Bonding, structure and properties

Model answers and marking points

GCSE science 6-mark questions

This topic online

1 Magnesium burns in oxygen to form magnesium oxide, MgO. Magnesium has the electronic structure 2,8,2 and oxygen has the electronic structure 2,6.

Describe how magnesium and oxygen atoms form magnesium oxide, and describe the structure of the compound formed.

(6 marks)

Model answer

Magnesium is a metal with two electrons in its outer shell and oxygen is a non-metal with six. When they react, each magnesium atom transfers its two outer electrons to an oxygen atom.

The magnesium atom becomes a Mg^{2+} ion with the electronic structure 2,8. The oxygen atom gains two electrons and becomes an O^{2-} ion, also 2,8. Both ions now have a full outer shell, like the noble gas neon.

The positive magnesium ions and negative oxide ions are attracted to each other by strong electrostatic forces. This attraction is the ionic bond. The ions pack together in a giant lattice, which is a regular repeating arrangement in three dimensions, with the attractions acting in all directions. There is one Mg^{2+} ion for every O^{2-} ion, so the formula is MgO.

Because there are so many strong attractions in the lattice, a lot of energy is needed to overcome them, so magnesium oxide has a very high melting point.

Marking points (credit any 6 relevant points, linked in a sensible order)

- Magnesium is a metal with two electrons in its outer shell; oxygen is a non-metal with six
- Each magnesium atom transfers two electrons to an oxygen atom
- Magnesium becomes a Mg^{2+} ion with electronic structure 2,8
- Oxygen becomes an O^{2-} ion with electronic structure 2,8
- Both ions have a full outer shell, the same structure as a noble gas (neon)
- The oppositely charged ions are held together by strong electrostatic attraction: the ionic bond
- The ions form a giant lattice: a regular, repeating 3D arrangement
- The attractions act in all directions throughout the lattice
- One Mg^{2+} for every O^{2-}, so the formula is MgO
- Lots of energy is needed to overcome the attractions, so magnesium oxide has a very high melting point

How it is marked

- 5-6 marks: describes the transfer of two electrons, gives both ions with correct charges and electronic structures, and describes a giant lattice held by strong electrostatic forces in all directions.
- 3-4 marks: describes electron transfer and the ions formed, but the structure is vague, or the charges or electron numbers contain a slip.
- 1-2 marks: says electrons are transferred or that ions form, with little detail.

What loses marks

- Saying the atoms share electrons, which describes covalent bonding
- Giving the ions charges of 1+ and 1-
- Calling magnesium oxide a molecule instead of a giant lattice

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2 Diamond and graphite are both made only of carbon atoms. Diamond is used on the tips of drill bits. Graphite is used in pencils and as electrodes.

Compare the structures of diamond and graphite and use them to explain the differences in their properties.

(6 marks)

Model answer

Diamond and graphite are both giant covalent structures made only of carbon atoms held together by strong covalent bonds. Because a huge number of strong bonds have to be broken, both have very high melting points, and neither dissolves in water.

In diamond, each carbon atom is covalently bonded to four other carbon atoms, making a rigid three-dimensional network. This makes diamond extremely hard, which is why it is used on drill bits. In graphite, each carbon atom is bonded to only three others, forming flat layers of hexagonal rings. There are no covalent bonds between the layers, only weak forces, so the layers can slide over each other. This makes graphite soft and slippery, so it rubs off onto paper in a pencil.

In graphite, each carbon atom has one electron that is not used in bonding. These delocalised electrons can move through the structure, so graphite conducts electricity and is used for electrodes. In diamond all four outer electrons are used in bonds, so there are no free electrons and diamond does not conduct.

Marking points (credit any 6 relevant points, linked in a sensible order)

- Both are giant covalent structures made of carbon atoms joined by strong covalent bonds
- Both have very high melting points because many strong covalent bonds must be broken
- In diamond each carbon atom forms four covalent bonds; in graphite each forms three
- Diamond has a rigid 3D network; graphite is made of layers of hexagonal rings
- There are no covalent bonds between graphite layers, only weak forces, so layers slide over each other
- So graphite is soft and slippery, useful in pencils; diamond is very hard, useful for drill bits
- In graphite one electron per atom is delocalised and can move through the layers
- So graphite conducts electricity; diamond has no free electrons and does not conduct
- Both are insoluble in water

How it is marked

- 5-6 marks: compares bonding and arrangement point by point and links each structural difference to hardness and electrical conductivity, and notes what the two share.
- 3-4 marks: describes both structures and gives at least one property linked correctly to structure, or makes comparisons without fully explaining them.
- 1-2 marks: states one or two property differences, such as 'diamond is hard and graphite is soft', with no link to structure.

