2.2 Bonding, structure and properties

Name: _____ Class: _____ Date: _____ **Total: 32 marks**

KEY WORDS intermolecular force • state symbol • alloy

Objective

Link structure to melting point and conductivity for the four structure types, and explain alloys. Original questions for spec statements 4.2.2.1–4.2.2.8.

1 Key knowledge and worked examples

States of matter: melting/freezing at the **melting point**, boiling/condensing at the **boiling point**; particle theory explains them; stronger forces between particles → higher melting and boiling points. State symbols: **(s), (l), (g), (aq)**. (HT) Limits of the model: no forces between the spheres; all particles drawn as solid spheres.

Structure	Melting/boiling point	Conducts?
ionic lattice	high – many strong electrostatic forces to break	only molten or dissolved – ions free to move
small molecules	low – weak **intermolecular forces** overcome; the covalent bonds do NOT break	no – no mobile ions or delocalised electrons
polymers	solid at room temperature – stronger intermolecular forces between long chains	no
giant covalent	very high – every atom covalently bonded	generally no; graphite and graphene conduct
metals	mostly high – strong metallic bonding	yes – delocalised electrons carry charge; also good thermal conductors

Bigger molecules → stronger intermolecular forces → higher melting/boiling points.

Alloys: in a pure metal the same-sized atoms sit in **layers that slide** – soft, malleable. Adding different-sized atoms **distorts the layers**, so sliding is harder – the alloy is **harder**.

Worked example (3 marks). Explain why chlorine (bp −34 °C) has a much lower boiling point than sodium chloride (1465 °C).

Chlorine is made of small molecules – only weak intermolecular forces between them, so little energy is needed. Sodium chloride is a giant ionic lattice – strong electrostatic forces between oppositely charged ions act in all directions and many must be broken, so much more energy is needed for a far higher boiling point.

2 Practice

2.1 Which forces are overcome when water boils – covalent bonds or intermolecular forces? [1]

2.2 Why does molten sodium chloride conduct electricity but solid sodium chloride does not? [2]

2.3 Give the state symbols for a solid reactant and an aqueous solution. [2]

2.4 At the stated pressure, X melts at −15 °C and boils at 65 °C. Predict its state at −30 °C, 20 °C and 90 °C. Explain why the particles do not become larger atoms on heating. [4]

3 Exam-style questions

3.1 Explain why propane is a gas at room temperature but hexane is a liquid, in terms of structure and forces. [4]

3.2 Explain why silicon dioxide has a very high melting point and does not conduct electricity. [4]

3.3 A student says "when iodine crystals are heated, the covalent bonds break, so iodine becomes a gas." Correct the student. [3]

3.4 A pure metal and an alloy conduct electricity. The alloy is harder. Explain both observations using their structures. [4]

3.5 *(HT)* A sphere-only drawing shows 16 particles close together in a liquid and 22 far apart in a gas, with no particles entering. Identify the counting error, then explain one feature the model omits that is needed to explain boiling energy. [3]

3.6 A solid magnesium strip reacts with aqueous hydrochloric acid. Magnesium chloride remains dissolved and hydrogen gas is collected. Complete the balanced equation with state symbols: $Mg + 2HCl \rightarrow MgCl_2 + H_2$. Explain why the salt product uses (aq), rather than (l). [5]

Solutions

2.1 Intermolecular forces.

2.2 In the molten state the ions are free to move, so charge can flow; in the solid the ions are held fixed in the lattice.

2.3 (s) for solid; (aq) for aqueous solution.

2.4

Solid at −30 °C; liquid at 20 °C; gas at 90 °C. Heating changes particle energy, motion and separation rather than the size of each atom.

3.1 Both are small molecules with weak intermolecular forces between them; hexane is a bigger molecule than propane; so the intermolecular forces between hexane molecules are stronger; more energy is needed to separate them, giving the higher boiling point of a liquid at room temperature.

3.2 Silicon dioxide is a giant covalent structure; every atom is joined to others by strong covalent bonds; a very large amount of energy is needed to break the many bonds, so the melting point is very high; there are no free electrons or ions to carry charge.

3.3 The covalent bonds inside each I_2 molecule do not break when it boils; only the weak intermolecular forces between molecules are overcome; the molecules separate into a gas while each molecule stays intact.

3.4

Both have mobile delocalised electrons, which carry electrical charge. Different-sized atoms distort the regular metal layers, making them harder to slide, increasing hardness. Hardness is not evidence that every electron is fixed.

3.5 Six extra spheres were introduced without particles entering; particle number should remain 16. The sphere-only model omits attractions between particles; energy is needed to overcome these attractions during boiling, which distance/arrangement symbols alone do not explain.

3.6 $Mg(s) + 2HCl(aq) \rightarrow MgCl_2(aq) + H_2(g)$, one mark for each correct symbol (4 marks). Magnesium chloride is dissolved in water, not a pure melted liquid, so its state is aqueous.