PROVISIONAL

DELIVERY GUIDE

Theme: Atomic structure and bonding

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GCSE (9–1) Twenty First Century Combined Science B

GCSE REFORM

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Introduction

Delivery guides are designed to represent a body of knowledge about teaching a particular topic and contain:

- Content: A clear outline of the content covered by the delivery guide;
- Thinking Conceptually: Expert guidance on the key concepts involved, common difficulties students may have, approaches to teaching that can help students understand these concepts and how this topic links conceptually to other areas of the subject;
- Thinking Contextually: A range of suggested teaching activities using a variety of themes so that different activities can be selected which best suit particular classes, learning styles or teaching approaches.

If you have any feedback on this Delivery Guide or suggestions for other resources you would like OCR to develop, please email resourcesfeedback@ocr.org.uk.

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Curriculum Content C2.1 The history of an atom

C2.1 The history of an atom

Section C2.1 looks at the development of ideas about the atom and introduces the modern model for atomic structure, including electron arrangements. The Periodic Table can be used to find the atomic number and relative atomic mass of an atom of an element, and then work out the numbers of protons, neutrons and electrons. The number of electrons in each shell can be represented by simple conventions such as dots in circles or as a set of numbers (for example, sodium as 2.8.1).

Atomic structure is used to help explain the behaviour of the elements. Atoms are small – about 10^{-10} m across, and the nucleus is at the centre, about a hundred-thousandth of the diameter of the atom. Molecules are larger, containing from two to hundreds of atoms. Objects that can be seen with the naked eye contain millions of atoms.

Thinking Conceptually C2.1 The history of an atom

Approaches to teaching the content

Build on the idea of an atom, dating from Ancient Greeks introduced for the first time in module C1.1 and modern scientists such as Dalton, Thompson and Rutherford. Present Bohr's theory of the electrons orbiting the nucleus on the shells first mentioned in 1913. This whole concept can be represented as a 'Time line'. This then leads to the presentation of the elements found on the Periodic Table by their electronic structures. The number of protons, neutrons and electrons can be identified from the position of an element in the Periodic Table. Modelling can be used to represent the nucleus and its sub particles, protons and neutrons as well as the building of the shells and orbiting electrons. The Periodic Table used for teaching should have a clear 'key' such as Atomic number, Relative atomic mass and definitions of the latter.

Common misconceptions or difficulties students may have

Often atomic shells are called 'rings'. Students need to learn to use a Periodic Table in every lesson to understand the position of the elements and their atomic numbers to enable them to deduce the number of protons. Atomic number must be defined as the number of protons. Number of electrons should be defined to be the same as number of protons. Number of neutrons is calculated as difference between the mass number and the atomic number, i.e. the sum of the neutrons and protons in an atom gives us the mass number of that atom/element.

Conceptual links to other areas of the specification - useful ways to approach this topic to set students up for topics later in the course

The concept of an atom, its history and its constituents, is a very good basis for the introduction to bonding. The outer electrons are responsible for the properties of the elements. This can be applied to groups 1 and 7 in the subtopic C2.3.

Approaches to teaching the content

Start with a definition of an atom from Greek – atomos means 'not to be divided'. Introduce the idea of the scientists through the centuries investigating the structure of the elements and link to discovery of an electron by J.J. Thomson in 1897 and the fact that atoms are not the smallest particles. Then take it further to Rutherford's idea of atomic nucleus and complete the story by introducing Bohr's model of an atom that contains shells of electrons. Discuss further the arrangements of the electrons on shells and the position of the elements in the Periodic table. Use the Periodic Table to find the atomic number and the mass number of some elements and from there the number of protons, electrons and neutrons.

Activities C2.1 The history of an atom

Activities	**Resources**
Activity 1 **The discovery of the atomic nucleus** *(Science and Technology Facilities Council; 3 of 15)* https://www.youtube.com/watch?v=wzALbzTdnc8 Dr Brian Cox takes us on a journey of Rutherford's discovery of an atom's nucleus and its mass made of protons and neutrons.	Click here to see the clip

Curriculum Content C2.2 The history of the Periodic Table and its use

C2.2 The history of the Periodic Table and its use

Section C2.2 considers the development of the modern Periodic Table and the patterns that exist within it, focusing on Groups 1 and 7, with some reference to Group 0.

