Collins

Cambridge IGCSE™

Chemistry

TEACHER'S GUIDE

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C2.2 Ions and ionic bonds

Introduction

This topic builds on previous ideas about atomic structure from Topic 2.1 *Atoms, elements and compounds*. It links to covalent bonding in Topic 2.3 *Molecules and covalent bonds.* There are also a number of other topics where knowledge of ions and ionic bonding is fundamental to understanding the content. These include Topic 4.1 *Electrochemistry*; Topic 7.1 *Acids, bases and salts*; Topic 8.2 *Group I elements*; Topic 8.3 *Group VII elements*; Topic 12.2 *Identification of ions and gases*. For the supplementary syllabus there are also links to Topic 6.3 *Redox reactions*.

This topic has two main aspects: the nature of ionic bonding and, for following the supplementary syllabus, the lattice structure and associated properties of ionic compounds.

Links to other topics

Section	Essential background knowledge	Useful links
2 Atoms, elements and compounds	2.1 Atoms, elements and compounds	2.3 Molecules and covalent bonds
4 Electrochemistry		4.1 Electrochemistry
6 Chemical reactions		6.3 Redox reactions
8 The Periodic Table		8.2 Group I elements 8.3 Group VII elements
12 Experimental techniques		12.2 Identification of ions and gases

Topic overview

C2.2a	**Orientation** This learning episode recaps previous work on atomic structure, with emphasis on electron arrangements. Considering the properties of ionic compounds provides an insight into the nature of the bonding in these compounds.
C2.2b	**The formation of ions** This learning episode involves modelling the process of ionic bonding and then provides plenty of practice for producing dot-and-cross diagrams. Reference to the relationship between ion charges and the Periodic Table will provide a link to future work in that area. **Supplement** Consideration is given to compounds formed by elements other than those in Group I and Group VII.
C2.2c	**Properties of ionic compounds** This learning episode focuses on the description of the characteristic properties of ionic compounds and contrasts them with other compounds (essentially covalent compounds). **Supplement** An explanation of the properties of ionic compounds in terms of structure and bonding provides greater depth. The idea of a giant ionic lattice structure as a representation of how ions are arranged in an ionic compound is also covered.
C2.2d	**Consolidation and summary** This learning episode provides a quick recap of the ideas encountered and an opportunity to answer the end of topic questions in the Student Book.

Career links

These are some scientific careers that focus on this area of chemistry but careers in many other fields use the knowledge and skills gained studying science.

Geochemists study the composition of ionic compounds in the form of minerals in the Earth's mantle and crust to find resources such as metals and help with the understanding of environmental issues such as soil depletion.

Oceanographers study the presence of ions dissolved in seawater to measure changes in salinity which are influenced by climate change.

Learning episode C2.2a Orientation

Learning aims

- To revise ideas on atomic structure.
- To map out the main purposes of the topic.
- Know the structure of an atom by interpreting proton and nucleon numbers.
- Know the arrangement of electrons in shells for the first 20 elements.

Common misconceptions

Some students think that all compounds are made up of molecules.

Resources

Student Book page 26

Approach

Start by revising the ideas on atomic structure, emphasising the electronic structures of atoms and the arrangement of electrons in shells around the nucleus.

Ask students to research the melting points of some common substances, including a range of ionic compounds and covalent compounds. Ask them to see if there is a pattern in the compounds that have melting points in the higher ranges. The students should identify the inclusion of a metal as a common feature.

Supplement Explain that these properties must be a result of how metals and non-metals combine together – a process that produces particles known as ions.

Learning episode C2.2b The formation of ions

Learning objectives

- Describe the formation of positive ions, known as cations, and negative ions, known as anions.
- State that an ionic bond is a strong electrostatic attraction between oppositely charged ions.
- Describe the formation of ionic bonds between elements from Group I and Group VII, including the use of dot-and-cross diagrams.
- **Supplement** Describe the formation of ionic bonds between ions of metallic and non-metallic elements, including the use of dot-and-cross diagrams.

Common misconceptions

Some students think that all compounds are made up of molecules.

Resources

Student Book pages 38–40

Worksheet C2.2b Ionic bonding: dot-and-cross diagrams

Approach

Revise the idea of atom diagrams. Use the examples on page 39 of the Student Book to introduce dot-and-cross diagrams.

