Unit 6: Principles and Applications of Chemistry II

Delivery guidance

Scientists and laboratory technicians must be able to use and apply key science concepts to work efficiently and effectively in science and science-related organisations. This unit builds on and extends the key science concepts covered in *Unit 2: Principles and Applications of Chemistry I*. A strong grasp of these concepts will enable learners to use and apply their knowledge and understanding in vocational contexts when studying other units in the specification.

Learners will develop an understanding of the importance of energy changes in chemical reactions, how the rate of reaction is governed by different factors and the implications of these factors for the production of chemical substances. Learners will also gain insight into the structure of organic chemicals and their physical and chemical properties.

Learners require access to laboratory facilities to carry out practical activities, to investigate the rate of chemical reactions, the concept of equilibrium, the preparation and testing of organic compounds, and the use of chromatography to separate mixtures. If possible, arrange visits to organisations involved in a range of chemical techniques.

Approaching the unit

This unit includes energetics, rate of reaction and equilibrium, and structures, names, reactions and properties of commercially-important organic compounds. Learners must understand how the physical and chemical properties of substances relate to their uses and methods of production and extraction. For example, knowledge of energetics, and the rate and extent of chemical reactions, is necessary to ensure the correct processes are used safely in the production of chemical substances. Learners will also need a good working knowledge of the structure of organic chemicals and their physical and chemical properties.

Learning aim A is primarily concerned with energetics in terms of the energy changes for different types of chemical reaction. A key requirement is for learners to be able to define these types of reaction and apply the correct symbols, units and signs (as applied to exothermic and endothermic). The aim explores the use of reaction profiles to illustrate exothermic and endothermic processes and applies the law of conservation of energy to the calculation of energy changes in chemical systems. For example, learners will use Hess's law, bond energies and standard enthalpies of combustion to calculate the enthalpy of a reaction. Give learners opportunities to complete safe practical activities which involve measuring temperature changes for different types of reaction (e.g. combustion of hydrocarbons and alcohols, acid–base neutralisations and dissolving compounds). They can use the data obtained to calculate the energy change (using the equation $Q = mc_p\Delta T$) and, from this, they can calculate the enthalpy change for the reaction.

Learning aim B explores how the rate of reaction and equilibrium influence chemical reactions. A key concept is collision theory: chemical reactions are primarily due to the reacting particles colliding with the minimum energy required for a reaction (i.e. activation energy). The aim explores the various factors which can affect the rate of a chemical reaction, including concentration, surface area, temperature and the presence of a catalyst. Learners must carry out practical investigations relating to these factors, using appropriate methods to determine the rate (e.g. change of mass, volume of gas evolved, time taken for a colour change etc.). The results from these practical investigations (as well as data from other sources) can be used to plot graphs (e.g. volume/time), draw tangents and determine the rate of reaction.

Learning aim B also deals with equilibrium. Learners should understand that many chemical reactions can be reversible and that, in a closed system, reactants and products exist in a state of dynamic equilibrium. It explores how the position of equilibrium can be affected by conditions and factors such as concentration, pressure, temperature and the presence of a catalyst. Learners will need to be able to apply the concept of an equilibrium constant (K_c) to determine whether the equilibrium of a system lies to the left or right; they should also be able to write the correct expressions for homogeneous and heterogeneous systems. The latter can be used to calculate K_c for given concentrations of reactants and products and this value can then be used to determine whether the equilibrium lies towards the left or right. Finally, learners should be aware of the importance of equilibrium in determining the efficiency of industrial systems such as the Haber process and Contact process.

Learning aim C is concerned with the principles of organic chemistry. Learners should be aware that the tetravalency of carbon can result in strong bonds between carbon atoms and, with hydrogen atoms, can result in chain, branched chain and ring structures. The aim explores the different types of hydrocarbon, including chain, branched chain and ring structures, saturated and unsaturated and those with double and triple bonds. Learners should be able to illustrate the bonding in various hydrocarbons, with reference to σ and ϖ bonding as well as the shapes of molecules, showing the bond angles and symmetry or asymmetry.