Elements in the modern Periodic Table are arranged in periods and groups, based on their atomic numbers. Elements in the same group have the same number of electrons in their outer shells. The number of electron shells increases down a group but stays the same across a period.

Mendeleev proposed the first arrangement of elements in the Periodic Table. Although he did not know about atomic structure, he reversed the order of some elements with respect to their masses, left gaps for undiscovered elements and predicted their properties. His ideas were accepted because when certain elements were discovered they fitted his gaps and the development of a model for atomic structure supported his arrangement. The later determination of the number of protons in atoms provided an explanation for the order he proposed.

The Periodic Table shows repeating patterns in the properties of the elements. Metals and non-metals can be identified by their position in the Periodic Table and by comparing their properties (physical properties including electrical conductivity).

Trends and patterns shown by the physical and chemical properties in groups.

Properties of elements within a group show trends. The reactivity of Group 1 metals elements increases down the group, shown by their reactivity with moist air, water and chlorine.

The Group 7 halogens are non-metals and become less reactive down the group. This is shown in reactions such as their displacement reactions with compounds of other halogens in the group.

Thinking Conceptually C2.2 The history of the Periodic Table and its use

Approaches to teaching the content

The history of the Periodic Table starts with John Dalton's table of triads which then leads to John Newlands who built on Dalton's theory and produced a table of 'octaves'. In 1869 Dmitri Mendeleev placed the elements in order of their atomic masses and arranged them to follow chemical and physical patterns as first mentioned in C1.2b. Soon after the modern Periodic Table is introduced where elements are arranged in order of their atomic number. Build on the concept of C1.2h that metals are found on the left hand side of the Periodic Table where non-metals are found on the right. Here we introduce the groups – vertical columns and periods - horizontal rows. Recall from C1.2e and C1.2g the reactivity of elements and those elements within groups show chemical trends. Introduce that the most important groups for our further progress are 1, 7 and 0.

Common misconceptions or difficulties students may have

Prior to Mendeleev, scientists put the elements in order of their atomic weight - now called relative atomic mass. Mendeleev discovered that when he arranged elements in a grid there were patterns where the characteristics of each element gradually changed across each row and down each column (periodicity) hence the Periodic Table. Using periodicity Mendeleev saw that the atomic weights (relative atomic mass) of elements were sometimes out of sequence and left the gaps, accurately predicting the characteristics of missing elements. Although in 1869 Mendeleev did not know what order he is arranging the elements in, we now know that he arranged them by atomic number. There is a direct link between the atomic model and the chemical characteristics of elements in terms of their chemical properties and the number of the electrons on the outermost shell.

Conceptual links to other areas of the specification - useful ways to approach this topic to set students up for topics later in the course

The periodicity is used throughout the whole of the chemistry course, but in particular when building the Periodic Table chart through ages. The idea of a timeline would be a possible way of representing the topic and build on the changes up to modern days. Compare the old Mendeleev's Periodic table and the modern, more organised version.

Thinking Contextually C2.2 The history of the Periodic Table and its use

Approaches to teaching the content

As the idea of the Periodic Table was already introduced in the previous sub-topic C2.1, Here we can start with the history from Döbereiner's triads, via Newlands' octaves to Mendeleev's Periodic Table with gaps left for the undiscovered elements and finish with the modern Periodic Table that shows repeating patterns in the properties of the elements. Also, it should be emphasised that metals and non-metals can be identified by their position in the Periodic Table and by comparing their properties, particularly concentrating on Groups 1 and 7. From here we can compare the properties of two opposite groups, alkali metals – Group 1 and halogens – Group 7.

