National Unit Specification: general information

UNIT Principles to Production (SCQF 6)

CODE FE4D 12

COURSE Chemistry (Revised)

SUMMARY

This Unit develops a knowledge and understanding of the principles of physical chemistry which allow a chemical process to be taken from the researcher's bench through to industrial production. Candidates will calculate quantities of reagents and products, learn how to manipulate dynamic equilibria, understand the mechanisms by which rates can be controlled and predict enthalpy changes. It introduces aspects of analytical chemistry in the context of determining the purity of reagents and products. The Unit highlights the need for chemists to think creatively to develop new processes and products. Within the Unit, candidates will evaluate the environmental issues surrounding a chemical process in order to make informed choices and decisions about the most ethical means of production.

OUTCOMES

1 Demonstrate and apply knowledge and understanding of the principles of physical chemistry that allow chemical processes to be taken through the industrial production.
2 Demonstrate skills of scientific experimentation and investigation within the context of *Principles to Production*.

Administrative Information

Superclass: RD

Publication date: December 2010

Source: Scottish Qualifications Authority

Version: 01

National Unit Specification: general information (cont)

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RECOMMENDED ENTRY

Entry for this Unit is at the discretion of the centre. However candidates would normally be expected to have attained the skills and knowledge required by one or more of the following or equivalent:

- ♦ Standard Grade Chemistry at Credit level in both Knowledge and Understanding and Problem Solving

or

- ♦ the Intermediate 2 Chemistry course at grade B

and

- ♦ Standard Grade Mathematics at Credit level or Intermediate 2 Mathematics.

CREDIT VALUE

1 credit(s) at Higher (6 SCQF credit points at SCQF level 6).

**SCQF credit points are used to allocate credit to qualifications in the Scottish Credit and Qualifications Framework (SCQF). Each qualification in the Framework is allocated a number of SCQF credit points at an SCQF level. There are 12 SCQF levels, ranging from Access 1 to Doctorates.*

CORE SKILLS

Core skills for this qualification remain subject to confirmation and details will be available at a later date.

Additional information about core skills is published in the *Catalogue of Core Skills in National Qualifications* (SQA, 2001).

National Unit Specification: statement of standards

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Acceptable performance in this Unit will be the satisfactory achievement of the standards set out in this part of the Unit Specification. All sections of the statement of standards are mandatory and cannot be altered without reference to SQA.

OUTCOME 1

Demonstrate and apply knowledge and understanding related to *Principles to Production*.

Performance Criteria

(a) Make accurate statements about facts, concepts and relationships relevant to *Principles to Production.*
(b) Use knowledge of *Principles to Production* to solve problems.
(c) Use knowledge of *Principles to Production* to explain observations and phenomena.

OUTCOME 2

Demonstrate skills of scientific experimentation and investigation in the context of *Principles to Production.*

Performance Criteria

(a) Use a range of data-handling skills in a scientific context.
(b) Use a range of skills related to the evaluation of scientific evidence.

National Unit Specification: statement of standards

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EVIDENCE REQUIREMENTS FOR THIS UNIT

Evidence is required to demonstrate that candidates have met the requirements of the Outcomes.

For each of the Unit Outcomes, written and/or recorded oral evidence of the appropriate level of achievement is required. This evidence must be produced under closed-book, supervised conditions within a time limit of 45 minutes.

The Instrument of Assessment used must sample the content in each of the following areas:

- Getting the most from costly reactants
- Controlling the rate
- Chemical energy
- Chemical analysis as a part of quality control

An appropriate Instrument of Assessment would be a closed-book, supervised test with a time limit of 45 minutes. Items in the test should cover all of the Performance Criteria associated with both Outcomes 1 and 2 and could be set in familiar or unfamiliar contexts.

For Outcome 2, PC(a), candidates are required to demonstrate that they can use a range of data-handling skills. These skills include selecting, processing and presenting information. Information can be presented in a number of formats including: chemical formulae, balanced chemical equations, diagrams depicting laboratory apparatus, line graphs, scatter graphs, bar and pie charts, tables, diagrams and text.

For Outcome 2, PC(b), candidates are required to demonstrate they can use a range of skills associated with the evaluation of scientific evidence. These skills include drawing valid conclusions and making predictions.

