ROYAL SOCIETY OF CHEMISTRY

Chemistry in Curriculum for Wales

Curriculum planning support (progression step 4)

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Overview

This document is designed to aid teachers in Wales planning their new chemistry curriculum for first teaching from September 2022. It is recommended that this document is used once a good understanding of the principles and fundamentals of the Curriculum for Wales[1] has been developed. The document draws on information from appropriate resources, including the Royal Society of Chemistry's curriculum framework[2], to outline what suitable progression could look like.

This document aims to support schools planning chemistry progression within the Science and Technology Area of Learning and Experience (AoLE) specifically focussing on the What Matters statement *Matter and the way it behaves defines our universe and shapes our lives*, as well as parts of *Being curious and searching for answers is essential to understanding and predicting phenomena*. It is not intended to be prescriptive, but we hope it will prove useful to support curriculum planning.

Background

The Royal Society of Chemistry developed a curriculum framework as a resource for curriculum designers. The aim of the framework is to visualise the most important aspects of chemistry – the key things that we would like young people to learn about chemistry.

At the heart of the framework sits a model for the discipline of chemistry. It is vital that learners gain a complete view of chemistry: how it works, what types of things we can understand through chemistry, and – particularly importantly – how chemical methods and ideas help us to understand the world around us and also form the basis for new innovations. Any curriculum must help learners understand this, so that they can see the value of what they are learning.

The model identifies three main aspects of chemistry as a discipline:

- **Chemistry as a science:** the methods and procedures of chemical practice and the conventions of chemical reasoning through which the understanding of matter is developed, organised and represented.
- **Chemical concepts:** the body of knowledge and understanding about matter, its properties and changes that have developed over time.
- **Chemistry and the world:** the interactions between chemistry and the world around us, and the interplay with society and other disciplines.

Each of these aspects of chemistry is important in its own right and should be made explicit through the curriculum. However, chemistry can only be fully understood through grasping the relationship between them.

Some of the guiding principles for the Royal Society of Chemistry curriculum framework are that:

- There should be clear progression, in which deepening understanding is built on a secure foundation in each aspect of the framework.
- It should encourage understanding of fundamental principles of chemistry and how these are connected, rather than encountering chemistry as a series of topics.

These principles align well with the design of Curriculum for Wales progression steps and the What Matters statements. The framework offers a next level of detail to the Curriculum for Wales, and teachers may find it helpful to use the framework alongside the Curriculum for Wales when designing their school curriculum.