The aim goes on to look at the properties of organic molecules (alkanes, alkenes, halogenoalkanes and alcohols). There may be some scope for learners to complete relevant practical activities when exploring aspects such as melting/boiling points, solubility, chain length/branching, intermolecular forces, functional groups etc. A key concept in organic chemistry is the homologous series and learners should be able to write the general formula for each series and the molecular and structural formulae for different members of each series. The IUPAC system should be used to name alkanes, alkenes, halogenoalkanes, alcohols, and branched and cyclic compounds. The aim goes on to explore the properties of organic compounds in terms of structural and geometric isomerism.

Learning aim D is concerned with the chemical properties of organic compounds, their preparation and separation as well as applications. Alkanes and alkenes are explored in further detail and learners should be aware of the importance of processes such as fractional distillation and cracking for their separation and production. An important reaction of alkanes is combustion, but learners should also be able to describe other reactions such as polymerisation, hydration and various addition reactions (with halogens, hydrogen halides and hydrogen). Learners should generally be able to compare the reactivity of alkanes and alkenes and there is some scope for practical activity here.

The aim also explores halogenoalkanes and alcohols. Learners will compare the reactivity of the former in terms of the halogen group, consider the involvement of both halogenoalkanes and alcohols in substitution and elimination reactions, and learn about oxidation of alcohols (primary, secondary and tertiary). Learners should be able to write balanced equations and state the conditions for all reactions studied. They should also be able to construct mechanisms for the reactions. Learners must have the opportunity to prepare organic compounds, applying techniques such as refluxing, distillation, recrystallisation, filtration, drying, MP/BP determination etc. They should understand tests for functional group and be able to calculate percentage yield, identifying reasons for low yield.

Learners must know the types of chromatographic technique and be able to explain the principles involved, interpret chromatograms and calculate Rf values. They should also compare these techniques with other methods of separation and identify situations where they are used to separate and identify components of mixtures. There is some scope for practical activities here.

Assessment model

Learning aim	Key content areas	Recommended assessment approach
A Understand energy changes in chemical reactions	**A1** Energetics	A report of a practical investigation into endothermic and exothermic reactions, explaining how the different enthalpy changes arise. Calculations to show how enthalpy change for a reaction can be determined by experiment or by using other enthalpy changes. A discussion of the assumptions and sources of error that arise in measurements and calculations of enthalpy change.
B Understand how rate and equilibrium influence chemical reactions	**B1** Rate of reaction **B2** Dynamic equilibrium	A report of a practical investigation into the factors that affect rate of reaction and analyse gradients from graphs to determine rate. A report investigating the factors that affect equilibrium. Calculations to find K_c or equilibrium concentrations, how to interpret the values and the implications of K_c change with temperature. Explanation of the operational conditions for industrial equilibrium processes to obtain optimum rate and yield of product.
C Understand the principles of organic chemistry	**C1** Structures and naming of organic compounds	A report that shows how to determine structures and names for a range of organic compounds, and the differences in bonding between saturated and unsaturated hydrocarbons. Diagrams of structures and bonding will be shown. The report will also provide an explanation and assessment of how functional groups, homologous series, structure and isomerism all characterise and influence physical properties and chemical behaviour.

Learning aim	Key content areas	Recommended assessment approach
D Understand the chemical behaviour, separation and applications of organic compounds	**D1** Reactions of alkanes and alkenes **D2** Reactions of halogenoalkanes and alcohols **D3** Organic chemistry mechanisms **D4** Preparation and testing of organic compounds **D5** Chromatographic techniques	A report which reviews the commercially important reactions of hydrocarbons, following the reactions and products from a specific molecule. A comparison of the reactions of alkanes and alkenes and explanation of the main reactions of halogenoalkanes and alcohols. Drawings of mechanisms will complement the comparisons and explanations. Observations and results from the preparation and testing of an organic compound. An explanation of the principles behind the chromatographic separations. Results from the paper chromatography or TLC of an organic compound mixture. Explanations of factors affecting separation and consideration of other separation techniques. An observation report with a checklist, completed by the teacher, including safety. Assessment of different ways to make an organic compound, including factors that would affect the yield and purity.