The standard to be applied and the breadth of coverage are illustrated in the National Assessment Bank items available for this Unit. If a centre wishes to design its own assessments for this Unit they should be of a comparable standard.

National Unit Specification: support notes

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This part of the Unit Specification is offered as guidance. The support notes are not mandatory.

While the exact time allocated to this Unit is at the discretion of the centre, the notional design length is 40 hours.

GUIDANCE ON THE CONTENT AND CONTEXT FOR THIS UNIT

The recommended content together with suggestions for possible contexts and activities to support and enrich learning and teaching are detailed in the Appendix to this Unit Specification.

This Unit develops a candidate's knowledge and understanding of the fundamental physical chemical principles which must be mastered in order to allow a chemical process to be taken from the researcher's bench through to industrial production. Candidates will learn how to calculate the quantities of reagents and products, learn how to manipulate dynamic equilibria, understand the mechanisms by which rates can be controlled and predict enthalpy changes. The Unit also introduces elements of analytical chemistry in the context of measuring the purity of reagents and products. The Unit highlights the need for Chemists to think creatively to develop new processes and products. Within the Unit, candidates will evaluate the environmental issues surrounding a chemical process in order to make informed choices and decisions about the most ethical means of production.

This Unit offers a diverse and rich vein of contexts and opportunities for practical work as highlighted in the 'Possible contexts and activities' column of the content tables in the Appendix. Opportunities exist for candidates to learn as part of a group through practical work undertaken in partnership or in teams.

GUIDANCE ON LEARNING AND TEACHING APPROACHES FOR THIS UNIT

General advice on approaches to learning and teaching is contained in the course specification.

OPPORTUNITIES FOR CORE SKILL DEVELOPMENT

This Unit provides opportunities to develop Communication, Numeracy, Information and Communication Technology and Problem Solving skills in addition to providing contexts and activities within which the skills associated with Working with Others can be developed.

Outcome 1, PC(b) and (c) develop a candidate's ability to communicate effectively key concepts and to explain clearly chemical phenomena in written media.

Within this Unit candidates will need to extract and process information presented in both tabular and graphical formats developing the core skill of numeracy. Candidates will gain experience in a range of calculations building competence in number.

The appendix to this Unit Specification contains an extensive list of 'Possible Contexts and Activities' which include a large number of web based activities, computer simulations and modelling opportunities which all serve to develop higher levels of competence in the key ICT skill s including; accessing information and providing/creating information.

The Unit appendix contains an extensive range of practical laboratory exercises which provide candidates with the opportunity to working co-operatively with others.

Problem solving skills are central to the sciences and are assessed through Outcome 1, PCs (b) & (c) and also through Outcome 2, PCs (a) & (b).

National Unit Specification: support notes

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GUIDANCE ON APPROACHES TO ASSESSMENT FOR THIS UNIT

Outcomes 1 and 2

It is recommended that a holistic approach is taken for assessment of these Outcomes. Outcomes 1 and 2 can be assessed by an integrated end of Unit test with questions covering all the Performance Criteria. Within one question, assessment of knowledge and understanding and skills of experimentation and investigation can occur. Each question can address a number of Performance Criteria from either Outcome 1 or 2.

Appropriate assessment items are available from the National Assessment Bank.

DISABLED CANDIDATES AND/OR THOSE WITH ADDITIONAL SUPPORT NEEDS

The additional support needs of individual candidates should be taken into account when planning learning experiences, selecting assessment instruments, or considering whether any reasonable adjustments for may be required. Further advice can be found on our website www.sqa.org.uk/assessmentarrangements

National Unit Specification: general information

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The left hand column below details the content in which candidates should develop knowledge and understanding. The middle column contains notes, which give further details of the breadth and depth of content expected. The right-hand column gives possible contexts and activities which could be used to develop knowledge, understanding and skills. Further details on many of the activities mentioned in the final column can be obtained from **National Qualifications Online**, part of the Learning and Teaching Scotland online service. Where such online support exists the 💻 symbol appears in the text.