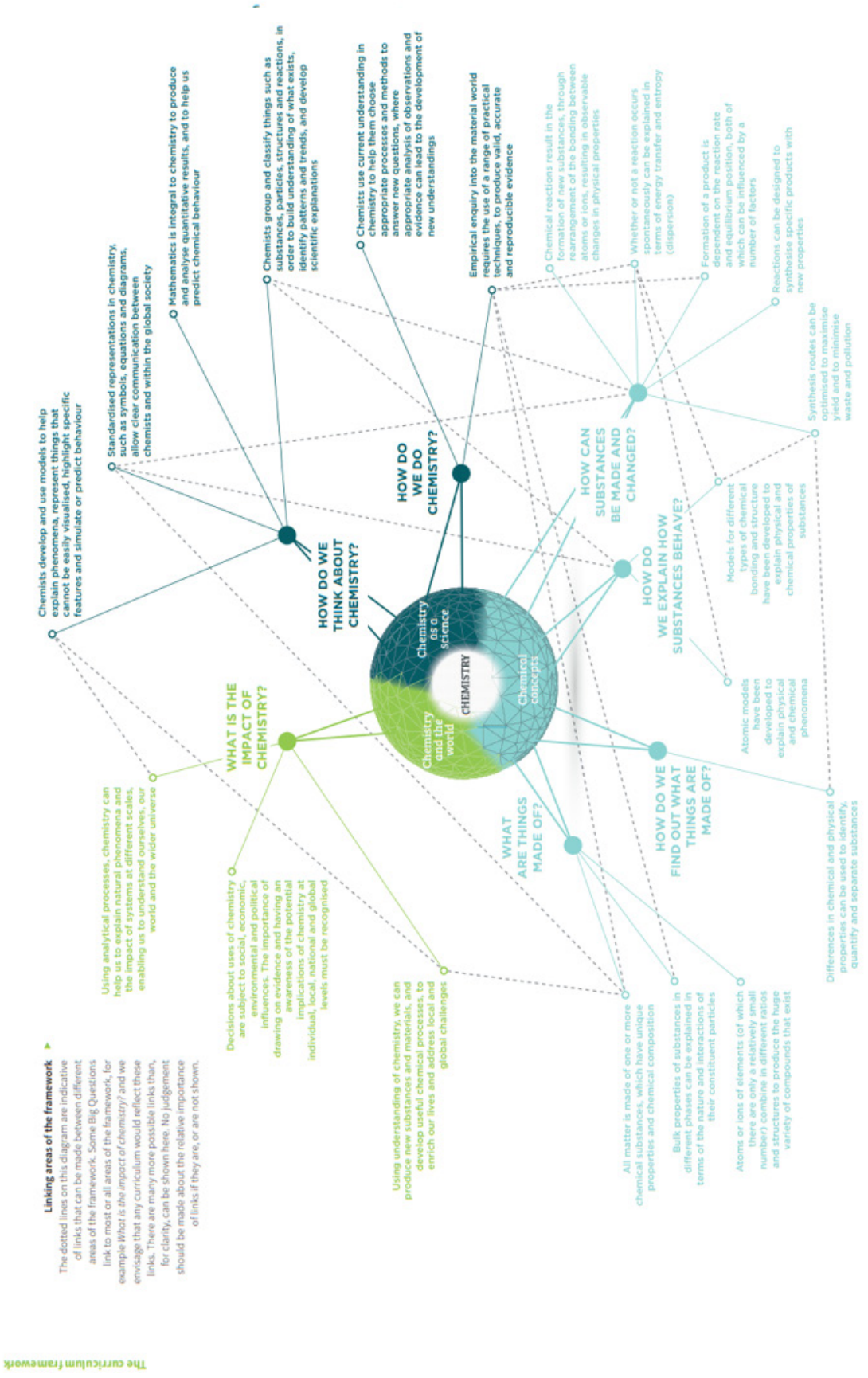
The building blocks of the framework within the central model consist of:

- **Big questions:** these help to define the central areas of interest in studying chemistry and reflect the enquiring nature of the discipline. Learners demonstrate progression by being able to answer the big questions in greater breadth and depth over time.
- **Key ideas:** these are the central ideas that answer the big questions. We have developed a set of key ideas that we feel all learners should be able to study by the age of 16. Learners demonstrate progression by being able to understand the ideas in more detail, and by encountering more ideas over time. For example, the key idea that 'all matter is made of one or more chemical substances, which have unique properties and chemical composition' is foundational and should be developed early in secondary learning. By contrast, we would expect the idea that 'whether or not a reaction occurs spontaneously can be explained in terms of energy transfer and entropy' to be introduced much later.

Connecting Curriculum for Wales with Royal Society of Chemistry's curriculum framework

This document connects the What Matters statements in the Curriculum for Wales with the Royal Society of Chemistry's curriculum framework, providing further guidance for teachers during phase 2 (and beyond) of 'The Journey to 2022'[3]. The diagram on page 4 shows the relationships between the three aspects of the framework, the big questions and key ideas. The dotted lines are indicative of the links that can be made between different areas of the framework. For example, some big questions such as 'what is the impact of chemistry?' link to most or all areas of the framework. For clarity, it has not been possible to show all the links that can be made between different areas of the framework, there are many more links than can possibly be shown here and we envisage any curriculum would reflect these links.

