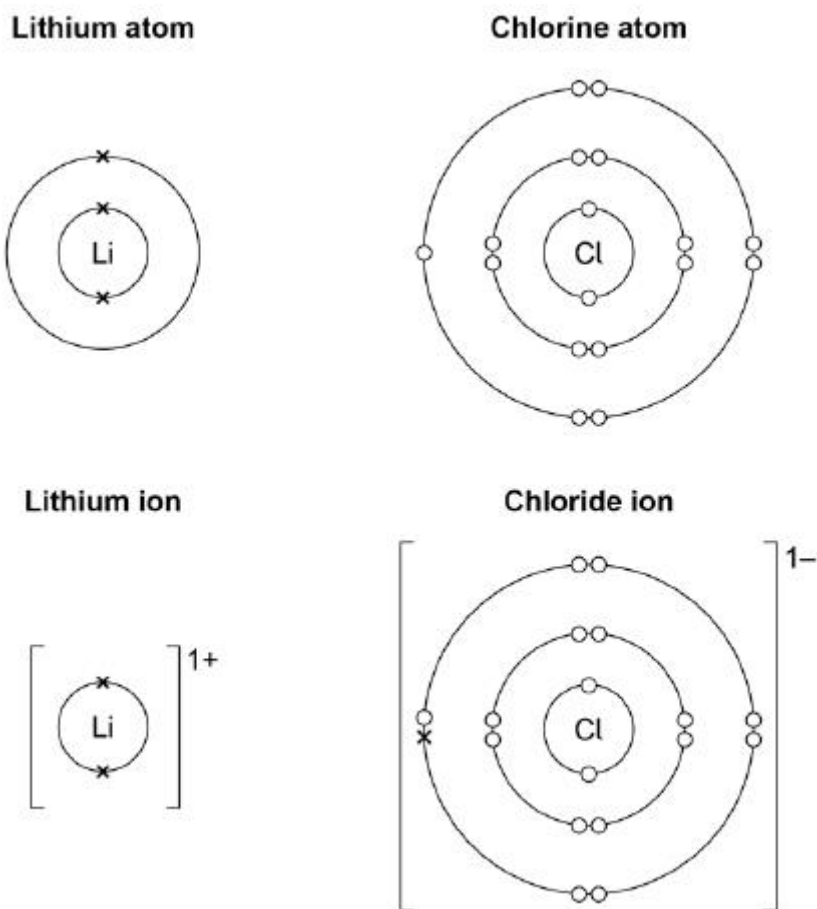
This question is about metal compounds.

- (a) Lithium reacts with chlorine to produce lithium chloride.

When lithium atoms and chlorine atoms react to produce lithium chloride, lithium ions and chloride ions are formed.

The diagram shows the electronic structures of the atoms and ions.

The symbols **o** and **x** are used to represent electrons.



Describe what happens when a lithium atom reacts with a chlorine atom.

Answer in terms of electrons.

Li atom loses one electron

Cl atom gains one electron

During the reaction, the electron is transferred from Li to Cl to form ions.

Li forms a positive ion $\text{Li} \rightarrow \text{Li}^+ + \text{e}^-$

Cl forms a negative ion $\text{Cl} + \text{e}^- \rightarrow \text{Cl}^-$

(4)

Zinc sulfate can be made by two methods.

The equations for the two methods are:





- (b) Calculate the **percentage atom economy** for making zinc sulfate in **Method 1**.

Use the equation: $\% \text{ atom economy} = \frac{\text{Mass of desired product}}{\text{Total mass of reactants}} \times 100$

percentage atom economy =

$$\frac{\text{relative formula mass of ZnSO}_4}{\text{relative formula mass of ZnO} + \text{relative formula mass of H}_2\text{SO}_4} \times 100$$

Give your answer to **3 significant figures**.

