Cambridge IGCSE · Chemistry 0620 · Notes

Ionic and metallic bonding

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Read first: **Elements, compounds and atomic structure**

What you need to know

By the end of this topic you should be able to:

1. **Describe how ions form**: atoms that lose electrons become positive ions (**cations**); atoms that gain electrons become negative ions (**anions**).
2. **State what an ionic bond is**: a strong electrostatic attraction between oppositely charged ions.
3. **Describe how ionic bonds form between Group I and Group VII elements**, and show it with dot-and-cross diagrams.
4. **Describe the properties of ionic compounds**: high melting and boiling points; good electrical conductivity when molten or in aqueous solution, but poor when solid.
5. **Deduce the formula of a simple compound** from the numbers of each particle in a model or diagram (syllabus 3.1).
6. **Extended only:** describe the giant lattice of an ionic compound as a regular arrangement of alternating positive and negative ions.
7. **Extended only:** describe how ionic bonds form between any metal and non-metal, with dot-and-cross diagrams.
8. **Extended only:** explain the properties of ionic compounds (melting and boiling points, conductivity) in terms of their structure and bonding.
9. **Extended only:** deduce the formula of an ionic compound from the charges on its ions or from a diagram of its ions (syllabus 3.1).
10. **Extended only:** describe metallic bonding as the electrostatic attraction between the positive ions in a giant metallic lattice and a "sea" of delocalised electrons.
11. **Extended only:** explain in terms of structure and bonding why metals conduct electricity and why they are malleable and ductile.

Understand it

Why atoms form ions

In the note on atomic structure you saw that the noble gases have a **full outer shell** and are unreactive. Other atoms can reach the same stable arrangement by **losing or gaining electrons**. When they do, the numbers of protons and electrons no longer match, so the particle has a charge: it is an **ion**.

- **Metal atoms lose electrons** (their few outer electrons) and become **positive ions**, called **cations**. Sodium, 2,8,1, loses one electron and becomes Na^+, 2,8.
- **Non-metal atoms gain electrons** to fill their outer shell and become **negative ions**, called **anions**. Chlorine, 2,8,7, gains one electron and becomes Cl^-, 2,8,8.

The charge on the ion equals the number of electrons lost (+) or gained (−). For elements in Groups I, II, III, V, VI and VII it follows from the group:

Group	Outer electrons	What the atom does	Ion charge	Examples
I	1	loses 1	$1+$	Li^+, Na^+, K^+
II	2	loses 2	$2+$	Mg^{2+}, Ca^{2+}
III	3	loses 3	$3+$	Al^{3+}
V	5	gains 3	$3-$	N^{3-}
VI	6	gains 2	$2-$	O^{2-}, S^{2-}
VII	7	gains 1	$1-$	F^-, Cl^-, Br^-, I^-

Only electrons move. The number of protons never changes, which is why the ion keeps the element's name: a sodium ion, Na^+, still has 11 protons, but now only 10 electrons. Negative ions of single elements take the ending **-ide**: chloride, oxide, sulfide, nitride.

The ionic bond

When a metal reacts with a non-metal, **electrons are transferred from the metal atoms to the non-metal atoms**. The metal atoms become positive ions and the non-metal atoms become negative ions. Opposite charges attract, so the ions are held together. This attraction is the **ionic bond**:

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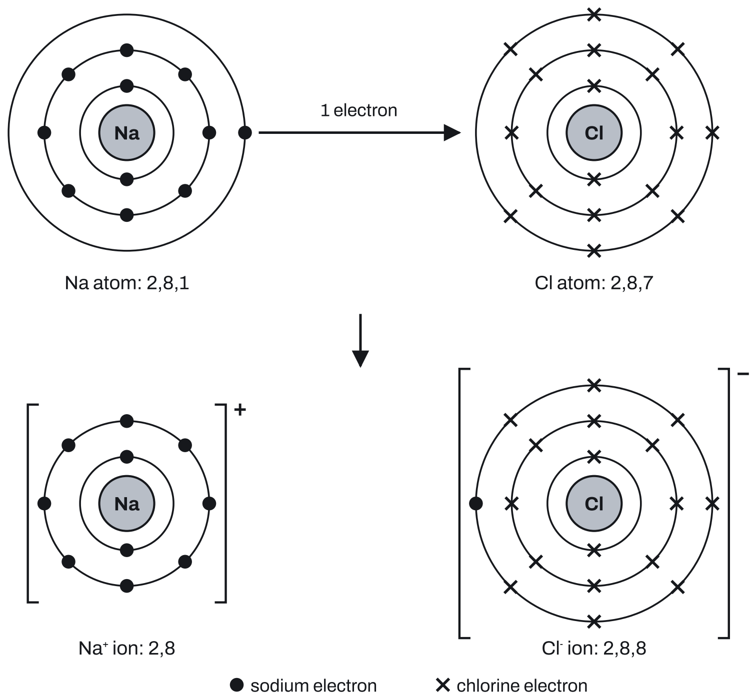
an ionic bond is a **strong electrostatic attraction between oppositely charged ions**.