The Royal Society of Chemistry's curriculum framework web



In this document the three aspects of the framework (chemistry as a science, chemical concepts and chemistry and the world) are presented in table format for ease of planning; however, the relationships between the areas of the framework, as represented in the diagram, remain very important.

On pages 7–12 you will find a table that includes information from our framework and descriptions of learning from the relevant What Matters statements from Curriculum for Wales. A detailed outline for suggested progression within progression step 4 (pages 11–14) is sandwiched in between. This is not prescriptive, but offered to inspire and inform teachers when planning their curriculum.

Further guidance on how to sequence this learning appropriately can be found on the Best Evidence Science Teaching website[4] – elements of this advice have been used to create this document.

How to use this document

The aim is not to use the table from top to bottom (as the topics are not in any specific order). The table enables teachers to pick out related skills, concepts and understanding from the left, at first, and teach these in a cohesive, logical order before developing these further by moving across to the right. This should be done over the three or so years of this progression step. Teachers should use their professional judgement on how much of the concepts and skills in this document can be covered in the time they have allocated and omit/differentiate their curriculum appropriately to suit their school's curriculum model.

On the next page is a visual guide to the table and the different columns and content within these.

A detailed outline of what good progression in chemistry (and related science) might look like in order to build deeper understanding and lay suitable foundations for progression step 5. For 'chemistry as a science' and 'chemical concepts', Best Evidence Science Teaching resources along with other STEM resources on working scientifically[5] were used to develop this section. The 'chemistry and the world' contextual information was provided by the Royal Society of Chemistry's curriculum working group alongside some more specific ideas identified in navy.

Directly from the Royal Society of Chemistry curriculum framework: a big question followed by the key ideas that help us to answer the question

Cross-curricular links have been highlighted using the following symbols:

- Design thinking and engineering offer technical and creative ways to meet society's needs and wants
- The world around us is full of living things which depend on each other for survival
- Forces and energy provide a foundation for understanding our universe
- Computation is the foundation for our digital world

Big question	Key ideas	Progression step 4 – suggested progression			Descriptions of learning from curriculum
Chemistry as a science					
How do we think about chemistry?	Chemists develop and use models to help explain phenomena, represent things that cannot be easily visualised, highlight specific features and simulate or predict behaviour	Apply the particle model to: • explain the arrangement of particles in each state of matter • explain what happens when a solute is dissolved in a solvent	Use the particle model to explain what happens during changes of state Use the particle model to explain diffusion in liquids and gases Use appropriate particle diagrams to distinguish between an element, compound and mixture	Recognise that an atomic model is not a representation of reality Describe how new experimental evidence led to changes in the atomic model	I can… • describe different types of chemical reactions explain their uses and identify any effects of the products formed • use different methods to analyse materials in order to understand their composition • describe how various materials need different techniques in order to separate and refine them • use a range of models to explain and make predictions
	Standardised representations in chemistry, such as symbols, equations and diagrams, allow clear communication between chemists and within the global society	Take a measu… including units, … observ… practic…	Identify chemical symbols of … and understand the … can apply this to chemical reactions	…ng … use	
	Mathematics is integral to chemistry to produce and analyse quantitative results, and to help us predict chemical behaviour				
	Chemists group and classify things such as substances, particles, structures and reactions, in order to build understanding of what exists, identify patterns and trends, and develop scientific explanations	Understand that materials and substances can be grouped according to their physical or chemical properties (for example, metals and non-metals)	Distinguish between a group and a period on the periodic table Use data to describe trends in physical properties of a group Apply knowledge of trends to predict properties	Be aware of the developments in chemistry that lead to the modern periodic table Understand that elements have been grouped in the periodic table due to their similar chemical properties Relate an element's position in the periodic table to its atomic structure	

Please note that each box is not a suggested teaching topic. It is recommended that you move from left to right of these columns in an order that best suits your curriculum design, interlinking the big questions and key ideas where relevant and referring back to the Royal Society of Chemistry curriculum framework web