Content	Notes	Possible Contexts and Activities
1) Getting the most from costly reactants		
(a) Factors influencing the design of an industrial process	Industrial processes are designed to maximise profit and minimise the impact on the environment. Factors influencing process design include: availability, sustainability and cost of feedstock(s); opportunities for recycling; energy requirements; marketability of by-products; product yield. Environmental considerations include: minimising waste; avoiding the use or production of toxic substances; designing products which will biodegrade if appropriate.	Candidates can be given the opportunity to consider descriptions or flow diagrams for an industrial process with a view to recognising the various strategies employed to maximise profitability and to reduce the impact on the environment. The RSC 'Alchemy' resource allows candidates to look in detail at Industrial processes. 💻 An industrial case study demonstrating the ways in which concern for the environment has shaped the design of an industrial process is provided for ibuprofen. 💻 Some more general Industrial Chemistry Case Studies are available. 💻 Details of Green Chemistry can be obtained from the ChemistryTeachers website. 💻
(b) Calculation of the mass or volume (for gases) of products, assuming complete conversion of reactant(s).	Balanced equations show the mole ratio(s) of reactants and products. Using the balanced equation and the gram formula masses (GFM), mass to mass calculations can be performed. The quantity of a reactant or product can also be expressed in terms of moles.	The mole is a central concept in chemistry. It can be defined in terms of the number of particles present (Avogadro's constant). The quantitative link between the masses of reactants and products can be established experimentally.

	The molar volume (in units of litres mol^{-1}) is the same for all gases at the same temperature and pressure. The volume of a gas can be calculated from the number of moles and vice versa. The volumes of reactant and product gases can be calculated from the number of moles of each reactant and product.	A known mass of magnesium can be burned forming magnesium oxide and the relationship between the mass of magnesium metal and magnesium oxide explored. The reduction of copper(II) oxide by methane can be used to confirm the quantitative link between the mass of reactants and products. Details of how to carry out this experiment are provided in 'Classic Chemistry Demonstrations', Lister T. The Royal Society of Chemistry (1995) pp. 132-135. Videos of this experiment can be viewed. The molar volume of hydrogen can be measured by candidates using a method such as that found in 'Classic Chemistry Experiments', Kevin Hutchings 2000 pp. 171-173. Candidates can develop their own method of measuring molar volumes in a practical problem solving exercise such as that found in 'In Search of More Solutions', Janet Taylor, Royal Society of Chemistry (1994) number 36.
(c) Calculations concerning reactions which involve solutions, assuming complete conversion of reactant(s).	The concentration of a solution can be expressed in mol l^{-1}. Balanced equations can be used in conjunction with concentrations and volumes of solutions and/or masses of solutes to determine quantities of reactants and/or products.	Candidates should have the opportunity to engage in a wide range of calculations involving mass, volume and concentration of solution, GFM and balanced equations. Chemical Egg Race activities can be used to provide opportunities to practice or consolidate the mathematical skills being developed. In the 'Chemical Egg Timer', teams are given a graph showing how the concentration of potassium iodide affects the time taken for the blue-black colour to appear in a hydrogen peroxide/iodide clock reaction. The challenge for each team is to prepare 50 cm^3 of potassium iodide solution for use in a chemical egg timer which will turn blue-black one minute after the chemicals are

		mixed. ‘Colour Match Challenge’ is a far more demanding exercise and allows key calculation types to be consolidated. In the first part of the challenge, each team is given a 100 cm^3 measuring cylinder containing 5 cm^3 of 1 mol l^{-1} $CuSO_4$ solution. The aim of the egg race is to match as closely as possible two different shades of blue. The teacher/lecturer could choose shades from a paint catalogue, photograph or any two blue objects in the lab. The team must slowly add water to their measuring cylinder until the $CuSO_4$ solution matches the darker of the two shades selected. The team make a note of the total volume of solution. Further water is added until the solution matches the lighter of the two target shades. The team must now calculate the concentration of the $CuSO_4$ solutions which matched the two target colours. In the second part of the challenge, the candidates must calculate the mass of copper(II) sulfate pentahydrate ($CuSO_4.5H_2O$ GFM 249.7 g mol^{-1}) needed to produce 100 cm^3 of solution matching the darker shade of blue. They must also calculate the mass of zinc powder required to displace sufficient copper ions to lighten the solution to the point where it matches the lighter target shade. The teams weigh out copper(II) sulfate and zinc powder for use in a competition in which each team must try to reproduce the two target shades. If available, a colorimeter can be used to provide an ‘impartial’ judgement of how close the colours were to the target shades.