Notice what the definition does and doesn't say. The bond is the **attraction** between the **ions**, not the transfer of electrons (that is how the ions formed) and not an attraction between atoms or molecules. Ionic compounds have no molecules at all.

Dot-and-cross diagrams

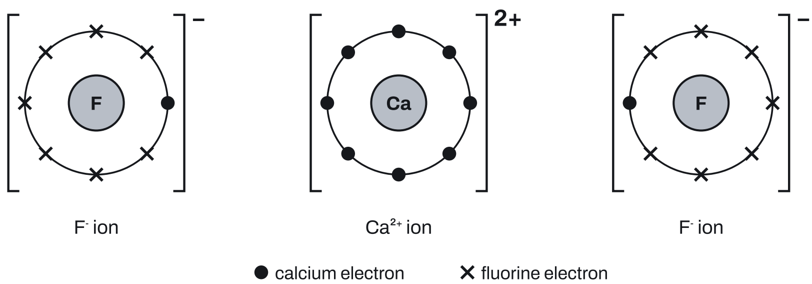
A dot-and-cross diagram shows where the electrons are. Electrons from one element are drawn as **dots**, and electrons from the other as **crosses**, so you can see which electron moved.



For sodium chloride (Group I with Group VII):

1. Sodium's one outer electron (a dot) moves to the chlorine atom.
2. The sodium ion is now 2,8. Its old third shell is empty, so it is not drawn.
3. The chloride ion is 2,8,8. Its outer shell has **7 crosses and 1 dot**.
4. Each ion goes in **square brackets** with its **charge** at the top right: $[Na]^+$ and $[Cl]^-$.

Extended only: the same method works for any metal and non-metal, but the numbers of electrons lost and gained must balance. A magnesium atom loses **two** electrons, but a fluorine atom can take only **one**, so **two** fluorine atoms are needed for each magnesium atom. The diagram then shows one Mg^{2+} ion and two F^- ions, and the formula is MgF_2. Calcium fluoride works the same way:



Questions often say "show outer shell electrons only". Then draw just the outer shell of each **ion**. For a metal ion that outer shell is the full shell underneath the one it lost, so Ca^{2+} shows **8** electrons, not 0 and not 2. Draw the non-metal ion with all 8 of its outer electrons: its own (crosses) plus the ones it gained (dots).

Formulae of ionic compounds

An ionic compound has **no overall charge**, so the positive and negative charges must cancel. Use the charges to find how many of each ion you need:

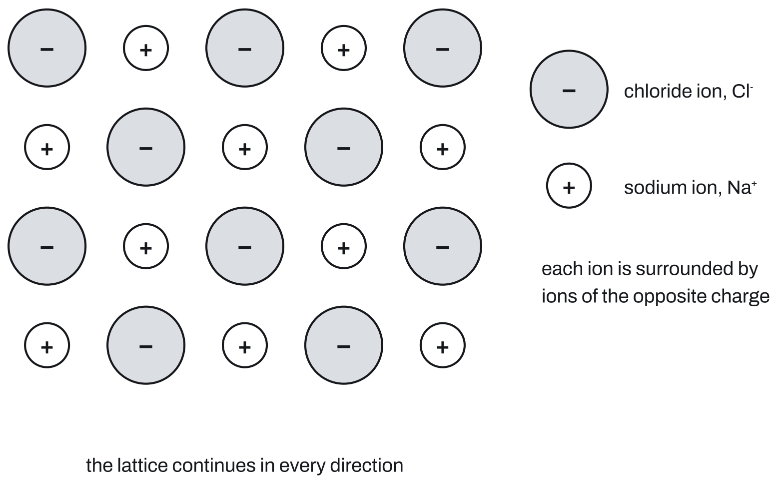
Ions	Balancing the charges	Formula
Na^+ and Cl^-	$(+1) + (-1) = 0$	NaCl
Mg^{2+} and O^{2-}	$(+2) + (-2) = 0$	MgO
Ca^{2+} and F^-	$(+2) + 2 \times (-1) = 0$	CaF_2
K^+ and S^{2-}	$2 \times (+1) + (-2) = 0$	K_2S
Al^{3+} and O^{2-}	$2 \times (+3) + 3 \times (-2) = 0$	Al_2O_3
Li^+ and N^{3-}	$3 \times (+1) + (-3) = 0$	Li_3N