Statements in blue are hyperlinked to relevant Royal Society of Chemistry resources and articles that support teaching and develop these particular concepts and skills

Descriptions of learning from each What Matters statement in the Science and Technology AoLE that could be relevant to this particular area of the framework. They are colour coded as follows:

- Being curious and searching for answers is essential to understanding and predicting phenomena
- Matter and the way it behaves defines our universe and shapes our lives
- Computation is the foundation for our digital world

Big question	Key ideas	Progression step 4 – suggested progression				Descriptions of learning from curriculum
Chemistry as a science						
How do we think about chemistry?	Chemists develop and use models to help explain phenomena, represent things that cannot be easily visualised, highlight specific features and simulate or predict behaviour	Apply the particle model to: • explain the arrangement of particles in each state of matter • explain what happens when a solute is dissolved in a solvent	Use the particle model to explain what happens during changes of state Use the particle model to explain diffusion in liquids and gases Use appropriate particle diagrams to distinguish between an element, compound and mixture		Recognise that an atomic model is not a representation of reality Describe how new experimental evidence led to changes in the atomic model	I can… • describe different types of chemical reactions explain their uses and identify any effects of the products formed • use different methods to analyse materials in order to understand their composition • describe how various materials need different techniques in order to separate and refine them • use a range of models to explain and make predictions
	Standardised representations in chemistry, such as symbols, equations and diagrams, allow clear communication between chemists and within the global society	Take accurate measurements, including appropriate units, and make observations during practical experiments	Distinguish between a reactant and a product and express what happens during an experiment/reaction in terms of a word equation Name common elements and compounds	Identify chemical symbols of elements and understand the meaning of subscripts within a chemical formula Interpret the meaning of chemical formulae in terms of a ratio of elements within a compound Convert word equations into symbol equations Understand the law of the conservation of mass and can apply this to chemical reactions	Calculate formula mass Understand the meaning of coefficients in terms of reacting ratios Convert appropriate units Use state symbols Calculate atom economy and use this to discuss sustainability	
	Mathematics is integral to chemistry to produce and analyse quantitative results, and to help us predict chemical behaviour					
	Chemists group and classify things such as substances, particles, structures and reactions, in order to build understanding of what exists, identify patterns and trends, and develop scientific explanations	Understand that materials and substances can be grouped according to their physical or chemical properties (for example, metals and non-metals)	Distinguish between a group and a period on the periodic table Use data to describe trends in physical properties of a group Apply knowledge of trends to predict properties		Be aware of the developments in chemistry that lead to the modern periodic table Understand that elements have been grouped in the periodic table due to their similar chemical properties Relate an element's position in the periodic table to its atomic structure	

Big question	Key ideas	Progression step 4 – suggested progression				Descriptions of learning from curriculum
Chemistry as a science (continued)						
How do we do chemistry?	Chemists use current understanding in chemistry to help them choose appropriate processes and methods to answer new questions, where appropriate analysis of observations and evidence can lead to the development of new understandings	Follow a method Identify hazards Record data appropriately using appropriate SI units	Propose a question that can be tested practically Present data as an appropriate graph Describe trends in data and form a basic conclusion based on experimental evidence	Explain the associated risks of hazards Understand the importance of repeating an experiment Process data e.g. handling anomalies and calculating a mean Evaluate the designed method and identify reasons for anomalous results Experience of reporting the outcome of an investigation to my peers Explain trends in data	Design an investigative method including variables and suitable parameters to be tested Carry out a risk assessment e.g. hazards, related risks and preventative measures Relate conclusions back the original question and the underlying chemical concept(s) Evaluate an investigative procedure and suggests improvements and further work to be carried out Relate suggested improvements to a scientific investigation to their effect on data collected Use ICT to process and present data	I can… • research, devise and use suitable methods of inquiry to investigate my scientific questions • use my findings to draw valid conclusions • evaluate and identify ways of improving the reliability of data, taking anomalies into account • choose the most appropriate format for the storage and interrogation of data
	Empirical enquiry into the material world requires the use of a range of practical techniques, to produce valid, accurate and reproducible evidence	Accurately measure the mass of a substance using a balance Accurately measure the volume of a liquid using a measuring cylinder Safely use a Bunsen burner to a heat substance Accurately measure the temperature of a substance	Use different indicators to measure pH Have knowledge of appropriate glassware and apparatus and their functions Know the meaning of common hazard symbols	Experience of filtration and crystallisation (evaporation) Carried out paper chromatography	Experience of distillation carried out using quick-fit apparatus Carried out rudimentary distillation using common glassware Select a suitable separation technique for a given mixture Carried out displacement reactions and made conclusions based on my results	

