Unit 26: Industrial Chemical Reactions

Unit code: Y/502/5571

QCF Level 3: BTEC National

Credit value: 10

Guided learning hours: 60

Aim and purpose

This unit aims to familiarise learners with the basic concepts of physical chemistry, such as enthalpy changes, rates of chemical reactions, equilibrium, and show how they are applied to industrial reactions.

Unit introduction

Industry produces a vast range of substances from bulk chemicals such as sodium hydroxide (caustic soda) and ammonia to medicines, chemicals used in the electronics industry and substances of biological origin like vaccines and material for biofuels. Whatever the product, it is important to produce it in the most economic way. This can be achieved through an understanding of the factors that control a chemical reaction. These are the focus of study in this unit.

Energy, usually in the form of heat, may need to be supplied to a chemical reaction, or the reaction itself may release energy. Such energy changes have economic and safety consequences, if not controlled. These energy changes and their implications are studied in the first part of this unit.

It is important to consider how much product a reaction will produce – they seldom, if ever, give 100 per cent of the desired substance. Learners will then study how far a chemical reaction goes and the factors that affect this. Not only do we need to consider how much of a product a reaction gives and what the energy costs are, but we need to know how quickly it can be produced as time is money. In the final part of this unit learners will study chemical kinetics – how quickly reactions occur and the factors affecting this.

During this unit learners will apply the principles studied to examples of industrial processes.

Learning outcomes

On completion of this unit a learner should:

1 Understand how to calculate enthalpy changes from experimental and supplied data

2 Be able to investigate rates of chemical reactions in terms of the factors that influence them

3 Understand the principles of chemical equilibrium

4 Understand how physical chemistry concepts are applied to the control of industrial processes.

Unit content

1 Understand how to calculate enthalpy changes from experimental and supplied data

Enthalpy change: definition and units of enthalpy change; standard molar enthalpy change; standard conditions; sign convention; reaction profiles; exothermic and endothermic processes, eg combustion, formation, solution, neutralisation; dissociation, ionisation, electron affinity, sublimation, fusion, vaporisation, hydration; interpretation of the size and sign of values; literature values; specific heat capacity; system and surroundings; enthalpy gained by water in contact with a reaction

Principle of conservation of energy: law of conservation of energy; Hess's law

Calculation of enthalpy changes from experimental data: measurement of standard molar enthalpy changes for reactions, eg neutralisation, combustion, solubility

Calculation of enthalpy changes from supplied data: calculation of standard molar enthalpy change for a reaction from supplied data, eg enthalpy of combustion from enthalpy of formation data, enthalpy of formation from bond enthalpy values

2 Be able to investigate rates of chemical reactions in terms of the factors that influence them

Rate of reaction: definition of reaction rate; rate equations; order of reaction; rate constants; units of rate constant; measurement of rate; method of initial rates and its use to determine reaction order and rate constant; reaction profile and activation energy; distribution of energies of molecules and how that changes with temperature – relationship to activation energy; definition of catalyst; heterogeneous and homogeneous catalysts; modes of action of catalysts

Factors influencing rate of reaction: concentration; particle size; temperature; presence of a catalyst

Experimental investigations: investigations, eg variation in concentration, temperature and particle size with the reaction between hydrochloric acid with calcium carbonate, effect of variation of concentration and temperature on thiosulphate with acid, effect of variation of concentration and temperature on persulphate with iodide, crystal violet with hydroxide, effect of the heterogeneous catalyst, MnO_2, on rate of decomposition of hydrogen peroxide, effect of the homogeneous catalyst, cobalt (II) chloride, on the rate of the reaction between potassium sodium 2,3-dihydroxybutanedioate and hydrogen peroxide; method of initial rates; graphical representations of data; rate constant for a first order reaction

Interpretation of supplied data: determination of order of reaction and rate equations from experimental data

3 Understand the principles of chemical equilibrium

Principles of chemical equilibrium: eg reversible processes; equilibrium law, Kc; effects of changes in concentration, pressure and temperature on equilibrium position (Le Chatelier's principle); effects of changes in concentration, pressure and temperature on Kc; catalysts and equilibrium; calculations involving Kc and concentrations of reactants and products

Proton transfer in aqueous solution: pH scale and definition of pH; sources of H_3O^+ and OH^- ions; Bronsted-Lowry definition of acids and bases, conjugate acids and bases; dissociation of water, Kw and pKw; calculation of pH of strong acid and base solutions; acid/base strength, Ka, pKa; calculation of pH from Ka; acid-base indicators; pH titration curves; choice of indicator; buffer mixtures; Henderson-Hasselbach equation; calculation of pH of buffer mixtures; effect of addition of acid and alkali to buffer solutions

Electron transfer processes: definitions of oxidation and reduction; equilibrium nature of electron transfer, oxidising and reducing agents; half-cell (electrode) reactions; standard electrode potentials, E^θ; standard hydrogen electrode, standard conditions; electrochemical cells, cell reactions and calculation of cell EMF; use of E^θ in prediction of corrosion tendency; corrosion in situations where the conditions are non-standard

4 Understand how physical chemistry concepts are applied the control of industrial processes

Physical chemistry concepts: enthalpy changes; reaction rate; chemical equilibrium; pH; electron transfer; application of more than one concept in a given situation

Enthalpy changes and reaction rate in industrial processes: examples of enthalpy changes in industrial processes, eg polymerisation of ethene, oxidation of methanol, hydrolysis of ethanoic anhydride, synthesis of Grignard reagents; implications for process design and operating conditions; hot spots; mixing; heat exchangers; differential reaction calorimeters; controlled addition of reagents; process design to optimise rate; examples of industrial catalysis

Chemical equilibrium in industrial processes: examples of industrial processes involving chemical equilibria eg reduction of propanone, Haber process, Contact process; use of pressure and temperature to drive equilibria; reasons for operation under non-equilibrium conditions

Industrial applications of pH and electron transfer: pH control in processes and products eg industrial wastewater treatment and products, manufacture of cosmetics; examples of electron transfer, eg extraction of metals from ores, chlor-alkali industry (electrolysis of brine), corrosion control

Assessment and grading criteria

In order to pass this unit, the evidence that the learner presents for assessment needs to demonstrate that they can meet all the learning outcomes for the unit. The assessment criteria for a pass grade describe the level of achievement required to pass this unit.