Assessment guidance

The unit will be assessed using up to four assignments, one per learning aim. Learners must produce individual evidence that is both original and can be authenticated.

For learning aim A, learners must produce a report on investigations into endothermic and exothermic reactions. Learners will:

- measure temperature changes of the solutions or water that absorb or release heat due to the reaction
- calibrate the thermometers used
- accurately measure and record values for temperature, mass and volume
- carry out a risk assessment
- calculate values for enthalpy change for each reaction, using the equation $Q = mc_p\Delta T$ and converting values to kJ mol^{-1} for comparison
- categorise each reaction as endothermic or exothermic, commenting on the magnitude and sign of the enthalpy change and explaining the underlying processes involved in terms of bond breaking, bond making and reaction profile diagrams

- calculate a range of standard enthalpy changes for reactions that cannot be determined practically, using values from other sources
- discuss assumptions and sources of error that arise in measurements and calculations of enthalpy change.

For learning aim B, learners need to produce a report of practical investigations they have carried out to examine the four factors that affect rate of reaction (concentration, temperature, particle size and presence of a catalyst). Methods used to measure the rate can include:

- change in mass over time (due to loss of a gas)
- change in volume of gas over time/time taken to collect a fixed volume of gas
- time taken for a colour change/clock reaction.

Learners will use their results to plot graphs and analyse gradients to determine rate.

The report will also include an investigation into the factors that affect dynamic equilibrium (concentration, pressure, temperature and catalysis). Learners will write expressions for the equilibrium constant K_c and use this to calculate K_c or equilibrium concentrations. They should be able to interpret the values and the implications of K_c change with temperature (with reference to Le Chatelier's Principle). They should also justify the operational conditions for at least two industrial equilibrium processes to obtain optimum rate and yield of product.

For learning aim C, learners must produce a report that:

- shows how to determine, from molecular formulae, the structures of alkanes, alkenes, halogenoalkanes and alcohols (including straight chain, branched and cyclic compounds)
- includes structures of the molecules, drawn by learners and named using the IUPAC system
- explains the differences in bonding between saturated and unsaturated hydrocarbons, including diagrams of structures and bonding (using a variety of models such as dot-and-cross diagrams, stick diagrams and representations of sigma and pi orbitals)
- explains and assesses how functional groups, homologous series, structure and isomerism characterise and influence physical properties and chemical behaviour.

For learning aim D, learners must produce a report which reviews the commercially-important reactions of hydrocarbons, following the reactions and products from a specific molecule. These reactions should include:

- combustion of alkanes and applications as fuel
- polymerisation of alkenes and applications
- hydration of alkenes (e.g. ethene to ethanol) and applications.

Learners' reports should:

- compare the reactions of alkanes and alkenes and explain the main reactions of halogenoalkanes and alcohols (to include substitution, elimination and alcohol oxidation); learners should include drawings of the mechanisms of these reactions, to complement the comparisons and explanations
- include observations and results from the preparation of an organic compound (from examples listed in the unit content) and testing to confirm a property (e.g. boiling point, melting point) or identify the presence of a desired functional group

- explain the principles behind chromatographic separations and analyse results from the paper chromatography or TLC of an organic compound mixture
- explain factors affecting separation and consider other separation techniques
- include an assessment of different ways to make an organic compound, including factors that would affect yield and purity.

An observation report with a checklist can be completed by the tutor to confirm learners’ skills in carrying out the preparation, separation, testing and risk assessment.