Big question	Key ideas	Progression step 4 – suggested progression			Descriptions of learning from curriculum
Chemical concepts					
What are things made of?	Bulk properties of substances in different phases can be explained in terms of the nature and interactions of their constituent particles ✸	Identify if a material is a metal, ceramic or polymer based on its physical properties Distinguish between a chemical property and a physical property Understand that substances can exist as different states (solid, liquid and gas) Understand what is meant by melting point and boiling point of a substance	Describe physical properties of polymers Explain how to alter physical properties of a polymer Describe changes of state Understand what is meant by a solution, solvent and solute Understand that different elements and compounds have different properties due to their difference in structure	Understand that solubility is a property of a substance that can change with temperature Understand the difference between a dilute and concentrated solution Explain why evaporation may occur before the boiling point of a substance is reached Understand that mixtures can be separated because the properties of its constituents is unchanged	I can… • use different methods to analyse materials in order to understand their composition • describe how various materials need different techniques in order to separate and refine them • describe and explain the properties of different types of matter and relate these to how they are used
	All matter is made of one or more chemical substances, which have unique properties and chemical composition ✸ Atoms or ions of elements (of which there are only a relatively small number) combine in different ratios and structures to produce the huge variety of compounds that exist		Understand that: • elements are made of the same type of atom • different elements are summarised in the periodic table and that each element as a symbol • a compound is made up of more than one type of atom chemically bonded in a fixed ratio • properties of a compound are different to those of elements made up of its constituent atoms • a mixture can be made up of different elements and/ or compounds that are not chemically combined and can therefore be separated	Understand that an element or compound can be made up of a single giant structure or separate molecules Recall that an element can also be made up of separate atoms Link the structure of the element or compound to it having a high or low melting/boiling point.	Name chemical compounds when given the formula using the international system of units (SI) Understand that the formula represents the ratio of atoms in the compound Recognise that the periodic table contains over 100 elements and that they are arranged in groups and periods and ordered by atomic number Recognise that elements and compounds can be made up of atoms, ions§ and molecules § at this stage a basic understanding that atoms can be charged species that we call an ion is sufficient, development of the understanding of ions is in progression step 5	

Big question	Key ideas	Progression step 4 – suggested progression				Descriptions of learning from curriculum
Chemical concepts (continued)						
How do we find out what things are made of?	Differences in chemical and physical properties can be used to identify, quantify and separate substances		Distinguish between a pure and impure substance Use melting point data to determine purity Identify if a substance is acidic, neutral or alkaline using various indicators	Describe changes of state Understand that different elements and compounds have different chemical properties	Explain how different separation techniques separate mixtures in relation to changes of state and/or solubility Select an appropriate separation technique for a given purpose	I can… • use different methods to analyse materials in order to understand their composition • describe how various materials need different techniques in order to separate and refine them • describe and explain the properties of different types of matter and relate these to how they are used • describe different types of chemical reactions, explain their uses and identify any effects of the products formed
How do we explain how substances behave?	Atomic models have been developed to explain physical and chemical phenomena			Describe the key features of the structure of an atom based on the nuclear model of an atom	Recall the relative mass and charge of sub-atomic particles Use the periodic table to deduce the number of sub-atomic particles in an atom of an element Understand that the relative atomic mass of an atom is due to the number of protons and neutrons	
	Models for different types of chemical bonding and structure have been developed to explain physical and chemical properties of substances			Recognise that giant structures are held together by strong electrostatic forces and that there are weaker electrostatic forces between separate molecules	Have an appreciation for electrostatic attraction. Understand that positive and negative charges attract and that it is this force that holds atoms and molecules together	

