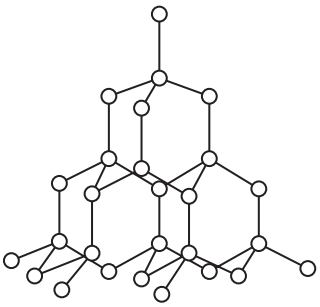
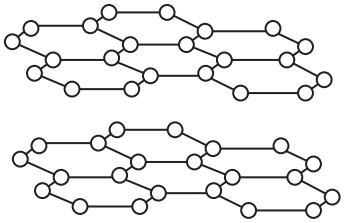
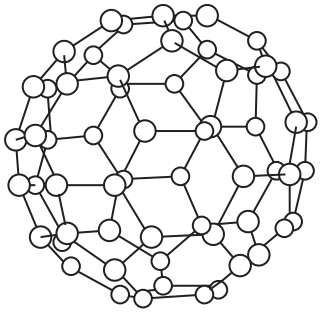
**1** The diagram shows three different forms of carbon.



diamond structure



graphite structure



fullerene molecule

(a) Name the type of bond that exists between the carbon atoms in all three structures.

**(1)**

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(b) (i) Explain why diamond has a very high melting point.

**(4)**

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(ii) Fullerene has a simple molecular structure.

Explain why it has a low melting point.

**(2)**

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(c) There are two theories used to explain why graphite can act as a solid lubricant.

Theory A — The forces of attraction between the layers are weak, allowing the layers to slide over one another.

Theory B — Gas molecules are trapped between the layers allowing the layers to slide over one another.

The table shows the ability of graphite to act as a lubricant in different locations.

| Location | Ability to act as a lubricant |
|---|---|
| Earth's surface | good |
| high altitude | average |
| outer space | very poor |

Suggest which theory is supported by the evidence in the table.

Give a reason for your choice.

**(1)**

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(d) Graphite and diamond can be changed from one form to the other according to the equation

$$C(\text{graphite}) \rightleftharpoons C(\text{diamond}) \qquad \Delta H = +1.9 \text{ kJ/mol}$$

Would a low or a high temperature favour the conversion of graphite into diamond?

Give a reason for your choice.

**(1)**

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**(Total for Question 1 = 9 marks)**

**2** Ethene can be converted into many useful substances.

(a) Draw a dot and cross diagram to show the covalent bonding in a molecule of ethene. Only the outer electrons in each atom need to be shown.

**(2)**

(b) Compound X is made from ethene and is used in cars to prevent the engine coolant from freezing in cold weather.

(i) Compound X contains 38.7% carbon, 9.7% hydrogen and 51.6% oxygen by mass.

Calculate the empirical formula of X.

**(3)**

Empirical formula .....

(ii) The relative formula mass ($M_r$) of X is 62

What is the molecular formula of X?

**(1)**

Molecular formula .....

**(Total for Question 2 = 6 marks)**

**3** Hydrogen chloride is formed in the reaction between hydrogen and chlorine.
The equation for the reaction is

$$H_2 + Cl_2 \rightarrow 2HCl$$

(a) Each molecule in this equation contains the same type of bonding.

Name this type of bonding.

**(1)**

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(b) The bonding in a hydrogen molecule is strong.

Explain why the boiling point of hydrogen is low.

**(2)**

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(c) Explain how the two atoms in a chlorine molecule are held together.

**(2)**

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(d) Draw a dot and cross diagram to show the bonding in a hydrogen chloride molecule.

Show only the outer electrons in each atom.

**(2)**

(e) Hydrogen chloride gas dissolves in water to form solution A.

Hydrogen chloride gas dissolves in methylbenzene to form solution B.

A teacher adds a piece of magnesium ribbon to each solution.

Explain why she observes effervescence with solution A but not with solution B.

**(3)**

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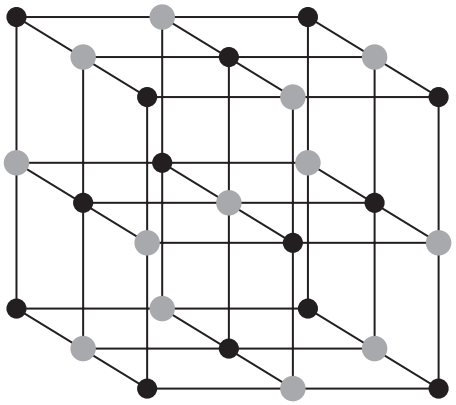
**(Total for Question 3 = 10 marks)**

**4** Sodium chloride (NaCl) and silicon dioxide ($SiO_2$) both have giant lattice structures.

Sodium chloride is an ionic compound.

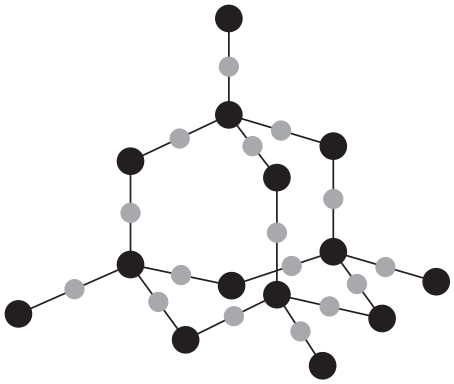
Silicon dioxide is a covalent compound.

