Structure and Bonding

Mark Scheme

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1. At the core of all chemical reactions is the drive for atoms to achieve a stable, full outer shell of electrons, which they do by forming ionic, covalent, or metallic bonds.

   Circle the letter of the correct answer for each of the following questions.

a) A chemist was examining the structure of an alloy. The figure below shows the image of the alloy.

What is the simplest ratio of lead atoms to tin atoms in the alloy?

D – is the only correct answer.	(1)
	Total: 1 mark

b) Graphite is an allotrope of carbon with a giant covalent structure.
Which statement gives a **correct** description of graphite?

C – is the only correct answer.	(1)
	Total: 1 mark

c) Which of the following figures shows the structure of an alloy?

B – is the only correct answer.	(1)
	Total: 1 mark

d) A student is given an unknown substance, **Q**. They record the following properties:

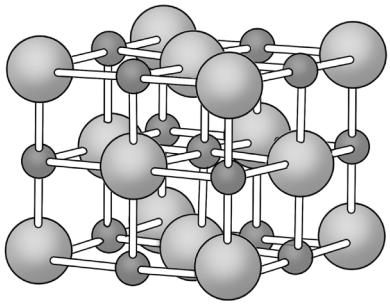
- It is a shiny, silver-coloured solid.
- It is a good conductor of heat and electricity.

Which of the following statements about substance **Q** is correct?

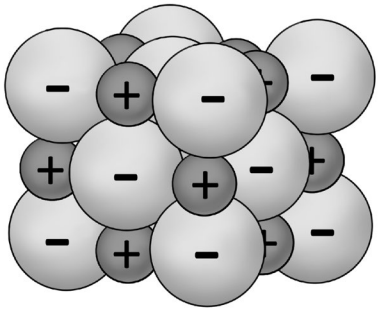
D – is the only correct answer.	(1)
	Total: 1 mark

(Total for Question 1 is 4 marks)

2. The figures below show **two** different models that can be used to represent the giant ionic lattice of sodium chloride, NaCl.



Ball and stick model



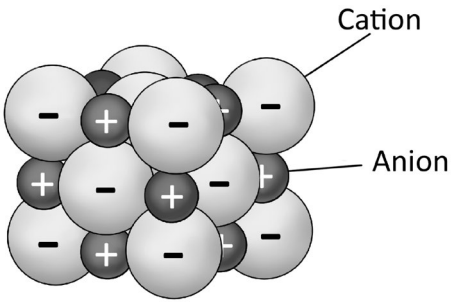
Space filling model

a) A student is using the ball-and-stick model to represent an ionic compound.

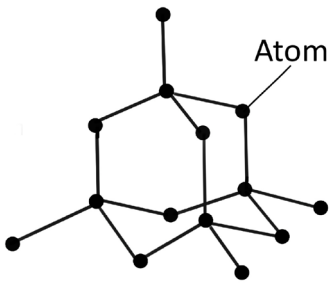
Describe **two** limitations of this model for showing the structure of an ionic compound.

Any **two** from:	
• It shows gaps between the ions (which do not exist in reality). • It does not show the correct relative sizes of the ions. • It implies there are physical 'sticks' holding ions together (forces are electrostatic). • It is 2D / does not show the 3D lattice (if referring to a 2D drawing).	
	Total: 2 marks

The figures below show two different arrangements of particles in the solid state.
Structure **A** is formed from charged ions, while structure **B** is formed from neutral atoms



A



B

b) Describe the bonding shown in structure A.
Your answer should identify the type of bonding and a reason for your choice.

Structure A: Ionic bonding. **Structure B:** Covalent bonding.	(1)
Reason: A is formed from charged particles / ions, whereas B is formed from neutral atoms (sharing electrons).	(1)
	Total: 2 marks

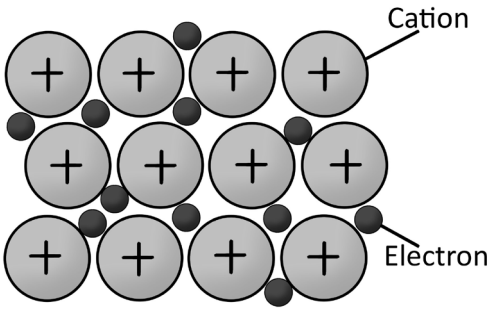
c) Explain, in terms of its **structure and bonding**, why substance B has a high melting point.