Big question	Key ideas	Progression step 4 – suggested progression				Descriptions of learning from curriculum
Chemical concepts (continued)						
How can substances be made and changed?	Chemical reactions result in the formation of new substances, through rearrangement of the bonding between atoms or ions, resulting in observable changes in physical properties Whether or not a reaction occurs spontaneously can be explained in terms of energy transfer and entropy (dispersion)	Understand the key observations that show a chemical change (reaction) has occurred e.g. colour change	Understand that word equations represent what happens during a chemical reaction Recognise that during a chemical reaction mass is conserved. The mass of reactants is equal to the mass of the products.	Convert word equations into symbols equations (when given formulae) Explain conservation of mass in a chemical reaction by the idea that atoms are rearranged, no atoms are created or destroyed Categorise a reaction as exothermic or endothermic Describe trends in reactivity of key groups of the periodic table and am aware that elements have been placed in a reactivity series based on historical experimental data	Understand that a balanced equation represents reacting ratios of substances Use the idea of conservation of atoms to balance a chemical equation Categorise a reaction as oxidation, precipitation or decomposition Understand that during a reaction energy can be lost to or taken from the surroundings Use the reactivity series to explain why displacement happens Understand what is happening during a neutralisation reaction	I can… • describe how various materials need different techniques in order to separate and refine them • describe and explain the properties of different types of matter and relate these to how they are used • describe different types of chemical reactions, explain their uses and identify any effects of the products formed • use my knowledge of chemical reactions to explain what happens when conditions are changed
	Formation of a product is dependent on the reaction rate and equilibrium position, both of which can be influenced by a number of factors				Recognise that reactions can be reversible	
	Reactions can be designed to synthesise specific products with new properties Synthesis routes can be optimised to maximise yield and to minimise waste and pollution		Recognise that reactions have a purpose and are designed to make a new product with new, often more desirable properties such as baking and metal extraction			

Big question	Key ideas	Progression step 4 – suggested progression	Descriptions of learning from curriculum
Chemistry and the world			
What is the impact of chemistry?	Using analytical processes, chemistry can help us to explain natural phenomena and the impact of systems at different scales, enabling us to understand ourselves, our world and the wider universe	Know that analytical chemistry is used to study the environment, including monitoring the environmental impacts of man-made chemicals Understand that there are limitations and difficulties to using real-world samples Explain real-life scenarios using chemistry concepts. For example, the link between particle theory and wet clothes drying over time, or the link between chemical reactions and metabolism in animals Recognise that chemistry has contributed to understanding the causes, effects and solutions in relation to climate change. Understand that several underlying chemical concepts are required to explain many phenomena, for example in climate change: • the effects of gases in the atmosphere on warming of the Earth's surface • the production of gases from human activity such as burning fuels and agriculture • the effect of increased temperature on sea level via melting of ice and by water expanding • the idea that carbon dioxide levels in the atmosphere depend on its production and absorption processes **Possible contexts:** monitoring air pollution, importance of water, water pollution, plastics and links to materials and their properties (such as biodegradability), climate monitoring, chemistry in the home, chemistry of cooking, chemistry of our garden/plants/agriculture	I can… • explain how the impact of our actions contribute to the changes in the environment and biodiversity • describe the impacts of science and technology, past and present, on society • review my own opinions based on new scientific evidence • select relevant scientific knowledge from a range of evidence sources to evaluate claims presented as scientific facts • describe different types of chemical reactions, explain their uses and identify any effects of the products formed
	Using understanding of chemistry, we can produce new substances and materials, and develop useful chemical processes, to enrich our lives and address local and global challenges	Understand that industrial processes are used to convert raw materials into useful products Know that chemistry can be used to make novel materials, for example medicines and materials for clothing or building shelters Appreciate that these novel materials have properties that would not otherwise be available Recognise that cost-benefit analysis and considerations of sustainability are important in understanding the impacts of producing novel materials on an industrial scale Chosen examples should reflect a wide range of contexts and applications and, ideally, be situated within local, national and global contexts such as energy, environment, food, health and water **Possible contexts:** metal extraction, mobile phone technology, sustainability of processes and materials used, pharmaceutical/biochemistry, chemical engineering (scaling up), various contemporary materials, clothing/textiles, greenhouse gas emissions	
	Decisions about uses of chemistry are subject to social, economic, environmental and political influences. The importance of drawing on evidence and having an awareness of the potential implications of chemistry at individual, local, national and global levels must be recognised	Appreciate that there are always ethical and moral implications to the development of new technologies, and economic and political influences on which new technologies are developed and how they are managed Realise that identifying these impacts is important and should be discussed and debated, showing which aspects are backed up by evidence and which are opinion Understand that in many cases the ethical, moral, economic and political issues surrounding chemistry may have conflicting influences. The arguments for and against production of new technologies involves marshalling evidence and ideas and weighing up conflicting views **Possible contexts:** climate change (with a green chemistry focus), making decisions about how we get our energy, mining, use of materials that are made from finite resources	