A quick way: the number of each ion is the size of the **other** ion's charge, then cancel to the smallest whole numbers. Mg^{2+} and O^{2-} give Mg_2O_2, which cancels to MgO.

If you are given a diagram or model of the ions, count them: a lattice with equal numbers of + and – ions of charge 1 has the formula XY; a diagram with two K^+ for each S^{2-} is K_2S. Always write the **metal first**.

The giant ionic lattice

Extended only. In solid sodium chloride, each ion is attracted to all the oppositely charged ions around it, not just one partner. The ions pack into a **giant lattice**: a **regular arrangement of alternating positive and negative ions** that repeats in every direction, through the whole crystal.



Each ion's nearest neighbours have the **opposite** charge; ions of the same charge are further apart. In sodium chloride there is one Na^+ for every Cl^-, which is why its formula is NaCl, not a number of "molecules". Magnesium ions are smaller than oxide ions (both have 10 electrons in two shells, but Mg^{2+} has 12 protons pulling on them and O^{2-} only 8), so in a drawing of magnesium oxide the small ions are Mg^{2+}.

Properties of ionic compounds

Ionic compounds share two properties you must know (Core) and be able to explain (**Extended only**):

1. High melting points and boiling points. Sodium chloride melts at 801 °C.

- **Extended only, why:** the giant lattice is held together by **strong electrostatic attractions between oppositely charged ions**, and there are very many of them. **A lot of energy** is needed to overcome these attractions, so a high temperature is needed.

2. Electrical conductivity: poor when solid, good when molten or in aqueous solution. An electric current needs **charged particles that can move**.

- **Extended only, why:** in the solid, the ions are held in fixed positions in the lattice, so they **cannot move**. When the compound is melted or dissolved in water, the lattice breaks up and the **ions can move**, so the liquid conducts. Ionic compounds have **no mobile electrons**: it is the ions that carry the charge.

A high boiling point also means the compound is **not volatile** (it does not evaporate easily). Many ionic compounds, such as sodium chloride and potassium bromide, are also soluble in water, and some multiple-choice options use this.

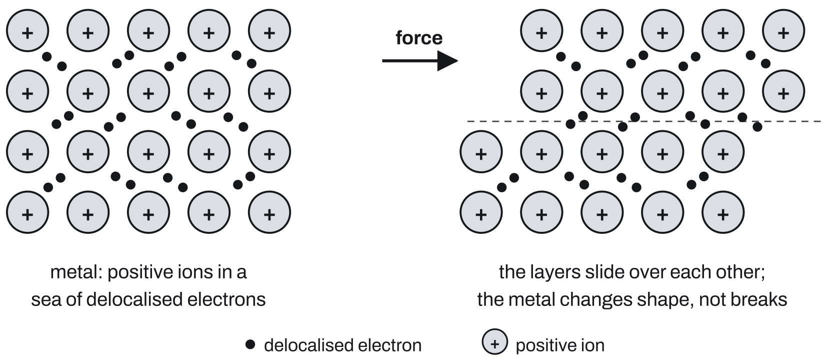
These properties let you **identify** an ionic compound from data: a high melting point, not conducting as a solid, conducting when molten (or in solution).

Metallic bonding

Extended only. A metal element is also a **giant lattice**, but of only one kind of ion. Each metal atom releases its outer electrons, which no longer belong to any one atom. The metal is then:

- a regular lattice of **positive ions**, in layers,
- surrounded by a **"sea" of delocalised electrons** that can move through the whole structure.

Metallic bonding is the **electrostatic attraction between the positive ions and the delocalised electrons**. All three parts earn marks: positive ions, delocalised (mobile) electrons, and the attraction between them.