Relative formula masses (M_r): ZnO = 81 H₂SO₄ = 98 ZnSO₄ = 161 (**separate only**)

$$\begin{aligned} \% \text{ atom economy} &= \frac{161}{81 + 98} \times 100 \\ &= \frac{161}{179} \times 100 \\ &= 89.944 \end{aligned}$$

Percentage atom economy = 89.9 (3 s.f.) %

(3)

- (c) **Method 1** gives a higher percentage atom economy for making zinc sulfate than **Method 2**.

Give a reason why it is important to use a reaction with a high atom economy. (**separate only**)

Reaction is more sustainable
(there will be less waste)

(1)

- (d) A student uses 50 cm³ of a zinc sulfate solution of 80 g/dm³

What mass of zinc sulfate is dissolved in 50 cm³ of this zinc sulfate solution?

$$\begin{aligned} \text{Sol}^n \text{ contains } 80\text{g per dm}^3 \\ \text{Convert } 50 \text{ cm}^3 \text{ to } \text{dm}^3 &= \frac{50}{1000} = 0.05 \text{ dm}^3 \\ \text{Mass of ZnSO}_4 \text{ in } 50 \text{ cm}^3 &= 0.05 \text{ dm}^3 \times \frac{80 \text{ g}}{\text{dm}^3} \end{aligned}$$

Mass = 4 g

(2)

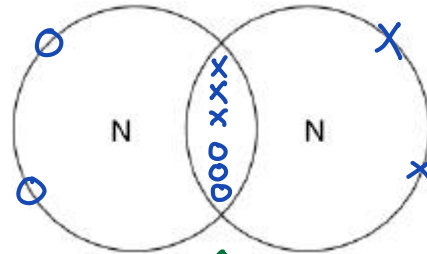
(Total 10 marks)

Q8.

This question is about structure and bonding.

- (a) Complete the dot and cross diagram to show the covalent bonding in a nitrogen molecule, N_2

Show only the electrons in the outer shell.



N in Group 5 $\therefore 5e^-$ in outer shell
Needs $8-5 = 3e^-$ for full shell

Triple bond
 $N \equiv N$
 \uparrow W.B. $6e^-$ shared, 3 bonding pairs⁽²⁾

- (b) Explain why nitrogen is a gas at room temperature.

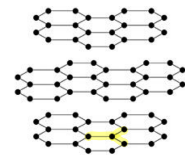
Answer in terms of nitrogen's structure.

N_2 is a gas at room temperature due to weak forces between molecules (weak intermolecular forces) which need very little energy to overcome.

(3)

- (c) Graphite and fullerenes are forms of carbon.

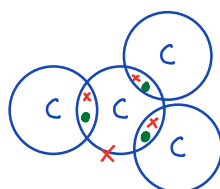
Graphite is soft and is a good conductor of electricity.



Explain why graphite has these properties.

Answer in terms of structure and bonding.

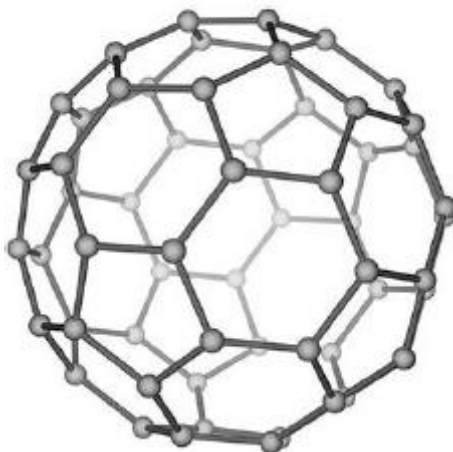
Each Carbon atom forms 3 covalent bonds to form layers of hexagonal rings. Weak bonds between layers.
SOFT: because layers can slide over each other
CONDUCTS: C in Group 4 has 4 outer shell e^- . 3 used in bonding. Remaining e^- is delocalised and can conduct electricity.



(4)

(d) **Figure 1** shows a model of a Buckminsterfullerene molecule.

Figure 1



A lubricant is a substance that allows materials to move over each other easily.

Suggest why Buckminsterfullerene is a good lubricant.

Use **Figure 1**.