It is a giant covalent structure / giant lattice.	(1)
Each atom forms four strong covalent bonds.	(1)
A large amount of energy is needed to break these bonds.	(1)
	Total: 3 marks

d) Explain why substance B cannot conduct electricity.
Your answer should refer to the electrons in its structure.

It has no delocalized electrons / no free ions.	(1)
So charge cannot flow / move through the structure.	(1)
	Total: 2 marks

e) Use the figure of the model below to explain why metals are **malleable**.



Your answer should describe:

- The particles in a metal.
- How these particles are arranged.

The atoms/ions are arranged in layers. **Allow**: Rows.	(1)
These layers can slide over each other (when a force is applied).	(1)
	Total: 2 marks

(Total for Question 2 is 11 marks)

3. The figure below shows models of three different substances, P, Q, and R.

Compare the structure and bonding of substances P, Q, and R.

Marking guidance		
Level	**Marks**	**Descriptor**
Level 1	1 - 2	Basic recognition of at least one structure type (e.g. "P is a gas"). Vocabulary may be limited (e.g. mixing up atoms/molecules).
Level 2	3 - 4	Type of bonding is identified for at least two substances. Some description of structure or properties is given but comparison may be unbalanced.
Level 3	5 - 6	Relevant features of structure and bonding are identified for all three substances. Comparison of particle arrangement and movement is clear and detailed.

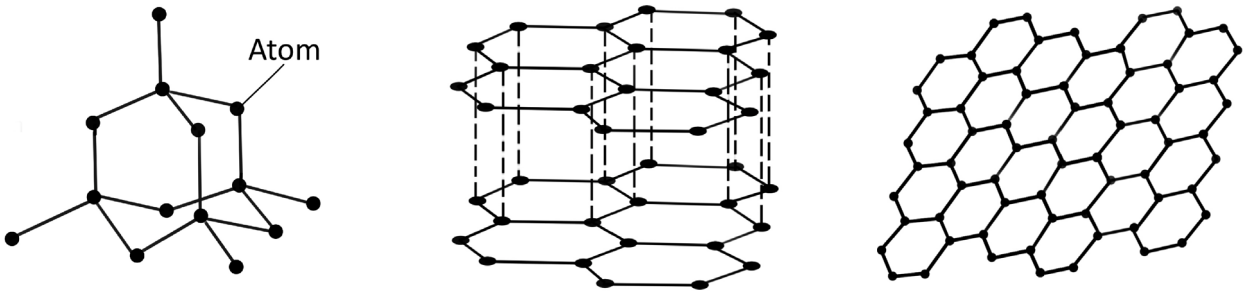
Indicative content:	
Substance P - Carbon Dioxide / Simple Molecular. • **Bonding**: Simple covalent / simple molecular. • **Structure**: Small molecules containing strong covalent bonds between atoms, but weak intermolecular forces between the molecules. • **Arrangement**: The molecules are not organised in a lattice; they are random. • **Movement**: At room temperature, P is likely a gas (or liquid), so the particles are moving randomly and quickly. **Substance Q -** Graphite / Giant Covalent • **Bonding:** Giant covalent bonding. • **Structure:** Each carbon atom is bonded to 3 others. They form hexagonal rings arranged in layers. • **Arrangement:** Regular giant lattice structure. • **Movement:** It is a solid at room temperature, so particles vibrate in fixed positions (they do not move around). • **Note**: Mention of delocalised electrons is credited but the focus is on the comparison of the main structure. **Substance R - Ionic Compound / Giant Ionic** • **Bonding**: Ionic bonding (electrostatic attraction between oppositely charged ions). • **Structure**: Giant ionic lattice. • **Arrangement**: Regular alternating positive and negative ions. • **Movement**: It is a solid at room temperature, so the ions vibrate in fixed positions. **Comparison Summary** • **P** consists of small separate molecules, whereas Q and R are giant continuous lattices. • **P** has weak forces between molecules (low melting point), whereas Q and R have strong bonds throughout (high melting points). • **P** particles move freely (gas), whereas Q and R particles are fixed solids	
	Total: 6 marks

(Total for Question 3 is 6 marks)

4. Carbon can exist in different forms called allotropes.

The figure below shows three different allotropes of carbon.

a) Complete the missing values in the table below.



Diamond **Graphite** **Graphene**

Allotrope	Covalent bonds
Diamond	.....
Graphite	3
Graphene	.....