This picture explains the typical properties of metals:

- **Good electrical conductivity (solid or liquid).** The delocalised electrons are **mobile**: they can **move** through the lattice and carry the current. The positive ions stay in place; they do not carry the current in a solid metal.
- **Malleable (can be hammered into shape) and ductile (can be drawn into wires).** The **layers of positive ions can slide over each other** when a force is applied. The sea of electrons moves with them, so the attraction holding the lattice together is kept and the metal changes shape instead of breaking.

Compare the two giant lattices: both contain **positive ions**, but an ionic lattice has **negative ions** between them while a metal has **electrons**. That is why a solid metal conducts and a solid ionic compound does not.

Key facts and formulas

Nothing for this topic is printed in the exam except the **Periodic Table**, which gives each element's group. Everything else is **Learn it**.

Formula	Status
Group number and proton number of each element, from the Periodic Table	Given
Metals lose electrons → positive ions (cations); non-metals gain electrons → negative ions (anions)	Learn it
Ion charges: Group I $1+$, II $2+$, III $3+$, V $3-$, VI $2-$, VII $1-$	Learn it
Ionic bond = strong electrostatic attraction between oppositely charged ions	Learn it
Ionic compounds: high melting and boiling points; conduct when molten or aqueous, not when solid	Learn it
Formula of an ionic compound: total positive charge + total negative charge $= 0$	Learn it
Extended only: giant ionic lattice = regular arrangement of alternating positive and negative ions	Learn it

Formula	Status
Extended only: metallic bonding = electrostatic attraction between positive ions in a giant lattice and a sea of delocalised electrons	Learn it
Extended only: metals conduct because delocalised electrons move; they are malleable and ductile because layers of ions slide over each other	Learn it

How to do it

In the questions we have tagged for this topic (152 questions, 2021–2025, on Papers 1–4), the types came up this often. 20 of the 152 questions mix types, so the counts add up to more than 152.

Question type	Questions
Forming ions: electron transfer, charges, cations and anions	54
Properties of ionic compounds, and identifying them from data	47
Metallic bonding and the properties of metals	30
Dot-and-cross diagrams of ionic compounds	20
Formulae of ionic compounds, and which elements bond ionically	13
The ionic bond and the giant ionic lattice	12

1. Forming ions: electron transfer, charges, cations and anions (54 questions)

Mostly multiple choice ("which row describes what happens to the sodium atoms?") or "complete the diagram to show the configuration of a potassium ion and its charge".

1. **Find the group** of each element (Periodic Table or configuration).
2. **Metal** (Groups I–III): **loses** as many electrons as its group number, forming a **positive ion (cation)**. **Non-metal** (Groups V–VII): **gains** $8 - \text{group}$ electrons, forming a **negative ion (anion)**.
3. **Write the ion's configuration**: take away or add those electrons. The ion always has a noble-gas configuration (2, 2,8 or 2,8,8).
4. For a diagram of one ion, draw its shells, put it in **square brackets** and write the **charge** at the top right.

Variations you will meet:

- **Direction of transfer.** In NaCl, electrons go **from sodium to chlorine**. Options that say chlorine gives electrons to sodium, or that the atoms share electrons, are wrong.
- **"Which ion has the configuration 2,8,8?"** Count electrons: S^{2-} has $16 + 2 = 18$ and Ca^{2+} has $20 - 2 = 18$, so both do. K^+ and Cl^- also have 18.
- **"Explain why a potassium ion has a single positive charge"**: the atom (2,8,8,1) **loses one electron**, so it has 19 protons but only 18 electrons. For a charge of $2-$ (sulfide): the atom gains two electrons, so it has two more electrons than protons.

- **"State the general name"** for any positive ion: **cation**; any negative ion: **anion**. Watch for options that swap them ("potassium anions").
- **Protons never move.** "Positive ions form when atoms lose protons" is always wrong.
- **An unfamiliar element**, such as livermorium in Group VI: use the group rule. It gains two electrons to form a $2-$ ion.
- **Which configurations form a $2-$ ion**: those with **6** outer electrons (2,6 and 2,8,6).
- **Pick a compound containing a $2+$ ion or a $1+$ ion** from a list of formulae: $MgCl_2$ has Mg^{2+}; NaCl and LiCl have a $1+$ ion.