(d) Reversible reactions	Many reactions are reversible, so products may be in equilibrium with reactants. This may result in costly reactants failing to be completely converted into products. In a closed system, reversible reactions attain a state of dynamic equilibrium when the rates of forward and reverse reactions are equal. At equilibrium, the concentrations of reactants and products remain constant, but are rarely equal.	Candidates can investigate reversible reactions for themselves using hydrated copper(II) sulfate. A spectacular demonstration of a reversible reaction involving colour changes and clouds of white fumes can be performed using copper sulfate, concentrated hydrochloric acid and concentrated ammonia solution. The demonstration is started by making a yellow-green copper chloride complex by adding concentrated hydrochloric acid to very dilute solution of copper sulfate. When concentrated ammonia solution is added, copious quantities of white smoke are produced as HCl is driven off, heat is generated and a dark blue tetraamminocopper(II) complex forms. Adding concentrated HCl will reverse this reaction again turning the solution yellow-green colour again. Details can be found in ‘A spectacular reversible reaction’ by Colin Baker in Education in Chemistry, vol. 43, n 3, May 2006.
(e) Altering Equilibrium Position	To maximise profits, chemists employ strategies to move the position of equilibrium in favour of products. Changes in concentration, pressure and temperature can alter the position of equilibrium. A catalyst increases the rate of attainment of equilibrium but does not affect the position of equilibrium. The effects of altering pressure, altering temperature, the addition or removal of reactants or products can be predicted for a given reaction.	Experiments in which the position of equilibrium can be altered by changing conditions include; $CoCl_2$/$CoCl_2$ $2H_2O$ SSERC Bulletin 219, ‘Equilibrium and Le Chatelier’ SSERC Bulletin 220, ‘Equilibrium of Cobalt Chloride (Continued) ICl/ICl_3 equilibrium NO_2/N_2O_4 CO_2 in soda water Candidates should have the opportunity to consider industrial processes where equilibrium conditions are optimised. The

		RSC Alchemy resource contains video material and activities allowing candidates to research processes such as ammonia production (Haber process), Nitric Acid (Ostwald process) sulfuric acid (Contact process). Worksheets, fact files and videos for these processes are available. 💻 Simulation of the Haber process can also be used. 💻
(f) Percentage Yield and Atom Economy	The efficiency with which reactants are converted into the desired product is measured in terms of the percentage yield and atom economy. Percentage yields can be calculated from mass of reactant(s) and product(s) using a balanced equation. Given costs for the reactants, a percentage yield can be used to calculate the feedstocks' cost for producing a given mass of product. The atom economy measures the proportion of the total mass of all starting materials successfully converted into the desired product. It can be calculated using the formula shown below in which the masses of products and reactants are those appearing in the balanced equation for the reaction. $atom\ economy = \frac{mass\ of\ desired\ product(s)}{total\ mass\ of\ reactants} \times 100$ Reactions which have a high percentage yield may have a low atom economy value if large quantities of unwanted by-products are formed.	For a particular set of reaction conditions, the percentage yield provides a measure of the degree to which the limiting reagent is converted into the desired product. It is possible to calculate the percentage yield using equations of the type shown below. $percentage\ yield = \frac{actual\ yield}{theoretical\ yield} \times 100$ In this expression the 'actual yield' is taken to refer to the quantity of the desired product formed under the prevailing reactions conditions whilst the 'theoretical yield' is the quantity of desired product which would be obtained, assuming full conversion of the limiting reagent, as calculated from the balanced equation. For reactions in which the masses of both the limiting reagent used and the desired product obtained are known, the actual yield and theoretical yields can be expressed in terms of masses. It is equally valid, however, to calculate percentage yields using the actual and theoretical numbers of moles of desired compound. In the debate over whether candidates should be encouraged to perform percentage yield calculations using masses or using the numbers of moles there are strong arguments on either side. For assessment purposes either method will be awarded equal credit and there is no need for candidates to be familiar with both methods.

Atom Economy figures are of interest because they provide a measure of how successfully all of the reagents, not just the limiting reagent, are being converted into the desired product.

A case study illustrating how the atom economy and percentage yields for different synthetic routes led to a switch in the method used to produce ibuprofen is available.

Candidates can synthesise substances of use in everyday contexts and calculate the percentage yield and atom economy achieved.