Getting started

This gives you a starting place for one way of delivering the unit, based around the recommended assessment approach in the specification.

Unit 6: Principles and Applications of Chemistry II

Introduction

This unit gives learners the opportunity to develop their knowledge, skills and understanding of the basic principles of chemistry, extending their learning from *Unit 2*. At the start of each learning aim, it will be useful to test prior knowledge and understanding using activities such as quizzes and/or question and answer sessions. The unit covers key chemistry concepts including chemical energetics, rates of reaction, chemical equilibrium, principles of organic chemistry and properties of the main types of organic compound. The knowledge and understanding gained in this unit will give learners a strong basis for progression in the applied science sector and to a variety of science and related programmes, such as higher nationals and degrees. (The delivery guidance for each learning aim closely aligns with the key content areas as provided in the unit specification and represented by A1, B2, C3 etc.)

Learning aim A: Understand energy changes in chemical reactions

- For learning aim A, the teaching focuses solely on energetics and the energy changes that occur in chemical reactions. Learners should be able to define relevant terms, calculate enthalpy changes for reactions from supplied values and measure enthalpy changes for some reactions. Although learners will not have experienced energetics much in *Unit 2*, it is likely some will have encountered it on previous programmes so some activity to gauge prior learning and knowledge will be useful. This could involve a quiz or similar activity on energetics as applied to bond breaking, bond formation and overall enthalpy changes for reactions. In *Unit 2*, learners will have covered the mole concept, and this will be important when calculating molar enthalpies; preliminary activities should recap this learning.
- Learners should be aware that bond breaking in a reaction is an endothermic process, while bond formation is exothermic. They should be able to use reaction profile diagrams to illustrate this in terms of the overall enthalpy of reaction. An animated video on thermochemistry may help to illustrate these ideas.
- Learners should be able to define standard molar enthalpies in terms of the type of reaction/process involved, showing the correct symbols, signs and units. Use activities such as quizzes or 'mix and match' tasks to reinforce this knowledge.
- Introduce applications of the law of conservation of energy to calculate enthalpy changes, including Hess's law and bond energies.
- Ask learners to produce a fact sheet of rules and formulae which will help them to calculate enthalpy changes, using given values. They must be able to assess the limitations and assumptions of the values provided and the calculations themselves.
- There is considerable scope for practical activities in which learners can measure the enthalpy changes in different types of reaction. This will ensure they have the necessary skills for assessment. Practical activities will involve:
    - combustion of hydrocarbons and alcohols (using a burner to heat water)
    - neutralisation reactions (e.g. sodium carbonate and hydrochloric acid)

- dissolving compounds in water (e.g. anhydrous copper sulphate).

- Encourage learners to record their results in table form, showing amounts of substance burned/reacted, mass of water heated (if appropriate), initial temperature, final temperature and temperature change. Using the latter values, they can calculate the energy change using the equation $Q = m_c p \Delta T$. From this, they should be able to calculate the molar enthalpy changes. This learning could be extended to use, for example, Hess's law to determine the standard molar enthalpy change for the decomposition of sodium hydrogencarbonate. Again, it is important to encourage learners to assess the limitations and sources of error in experimental methods and to suggest improvements.