Emphasise the importance of electron transfer from metal to non-metal. In the examples that students are likely to meet, both the metal and non-metal acquire a full outer shell of electrons (that is, 2 or 8). Take time to explain that the resulting particles are no longer atoms (no longer neutral) and are known as ions.

Emphasise that the ion charges in the chemical formula of an ionic compound cancel each other out. Use the questions on page 41 of the Student Book to allow for practice producing simple dot-and-cross diagrams.

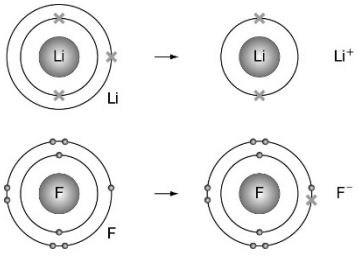
Ask students if they can see a pattern between the charge on the resulting ions and their position in the Periodic Table.

Supplement Students consider the formation of ionic bonds where more than one electron is transferred (that is, compounds other than those formed from Group I and Group VII elements). Worksheet C2b.2 gives some examples of the transfer of more than one electron.

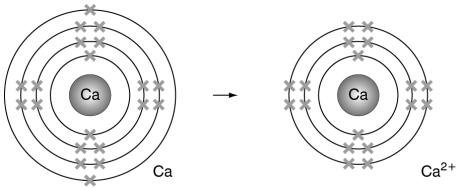
Answers

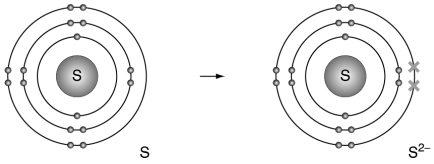
Page 41

1.



Supplement 2.



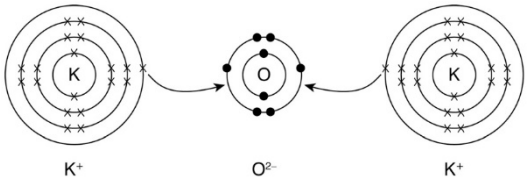


Supplement 3. Both phosphorus and oxygen are non-metals. (A metal is needed to form an ionic bond.)

Supplement Worksheet C2.2b

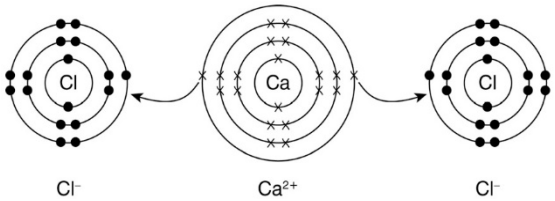
Potassium oxide

$2K\ (2,8,8,1) \rightarrow 2K^{+}\ (2,8,8)$ $O\ (2,6) \rightarrow O^{2-}\ (2,8)$



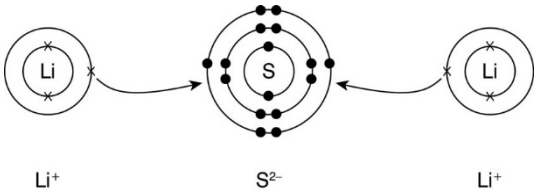
Calcium chloride

$Ca\ (2,8,8,2) \rightarrow Ca^{2+}\ (2,8,8)$ $2Cl\ (2,8,7) \rightarrow 2Cl^{-}\ (2,8,8)$



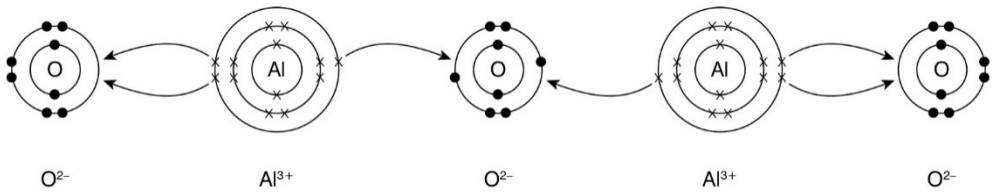
Lithium sulfide

$2Li\ (2,1) \rightarrow 2Li^{+}\ (2)$ $S\ (2,8,6) \rightarrow S^{2-}\ (2,8,8)$



Aluminium oxide

$2Al\ (2,8,3) \rightarrow 2Al^{3+}\ (2,8)$ $3O\ (2,6) \rightarrow 3O^{2-}\ (2,8)$



Supplement Worksheet C2.2b Ionic bonding: dot-and-cross diagrams

Ionic bonding is the type of bonding that occurs between metals and non-metals. Metal atoms lose electrons from their outer electron shells and form positive ions; non-metal atoms gain electrons to fill their outer electron shells and form negative ions.