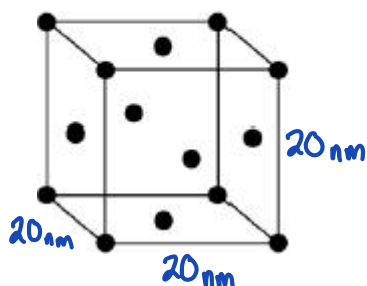
The molecule is spherical, so can 'roll' like a ball bearing.

(2)

Silver can form cubic nanocrystals.

Figure 2 represents a silver nanocrystal.

Figure 2



- (e) A silver nanocrystal is a cube of side 20 nm

Calculate the surface area to volume ratio of the nanocrystal. (separate only)

$$\begin{aligned} \text{Surface Area: Area of 1 side} &= 20_{\text{nm}} \times 20_{\text{nm}} = 400 \text{ nm}^2 \\ \text{N. of sides} &= 6 \\ \text{Total S.A.} &= 6 \times 400 \text{ nm}^2 = 2400 \text{ nm}^2 \\ \text{Volume: } 20_{\text{nm}} \times 20_{\text{nm}} \times 20_{\text{nm}} &= (20_{\text{nm}})^3 = 8000 \text{ nm}^3 \\ \text{S.A. : V} & 2400 : 8000 \end{aligned}$$

$$\frac{2400}{2400} : \frac{8000}{2400} \quad \text{Surface area to volume ratio} = \frac{1}{3.33} : 3.33$$

$$\frac{1}{3} : \frac{3.33}{10} \times 3 \quad \text{or } 3 : 10 \quad (3)$$

- (f) Silver nanoparticles are sometimes used in socks to prevent foot odour.

Suggest why it is cheaper to use nanoparticles of silver rather than coarse particles of silver. (separate only)

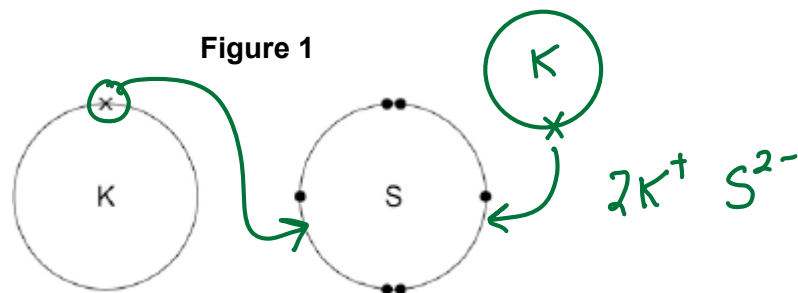
Since nanoparticles have a larger S.A. to Volume ratio, less silver is used for the same effect.

(2)

(Total 16 marks)

Q9.

Figure 1 shows the outer electrons in an atom of the Group 1 element potassium and in an atom of the Group 6 element sulfur.



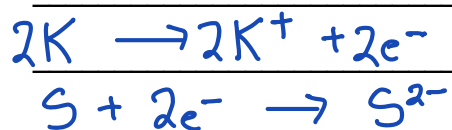
- (a) Potassium forms an ionic compound with sulfur.

Describe what happens when **two** atoms of potassium react with **one** atom of sulfur.

Give your answer in terms of **electron transfer**.

Give the **formulae** of the **ions** formed.

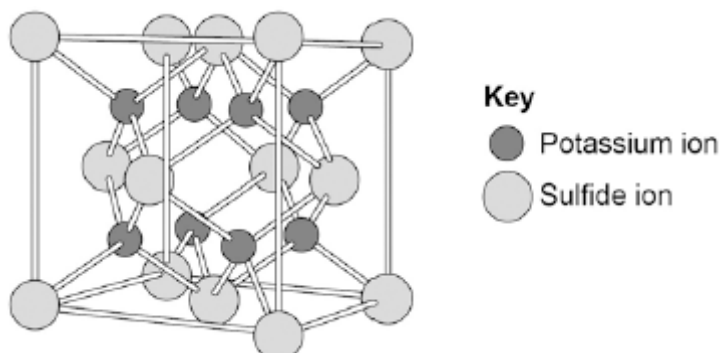
2 K atoms each lose 1 outer electron.
 (to have full outer shell), forming K^+ +1 ions
 Both electrons are transferred to, and gained by
 an S atom to form S^{2-} 2- ion



(5)

- (b) The structure of potassium sulfide can be represented using the ball and stick model in **Figure 2**.