Learning aim B: Understand how rate and equilibrium influence chemical reactions

- The teaching for learning aim B focuses on two main areas: rate of reaction and chemical equilibrium. Although learners will not really have experienced these concepts in *Unit 2*, it is likely some will have encountered rates of reaction on previous programmes. Thus, some activity to gauge prior learning and knowledge will be useful – for example, a quiz on aspects such as collision theory, activation energy, factors affecting rate of reaction, measuring rate of reaction etc. Learners should be aware that some reactions are reversible; reinforce that certain conditions can influence whether a reaction mainly goes in the forward or reverse direction and that this is more pronounced in closed systems.
- Start by ensuring learners can define rate of reaction, using appropriate examples.
- Give learners a list of reactions and ask them to write simple expressions for the change in concentration of reactants or products with time.
- Learners must fully understand collision theory and know that, to bring about a reaction, particles must collide with sufficient energy (activation energy). They can use the reaction profiles from learning aim A to illustrate the relevance of activation energy in relation to the enthalpy change and highlight the concept of kinetic and thermodynamic stability for chemical reactions.
- Learners should understand that the rate of reaction is affected by several factors such as concentration of reactants, surface area of reactants, temperature and presence of a catalyst. Encourage learners to carry out individual research to extend their understanding.
- Arrange practical activities in which learners explore methods to determine the rate of a reaction, for example:
  - change in mass over time (due to loss of a gas)
  - change in volume of gas over time/time taken to collect a fixed volume of gas
  - time taken for a colour change/clock reaction/colorimetry.
- Encourage learners to record their results in table form, showing the change and time taken (using the correct units). From their results, learners will plot a graph and draw tangents on the curve (of volume/time or mass/time) to determine the gradient, which represents the rate of reaction.
- When teaching about chemical equilibrium, begin by ensuring learners understand that a chemical reaction can go backwards as well as forward. Give learners opportunities to identify reactions that are easily reversible.
- Ensure learners understand that the phenomenon is more pronounced in a closed system where reactants and products cannot be exchanged with the environment, and that

equilibrium is established when the rate of the forward reaction equals that of the reverse reaction.

- Use examples of equilibrium systems to explain Le Chatelier's principle for predicting what happens when changes are applied. You could use an appropriate video to illustrate these ideas, e.g. the colour change in the $H_2 + I_2 = HI$ system.
- There may be some scope for practical work involving, for example, acid–base systems, where learners can observe the colour of an indicator when additional H^+ or OH^- ions are added. Learners must be able to consider the effect of different conditions and factors on different systems, including concentration, pressure, temperature and presence of a catalyst.
- Learners should look at a range of reactions and predict what will happen when reactants/products are added/removed, pressure (in gaseous systems) is increased/reduced, temperature is increased/reduced and a catalyst is added.
- Introduce the concept of the equilibrium constant, K_c, and ask learners to write expressions for K_c for a range of systems (perhaps with reference to the use of K_p for gaseous systems). These expressions can then be used to calculate K_c using given values for concentration (and vice versa), and to determine from the magnitude whether the equilibrium lies to the left or right.
- Ensure learners can determine how the value of K_c will be affected by increasing and reducing the temperature for endothermic and exothermic reactions and the implications for the enthalpy of reaction.
- Finally, direct learners to explore the importance of equilibrium in industrial applications, such as the Haber process for producing ammonia and the contact process for producing sulphuric acid. This learning can be supported by appropriate videos and further independent research by the learners themselves.

Learning aim C: Understand the principles of organic chemistry

- Learning aim C deals with the principles of organic chemistry, focusing on three areas: structure and bonding, nomenclature, and isomerism and properties. While learners will not really have experienced organic chemistry in *Unit 2*, it is likely some will have encountered related ideas in previous programmes. Use appropriate activities to test learners' knowledge of hydrocarbons, alcohols, their basic structure and chemistry.
- Recap key aspects of bonding, particularly covalent bonding, as this is important for understanding the context of bonding structures in organic compounds. It would also be sensible to briefly revisit intermolecular forces, as these ideas are important for understanding physical properties.
- From their knowledge of covalent bonding, learners should understand that carbon atoms can form strong bonds with each other and with hydrogen atoms, resulting in chain, branched chain and ring structures. It can also form double and triple bonds with other carbon atoms and double bonds with oxygen atoms.
- Begin by explaining the different types of hydrocarbon, in terms of definitions, general formulae, and saturated/unsaturated. Encourage learners to draw the different structures (perhaps with the aid of ball and stick models). Also explain σ and ϖ bonding in single, double and triple bonds, with reference to bond angles, symmetry and asymmetry.
- Then explore the properties of organic molecules (alkanes, alkenes, halogenoalkanes and alcohols). There is scope for practical activity here, looking at aspects such as boiling/melting point and solubility.