The food additive E331 (sodium citrate) is well suited to this type of exercise. 50.0 cm^3 *of 1.0 mol* l^{-1} *sodium hydroxide are added to 3.50 g of citric acid crystals in a beaker and the mixture stirred until all the crystals have dissolved. The solution is evaporated to dryness and the product weighed.*

Zinc sulfate is used in mineral supplements and as a paste mixed with zinc oxide to treat acne. Zinc sulfate is also an astringent; it closes up the pores of the skin to keep out bacteria and can be used for this reason to treat some skin conditions or prevent sunburn. Between 4.4 g and 5.0 g of zinc oxide is added with stirring to 50 cm^3 *of warm 1.0 mol* l^{-1} *sulfuric acid (50* ^oC*). The reaction mixture is allowed to cool and filtered. The filtrate is evaporated to dryness and the product weighed.*

Calcium benzoate (E213), a preservative in foods, can be made from the reaction between benzoic acid and calcium

		carbonate. 💻 *Aspirin can easily be prepared without the use of quickfit or distillation apparatus using only a conical flask* 💻 *or on a test-tube scale using a 20 minute method.* 💻 *A range of esters can be synthesised without the use of quickfit apparatus and the yield determined.* 💻
(g) Excess	In order to ensure that costly reactant(s) are converted into product, an excess of less expensive reactant(s) can be used. By considering a balanced equation, the limiting reactant and the reactant(s) in excess can be identified. Whilst the use of excess reactants may help to increase percentage yields, this will be at the expense of the atom economy so an economic/environmental balance must be struck.	Some candidates struggle with the concept of excess in the context of identifying which substance(s) is/are present in excess and which is the limiting reagent in a given reaction mixture. A 'roast beef' sandwich analogy has been reported to be useful. To make a sandwich, two slices of bread and one slice of roast beef are required. If, for example, ten slices of roast beef and sixteen slices of bread are available, how many sandwiches can be made? In this case, only eight sandwiches can be made because bread is the limiting reagent and there is excess roast beef. This analogy is part of a computer simulation available from PhET which also includes examples of chemical reactions and a game to test understanding of the concept of excess. 💻
2) Controlling the Rate		
(a) Collision theory	Reaction rates can be controlled by chemists. If they are too low a manufacturing process will not be economically viable, too high and there is a risk of thermal explosion. Collision theory can be used to explain the effects of concentration, pressure, surface area (particle size), temperature and collision geometry on reaction rates.	There are a considerable number of experiments illustrating the factors influencing reaction rates, and a number of animations. The effect of concentration on reaction rate can be explored in a class experiment in which a strip of magnesium is dropped into various concentrations of hydrochloric acid and the time taken for the effervescence to stop recorded. The rate of reaction is calculated, and the relationship to the concentration of acid is analysed. 💻

		An unusual experiment demonstrating the effect of concentration on reaction rate is provided in the decolourisation of permanganate using rhubarb. The effect of temperature can also be investigated using the reaction between sodium thiosulfate and acid in which a sulfur precipitate forms. The time taken for a certain amount of sulfur to form can be used to estimate the rate of the reaction. Candidates can react potassium iodate and bisulfite/starch solution varying concentration and temperature to affect the reaction time. When sodium thiosulfate solution is reacted with acid, a precipitate of sulfur forms. The time taken for a certain amount of sulfur to form is used to indicate the rate of reaction. The effect of temperature on the rate of reaction can be investigated. This experiment is also available as a computer simulation. A very simple practical problem solving exercise in which the rate of an industrial process must be controlled is provided within ‘In Search of Solutions’. The dramatic effect that temperature has on reaction rate can be demonstrated using the simulation. To illustrate the effect of catalysts on reaction rates a number of experiments are listed below under ‘Catalysts’. The phET initiative from the University of Colorado also has an interactive simulation.

