

## C2 Bonding, structure and the properties of matter

### What's the science story?

Chemists use theories of structure and bonding to explain the physical and chemical properties of materials. Analysis of structures shows that atoms can be arranged in a variety of ways, some of which are molecular while others are giant structures. Theories of bonding explain how atoms are held together in these structures. Scientists use this knowledge of structure and bonding to engineer new materials with desirable properties. The properties of these materials may offer new applications in a range of different technologies.

### Previous knowledge:

#### KS3

Year 7 – Reactions

Year 8 – Reactions 2

Year 9 – Reactions 3

#### KS4

C1 Atomic structure and the periodic table

### Next steps...

C3 Quantitative chemistry

C4 Chemical changes

C5 Energy changes

C7 Organic chemistry

C8 Chemical analysis



### Keywords

Bonds  
Energy  
Evaporation  
Freezing  
Condensing  
Melting  
Boiling  
Atom  
Ion  
Electron  
Ionic

Compound  
Dot and cross  
Formula  
Ratio  
Strong  
Properties  
Conduct  
Electricity  
Lattice  
Sharing  
Transfer

Stable  
Intermolecular  
Weak  
Allotrope  
Conductor  
Delocalised  
Malleable  
Alloy  
Monomer  
Polymer  
Polymerisation

### Working scientifically skills:

WS1 Models of dot and cross diagrams

WS11 Hazards and precautions during practicals

WS15 Using given data (in table form)

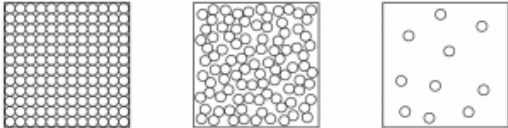
WS17 Making conclusions

### Assessments:

End of unit test (summative) (Out of 30)

Exit tickets x 2/3 (formative)

- **ET Ionic bonding**
- **ET Covalent bonding**

Lesson No. and Title	Learning objectives	AQA Specification	Practical equipment
1. States of matter	<p>4 – To describe the process of melting, freezing, boiling and condensing.</p> <p>6 – To compare the properties of the states of matter.</p> <p>8 – To suggest why substances have different melting and boiling points from each other.</p>	<p>The three states of matter are solid, liquid and gas. Melting and freezing take place at the melting point, boiling and condensing take place at the boiling point.</p> <p>The three states of matter can be represented by a simple model. In this model, particles are represented by small solid spheres. Particle theory can help to explain melting, boiling, freezing and condensing.</p> <div style="text-align: center;">  <div style="display: flex; justify-content: space-around; margin-top: 5px;"> <span>Solid</span> <span>Liquid</span> <span>Gas</span> </div> </div> <p>The amount of energy needed to change state from solid to liquid and from liquid to gas depends on the strength of the forces between the particles of the substance. The nature of the particles involved depends on the type of bonding and the structure of the substance. The stronger the forces between the particles the higher the melting point and boiling point of the substance.</p> <p>(HT only) Limitations of the simple model above include that in the model there are no forces, that all particles are represented as spheres and that the spheres are solid.</p> <p>Students should be able to:</p> <ul style="list-style-type: none"> <li>• predict the states of substances at different temperatures given appropriate data</li> <li>• explain the different temperatures at which changes of state occur in terms of energy transfers and types of bonding</li> <li>• recognise that atoms themselves do not have the bulk properties of materials</li> <li>• (HT only) explain the limitations of the particle theory in relation to changes of state when particles are represented by solid inelastic spheres which have no forces between them.</li> </ul> <p>In chemical equations, the three states of matter are shown as (s), (l) and (g), with (aq) for aqueous solutions.</p> <p>Students should be able to include appropriate state symbols in chemical equations for the reactions in this specification.</p>	