2. Properties of ionic compounds, and identifying them from data (47 questions)

1. **Know the two properties**: high melting and boiling points; conducts electricity **when molten or in aqueous solution but not when solid**.
2. **Extended only: explain them.** High melting point: **strong electrostatic attractions between oppositely charged ions**, in a giant lattice, need **a lot of energy** to overcome. Conductivity: when molten or dissolved, the **ions can move**; in the solid they are **held in fixed positions** and cannot move.
3. **To identify substances from a table**, sort them with these rules:

Melting point	Conducts when solid?	Conducts when molten?	Type
high	yes	yes	metal
high	no	yes	ionic compound
high	no	no	giant covalent (such as diamond or silicon(IV) oxide)
low	no	no	simple molecular substance

A metal with a low melting point, such as mercury (a liquid at room temperature), still conducts when solid and when liquid. To find the **state at 25 °C**, compare 25 °C with the melting and boiling points: below the melting point it is solid, between them liquid, above the boiling point gas.

Variations you will meet:

- **"State two physical properties of ionic compounds"**: high melting point, high boiling point, conducts when molten, conducts in aqueous solution (any two, but "conducts when molten" must say **molten** or **aqueous**, not just "conducts").
- **"Which statements about potassium chloride are correct?"** Reject anything that says it conducts when **solid**, has a **low** melting point, has **molecules** or **intermolecular forces**, or is held by **covalent** bonds.
- **Comparing an ionic compound with a simple molecular one** (such as sodium fluoride and fluorine): name the particles and the forces for **both**. In sodium fluoride, strong attractions between **oppositely charged ions**; in fluorine, weak attractions **between molecules** (intermolecular forces); so much more energy is needed to melt sodium fluoride.

- **"State one other change that lets solid magnesium fluoride conduct"** when dissolving is already given: **melt it**.
- **Volatility**: ionic compounds have **low volatility** (they don't evaporate easily), because of their high boiling points; simple molecular substances such as pentane or bromine are volatile.
- **Matching four substances** (graphite, poly(ethene), sodium chloride, silicon(IV) oxide) to their data: the one that conducts only when **molten** and melts at 801 °C is sodium chloride; the one that conducts when solid is graphite.

3. Metallic bonding and the properties of metals (30 questions)

Extended only.

1. **Name** the bonding: **metallic**.
2. **Describe** it with three points: **positive ions** (in a lattice), a **sea of delocalised (mobile) electrons**, and the **electrostatic attraction between the positive ions and the electrons**. A labelled diagram (positive ions in rows, electrons between them) can help.
3. **Conductivity**: the delocalised electrons **move** through the structure.
4. **Malleability and ductility**: the **layers of positive ions slide over each other**.

Variations you will meet:

- **"Name the two types of particle"** held together in zinc: **positive ions** and **electrons**. **"Name the particle whose movement lets zinc conduct"**: **electrons** (not ions).
- **Structure and bonding of cobalt, copper or iron**: **giant metallic**.
- **"Describe what happens to the particles in iron when it is hammered into shape"**: the layers of ions slide over each other.
- **"The ability to be hammered into shape"**: **malleable**; drawn into wires: **ductile**.
- **Rows to choose from.** Metals have a lattice of **positive** ions (not negative ions) in a sea of electrons; they conduct because **electrons** move (not ions); they are malleable because **layers slide** (not because electrons move or bonds are weak).
- **"Which element is malleable and conducts?"** It has a **metallic lattice**.
- **One other physical property of potassium** (beyond low density and low melting point): it conducts electricity (or heat), or is malleable or ductile.
- **Similarities and differences with ionic compounds**: both contain positive ions; only ionic compounds contain anions; only metals have a sea of electrons.

4. Dot-and-cross diagrams of ionic compounds (20 questions)

1. **Write the configurations** of both atoms and work out the charges (type 1).
2. **Balance the charges** to find how many of each ion (type 5). The diagram usually gives you the right number of symbols to fill in.

3. **Draw each ion**: the metal ion with its new outer shell **full** (for example 8 for Na^+, K^+, Mg^{2+}, Ca^{2+}, Al^{3+}; 2 for Li^+), in the metal's symbol (dots); the non-metal ion with its own electrons (crosses) **plus** the gained ones (dots), 8 in total.
4. Put every ion in **square brackets** and write its **charge** on the correct side, top right.