(b) Reaction Profiles	A potential energy diagram can be used to show the energy pathway for a reaction. The enthalpy change is the energy difference between products and reactants. It can be calculated from a potential energy diagram. The enthalpy change has a negative value for exothermic reactions and a positive value for endothermic reactions. The activated complex is an unstable arrangement of atoms formed at the maximum of the potential energy barrier, during a reaction. The activation energy is the energy required by colliding particles to form an activated complex. It can be calculated from potential energy diagrams.	A number of animations showing reaction profiles are available. Entering the search terms ‘*‘Activation energy’ animation’* into an internet search engine will produce a large number of hits. The phET initiative from the University of Colorado also has an interactive simulation.
(c) Temperature and Kinetic Energy	Temperature is a measure of the average kinetic energy of the particles of a substance. The activation energy is the minimum kinetic energy required by colliding particles before reaction may occur. Energy distribution diagrams can be used to explain the effect of changing temperature on the kinetic energy of particles. The effect of temperature on reaction rate can be explained in terms of an increase in the number of particles with energy greater than the activation energy.	‘Effect of Temperature on Reaction Rate’ could be explored using either the reaction between sodium thiosulfate solution and hydrochloric acid or the reaction between oxalic acid and an acidified solution of potassium permanganate. These experiments can be used to produce rate versus temperature graphs illustrating the exponential increase in rate with temperature.
(d) Catalysts	A catalyst provides an alternative reaction pathway with a lower activation energy. A potential energy diagram can be used to show the effect of a catalyst on activation energy.	A large number of experiments are available to demonstrate the action of catalysts including; • a demonstration of the catalytic decomposition of hydrogen peroxide • a practical problem solving exercise based on the catalytic decomposition of hydrogen peroxide • a visually attractive and colourful reaction between sodium thiosulfate and hydrogen peroxide in the presence of universal indicator

		• an attention grabbing demonstration is the classic cannon fire experiment. A common misconception is that ‘catalysts speed up reactions without taking part’. An experiment which could help to address this issue is the Rochelle salt/sodium tartrate reaction in which the cobalt compound used as the catalyst changes colour during reaction, but returns to its original colour when the reaction is over.
3) Chemical Energy		
(a) Enthalpy	For industrial processes, it is essential that chemists can predict the quantity of heat energy taken in or given out. If reactions are endothermic, costs will be incurred in supplying heat energy in order to maintain the reaction rate. If reactions are exothermic, the heat produced may need to be removed to prevent the temperature rising. Chemical energy is also known as enthalpy. The change in chemical energy associated with chemical reactions can be measured. The specific heat capacity, mass and temperature can be used to calculate the enthalpy change for a reaction.	Test-tube scale reactions for candidates to undertake which can be used to illustrate endo- and exo- thermic reactions, and which are suitable for use in enthalpy change measurement include; dissolving a spatula of anhydrous copper(II) sulfate in 2 cm^3 of water (exothermic), adding 2 cm^3 of water to a dry mixture of one spatula of citric acid and one spatula of sodium hydrogencarbonate (endothermic), adding a spatula of zinc to 5 cm^3 of 0.5 mol l^{-1} copper(II) sulfate solution. Polystyrene cups can also be used by all candidates to explore chemical energy changes. 10 cm^3 of sodium hydroxide solution is placed in the cup, the temperature recorded, and 10 cm^3 of dilute hydrochloric acid added. The temperature is recorded whilst stirring. This procedure can be repeated using: sodium hydrogen carbonate solution and citric acid; copper(II) sulfate solution and magnesium powder; dilute sulfuric acid and magnesium ribbon. Spectacular teacher demonstrations of exothermic reactions would including the thermit/thermite reaction or the reaction between zinc and copper(II) oxide.

		Demonstrations of endothermic reactions are offered by either: the solid-phase reaction between barium hydroxide-8-water and solid ammonium chloride (or ammonium thiocyanate) in which the mixture of stoichiometric quantities results in a reaction producing a liquid, with the temperature dropping to below -20 °C; or when 25g of ammonium nitrate is added rapidly, with vigorous stirring, to 100 cm^3 of water in a beaker which is resting on paper towel soaked in water. The wet paper towel freezes fixing the beaker to the bench surface. Runaway reactions, such as those resulting in disaster at Seveso and Bhopal, occur when the rate at which a chemical reaction releases energy exceeds the capabilities of the plant to remove heat. Internet sources can provide further details of these incidents.
(b) Enthalpies of combustion	The enthalpy of combustion of a substance is the enthalpy change when one mole of the substance burns completely in oxygen. These values can often be directly measured using a calorimeter and values for common compounds are available from data books and online databases for use in Hess's law calculations.	The enthalpy of combustion of alcohols can be measured using apparatus available in schools. The RSC has an online data book with enthalpy of combustion values.
(c) Hess's Law	Hess's law states that the enthalpy change for a chemical reaction is independent of the route taken. Enthalpy changes can be calculated by application of Hess's law.	Solid potassium hydroxide can be converted into potassium chloride solution by two different routes: Route 1 is the direct route whereby potassium chloride solution is made by adding solid potassium hydroxide directly to hydrochloric acid. Route 2 is the indirect route and involves two steps. Solid potassium hydroxide first is dissolved in water and then the solution neutralised using hydrochloric acid. Hess's law can be confirmed by comparing the total enthalpy change for single-step route 1 with two-step route 2.