- Encourage learners to research these molecules independently and relate their properties to chain length, degree of branching, intermolecular forces and functional group.
- Show an appropriate video and follow up with an activity such as matching BP/MP to chain length, RMM etc.
- Learners should be able to distinguish and write the molecular formulae, structural formulae and skeletal formulae for alkanes, alkenes, halogenoalkanes and molecules). They should also be able to illustrate these structures using 3D representations. Computer-aided representations may be useful here.
- Ensure learners are able to name organic compounds using the IUPAC system of nomenclature. Exercises in which learners name organic compounds based on their structure, and draw structures from names, will be very useful in developing learners' understanding.
- Explain that, because of the nature of bonding in organic molecules, variations are possible in terms of the position of bonds and the special arrangements. Outline the different types of isomerism and ensure learners can explain structural and geometric isomerism.
- Give learners' ample opportunities to draw structural and geometric isomers for a given molecular formula. Computer-generated images and appropriate videos are likely to be useful here.
- Encourage learners to explore how isomerism can affect properties such as boiling point, melting point, and solubility in polar and non-polar solvents.
- There may be some scope for practical activities here, and independent research can also supplement teaching.

Learning aim D: Understand the chemical behaviour, separation and applications of organic compounds

- Learning aim D builds on knowledge and understanding from the previous aim and deals with the chemical behaviour of organic compounds, methods of separation and their applications. Learners should be aware of the importance of organic compounds in society and in life in general. They should understand that crude oil is a major source of hydrocarbons, particularly those used as fuels and as a feedstock for other organic compounds (such as alcohols, halogenoalkanes and many types of polymer). You could begin this aim with a discussion activity, to explore learners' existing knowledge of organic chemistry and reflect on contemporary issues surrounding the use of hydrocarbons. If possible, arrange for a visiting speaker (or speakers) from an organisation involved in the chemical, biochemical, biotechnology and pharmaceutical industries.
- Learners should be aware that, although there is movement away from the use of fossil fuels, hydrocarbons are still an important source of energy.
- Ask learners to work in groups to produce a large, annotated poster, describing in detail the fractional distillation process to produce different hydrocarbons from crude oil. From the previous learning aim, they will understand that the boiling point of hydrocarbons increases as chain length/RMM increases, so different fractions will separate at different temperatures.
- Supplement your teaching with appropriate videos and activities that involve matching chain length to fraction to boiling point to application.
- Describe the main reactions of alkanes and alkenes. Ensure learners understand that alkanes are used as fuels because they generally have a high enthalpy of combustion when they react

with oxygen.