Remember: The number of positive and negative charges must balance.

Draw dot-and-cross diagrams to show the ionic bonding in the following compounds. Write the formulae of the ions formed in each case.

Potassium oxide

(Proton numbers O = 8; K = 19)

Calcium chloride

(Proton numbers Cl = 17; Ca = 20)

Lithium sulfide

(Proton numbers Li = 3; S = 16)

Aluminium oxide

(Proton numbers O = 8; Al = 13)

Learning episode C2.2c Properties of ionic compounds

Learning objectives

- Describe the properties of ionic compounds:
  (a) high melting points and boiling points
  (b) good electrical conductivity when aqueous or molten and poor when solid.
- **Supplement** Describe the giant lattice structure of ionic compounds as a regular arrangement of alternating positive and negative ions.
- **Supplement** Explain in terms of structure and bonding the properties of ionic compounds:
  (a) high melting points and boiling points
  (b) good electrical conductivity when aqueous or molten and poor when solid.

Resources

Student Book pages 41–44

Resources for a demonstration (see Technician's notes, below)

Approach

Use Table 2.7 on page 42 of the Student Book to summarise the properties of sodium chloride. Mention that these properties apply to all ionic compounds. Refer to the Science in Context feature on ionic crystals (Student Book page 43). The content of these Science in Context features is beyond the syllabus but provides the opportunity to explore the content more deeply.

Supplement If possible, use models to illustrate the 3D structure of ionic compounds such as sodium chloride. Explain that the attractions between positive and negative ions are called electrostatic attractions and that multiple attractions in all directions produce a very strong structure that is not easily broken down; for example, the melting point of sodium chloride is 801 °C. Use this structure to support the explanations in Table 2.7.

Supplement Ask students how the properties of magnesium oxide would compare with those of sodium chloride. Explain the higher melting point of magnesium oxide in terms of a stronger electrostatic attraction between doubly charged ions. You may refer to aluminium oxide as a further example of the concept.

Technician's notes

Be sure to check the latest safety notes on these resources before proceeding.

The following resources are needed for the demonstration of models of ionic structure:

molecular model, made up to show two or three ionic compounds such as sodium chloride

Answers

Science in Context, page 43

Aluminium oxide is an ionic compound containing Al^{3+} ions and O^{2-} ions. As a result of the high charges on these ions, they form a lattice with very strong electrostatic forces.

Science in Context, page 44

As calcium is below magnesium in Group II the calcium ion will be larger than the magnesium ion. As a result the packing arrangements in the two oxides will be different, as will the attractive force between the ions in the structure.

Page 44

1. High melting point, high boiling point, good conductor of electricity when aqueous or molten.
2. **Supplement** The ions are held together strongly in a giant lattice structure. The ions can vibrate but cannot move around.
3. **Supplement** Sodium chloride is made up of singly charged ions, Na^+ and Cl^-, whereas the magnesium ion in magnesium oxide has a double charge, Mg^{2+}. The higher the charge on the positive ion the stronger the attractive forces between the positive ion and the negative ion.

Learning episode C2.2d Consolidation and summary

Learning aims

- Review the learning points of the topic summarised in the end of topic checklist.
  - Test understanding of the topic content by answering the end of topic questions.

Resources

Student Book pages 45–46

Approach

Ask students to work with a partner to make a list of key words from this topic. They could then work together to produce a spider diagram showing how the different concepts are linked. They could compare their list with the list of key terms given in the Student Book. Discuss the checklist and ask questions to see how much of the content students are comfortable with.

Students could make flashcards of the key content and then use the flashcards to quiz each other on the information.

Ask students to work individually through the end of topic questions in the Student Book without looking at the text. As they work, walk around the classroom observing their answers and questioning them as necessary to find out which questions are causing difficulties.