Figure 2



The ball and stick model is **not** a true representation of the structure of potassium sulfide.

Give **one** reason why.

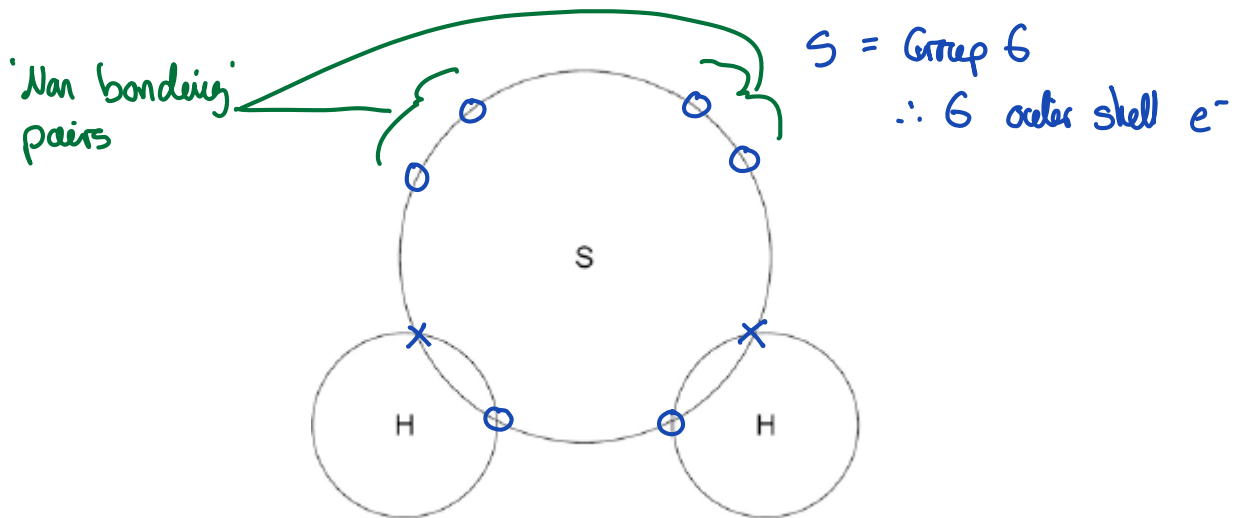
There are no gaps (or sticks) between the K^+ and S^{2-} ions.

(1)

- (c) Sulfur can also form covalent bonds.

Complete the dot and cross diagram to show the covalent bonding in a molecule of hydrogen sulfide.

Show the outer shell electrons only.



(2)

- (d) Calculate the relative formula mass (M_r) of aluminium sulfate $\text{Al}_2(\text{SO}_4)_3$

Relative atomic masses (A_r): oxygen = 16; aluminium = 27; sulfur = 32

$$\begin{array}{l}
 \text{Mass of Al: } 2 \text{ Al atoms} = 2 \times 27 = 54 \\
 \text{Mass of } \text{SO}_4: 1 \text{ S } 4 \text{ O atoms} = 32 + (4 \times 16) = 96 \\
 3 \text{ 'SO}_4\text{' ions } \therefore M_r \text{ Al}_2(\text{SO}_4)_3 = 54 + (96 \times 3) = 342 \\
 \text{Relative formula mass} = \underline{\underline{342}}
 \end{array}$$