		Hess's law can be used to determine enthalpy changes that cannot be measured directly. In one challenge, candidates are asked to determine the enthalpy change for the reaction in which anhydrous copper(II) sulfate reacts with water to form hydrated copper(II) sulfate. Candidates measure the temperature change observed when anhydrous copper(II) sulfate is dissolved in water to produce a solution of copper(II) sulfate. They then measure the temperature change when hydrated copper(II) sulfate is dissolved to form a solution of similar concentration. By applying Hess's law, the candidates can then calculate the enthalpy change for a reaction converting anhydrous copper(II) sulfate crystals into hydrated copper(II) sulfate crystals. 💻
(d) Bond Enthalpies	For a diatomic molecule, XY, the molar bond enthalpy is the energy required to break one mole of XY bonds. Mean molar bond enthalpies are average values which are quoted for bonds which occur in different molecular environments. Bond enthalpies can be used to estimate the enthalpy change occurring for a gas phase reaction by calculating the energy required to break bonds in the reactants and the energy released when new bonds are formed in the products.	Use bond enthalpies to estimate, by calculation, the enthalpy change associated with various gas phase reactions and compare the values obtained with experimental values obtained from literature. A common misunderstanding amongst candidates is that bond enthalpies can only be used to estimate the enthalpy change in reactions in which all of the reactants and all of the products are in the gas phase due to the assumption that the only bonds or interactions being broken or formed are covalent bonds.
4) Chemical Analysis as part of Quality Control		
(a) Chromatography can be used to check the composition and purity of reactants and products	In chromatography, differences in the polarity and/or size of molecules are exploited to separate the components present within a mixture. Depending on the type of chromatography in use, the identity of a component can be indicated either by the distance it has travelled or by the time it has taken to travel through the apparatus (retention time). The results of a chromatography experiment can sometimes be presented graphically showing an indication of the quantity of substance present on the y-axis and retention time	Many overviews of the key chromatographic techniques are available. 💻 A gas chromatograph can be made from a U-tube filled with soap powder. Natural gas acts as the carrier gas, and is burnt after it emerges from the U-tube 'column'. A mixture of alkanes is introduced at the inlet side of the u-tube. The component alkanes each take a different amount of time to travel through the soap powder 'column' and leave the u-tube at different times. Each time a compound leaves the u-tube,

	on the x-axis. Candidates are not required to know the details of any specific chromatographic method or experiment.	the flame formed by the burning carrier gas gets much larger and smokier. Column chromatography can be inexpensively carried out by candidates. Mixtures of food dyes can be separated using a 20 cm long glass tube or glass dropper containing a slurry of starch. A computer animation showing column chromatography in action is available. An interactive computer simulation of paper chromatography is available. Case studies concerning the use of chromatography are also available. *The National Horseracing Laboratory screens samples from racehorses and other animals to detect and identify traces of prohibited substances. A case study briefly describes gas chromatography and compares it with paper chromatography. There is information and questions for candidates, and additional notes and answers for teachers.* *In 1961, the seaside town of Capitola, California became the scene of a disturbing incident in which birds were reported to have flown into glass windows, attacked people on the ground and even, in less measured coverage, 'cry like babies'. The toxin responsible for the birds' altered behaviour was isolated and identified using a series of separation techniques, including chromatography.* A most unusual example of chromatography is provided by

