6.1 The ionic model

Name: _____ Class: _____ Date: _____ **Total: 25 marks**

KEY WORDS ionic bond • lattice • lattice enthalpy • polyatomic ion • brittle • electrostatic attraction

Objective

Build the skills to answer exam questions on **the ionic model** : forming ions, ionic formulas, lattices, lattice enthalpy and the properties of ionic compounds.

You must be able to:

- predict the charge of an ion from the position of the element in the periodic table
- write formulas and names of ionic compounds, including polyatomic ions
- describe an ionic lattice and explain how ion charge and radius affect lattice enthalpy
- explain the melting points, conductivity, brittleness and solubility of ionic compounds

1 Key knowledge and worked examples

■ Ions and ionic bonding

Metals lose electrons to form positive ions (group 1: +1, group 2: +2, Al: +3); non-metals gain electrons to form negative ions (group 17: −1, group 16: −2, N: −3). An **ionic bond** is the electrostatic attraction between oppositely charged ions.

polyatomic ion	formula	polyatomic ion	formula
ammonium	NH_4^+	sulfate	SO_4^{2-}
hydroxide	OH^-	carbonate	CO_3^{2-}
nitrate	NO_3^-	hydrogencarbonate	HCO_3^-
phosphate	PO_4^{3-}		

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Lattice: a 3-D repeating arrangement in which each ion is surrounded by ions of opposite charge. **Lattice enthalpy** is the energy needed to separate one mole of a solid ionic compound into gaseous ions: it is **larger** for **higher charges** and **smaller ions**.

property	**reason**
high melting point	many strong attractions in all directions must be overcome
conducts only when molten or dissolved	ions must be free to move; in the solid they are fixed
brittle	a shift brings like charges side by side, and they repel
often soluble in water	polar water molecules attract and surround the ions

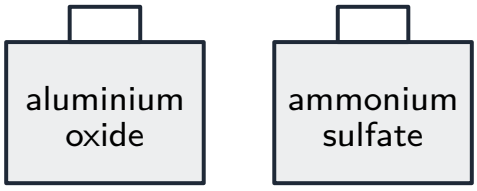
Worked example 1: a formula. Aluminium sulfate: Al^{3+} and SO_4^{2-}; balance charges: $\mathbf{Al_2(SO_4)_3}$ ($2 \times 3 = 3 \times 2$).

Worked example 2: comparing. NaCl melts at 801 °C, CaO at 2613 °C: Ca^{2+} and O^{2-} have **double charges**, so the attractions are much stronger.

Answer shapes: charges first, then ion size, then "stronger attraction, more energy needed".

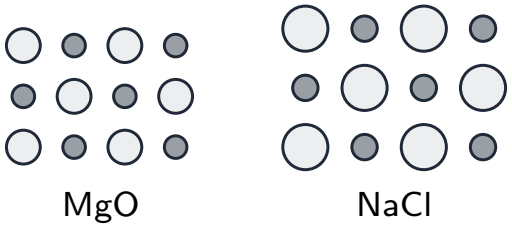
2 Practice

2.1 Write the formulas of aluminium oxide and of ammonium sulfate. [2]

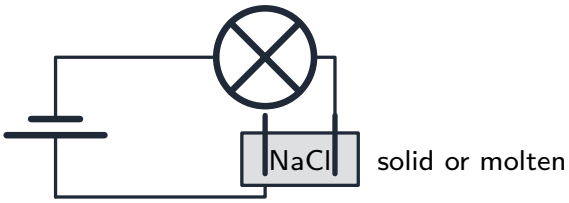


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2.2 Magnesium oxide melts at 2852 °C and sodium chloride at 801 °C. Both have the same lattice type. Explain the difference. [3]



2.3 Explain why solid sodium chloride does not conduct electricity, but molten sodium chloride does. [3]



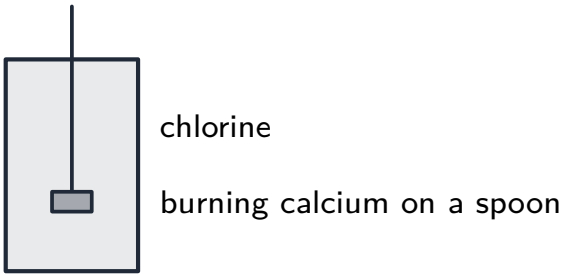
2.4 Write the formula of calcium phosphate and name the compound $Fe_2(SO_4)_3$. [2]



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3 Exam-style questions

3.1 Calcium reacts with chlorine to form an ionic compound.



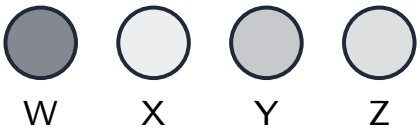
(a) Describe the electron transfer, giving the electron configurations of the ions formed. [2]

(b) State the formula and name of the compound. [1]

(c) Describe the structure of the solid compound. [2]

3.2 The table shows the properties of four solids, W to Z.

solid	melting point / °C	conducts as solid	conducts when molten	soluble in water
W	1083	yes	yes	no
X	770	no	yes	yes
Y	114	no	no	no
Z	1710	no	no	no



(a) Identify the ionic solid. Explain your choice using two properties. [3]

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(b) Explain why ionic solids are brittle. [2]

(c) Explain why the ionic solid dissolves in water. [2]

(d) Predict, with reasons, which of potassium fluoride and potassium iodide has the larger lattice enthalpy. [3]

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Solutions

Marking: **M1** a correct method, **A1** the correct answer, **B1** an independent mark.

Each answer shows the steps, then the **result**.

2.1

Al_2O_3; $(NH_4)_2SO_4$

2.2

Mg^{2+} and O^{2-} have higher charges than Na^+ and Cl^-; and are smaller ions; so the electrostatic attraction / lattice enthalpy is greater and more energy is needed to separate the ions

2.3

electricity needs mobile charged particles; in the solid the ions are held in fixed positions in the lattice; when molten the ions are free to move and carry charge

2.4

$Ca_3(PO_4)_2$; iron(III) sulfate

3.1

(a) each calcium atom loses two electrons and each of two chlorine atoms gains one; Ca^{2+} and Cl^- are both $[Ne]3s^23p^6$ / $1s^22s^22p^63s^23p^6$

(b) $CaCl_2$, calcium chloride

(c) a giant lattice of Ca^{2+} and Cl^- ions in a regular 3-D arrangement; each ion surrounded by ions of opposite charge, held by electrostatic attraction

3.2

(a) X; it conducts when molten but not as a solid (ions fixed, then free to move); high melting point / soluble in water

(b) a force moves layers so that ions of the same charge come side by side; they repel and the lattice breaks

(c) water molecules are polar; their partial charges attract the ions and pull them out of the lattice, surrounding them (hydration)

(d) potassium fluoride; same charges on the ions; F^- is smaller than I^-, so the ions are closer and attract more strongly

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