Activities C2.2 The history of the Periodic Table and its use

Activities	Resources
Activity 1 **Atoms and the Periodic Table** *(Science and Technology Facilities Council; 1 of 15)* https://www.youtube.com/watch?v=bw5TE5o7JtE Dr Brian Cox explains that the Greeks knew about atoms and how Mendeleev's Periodic Table was amongst the first clues that the atom had a deeper structure.	Click here to see the clip
Activity 2 **The Periodic table** *(Crash Course Chemistry #4)* https://www.youtube.com/watch?v=0RRVV4Diomg Hank Green gives a picturesque talk about the history of the Periodic Table.	Click here to see the clip
Activity 3 **Physical properties of Group 1 elements** *(Creative Chemistry Copyright, Nigel Saunders)* http://www.creative-chemistry.org.uk/gcse/documents/Module8/N-m08-06.pdf A worksheet comprising of structured questions to summarise the properties of Group 1 elements.	Click here
Activity 4 Reactions of Group1 elements with water *(Creative Chemistry Copyright, Nigel Saunders)* http://www.creative-chemistry.org.uk/gcse/documents/Module8/N-m08-03.pdf A students' worksheet to accompany teacher demonstration of the reactions of Group 1 elements with structured questions.	Click here
Activity 5 Physical and chemical trends in Group 7 *(Creative Chemistry Copyright, Nigel Saunders)* http://www.creative-chemistry.org.uk/gcse/documents/Module8/N-m08-14.pdf A homework worksheet with structured questions to reinforce the learning of Group 7 properties.	Click here
Activity 6 Reactivity of the Group 7 elements *(Creative Chemistry Copyright, Nigel Saunders)* http://www.creative-chemistry.org.uk/gcse/documents/Module8/N-m08-07.pdf A class practical supporting learning of displacement reactions of halogens. It can also be used as a teacher demonstration.	Click here

C2.3 Ionic bonding

Section C2.3 focuses on extending an understanding of atomic structure to explain the ionic bonding between ions in ionic compound.

Group 1 elements combine with Group 7 elements by ionic bonding. This involves a transfer of electrons leading to charged ions. Atoms and ions can be represented using dot and cross diagrams as simple models (IaS3). Metals, such as Group 1, lose electrons from the outer shell of their atoms to form ions with complete outer shells and with a positive charge. Non-metals, such as Group 7, form ions with a negative charge by gaining electrons to fill their outer shell. The number of electrons lost or gained determines the charge on the ion.

The properties of ionic compounds such as Group 1 halides can be explained in terms of the ionic bonding. Positive ions and negative ions are strongly attracted together and form giant lattices. Ionic compounds have high melting points in comparison to many other substances due to the strong attraction between ions which means a large amount of energy is needed to break the attraction between the ions. They dissolve in water because their charges allow them to interact with water molecules. They conduct electricity when molten or in solution because the charged ions can move, but not when solid because the ions are held in fixed positions.

The arrangement of ions can be represented in both 2-D and 3-D. These representations are simple models which have limitations, for example they do not fully show the nature or movement of the electrons or ions, the interaction between the ions, their arrangement in space and their relative sizes or scale. (IaS3).

Thinking Conceptually C2.3 Ionic bonding

Approaches to teaching the content

This could be introduced as the topic prior to writing formulae and balancing equations. Recall the simple properties of Groups 1, 7 and 0 covered in C1.2d – C1.2h. Metals and non-metals react by transfer of electrons from a metal to a non-metal and can be demonstrated by 'The migration of ions' experiment. They form ions that attract each other in a giant regular lattice. Group 1 elements form positive +1 ions by giving away/losing one electron. Group 7 elements form negative -1 ions by accepting/gaining one electron. These ions are attracted by very strong forces that hold the lattice together and huge amount of energy is needed to break the lattice. The molecular models can be used here to help understand the theory of transfer of electrons. The properties of ionic compounds can be tested by an experiment.

Common misconceptions or difficulties students may have

There has to be an emphasis on the loss and gain of electrons. Positive ions are formed by loss of electrons; negative ions are formed by gain of electrons. Transfer of electrons from a metal to a non-metal is vital to understand. Group 0 elements have stable electronic structure of either 2 or 8 electrons in their outer shell and cannot react to form ions. Ions are formed to achieve this stability of the full outer shell, the electronic structure that is the same as the structure of noble gases.

Conceptual links to other areas of the specification - useful ways to approach this topic to set students up for topics later in the course:

The transfer of electrons is applied to the electrolysis and the half equations on each electrode. Familiarisation and linking the regular group ions (Group 1, 2, 6 and 7) to the Periodic Table will enable students to apply the knowledge in electrolysis, acid-base reactions and in particular when applying the cross-over rule in writing formulae of compounds and then further symbol equations.

Thinking Contextually C2.3 Ionic bonding

Approaches to teaching the content

To introduce ionic bonding we can start with a story of kitchen salt, sodium chloride, continuing from the previous sub-topic C2.2. Sodium and chlorine are elements on the Periodic Table found in Groups 1 and 7. Group 1 elements are metals and to achieve a stable configuration of 8 electrons on their outermost shell, they need to lose the outer electron. On the other hand chlorine, being in Group 7, is a non-metal and achieves its stable configuration by receiving one electron. Both atoms consist of three types of subatomic particles: protons, electrons and neutrons. When these atoms react by a transfer of electrons they form ions that are attracted to each other by strong forces forming an ionic bond, a crystal lattice of sodium chloride.