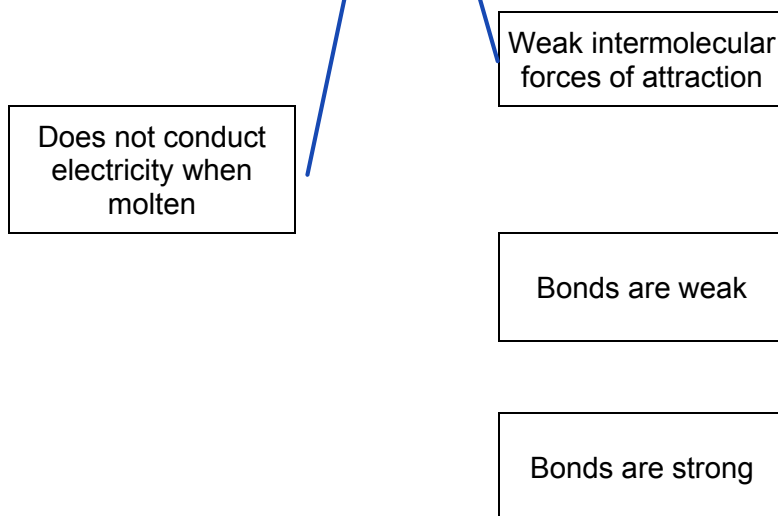
(2)

- (e) Covalent compounds such as hydrogen sulfide have low melting points and do **not** conduct electricity when molten.

Draw **one** line from each property to the explanation of the property.

Property	Explanation of property
Low melting point	Electrons are free to move
	There are no charged particles free to move
	Ions are free to move

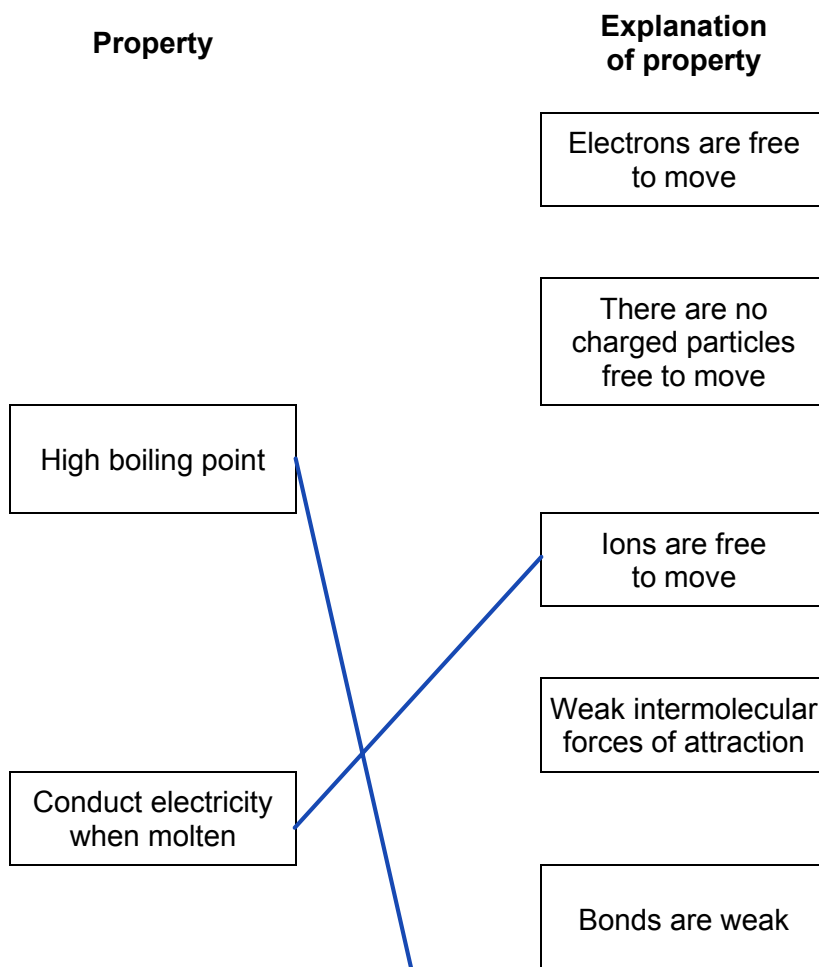
Note: Handwritten blue lines connect 'Low melting point' to 'There are no charged particles free to move' and 'Ions are free to move'.