		wool chromatography. A length of white wool approximately 1 m long , two 100 cm^3 beakers, approximately 20 cm^3 of methylated spirit and two crocodile clips are required. A short section (approximately 1 cm long) of the wool approximately 20 cm from the end of the wool is soaked in ink and allowed to dry. The length of wool between the inked area and the nearest end is soaked in alcohol. Crocodile clips are attached to each end of the wool to act as weights. The beaker containing the alcohol is placed on the edge of the bench. The clip on the end of the wool nearest the inked section is carefully lowered into the alcohol in such a way that the wool then passes over the spout of the beaker and descends towards the floor. The empty beaker is placed on the floor beneath the hanging clip. The alcohol is wicked up the wool, passes over the lip of the beaker and, under the action of gravity, starts to descend through the wool. As the ethanol passes through the inked area the components of the ink are carried by the solvent towards the floor at different rates resulting in a series of coloured bands moving down the wool towards the floor.
(b) Volumetric titration	Volumetric analysis involves using a solution of accurately known concentration in a quantitative reaction to determine the concentration of another substance. A solution of accurately known concentration is known as a standard solution. The volume of reactant solution required to complete the reaction is determined by titration. The 'end point' is the point at which the reaction is just complete. An indicator is a substance which changes colour at the end-point. Redox titrations are based on redox reactions. Substances such as potassium manganate (VII) which can act as their	Experimental work could include any acid/base or redox titration. Interesting examples could include the determination of: • the purity of aspirin • the purity of vitamin C tablets • the concentration of ethanoic acid in vinegars (by titration with sodium hydroxide using phenolphthalein indicator); • the mass of Citric Acid in Hubba Bubba Chewing gum (by titration with sodium hydroxide solution using phenolphthalein indicator) • the calcium carbonate content of antacid tablets (back titration in which tablet is dissolved in standard

	own indicators are very useful reactants in redox titrations. The concentration of a substance can be calculated from experimental results by use of a balanced equation.	hydrochloric acid, and the excess acid determined by titration with sodium hydroxide solution using phenolphthalein indicator; • the concentration of chloride ions in river water (a precipitation titration using silver nitrate solution and potassium chromate(VI) as the indicator) . A ‘desert island’ style practical problem solving exercise can be provided in which candidates investigate whether lemons or oranges contain more acid, using ash from burned plants (which contains potassium carbonate) to neutralise the acid, and an indicator made from plant material such as red cabbage.

National Unit Specification: general information

UNIT Researching Chemistry (SCQF 6)

CODE FE4J 12

COURSE Chemistry (Revised)

SUMMARY

In this Unit candidates will develop the key skills necessary to undertake research in Chemistry and demonstrate the relevance of chemical theory to everyday life by exploring the Chemistry behind a topical issue. Candidates will develop skills associated with collecting and synthesising information from a number of different sources. Equipped with a knowledge of common apparatus and techniques they will plan and undertake a practical investigation related to the topical issue. Candidates will prepare a scientific communication presenting the aim, results and conclusions of their practical investigation. The Unit offers opportunities for candidates to work in partnership and in teams set within the context of the evaluation of a current scientific issue. This Unit is suitable for candidates who are interested in pursuing a career in Chemistry, as well as those whose interest is more general.

OUTCOMES

1. Research the Chemistry underlying a topical issue to a given brief.
2. Plan and carry out investigative practical work related to a topical issue in Chemistry
3. Prepare a scientific communication which presents the aim, results and conclusions from a practical investigation related to a topical issue in Chemistry.

Administrative Information

Superclass: RD

Publication date: December 2010

Source: Scottish Qualifications Authority

Version: 01

National Unit Specification: general information (cont)

UNIT Researching Chemistry (SCQF 6)

RECOMMENDED ENTRY

Entry for this Unit is at the discretion of the centre. However candidates would normally be expected to have attained the skills and knowledge required by one or more of the following or equivalent:

- Standard Grade Chemistry at Credit level in both Knowledge and Understanding and Problem Solving

or

- the Intermediate 2 Chemistry course at grade B

and

- Standard Grade Mathematics at Credit level or Intermediate 2 Mathematics.

CREDIT VALUE

0.5 credit(s) at Higher (3 SCQF credit points at SCQF level 6).

**SCQF credit points are used to allocate credit to qualifications in the Scottish Credit and Qualifications Framework (SCQF). Each qualification in the Framework is allocated a number of SCQF credit points at an SCQF level. There are 12 SCQF levels, ranging from Access 1 to Doctorates*.

CORE SKILLS

Core skills for this qualification remain subject to confirmation and details will be available at a later date.

Additional information about core skills is published in the *Catalogue of Core Skills in National Qualifications* (SQA, 2001).