Activities C2.3 Ionic bonding

Activities	Resources
Activity 1 **The migration of ions demonstration** *(Royal Society of Chemistry)* http://www.rsc.org/learn-chemistry/content/filerepository/CMP/00/000/488/cce-34.pdf This can be used either as a demonstration or a practical to reinforce the theory of the movement of ions in solutions and property of ionic compounds.	Click here
Activity 2 **Chemical stability of atoms and ions – Chemical misconceptions** *(Royal Society of Chemistry)* http://www.rsc.org/images/Chemical_stability_tcm18-189335.pdf This is a PDF worksheet to reinforce the common misconception about atoms and ions. This is a link to the whole website: http://www.rsc.org/Education/Teachers/Resources/Books/Misconceptions.asp	Click here Click here
Activity 3 **Ionic bonding – true or false? - Chemical misconceptions** *(Royal Society of Chemistry)* http://www.rsc.org/images/Ionic_bonding_tcm18-189311.pdf A good way to revise learnt knowledge, either as a plenary of the same lesson or the starter of the next lesson.	Click here
Activity 4 **Common ions and formulae of ionic compounds** *(Creative Chemistry Copyright, Nigel Saunders)* http://www.creative-chemistry.org.uk/gcse/documents/Module8/N-m08-11.pdf A worksheet to explain cross-over rule, but it has a wrong spelling – sulphate instead of sulfate.	Click here
Activity 5 **Properties of ionic compounds Lesson Element** This lesson element will provide students with the opportunity to investigate the properties of sodium chloride and enable several practical skills to be observed and reinforced. http://www.ocr.org.uk/Images/221062-ionic-compounds-teacher-instructions.pdf http://www.ocr.org.uk/Images/221064-ionic-compounds-learner-activity.doc	Click here Click here

Curriculum Content C2.4 Formulae and equations

C2.4 Formulae and equations

Section C2.4 studies using equations and symbols to summarise reactions.

The reactions of Group 1 and Group 7 can be represented using word equations and balanced symbol equations with state symbols.

The formulae of ionic compounds, including Group 1 and Group 7 compounds can be worked out from the charges on their ions. Balanced equations for reactions can be constructed using the formulae of the substances involved, including hydrogen, water , halogens (chlorine, bromine and iodine) and the hydroxides, chlorides, bromides and iodides (halides) of Group 1 metals.

Thinking Conceptually C2.4 Formulae and equations

Approaches to teaching the content

Formulae of common simple compounds derive from the position of their constituents in the periodic table. All elements in Group 1 will have +1 ions, Group 2 will produce +2 ions, Group 7 will produce -1 ions. Depending on the number of electrons transferred, the formulae of compounds will differ. Emphasise on the ionic bonding between the Groups 1 and 7 elements. Cross-over rule can be applied to simplify the process.

Common misconceptions or difficulties learners may have

Students often do not link the group number and the ionic charge, valency. They need to be taught the cross-over rule linking the position of the elements in the Periodic Table and the gain or loss of electrons. Students often cannot comprehend that when electrons are lost, positive ions are formed and vice versa.

The symbol equations are often written without the application of the cross-over rule, so the formulae of the compounds are wrongly stated.

There has to be emphasis on the difference between the hydrogen atom (found as a symbol on the Periodic Table) and e.g. a hydrogen gas that is a diatomic molecule, H_2. The same applies for Group 7 elements, oxygen and nitrogen.

Conceptual links to other areas of the specification - useful ways to approach this topic to set students up for topics later in the course

Once cross-over rule applied and learnt, students can use it to write formulae of any molecules, and then write the symbol equations. The basic counting of atoms within a molecule will be useful here when balancing equations.

Thinking Contextually C2.4 Formulae and equations

Approaches to teaching the content

After ions being introduced in the previous sub-unit, here we can use this knowledge to teach how to write formulae of compounds. Using common ions, we can introduce the cross-over rule and emphasise the importance of keeping the ions unchanged if they are represented by the groups of atoms, such as CO_3^{2-}, NO_3^- and other similar ions. Here brackets can be used to help students see the ions as a whole when applying the cross-over rule. This then leads to writing the chemical equations including Group 1 and Group 7 compounds. The next step would be to teach how to balance the equations.