(2)

- (f) Ionic compounds such as potassium sulfide have high boiling points and conduct electricity when dissolved in water.

Draw **one** line from each property to the explanation of the property.



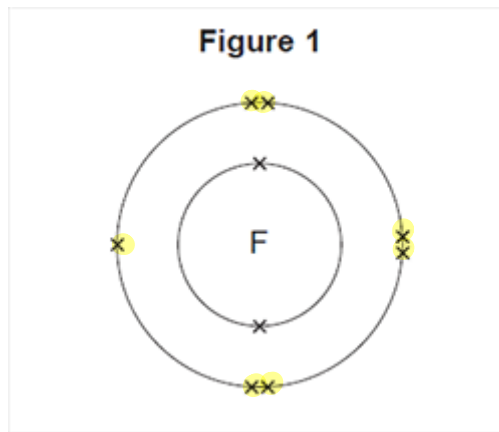
Bonds are strong

(2)
(Total 14 marks)

Q10.

This question is about fluorine.

(a) **Figure 1** shows the arrangement of electrons in a fluorine atom.



*W. e⁻ in outer shell: 7
∴ F in Group 7*

(i) In which group of the periodic table is fluorine?

Group 7

(1)

(ii) Complete the table below to show the particles in an atom and their relative masses.

Name of particle	Relative mass
Proton	1
Neutron	1
<i>Electron</i>	Very small

(2)

(iii) Use the correct answer from the box to complete the sentence.

alkalis alloys isotopes

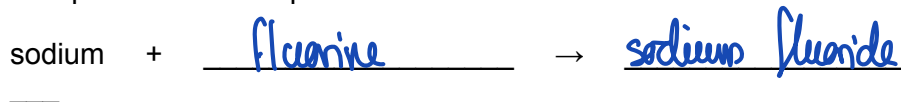
Atoms of fluorine with different numbers of neutrons are

called isotopes.

↳ Same element, different masses. (1)

(b) Sodium reacts with fluorine to produce sodium fluoride.

- (i) Complete the word equation for this reaction.



(1)

- (ii) Complete the sentence.

Substances in which atoms of two or more different elements are chemically

combined are called compounds.

(1)

- (iii) The relative formula mass (M_r) of sodium fluoride is 42.

Use the correct answer from the box to complete the sentence.

ion	mole	molecule
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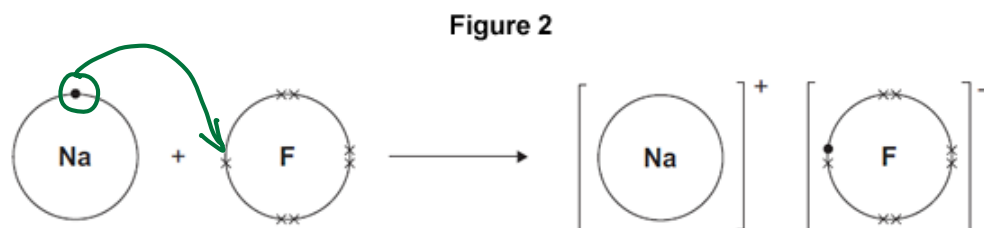
The relative formula mass (M_r), in grams, of sodium fluoride is one

mole of the substance.

(1)

- (iv) **Figure 2** shows what happens to the electrons in the outer shells when a sodium atom reacts with a fluorine atom.

The dots (•) and crosses (×) represent electrons.



Use **Figure 2** to help you answer this question.

Describe, as fully as you can, what happens when sodium reacts with fluorine to produce sodium fluoride.

Na atom loses e^- to form Na^+ ion
Electron transferred to, and gained by F atom
to form F^- negative ion.



(4)

(v) Sodium fluoride is an ionic substance.

What are two properties of ionic substances?

Tick (✓) two boxes.

Dissolve in water

Gas at room temperature

High melting point

Low boiling point

(2)

(Total 13 marks)