Variations you will meet:

- **"Show outer shells only"** or "the inner shells have been drawn": draw just one ring per ion, but still the full 8 on the metal ion. Leaving the metal ion's ring empty, or drawing its old outer electron, loses marks.
- **Two metal ions and one non-metal ion** (K_2S, Na_2S, Na_2O, Li_3N): each metal ion is drawn separately with the same shell and a $+$ charge; the anion has two (or three) dots.
- **One metal ion and two or three non-metal ions** ($MgCl_2$, $CaCl_2$, AlF_3): each anion has one dot; the metal ion has charge $2+$ or $3+$.
- **Given the atoms, draw only one of each ion** (MgF_2 in some papers): follow the question's layout, not the formula.
- **Group I with Group VII only** is Core; any metal with any non-metal is Extended.

5. Formulae of ionic compounds, and which elements bond ionically (13 questions)

1. **Ionic bonding** forms between a **metal** and a **non-metal**. Two non-metals bond covalently; two metals do not form a compound.
2. **Find the charges** from the groups.
3. **Balance** the charges to zero and write the formula, metal first.

Variations you will meet:

- **"X loses two electrons and Y gains one"**: X^{2+} and Y^-, so XY_2.
- **"X_2Y is ionic: which groups?"** Two $1+$ ions balance one $2-$ ion: X in Group I, Y in Group VI.
- **Configurations of P and Q given**: find the outer electrons, then the charges. An atom with 2 outer electrons and one with 6 give PQ; 1 and 6 give P_2Q.
- **Positions in the Periodic Table**: an element on the left (metal) and one on the right (non-metal) form an ionic compound; count the groups to get the charges.
- **Which pair forms a compound with oppositely charged ions?** A metal with a non-metal, such as sodium and oxygen.
- **Oxides of elements on a Periodic Table**: a metal oxide is ionic; a non-metal oxide is covalent.
- **A symbol equation** such as $2\mathrm{K} + \mathrm{Cl}_2 \rightarrow 2\mathrm{KCl}$: chlorine is diatomic, so two formula units of KCl form.

6. The ionic bond and the giant ionic lattice (12 questions)

1. **Define** the ionic bond: **strong electrostatic attraction between oppositely charged ions**.
2. **Extended only: describe** the lattice: a **giant**, **regular** arrangement of **alternating positive and negative ions**.

3. **To complete a lattice diagram**, alternate $+$ and $-$ along every row **and** every column, starting from the ion that is given.

Variations you will meet:

- **"Which statement describes the structure of sodium chloride?"** A lattice of alternating positive and negative ions. Not atoms, not molecules, not a sea of electrons.
- **"Which compound does this lattice represent?"** Equal numbers of $+$ and $-$ ions with single charges means a 1 : 1 compound of Group I and Group VII, such as potassium bromide (not sodium oxide, Na_2O, or magnesium chloride, $MgCl_2$).
- **Statements about ionic solids**: "ions of the same charge are closer together" (false); "melting breaks intermolecular forces" (false: there are no molecules); "oxide ions and magnesium ions are attracted to each other in a giant lattice" (true).
- **A tick-box of four descriptions**: choose "a **strong** electrostatic attraction between **cations and anions**".

Worked examples

The bold codes show where marks are earned, as in Cambridge mark schemes. The number is how many marks.

- **M1** method mark: for a correct method, even if the numbers slip.
- **A1** accuracy mark: for a correct answer; it needs the M mark before it.
- **B1** mark for a correct result on its own, with no method needed.

Example 1

Lithium is in Group I and fluorine is in Group VII. They react to form the ionic compound lithium fluoride.

(a) Describe what happens to the electrons when lithium atoms and fluorine atoms form ions. **[2]**

(b) Draw a dot-and-cross diagram of the ions in lithium fluoride. Show all the electrons and the charges on the ions. **[3]**

(c) State two physical properties of lithium fluoride. **[2]**

(a) Each lithium atom **loses one electron** to form Li^+; **B1** each fluorine atom **gains one electron** to form F^-. **B1**

(b) Lithium is 2,1, so Li^+ is **2**: one shell with 2 dots, in brackets, charge $+$. **B1** Fluorine is 2,7, so F^- is **2,8**: inner shell 2 crosses, outer shell 7 crosses and 1 dot, in brackets. **B1** Both charges correct: $[Li]^+$ and $[F]^-$. **B1**

(c) Any two of: **high melting point**; high boiling point; **conducts electricity when molten** or in aqueous solution; does not conduct when solid. **B1 B1**

Example 2

Extended. Calcium reacts with fluorine to form calcium fluoride.