Activities C2.4 Formulae and equations

Activities	Resources
Activity 1 **Chemical equations** *(Creative Chemistry Copyright, Nigel Saunders)* http://www.creative-chemistry.org.uk/gcse/documents/Module8/N-m08-13.pdf A worksheet with answers for teachers containing 20 word equations to be written as symbol equations and balanced.	Click here
Activity 2 **Balancing equations worksheet 1** *(About.com)* http://chemistry.about.com/library/formulabalance.pdf A worksheet with 10 unbalanced symbol equations with the answers: http://chemistry.about.com/library/formulabalanceanswer.pdf	Click here Click here
Activity 3 **Balancing equations worksheet 2** *(About.com)* http://chemistry.about.com/library/formulabalance2.pdf A worksheet with 10 unbalanced symbol equations with the answers: http://chemistry.about.com/library/formulabalance2answers.pdf	Click here Click here

Activities C2.4 Formulae and equations

Activities	Resources
Activity 4 **Balancing equations worksheet 3** *(About.com)* http://chemistry.about.com/library/formulabalance3.pdf A worksheet with 10 unbalanced symbol equations with the answers: http://chemistry.about.com/library/formulabalance3answers.pdf	Click here Click here
Activity 5 **Balancing equations worksheet 4** *(About.com)* http://chemistry.about.com/library/pdfs/worksheets/formulabalance4.pdf A worksheet with 10 unbalanced symbol equations with the answers: http://chemistry.about.com/library/pdfs/worksheets/formulabalance4key.pdf	Click here Click here
Activity 6 **Writing the formulae of compounds Lesson Element** This activity summarises the writing the formulae of compounds using ions and the cross-over rule. http://www.ocr.org.uk/Images/221065-writing-formulae-teacher-instructions.pdf http://www.ocr.org.uk/Images/221066-writing-formulae-learner-activity.doc	Click here Click here

C2.5 Transition metals

In section C2.5, triple award content addresses the unique nature of the transition elements.

The transition metals do not show group properties like the elements in Group 1 and Group 7; they form a family of elements with general properties that are different from those of other metals. These properties make the transition metals particularly useful. They all have relatively high melting points and densities.

Transitions metals are generally less reactive than Group 1 metals, and some are very unreactive (for example silver and gold).

Some transition metal elements and their compounds are used widely in the manufacture of consumer goods and as catalysts in industry, both of which represent beneficial applications of science. (IaS4)

Thinking Conceptually C2.5 Transition metals

Approaches to teaching the content

Starting again from the basics of the Periodic Table, we can reinforce C1.2a-C1.2d and C1.3a, and observe the transition elements are situated in the Periodic Table between Groups 2 and 3. They are all typically metallic elements, good conductors of heat and electricity and they all produce coloured compounds.

Common misconceptions or difficulties learners may have

It could be mentioned that not all transition elements are transition metals, such as zinc. Transition metals form coloured compounds, such as copper(II) in copper(II) carbonate –blue green, or iron(III) in iron(III) oxide – rust colour or lead(II) oxide - yellow. Zinc forms only white compounds, like the elements in Group 1 and Group 2. Therefore we classify zinc as a transition element but not a transition metal.

Conceptual links to other areas of the specification - useful ways to approach this topic to set students up for topics later in the course

The link with the Periodic table – C2.2, will place transition elements in-between the groups 2 and three. Another opportunity to recap the position of metals and the non-metals in the Periodic Table and to compare the properties of Group 1 and 2 metals with the transition metals. A selection of solid coloured metal compounds versus white metal compounds will emphasise on the property of the transition metals forming coloured compounds and that Group 1 and 2 metals form only white compounds.

Thinking Contextually C2.5 Transition metals

Approaches to teaching the content

Now we can introduce transition metals being mined from their ores. They are real metals with very specific properties that can be tested in the lab. Here we can compare the properties of metals in Group 1 with the properties of the transition metals. This can lead to their broad uses.

Activities C2.5 Transition metals

Activities	Resources
Activity 1 GCSE Science Revision – Transition Metals *(JamJarMMX)* https://www.youtube.com/watch?v=56DyU-46OKw A short video - A good visual representation of the transition metals within the Periodic Table and explaining their physical and chemical properties.	Click here to see the clip

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