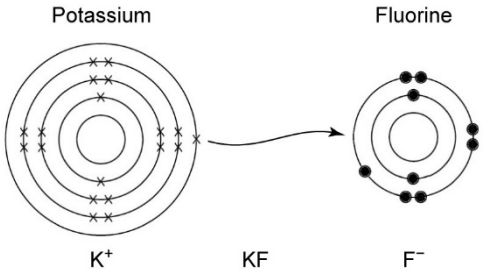
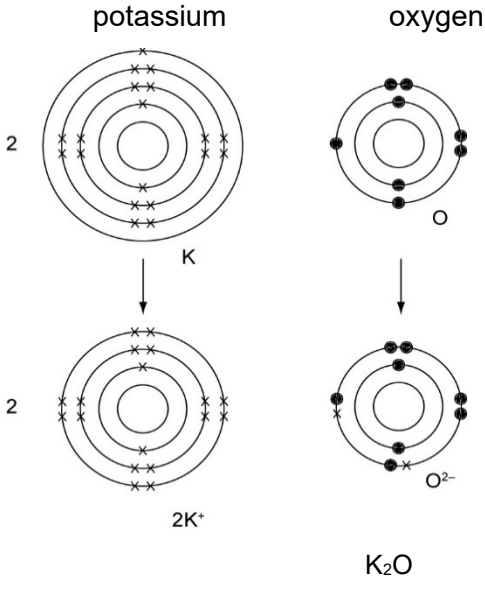
After a set period, ask students to stop working. Discuss any areas of difficulty you observed as you walked round the class.

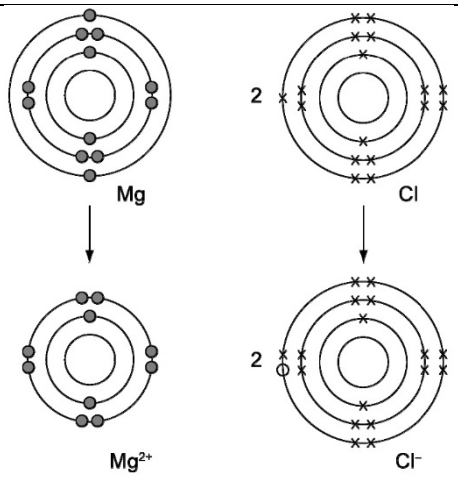
Students should complete any unanswered questions for homework, but you should stress that they should answer the questions without looking at the text, so that they can see how much they have remembered.

If you have chosen to teach Topic 2.3 M*olecules and covalent bonds* as the next topic, then the link can be emphasised.

End of topic questions mark scheme

The marks available for a question can indicate the level of detail you need to provide in your answer.

<table>
<tr><th>Question</th><th>Correct answer</th><th>Marks</th></tr>
<tr><td>1</td><td>C</td><td>1 mark</td></tr>
<tr><td>2 a)</td><td>K^+ OR $[K]^+$</td><td>1 mark</td></tr>
<tr><td>2 b)</td><td>Al^{3+} OR $[Al]^{3+}$</td><td>1 mark</td></tr>
<tr><td>2 c)</td><td>S^{2-} OR $[S]^{2-}$</td><td>1 mark</td></tr>
<tr><td>2 d)</td><td>F^- OR $[F]^-$</td><td>1 mark</td></tr>
<tr><td>3</td><td>Completed table as shown below:
<table>
<tr><th>Atom</th><th>Electronic arrangement of the atom</th><th>Electronic arrangement of the ion</th><th>Charge on the ion</th></tr>
<tr><td>X</td><td>2,6</td><td>2,8</td><td>2–</td></tr>
<tr><td>Y</td><td>2,8,8,2</td><td>2,8,8</td><td>2+</td></tr>
<tr><td>Z</td><td>2,1</td><td>2</td><td>1+ (or +)</td></tr>
</table></td><td>3 marks</td></tr>
<tr><td>4</td><td> 
</td><td>2 marks</td></tr>
<tr><td>Supplement
5 a)</td><td> 
</td><td>2 marks</td></tr>
<tr><td>Supplement
5 b)</td><td>magnesium chlorine</td><td>2 marks</td></tr>
</table>

Question	Correct answer	Marks
		
Supplement 6 a)	There are strong electrostatic attractive forces between the ions. A lot of energy needs to be applied to break these attractions to form a liquid.	1 mark 1 mark
Supplement 6 b)	The ions are able to carry the electric current. The ions need to be free to move; therefore the potassium chloride needs either to be in a molten state or in solution.	1 mark 1 mark
Supplement 7	Magnesium forms a 2+ ion, oxygen a 2– ion, sodium a 1+ ion and chlorine a 1– ion. The electrostatic attraction between 2+ and 2– ions is greater than between 1+ and 1– ions, resulting in a higher melting point and boiling point.	1 mark 1 mark
	Total:	20 marks