Structure of sodium chloride



● $Na^+$ ● $Cl^-$

Structure of silicon dioxide



● Si ● O

The table shows some properties of each compound.

| Sodium chloride | Silicon dioxide |
|---|---|
| melting point = 801 °C | melting point = 1610 °C |
| soluble in water | insoluble in water |
| conducts electricity when molten | does not conduct electricity when molten |

(a) (i) Explain why silicon dioxide has a high melting point.

**(2)**

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(ii) Suggest why the melting point of silicon dioxide is higher than the melting point of sodium chloride.

**(1)**

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(b) State why sodium chloride conducts electricity when molten.

**(1)**

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(c) Carbon dioxide is described as a simple molecular substance.

State why carbon dioxide ($CO_2$) is a gas at room temperature.

**(1)**

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**(Total for Question 4 = 5 marks)**

**5** A sample of a chlorofluorocarbon (CFC) contains 0.24 g of carbon, 0.38 g of fluorine and 1.42 g of chlorine.

(a) (i) Show, by calculation, that the empirical formula of the CFC is $CFCl_2$

**(3)**

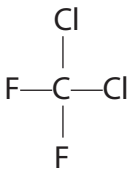
(ii) The relative formula mass of the CFC is 204.

Deduce the molecular formula of the CFC.

**(2)**

molecular formula .....

(b) The displayed formula of another CFC is




Draw a dot and cross diagram of this CFC.

Show only the outer electrons.

**(2)**

**(Total for Question 5 = 7 marks)**

**6** Molybdenum (Mo) is a metal. It is often used to make an alloy with iron.

Like iron, it is extracted from its oxide. Unlike iron, it occurs mainly as its sulfide.

(a) Molybdenum sulfide is converted into molybdenum oxide by heating in air.
The equation for this reaction is

$$2MoS_2 + 7O_2 \rightarrow 2MoO_3 + 4SO_2$$

(i) Why is molybdenum said to be oxidised in this reaction?

**(1)**

(ii) The sulfur dioxide formed in the reaction could form acid rain if it escaped into the atmosphere.

Write a chemical equation for the formation of an acid from sulfur dioxide.

**(1)**

(b) The table shows the melting points of molybdenum oxide and sulfur dioxide.

| | **Melting point in °C** |
|---|---|
| molybdenum oxide | 800 |
| sulfur dioxide | –75 |

The melting point indicates the type of bonding and structure in a compound.

(i) What is the type of bonding in a molecule of sulfur dioxide?

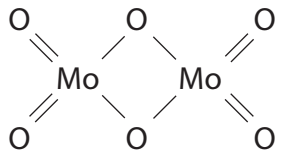
**(1)**

(ii) Explain why the melting point of sulfur dioxide is low.

**(2)**

(iii) The melting point of molybdenum oxide suggests that it has ionic bonding. However, it is often represented as a molecular structure.

Deduce the molecular formula of molybdenum oxide as shown in this structure.




**(1)**

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(c) The metallic structure of molybdenum gives it some typical properties.

(i) Describe the metallic structure of molybdenum.

**(2)**

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(ii) Explain why molybdenum is a good conductor of electricity.

**(2)**

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(iii) Explain why molybdenum is malleable.

**(2)**

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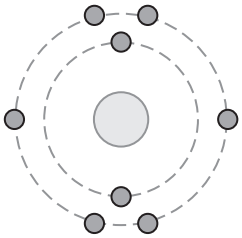
**(Total for Question 6 = 12 marks)**

**7** The diagram shows how the electrons are arranged in an atom of oxygen.



Oxygen atoms form both covalent and ionic bonds.

(a) Water is formed when two atoms of hydrogen combine with one atom of oxygen.

(i) Draw a dot and cross diagram of a molecule of water. You need only show the electrons in the outer shells.

**(2)**

(ii) Explain how the covalent bonds in the water molecule hold the hydrogen and oxygen atoms together.

**(2)**

(b) The electronic configuration of a sodium atom is 2.8.1
Sodium oxide, $Na_2O$, is an ionic compound formed when sodium reacts with oxygen.

(i) Describe, in terms of electrons, what happens when sodium oxide is formed in this reaction.

**(3)**

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(ii) The reaction of sodium to form sodium oxide can be described as oxidation because it involves the addition of oxygen.

State one other reason why this reaction can be described as oxidation.

**(1)**

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(c) Explain why water has a much lower melting point than sodium oxide.

**(2)**

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(d) A teacher added sodium oxide to water in a beaker.
The equation shows the reaction that occurred.

$$Na_2O(.....) + H_2O(.....) \rightarrow 2NaOH(.....)$$

(i) Insert the appropriate state symbols in this equation.

**(2)**

(ii) Some universal indicator was then added to the beaker. A colour change occurred. State the final colour of the universal indicator and identify the ion responsible for the colour change.

**(2)**

Final colour .....

Ion responsible for colour change .....

**(Total for Question 7 14 marks)**