Diamond = 4	(1)
Graphene = 3	(1)
1 mark for each correct answer.	
	Total: 2 marks

b) Diamond can be used as a cutting tool because it is so hard.

Explain, in terms of its **structure and bonding**, why diamond is a very hard substance.

It is a giant covalent structure / giant lattice. **Allow**: macromolecular.	(1)
Each carbon atom forms four (strong) covalent bonds.	(1)
Which require a lot of energy to break / holds the atoms rigidly in place.	(1)
	Total: 3 marks

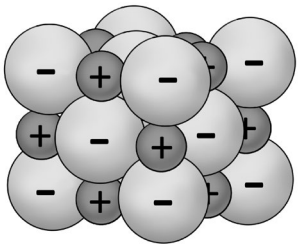
c) The layers in graphite can slide over each other easily, making it useful as a lubricant.

Explain why these layers can slide, with reference to the forces involved.

An explanation to include two of the following:	
The carbon atoms are arranged in layers.	(1)
There are weak forces (intermolecular forces) between the layers.	(1)
So the layers can slide over each other.	(1)
	Total: 2 marks

(Total for Question 4 is 7 marks)

5. This question is about the ionic compound, sodium chloride, NaCl.
The figure below shows the structure on sodium chloride.



a) Describe, in terms of electrons, how a sodium atom and a chlorine atom react to form a sodium ion ,Na^+ and a chloride ion, Cl^-.

Sodium (atom) loses one electron. **Allow**: electron is transferred from sodium to chlorine for 1 mark.	(1)
Chlorine (atom) gains one electron.	(1)
	Total: 2 marks

b) The structure of solid sodium chloride is a giant ionic lattice.

i. What are the forces that hold the ions together in the lattice?

Electrostatic attraction / Electrostatic forces.	(1)
	Total: 1 mark

ii. Explain why sodium chloride has a high melting point.

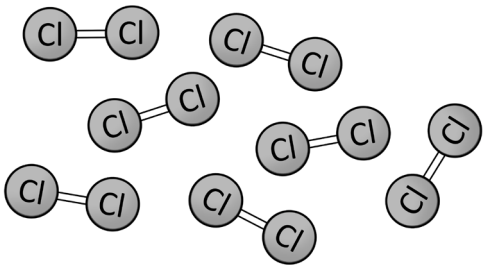
There are strong (electrostatic) forces/bonds between the ions.	(1)
Which require a large amount of energy to overcome / break.	(1)
	Total: 2 marks

c) Explain why solid sodium chloride **does not conduct electricity**, but **molten** sodium chloride **does**.

In solid: Ions are held in fixed positions / in a lattice (so cannot move).	(1)
In molten: Ions are free to move.	(1)
Role: So the ions can carry the charge / current.	(1)
	Total: 3 marks

(Total for Question 5 is 8 marks)

6. Chlorine exists as diatomic molecules. The figure below shows some molecules of chlorine gas.



In a molecule, two chlorine atoms are joined by a covalent bond.

a) Describe what is meant by a **covalent bond**.

A shared pair of electrons	(1)
between two atoms (nuclei).	(1)
	Total: 2 marks

b) Explain why chlorine is a gas, rather than a liquid, at room temperature.

An explanation to include two of	(1)
It is a simple molecular substance / made of small molecules.	
There are weak forces between the molecules (intermolecular forces).	(1)
Which require little energy to overcome.	(1)
	Total: 2 marks

c) This question is about four substances:

Chlorine: a simple molecular substance

Diamond: a giant covalent substance

Sodium chloride: a giant ionic substance

Zinc: a giant metallic substance

Explain the differences in the properties of these substances.

In your answer you should refer to structure and bonding to explain:

- Why chlorine has a very low melting point, while the other three have high melting points.
- Why sodium chloride dissolves in water but diamond does not."

Marking guidance		
Level	**Marks**	**Descriptor**
Level 1	1 - 2	Basic statements about bonding or properties. May confuse structures (e.g. saying chlorine has weak bonds).
Level 2	3 - 4	Relevant features of structure/bonding are identified. There is an attempt to explain both melting point and solubility, but one may be less detailed.
Level 3	5 - 6	A detailed and coherent explanation is provided that links structure and bonding to the specific properties (melting point and solubility) for the relevant substances.