What loses marks

- Saying graphite is soft because its covalent bonds are weak: the bonds within layers are strong
- Saying graphite conducts because of ions, or because it is a metal
- Writing about each substance separately with no direct comparison

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3 A technician has four unlabelled solids, W, X, Y and Z. She tests each one.

Solid	Melting point in °C	Conducts as a solid?	Conducts when melted or dissolved?	Soluble in water?
W	770	no	yes	yes
X	-23	no	no	no
Y	1084	yes	yes (when melted)	no
Z	1700	no	no	no

Use the data to identify the type of structure in each solid. Explain your choices. (6 marks)

Model answer

W is ionic. Its melting point of 770 °C is high because strong electrostatic forces between oppositely charged ions must be overcome. It does not conduct as a solid because the ions are fixed in the lattice, but it conducts when melted or dissolved because the ions are then free to move and carry charge.

X is a simple molecular substance. Its melting point is very low, -23 °C, so it is actually a liquid at room temperature. Only weak intermolecular forces have to be overcome, not the covalent bonds. It never conducts because the molecules have no overall charge and there are no free electrons.

Y is a metal. It conducts as a solid because it has delocalised electrons that can move through the structure. Its high melting point comes from strong metallic bonding between the positive metal ions and the delocalised electrons.

Z has a giant covalent structure, like silicon dioxide. Its very high melting point of 1700 °C is because many strong covalent bonds must be broken. It does not conduct because there are no ions or free electrons, and it is insoluble.

Marking points (credit any 6 relevant points, linked in a sensible order)

- W is ionic: high melting point from strong forces between oppositely charged ions
- W conducts only when melted or dissolved because ions are then free to move; in the solid they are fixed
- X is simple molecular: very low melting point because only weak intermolecular forces are overcome
- X does not conduct because molecules have no overall charge and there are no free electrons
- Y is a metal: conducts as a solid because of delocalised electrons that move through the structure
- Y has a high melting point due to strong metallic bonding between positive ions and delocalised electrons
- Z is giant covalent: very high melting point because many strong covalent bonds must be broken
- Z does not conduct because it has no ions or free electrons and is insoluble (like silicon dioxide)
- X is a liquid at room temperature since its melting point is below 20 °C

How it is marked

- 5-6 marks: identifies all four correctly and justifies each using both melting point and conductivity, explained in terms of particles and forces or bonds.
- 3-4 marks: identifies three or four correctly, with reasons that quote the data but give little explanation of particles.
- 1-2 marks: identifies one or two correctly with little justification.

What loses marks

- Saying X has a low melting point because its covalent bonds are weak
- Mixing up W and Y because both conduct when melted: only Y conducts as a solid
- Identifying the structures without explaining them using the data

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4 A kitchenware company sells plastic chopping boards with silver nanoparticles mixed into the surface. It claims the boards stay cleaner because the silver kills bacteria from raw meat.

Information:

- Silver nanoparticles are 1 to 100 nm across.
- A smaller mass of silver nanoparticles kills the same number of bacteria as a larger piece of normal silver.
- In a test, about 30% of the silver had worn away from the surface after a year of daily scrubbing.
- Silver washed down the sink can reach rivers, where it may harm useful bacteria.
- Scientists are still studying whether nanoparticles that rub off onto food can be absorbed by the body.

Evaluate the use of silver nanoparticles in chopping boards.

Separate science only

(6 marks)

Model answer

Silver nanoparticles have a very high surface area to volume ratio. This means a large proportion of their silver atoms are on the surface, in contact with bacteria, so a small mass of nanoparticles kills as many bacteria as a much larger piece of normal silver. Less silver is needed, which saves money and resources. Killing bacteria from raw meat on the board reduces the risk of spreading food poisoning to other foods.