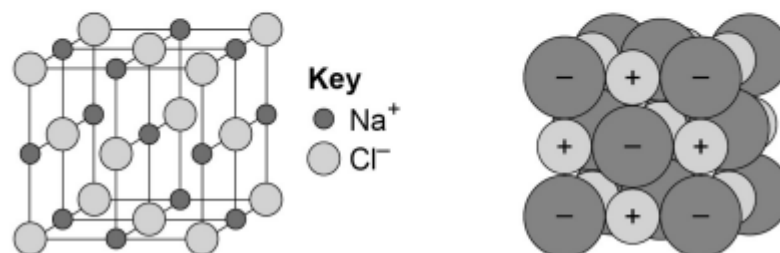
2. Atoms to ions	<p>4 – To describe how atoms become ions.</p> <p>6 – To explain how electron transfer allows ionic bonding to occur.</p> <p>8 – To draw dot and cross diagrams of unfamiliar ionic compounds.</p>	<p>When a metal atom reacts with a non-metal atom electrons in the outer shell of the metal atom are transferred. Metal atoms lose electrons to become positively charged ions. Non-metal atoms gain electrons to become negatively charged ions. The ions produced by metals in Groups 1 and 2 and by non-metals in Groups 6 and 7 have the electronic structure of a noble gas (Group 0).</p> <p>The electron transfer during the formation of an ionic compound can be represented by a dot and cross diagram, eg for sodium chloride</p> $\text{Na} \cdot + \begin{array}{c} \times \times \\ \times \text{Cl} \times \\ \times \times \end{array} \longrightarrow \left[ \text{Na} \right]^+ \left[ \begin{array}{c} \times \times \\ \times \text{Cl} \times \\ \times \times \end{array} \right]^-$ <p>(2,8,1)    (2,8,7)                      (2,8)    (2,8,8)</p>	
3. Ionic bonding		<p>Students should be able to draw dot and cross diagrams for ionic compounds formed by metals in Groups 1 and 2 with non-metals in Groups 6 and 7.</p> <p>The charge on the ions produced by metals in Groups 1 and 2 and by non-metals in Groups 6 and 7 relates to the group number of the element in the periodic table.</p> <p>Students should be able to work out the charge on the ions of metals and non-metals from the group number of the element, limited to the metals in Groups 1 and 2, and non-metals in Groups 6 and 7.</p>	
4. Ionic compounds	<p>4 – State that opposite ions attract.</p> <p>6 – Interpret formula of familiar ionic compounds to determine the number and type of each ion present.</p> <p>8 – Generate formula of wide range of ionic compounds when the charges of ions are given.</p>	<p>Students should be able to:</p> <ul style="list-style-type: none"> <li>deduce that a compound is ionic from a diagram of its structure in one of the specified forms</li> <li>describe the limitations of using dot and cross, ball and stick, two and three-dimensional diagrams to represent a giant ionic structure</li> <li>work out the empirical formula of an ionic compound from a given model or diagram that shows the ions in the structure.</li> </ul> <p>Students should be familiar with the structure of sodium chloride but do not need to know the structures of other ionic compounds.</p>	

## 5. Properties of ionic compounds

- 4 – State properties of ionic structures.  
 6 – Explain properties of ionic structures.  
 8 – Justify in terms of properties that a compound has ionic bonding.

An ionic compound is a giant structure of ions. Ionic compounds are held together by strong electrostatic forces of attraction between oppositely charged ions. These forces act in all directions in the lattice and this is called ionic bonding.

The structure of sodium chloride can be represented in the following forms:



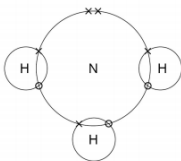
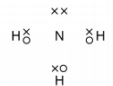

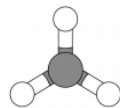
Ionic compounds have regular structures (giant ionic lattices) in which there are strong electrostatic forces of attraction in all directions between oppositely charged ions.

These compounds have high melting points and high boiling points because of the large amounts of energy needed to break the many strong bonds.

When melted or dissolved in water, ionic compounds conduct electricity because the ions are free to move and so charge can flow.

Knowledge of the structures of specific ionic compounds other than sodium chloride is not required.

PRAC: Properties of ionic compounds  
 large container of salt, microscopes and glass slides; glass test tubes, glass beakers, simple circuit equipment (wires, bulb, battery, electrodes)

6. Covalent bonding	<p>4 – Describe a covalent bond and give examples.</p> <p>6 – Draw dot and cross diagrams for a number of common covalent compounds and molecules.</p> <p>8 – Suggest how double and triple covalent bonds can be formed.</p>	<p>When atoms share pairs of electrons, they form covalent bonds. These bonds between atoms are strong.</p> <p>Covalently bonded substances may consist of small molecules.</p> <p>Students should be able to recognise common substances that consist of small molecules from their chemical formula.</p> <p>For ammonia (NH<sub>3</sub>)</p>  <p>and/or</p>  <p>and/or</p>  <p>and/or</p>  <ul style="list-style-type: none"> <li>draw dot and cross diagrams for the molecules of hydrogen, chlorine, oxygen, nitrogen, hydrogen chloride, water, ammonia and methane</li> <li>represent the covalent bonds in small molecules, in the repeating units of polymers and in part of giant covalent structures, using a line to represent a single bond</li> <li>describe the limitations of using dot and cross, ball and stick, two and three-dimensional diagrams to represent molecules or giant structures</li> <li>deduce the molecular formula of a substance from a given model or diagram in these forms showing the atoms and bonds in the molecule.</li> </ul>	
7. Simple molecules	<p>4 – State properties of simple molecules.</p> <p>6 – Explain properties of simple molecules.</p> <p>8 – Compare and contrast properties of substances with different bonding.</p>	<p>Substances that consist of small molecules are usually gases or liquids that have relatively low melting points and boiling points.</p> <p>These substances have only weak forces between the molecules (intermolecular forces). It is these intermolecular forces that are overcome, not the covalent bonds, when the substance melts or boils.</p> <p>The intermolecular forces increase with the size of the molecules, so larger molecules have higher melting and boiling points.</p> <p>These substances do not conduct electricity because the molecules do not have an overall electric charge.</p> <p>Students should be able to use the idea that intermolecular forces are weak compared with covalent bonds to explain the bulk properties of molecular substances.</p>	