- Ask learners to write equations for the complete and incomplete combustion of certain alkanes. Emphasise that, apart from this, alkanes are generally quite unreactive because there are no electron rich or electron deficient sites in the molecule (due to the lack of non-bonding electrons or polar bonds).
- Discuss reactions of alkanes and alkenes with halogens, particularly with chlorine; this reaction involves the formation of free radicals by UV light.
- Ensure learners understand the reactivity of alkenes: their greater electron density (arising from pi bonding) enables them to partake in addition reactions which involve addition of other molecules (halogens, hydrogen and hydrogen halides etc.). Learners must understand that alkene molecules can also add to each other to produce polymers.
- Show a suitable video and ask learners to research polymerisation processes such as those producing polythene (LD and HD), polypropylene, polystyrene and PVC.
- Explain that a water molecule can be added to an alkene molecule, causing it to be hydrated to form an alcohol. Make some reference to the addition of halogens and hydrogen halides to alkenes to form halogenoalkanes. (This is included in the organic reaction mechanisms covered later, but learners should be familiar with the test for alkenes using bromine water.) Learners must be able to state the conditions for these reactions and represent them using appropriate equations.
- Encourage learners to explore halogenoalkanes by revising the nomenclature system and identifying those that are primary, secondary and tertiary. Ask them to review the lengths and energies of the different carbon halogen bonds, to compare the reactivity of the different halogenoalkanes. Learners must realise that the halogen atom is a good leaving group allowing halogenoalkanes to undergo nucleophilic substitution reactions. Consequently, they should understand that they can eliminate a hydrogen halide molecule to produce an alkene. Encourage learners to carry out independent research into these reactions, using appropriate websites.
- As with the halogenoalkanes, ask learners to revise the nomenclature of alcohols, identifying primary, secondary and tertiary. Explain that, because of the polarity of the carbon-oxygen bond, alcohols can also undergo nucleophilic substitution reactions; provide examples. Then explain that, like halogenoalkanes, they can also undergo elimination reactions involving the removal of a water molecule to produce an alkene. Ask learners to carry out independent research into these reactions.
- If possible, use practical demonstrations to reinforce key learning points, e.g. the dehydration of ethanol to form ethene (and testing the contents of the gas jar using bromine water).
- Ensure learners can describe and explain the oxidation of alcohols. There is some scope for practical activity here, observing the change of dichromate from an orange to a green solution when alcohols are oxidised.
- Learners should be able to identify the products formed when primary and secondary alcohols are oxidised in this way, and explain why no colour change is observed for tertiary alcohols.
- Encourage learners to write appropriate equations to represent all reactions, stating the required conditions.
- Outline different reaction mechanisms.
- Learners must understand that alkanes are relatively unreactive but can undergo free radical

substitution with halogens, especially chlorine, in the presence of UV light.

- Learners should be able to explain and illustrate the mechanism of each reaction in terms of the three stages: initiation, propagation and termination.
- With regard to addition reactions of alkenes, learners should be able to illustrate the mechanism of an addition such as hydrogen bromide and ethene. This should show the electrophilic H^+ ion, the nucleophilic Br^- ion, and curly arrows to depict the direction of electron flow and the formation of the carbocation intermediate.
- Ask learners to write the mechanisms for the addition of HBr to different alkenes and to investigate the possible products formed, identifying isomers.
- Discussion why some isomers may be more prevalent than others.
- Give learners opportunities to investigate the mechanism of nucleophilic addition in halogenoalkanes and alcohols. This should involve the use of illustrations which clearly show the nucleophile, the curly arrow direction and any intermediates or transition states involved. This will also apply to elimination reactions involving halogenoalkanes and alcohols. Learners should investigate the possible products formed, identifying isomers and discussing why some isomers may be more prevalent.
- Give learners the opportunity to prepare and test some organic compounds from those listed in the unit content; these activities should include most of the techniques included in the unit content. Learners must plan their preparation, identify how to test and confirm their product, and produce a risk assessment that will enable them to carry out their techniques safely. Their plans should be reviewed and approved by the tutor before the practical activities begin.
- You may complete observation reports with checklists, but learners should also understand the correct format for writing up their practical preparation as a scientific report, with an introduction, objective, methods, observations, recording of yield (with calculations of percentage yield clearly shown), etc.
- Lead a whole-class discussion to review all the preparations, in terms of the yields obtained and the influence of various factors (e.g. competing side reactions, conditions, transfer loss, volatile reactants or product) on the yield.
- Explain the importance of chromatography for separating and testing the purity of organic compounds.
- Allow learners to develop their knowledge and skills in chromatography though practical work involving the use of paper or thin layer chromatography to appreciate aspects such as solvent extraction, filtration, use of capillary tubes to apply spots, concentration of spots, choice of solvent and vessel and use of locating agents (e.g. Ninhydrin). Learners must also understand the principles underlying the techniques.
- Show a suitable video and encourage learners to carry out independent research to introduce and/or reinforce their knowledge of these processes.
- Give learners chromatograms of mixtures and ask them to identify the components through calculation of the Rf values.
- Lead a discussion about situations where chromatography is widely used (e.g. extraction of plant pigments and identification of amino acids). Identify shortcomings of the technique and compare it with other methods of separation.