Indicative content:	
Melting Points – Chlorine vs. The Rest • **Chlorine**: is a simple molecular substance. It has weak intermolecular forces between the molecules. These forces require very little energy to overcome, so it has a low melting point. • Diamond, NaCl, and Zinc: form giant lattices (covalent, ionic, and metallic respectively). • They contain strong bonds (covalent, electrostatic, or metallic) extending throughout the whole structure. • Breaking these bonds requires a large amount of energy, resulting in high melting points. **Solubility – sodium chloride vs. diamond** • **Sodium Chloride (Ionic)**: Water molecules are polar. They attract the charged ions (Na^+ and Cl^- in the lattice. The attraction is strong enough to pull the ions away from the lattice and surround them, causing it to dissolve. • **Diamond (Giant Covalent)**: The carbon atoms are held together by essentially immovable, very strong covalent bonds in a giant 3D network. Water molecules cannot break these strong bonds, so it does not dissolve.	
	Total: 6 marks

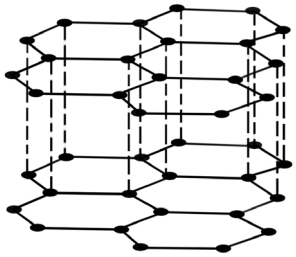
(Total for Question 6 is 10 marks)

7. Bromine is a liquid at room temperature and it vaporises easily.
Bromine has a simple molecular structure that has a low boiling point.

a) Explain, in terms of structure and bonding, why bromine has a low boiling point.

Bromine is simple molecular / made of small molecules.	(1)
There are weak intermolecular forces between the molecules.	(1)
Which require little energy to overcome/break.	(1)
	Total: 2 marks

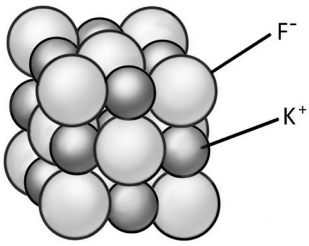
b) The figure below shows part of the structure of graphite.



Explain, in terms of bonding and electrons, why graphite will be a good conductor of an electric current.

Each carbon atom forms three covalent bonds.	(1)
One electron from each carbon atom is delocalised / not used in bonding.	(1)
These delocalised electrons are free to move through the structure and carry charge/current.	(1)
	Total: 3 marks

c) The figure below shows the structure of potassium fluoride.



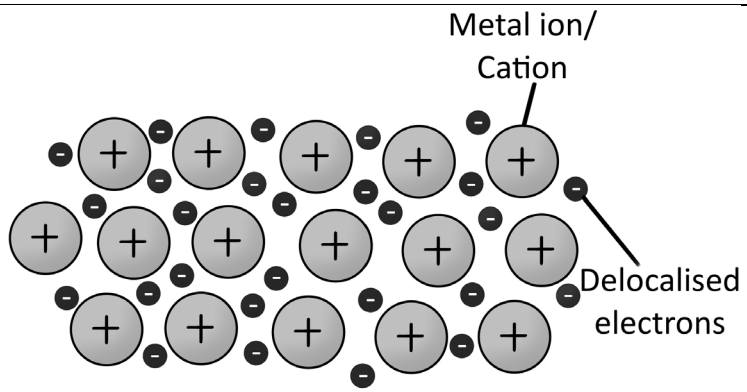
Potassium fluoride has a melting point of 858 °C. Explain why potassium chloride has a high melting point.

It has a giant ionic lattice structure.	(1)
There are strong electrostatic forces of attraction	(1)
between oppositely charged ions (K^+ and Cl^-)	(1)
	Total: 2 marks

(Total for Question 7 is 7 marks)

8. Metals, such as sodium and magnesium, have a giant metallic lattice structure.

a) In the space below, draw a **labelled** diagram to show the arrangement of particles in a metal.

	
Regular arrangement (rows/layers) of circles. Random dots/e- scattered between them.	(2)
Labels: Positive ions / cations (pointing to circles). Delocalised electrons / sea of electrons (pointing to dots).	(1)
	Total: 3 marks

b) Describe the bonding in a metal.

Strong electrostatic attraction.	(1)
between positive ions	(1)
and delocalised electrons.	(1)
	Total: 3 marks

c) Use the metallic bonding model to explain why metals are good conductors of electricity.

The delocalised electrons	(1)
are free to move and carry charge / current through the metal.	(1)
	Total: 2 marks

(Total for Question 8 is 8 marks)