Worked example

An example of how this document might be used is when teaching learners about mobile phone and smart device technology. You could start with teaching about the materials used in a mobile phone or a smart watch (polymers and metals, for example). Then discuss the physical properties of these materials and why these make them suitable for their function. At the same time, investigative skills could also be being developed. Building on this, you could then discuss the particle model and apply this to the materials used. This then opens up the possibility to discuss the materials' chemical properties, the materials on an atomic level and beyond (spectroscopy within a smart device, for example). This information can be taught and developed over a number of terms or even years depending on the depth you go into. A more detailed explanation of how this can be achieved is outlined in the accompanying document 'How to use the curriculum planning support document'.

This topic also lends itself to cross-curricular links such as:

- learning about materials and circuits in technology
- the particle model in physics
- electricity and circuits in physics
- coding in computer science
- measuring heart rate and effect of exercise on this in biology (links to spectroscopy in smart watch)
- use of smart technology and its impact on health and well-being

Ultimately the goal, as outlined in the principles for progression of the Curriculum for Wales Science and Technology AoLE, is that learners are able to **apply and use knowledge in various scenarios and contexts**. Therefore, other related topics can be taught alongside (or perhaps after) this topic to ensure this progression is developed.

Introducing learners to careers in chemistry

Increasing learners' awareness of chemistry related careers can help learners to understand the breadth of chemistry in everyday life. A Future in Chemistry[6] is a dedicated microsite to help inform teachers and learners about the wide range of careers options within chemistry – it includes case studies and videos of real people working in chemistry related roles.

References

1. Curriculum for Wales: Science and Technology AoLE, https://hwb.gov.wales/curriculum-for-wales/
2. Royal Society of Chemistry, The elements of a successful chemistry curriculum, www.rsc.org/new-perspectives/talent/chemistry-curriculum-framework/
3. Curriculum for Wales: the journey to 2022, hwb.gov.wales/curriculum-for-wales/curriculum-for-wales-the-journey-to-2022
4. BEST resources, www.stem.org.uk/best-evidence-science-teaching. Mapping progression in skills (working scientifically) and range and content across KS1-KS3, www.stem.org.uk/community/groups/37033/mapping-progression-in-skills-working-scientifically-and-range-and-content
5. https://www.stem.org.uk/community/groups/37033/mapping-progression-in-skills-working-scientifically-and-range-and-content
6. Royal Society of Chemistry, A future in chemistry, edu.rsc.org/future-in-chemistry