Details of links to other BTEC units and qualifications, and to other relevant units/qualifications

This unit links to:

- Unit 2: Principles and Applications of Chemistry I
- Unit 16: Applications of Inorganic Chemistry
- Unit 20: Applications of Physical Chemistry
- Unit 21: Applications of Organic Chemistry

Employer involvement

Centres may involve employers in the delivery of this unit if there are local opportunities to do so. A visit to, or a speaker from, any commercial laboratory will add value. Visits from chemical, biochemical, biotechnology and pharmaceutical manufacturers would also be helpful.

Resources

In addition to the resources listed below, publishers are likely to produce Pearson-endorsed textbooks that support this unit of the BTEC International Level 3 in Applied Science. Check the Pearson website at http://qualifications.pearson.com/endorsed-resources for more information as titles achieve endorsement.

Textbooks

- Annets, F., *BTEC Level 3 National Applied Science*, Pearson, 2010, ISBN 978-1-846-90680-0 – Supports the approach and subject matter for BTEC International Applied Science. Chapters 4 and 22 support the unit content and have activities relating to preparation and testing of compounds.
- Chapman, B. and Jarvis, A., *Organic Chemistry, Energetics, Kinetics and Equilibrium*, revised edition, Nelson Thornes, 2003, ISBN 978-0-748-77656-6 – Sets out the basics of organic chemistry and energy change.
- Clark, J., *Calculations in AS/A Level Chemistry*, Longman, 2000, ISBN 978-0-582-41127-2 – Contains many relevant calculations and worked examples.
- Hill, G., Holman, J. and Gardom Hulme, P., *Chemistry in Context for Cambridge International AS & A Level*, 7th edition, OUP, 2017, ISBN 978-0-198-39618-5 – Detailed and accessible general A level textbook.
- Ramsden, E., *Calculations for A-Level Chemistry*, 4th edition, Nelson Thornes, 2001, ISBN 978-0-748-75839-5 – Contains many relevant calculations and worked examples.
- Ramsden, E., *A-level Chemistry*, 4th edition, OUP, 2000, ISBN 978-0-748-75299-7 – An in-depth look at energy changes, organic and inorganic chemistry.

Journals

The following technical journals require high-level reading skills and an ability to use and understand technical terms. They contain the latest news and research into related topics.

- *Chemistry World*
- *Education in Chemistry*
- *Scientific American*

The *Guardian* newspaper's science section is also a useful source of relevant news articles.

Videos

You may wish to search YouTube for the following titles:

- Introduction to Enthalpy | A-level Chemistry | OCR, AQA, Edexcel
- Organic Chemistry Nomenclature IUPAC Practice Review - Naming Alkanes, Alcohols, Alkenes & Alkynes
- Tests for the Functional Group Present in the Organic Compounds - MeitY OLabs

Websites

- Association for Science Education – This website has many useful links for practical and engaging teaching.
- chemguide – Learners can access information and materials relating to energetics, equilibrium and various aspects of organic chemistry.
- CLEAPSS – This website provides health and safety information for handling chemicals and performing experiments.
- STEM Learning – This website provides resources to support teaching and learning and links with employers and industry.
- Nuffield Foundation – This website offers a good range of practical chemistry experiments.
- The Royal Society of Chemistry – This website has resources and videos to support the teaching of chemistry.
- The Association of Science Education – This website has links to resources, activities, events and research.

Pearson is not responsible for the content of any external internet sites. It is essential for tutors to preview each website before using it in class so as to ensure that the URL is still accurate, relevant and appropriate. We suggest that tutors bookmark useful websites and consider enabling students to access them through the school/college intranet.