(a) Write the electronic configurations of a calcium ion and a fluoride ion, with their charges. **[2]**

(b) Deduce the formula of calcium fluoride. Explain your answer. **[2]**

(c) Explain, in terms of structure and bonding, why calcium fluoride has a high melting point. **[3]**

(d) Solid calcium fluoride does not conduct electricity. State and explain one change that would make it conduct. **[2]**

(a) Ca (2,8,8,2) loses 2 electrons: **Ca^{2+}, 2,8,8**. **B1** F (2,7) gains 1 electron: **F^-, 2,8**. **B1**

(b) The charges must cancel: one Ca^{2+} $(+2)$ needs two F^- $(2 \times -1 = -2)$. **M1** Formula **CaF_2**. **A1**

(c) Calcium fluoride has a **giant ionic lattice B1** with **strong electrostatic attractions between oppositely charged ions**; **B1 a lot of energy** is needed to overcome these attractions. **B1**

(d) Melt it: **B1** in the molten compound the **ions can move** and carry the charge. **B1**

Example 3

Extended. Aluminium is a metal used in overhead power cables.

(a) Name and describe the bonding in aluminium. **[4]**

(b) Explain why aluminium conducts electricity when solid. **[1]**

(c) Explain why aluminium can be drawn out into wires. **[1]**

(a) Metallic bonding. **B1** A lattice of **positive ions**, **B1** in a **sea of delocalised electrons**, **B1** with **electrostatic attraction between the positive ions and the electrons**. **B1**

(b) The delocalised **electrons move** through the structure. **B1** ("Free electrons" alone does not score; say they **move**.)

(c) The **layers of positive ions can slide over each other**. **B1**

Example 4

The table gives data for five substances, P to T.

Substance	Melting point / °C	Boiling point / °C	Conducts when solid	Conducts when molten
P	1538	2862	good	good
Q	996	1704	poor	good
R	−114	−85	poor	poor

Substance	Melting point / °C	Boiling point / °C	Conducts when solid	Conducts when molten
S	1713	2950	poor	poor
T	80	218	poor	poor

(a) Identify the substance that is a gas at 25 °C. **[1]**

(b) Identify the ionic compound. Give one reason from the table. **[2]**

(c) Identify the metal. Give one reason. **[2]**

(d) Identify the giant covalent substance. Give two reasons. **[3]**

(a) R: its boiling point, -85 °C, is below 25 °C. **B1**

(b) Q B1: it conducts when molten but not when solid. **B1**

(c) P B1: it conducts when solid (and when molten). **B1**

(d) S B1: very high melting and boiling points **B1**; does not conduct when solid or when molten. **B1**

(T has a low melting point and does not conduct: it is a simple molecular solid at 25 °C.)

Common mistakes

- **Describing electron transfer when asked what an ionic bond is.** The bond is the **attraction between oppositely charged ions**. Saying "sodium gives an electron to chlorine" describes how the ions formed and scores nothing for the definition.
- **Getting the transfer the wrong way round**, or saying the atoms **share** electrons. Metals **lose** electrons; non-metals **gain** them. Sharing is covalent bonding.
- **Writing "strong forces" or "electrostatic" on their own.** Say "strong electrostatic **attraction**" and name what attracts what.
- **Mixing ionic with molecular words.** Examiners often see "ionic bonds between molecules", "intermolecular forces in sodium chloride" or "atoms" in an ionic lattice. Ionic compounds have **ions**, not atoms or molecules, and no intermolecular forces.
- **Saying electrons carry the current in a molten ionic compound.** It is the **ions** that move. Delocalised electrons belong to metals and graphite.
- **"The ions need to be free"** is too vague. Say the ions **can move** (are mobile) when molten or in solution.
- **Leaving out the full outer shell of a metal ion** in a dot-and-cross diagram, or drawing the atoms instead of the ions. Draw K^+ with its 8 outer electrons, and put brackets and charges on every ion.
- **Describing metallic bonding with ionic words**: negative ions, chloride ions, protons or nuclei instead of **positive ions**, or a "sea" of negative ions instead of **electrons**. And the most common omission: the **attraction** between the positive ions and the electrons.
- **Saying "free electrons" or just "delocalised electrons" to explain conduction.** The mark needs the electrons to **move** (be mobile).