However, about 30% of the silver wore away after a year of daily scrubbing, so the board will become less effective over time and the claim that it stays cleaner may not last. The silver that wears away is washed down the sink and could reach rivers, where it may harm useful bacteria in the environment. Nanoparticles are also so tiny that any that rub off onto food might be absorbed by the body, and scientists do not yet know the long-term effects on health. More research is needed.

Overall, I think the boards work in the short term, but because the silver wears away and the risks to the environment and health are uncertain, the benefit is not worth the risk until more research has been done.

Marking points (credit any 6 relevant points, linked in a sensible order)

- Nanoparticles have a very high surface area to volume ratio
- So more silver atoms are exposed and in contact with bacteria, making them more effective
- Less silver is needed, saving cost and resources
- Killing bacteria from raw meat reduces the risk of spreading food poisoning to other foods
- About 30% of the silver wore away in a year, so the effect fades and the claim does not last
- Silver washed down the sink could reach rivers and harm useful bacteria in the environment
- Nanoparticles that rub off onto food might be absorbed by the body; long-term health effects are not yet known
- More research is needed before the risks can be fully judged
- Conclusion: useful but with uncertain risks, so a justified judgement is made either way

How it is marked

- 5-6 marks: gives benefits explained by surface area to volume ratio, uses at least two pieces of the information as drawbacks, and reaches a justified conclusion.
- 3-4 marks: gives benefits and drawbacks from the information but with little scientific explanation, or no clear conclusion.
- 1-2 marks: gives one benefit or one risk, often copied from the information without comment.

What loses marks

- Saying nanoparticles work better because they are 'small' without mentioning surface area to volume ratio

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- Copying the information without explaining why it matters
- Leaving out a conclusion

5 **Higher tier**

In the simple particle model, the particles in a substance are drawn as small solid spheres.

Sodium chloride melts at 801 °C. Oxygen melts at -218 °C.

Use ideas about particles and forces to explain the difference in melting points. Then explain the limitations of the simple particle model.

(6 marks)

Model answer

A substance melts when enough energy is transferred to overcome the forces that hold its particles in fixed positions. The stronger these forces, the more energy is needed, so the higher the melting point.

Sodium chloride is a giant ionic lattice. Every ion is held by strong electrostatic forces to the oppositely charged ions around it, acting in all directions, so a lot of energy is needed to melt it. This is why its melting point is 801 °C.

Oxygen is made of small O_2 molecules. The forces between the molecules are weak intermolecular forces, so very little energy is needed to overcome them. The covalent bonds inside each molecule are not broken when oxygen melts. This explains its very low melting point of -218 °C.

The simple particle model has limitations. It does not show any forces between the particles, so it cannot show why one substance melts at a higher temperature than another. It shows particles as solid spheres, but real atoms, ions and molecules are not solid and many molecules have complicated shapes. It also draws all particles the same size when they are not. So the model cannot be used on its own to predict melting points.

Marking points (credit any 6 relevant points, linked in a sensible order)

- Melting happens when enough energy is transferred to overcome the forces holding particles in fixed positions
- The stronger the forces between particles, the more energy needed and the higher the melting point
- Sodium chloride is a giant lattice of ions held by strong electrostatic forces in all directions
- Oxygen is made of small O_2 molecules with only weak intermolecular forces between them
- When oxygen melts, the covalent bonds inside the molecules are not broken
- Limitation: the model shows no forces between the particles
- Limitation: real particles (atoms, ions, molecules) are not solid spheres; molecules have different shapes
- Limitation: the model draws all particles as identical spheres, but particles differ in size
- So the model cannot be used on its own to predict melting points

How it is marked

- 5-6 marks: explains both melting points in terms of the type and strength of forces overcome and gives at least two clear limitations of the model, linked to why it cannot predict melting points.
- 3-4 marks: explains that stronger forces mean a higher melting point with partial detail on the structures, and gives one limitation.
- 1-2 marks: states that sodium chloride has stronger forces, or gives one limitation, with little explanation.

What loses marks

- Saying covalent bonds break when oxygen melts
- Calling the forces in sodium chloride intermolecular forces
- Describing what the model shows instead of what it leaves out

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