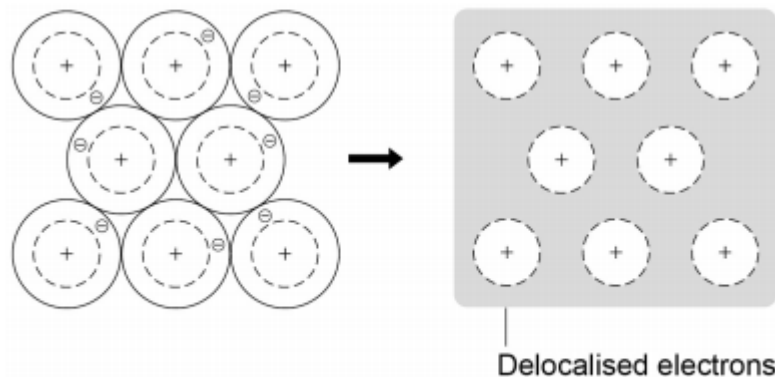
8. Giant covalent structures	<p>4 - To identify giant covalent structures and allotropes of carbon.</p> <p>6 - To define the properties of giant covalent structures and other carbon allotropes.</p> <p>8 - To explain the properties of giant covalent structures and other carbon allotropes.</p>	<p>Substances that consist of giant covalent structures are solids with very high melting points. All of the atoms in these structures are linked to other atoms by strong covalent bonds. These bonds must be overcome to melt or boil these substances. Diamond and graphite (forms of carbon) and silicon dioxide (silica) are examples of giant covalent structures.</p> <p>Students should be able to recognise giant covalent structures from diagrams showing their bonding and structure.</p> <p>In diamond, each carbon atom forms four covalent bonds with other carbon atoms in a giant covalent structure, so diamond is very hard, has a very high melting point and does not conduct electricity.</p> <p>In graphite, each carbon atom forms three covalent bonds with three other carbon atoms, forming layers of hexagonal rings which have no covalent bonds between the layers.</p> <p>In graphite, one electron from each carbon atom is delocalised.</p> <p>Students should be able to explain the properties of graphite in terms of its structure and bonding.</p> <p>Students should know that graphite is similar to metals in that it has delocalised electrons.</p> <p>Graphene is a single layer of graphite and has properties that make it useful in electronics and composites.</p> <p>Students should be able to explain the properties of graphene in terms of its structure and bonding.</p> <p>Fullerenes are molecules of carbon atoms with hollow shapes. The structure of fullerenes is based on hexagonal rings of carbon atoms but they may also contain rings with five or seven carbon atoms. The first fullerene to be discovered was Buckminsterfullerene (<math>C_{60}</math>) which has a spherical shape.</p> <p>Carbon nanotubes are cylindrical fullerenes with very high length to diameter ratios. Their properties make them useful for nanotechnology, electronics and materials.</p> <p>Students should be able to:</p> <ul style="list-style-type: none"> <li>• recognise graphene and fullerenes from diagrams and descriptions of their bonding and structure</li> <li>• give examples of the uses of fullerenes, including carbon nanotubes.</li> </ul>	
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## 9. Bonding in metals

- 4 – Recognise metallic bonding in diagrams.  
 6 – Describe metallic bonding.  
 8 – Explain how metal atoms form giant structures.

Metals consist of giant structures of atoms arranged in a regular pattern.

The electrons in the outer shell of metal atoms are delocalised and so are free to move through the whole structure. The sharing of delocalised electrons gives rise to strong metallic bonds. The bonding in metals may be represented in the following form:



Metals have giant structures of atoms with strong metallic bonding. This means that most metals have high melting and boiling points.

In pure metals, atoms are arranged in layers, which allows metals to be bent and shaped. Pure metals are too soft for many uses and so are mixed with other metals to make alloys which are harder.

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Students should be able to explain why alloys are harder than pure metals in terms of distortion of the layers of atoms in the structure of a pure metal.

Metals are good conductors of electricity because the delocalised electrons in the metal carry electrical charge through the metal. Metals are good conductors of thermal energy because energy is transferred by the delocalised electrons.

PRAC: Looking at metals  
 Examples of metals;  
 copper wire, steel fork,  
 aluminium foil, iron  
 magnet etc  
 Simple circuit  
 equipment, balances,  
 beakers, kettles

10. Polymers	<p>4 - To identify a polymer.</p> <p>6 - To describe the bonding in polymers.</p> <p>8 - To explain and justify the properties of some polymers.</p>	<p>Polymers have very large molecules. The atoms in the polymer molecules are linked to other atoms by strong covalent bonds. The intermolecular forces between polymer molecules are relatively strong and so these substances are solids at room temperature.</p> <p>Students should be able to recognise polymers from diagrams showing their bonding and structure.</p>	<p>PRAC: Polymers</p> <ol style="list-style-type: none"> <li>1. Polymer worms – sodium alginate, pipettes, gloves, spatulas, sodium chloride sol, calcium chloride sol</li> <li>2. Polymer nappies – Nappy, gloves, 150ml beaker, water, pipette</li> <li>3. Polymer hair gel – Petri dish, cheap hair gel, salt, water in a beaker, pipettes</li> <li>4. Polymer glue slime – Disposable cup, White glue, borax, spatula, stirring rod, food colouring</li> </ol>
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