- **Saying metals conduct because ions move**, or are malleable because electrons move. It is **electrons** for conduction and **layers of ions sliding** for malleability.
- **Answering a different question**: describing alloys, or listing metal properties, when the bonding was asked for.
- **Using "it" or "they" in a comparison** of two substances. Name the substance each time.

How to get the marks

- **Definitions are marked on key words.** Ionic bond: "strong electrostatic attraction" + "oppositely charged ions". Metallic bonding: "positive ions" + "delocalised (mobile) electrons" + "attraction between them" (usually one mark each). Lattice: "regular arrangement" + "alternating positive and negative ions".
- **Dot-and-cross diagrams** usually score one mark per ion (right number of electrons in each shell, dots and crosses in the right places) and one for **both charges**. Keep the key the question gives (for example "use crosses for lithium").
- **"Explain in terms of structure and bonding"** needs the **structure** (giant lattice), the **particles** (ions), the **force** (strong electrostatic attraction between oppositely charged ions) and the **consequence** (a lot of energy needed to overcome it). When comparing with a simple molecular substance, also say its **intermolecular forces are weak** and which substance's forces are **stronger**.
- **Conductivity answers** need the right **particle** and the word **move**: ions move (molten or aqueous ionic compound); electrons move (metal). Saying why the solid does not conduct (ions in fixed positions) is often also credited.
- **"State"** needs a short answer, such as "metallic" or "cation". **"Describe"** needs the features of the structure. **"Explain"** needs the reason, with the particles named. **"Deduce"** means use the information given, such as the charges or the data table.
- **Data-table questions** reward a **reason from the table** for each choice: quote the property ("conducts only when molten"), not a general fact.
- **Multiple-choice questions** hinge on one word: positive or negative, ions or electrons, lose or gain, strong or weak, solid or molten. Check each part of the row.

Quick check

1. Give the charge and the electronic configuration of the ion formed by each atom: aluminium, sulfur, potassium.
2. **Extended.** Deduce the formulae of aluminium oxide, potassium sulfide and magnesium nitride.
3. Solid potassium bromide does not conduct electricity, but molten potassium bromide does. Explain why.
4. Describe how the electrons are arranged in a dot-and-cross diagram of the ions in sodium oxide, Na_2O. Use dots for sodium's electrons and crosses for oxygen's, and show all shells.
5. **Extended.** Explain why copper conducts electricity and why it can be hammered into sheets.

Answers

1. Al (2,8,3) loses 3: **Al^{3+}, 2,8**. S (2,8,6) gains 2: **S^{2-}, 2,8,8**. K (2,8,8,1) loses 1: **K^+, 2,8,8**.
2. Al^{3+} and O^{2-}: $2 \times (+3) + 3 \times (-2) = 0$, so **$Al_2O_3$**. K^+ and S^{2-}: $2 \times (+1) + (-2) = 0$, so **K_2S**. Mg^{2+} and N^{3-}: $3 \times (+2) + 2 \times (-3) = 0$, so **$Mg_3N_2$**.
3. In the solid the ions are held in fixed positions in the lattice and **cannot move**. When molten, the lattice breaks down and the **ions can move**, so they carry the charge.
4. Two sodium ions, each **$[2,8]^+$**: 2 dots in the first shell and 8 dots in the second, in brackets with charge $+$. One oxide ion, **$[2,8]^{2-}$**: 2 crosses in the first shell, and in the second shell **6 crosses and 2 dots** (one dot from each sodium atom), in brackets with charge $2-$.
5. Copper has a lattice of positive ions in a sea of **delocalised electrons**, which **can move** through the structure and carry the current. When it is hammered, the **layers of positive ions slide over each other**, so it changes shape without breaking.

Past questions to try

- **0620/42/F/M/25 Q2**: the ionic bond, a dot-and-cross diagram of K_2S and completing the sodium chloride lattice.
- **0620/41/M/J/23 Q3**: dot-and-cross diagrams and formula of sodium oxide, and why it has a high melting point.
- **0620/42/O/N/21 Q5**: naming and describing the metallic bonding in iron and potassium, and the properties of metals.
- **0620/43/O/N/22 Q2**: identifying a metal and an ionic solid from a data table, with a reason for each.