Assessment and grading criteria					
To achieve a pass grade the evidence must show that the learner is able to:		**To achieve a merit grade the evidence must show that, in addition to the pass criteria, the learner is able to:**		**To achieve a distinction grade the evidence must show that, in addition to the pass and merit criteria, the learner is able to:**	
P1	compare measured values of enthalpy changes with standard enthalpy changes [CT2,5]	**M1**	calculate enthalpy changes for reactions using standard enthalpy change values from tables	**D1**	evaluate the sources of error in practical measurements
P2	carry out practical work to establish how various factors influence the rates of chemical reactions [EP3]	**M2**	explain why factors influence the rates of chemical reactions	**D2**	analyse rates of reaction in terms of order with respect to concentration of reactants
P3	explain chemical equilibrium in terms of the concentrations of reactants and products [RL2,5]	**M3**	explain how concentration, temperature, pressure and the presence of a catalyst influence the position of chemical equilibrium	**D3**	illustrate understanding of equilibrium principles by carrying out calculations involving Kc and concentrations of reactants and products
P4	explain the strength of acids and bases in terms of the acid dissociation constant [RL2,5]	**M4**	use acid dissociation constant in a range of pH calculations	**D4**	explain how the pH of a buffer solution is affected by the addition of small quantities of acid and of alkali
P5	explain corrosion tendency in terms of standard reduction potential [RL2,5]	**M5**	calculate the EMF of electrochemical cells using standard reduction potentials from oxidation/reduction half equations	**D5**	analyse the extent to which standard reduction potentials may predict the extent of corrosion in an industrial context.
P6	examine how physical chemistry concepts may be applied to the control of industrial processes. [CT2,5]	**M6**	analyse how physical chemistry concepts are applied to optimise the operation of a specific industrial process.		

PLTS: This summary references where applicable, in the square brackets, the elements of the personal, learning and thinking skills applicable in the pass criteria. It identifies opportunities for learners to demonstrate effective application of the referenced elements of the skills.

Key	IE – independent enquirers	RL – reflective learners	SM – self-managers
	CT – creative thinkers	TW – team workers	EP – effective participators

Essential guidance for tutors

Delivery

The delivery should involve as much practical work as possible. Learners would benefit from a visit to an industrial plant to see some of the principles in action.

Learners should be familiarised with the standard conditions and standard enthalpy changes for a range of processes, eg combustion, neutralisation, formation, solution, affinity, first ionisation, bond dissociation, lattice, hydration, melting, vaporisation, sublimation etc. Learners should have access to data for standard enthalpy changes so that they compare measured data to standard data and also use Hess's law to calculate enthalpy changes. Some practical work on measuring enthalpy changes is essential, eg enthalpy of neutralisation, enthalpy of combustion, enthalpy of solution. Learners must compare their measured values with reference values. This will lead on to evaluation of the possible sources of error in the measurements and the differences between the experimental conditions and the conditions to which the reference values relate. Heat exchange should be discussed and some limited work on heat exchange could be carried out.

Learners will be familiar with the factors that affect the rate of reactions from Key Stage 4. The emphasis here should be on describing in more detail how the rate is affected by the factors. It is not sufficient to say that the greater the concentration, the greater the rate. Learners should be able to plot data of initial rate compared to concentration and describe the outcome – is there a linear relationship? Is there experimental scatter of points? Learners should be instructed in how to use scientific and mathematical language. The calcium carbonate/hydrochloric acid experiment is often used to establish that rate increases as particle size decreases. Learners could look at large marble chips, small marble chips and calcium carbonate powder. Why is the reaction between acid and powder so fast? The non-linear relationship between reaction rate and temperature should be established. Learners could be asked to calculate the surface area of a cube and a cube cut in half to establish the relationship between particle size and surface area.

Explanations for the effect of temperature and the effect of catalyst should involve activation energy from the reaction profile and the distribution curve of particle energy at a particular temperature. Learners should observe or carry out reactions involving the presence and absence of a homogeneous and a heterogeneous catalyst. The reactions for practical investigations should be chosen carefully to allow learners to establish relationships in a reasonable time frame.

More advanced learners should understand that initial rate may be measured from the slope of the tangent, drawn at zero concentration for a concentration/time graph. They should be able to analyse given data to show the order of reaction with respect to the concentrations of two or three reactants and be able to calculate rate constant and establish the rate equation for the reaction. The data for this may be supplied by the tutor. The idea of rate being controlled to make products quickly, but not uncontrollably should be discussed. The economics of the use of high temperatures should be discussed. Industrial catalysts and the fact that these are often in a form which maximised surface area should be discussed.

To collect data to establish equilibrium principles would take a considerable time. One approach would be to introduce equilibrium principles using, say, an interactive website and then study one reaction, such as the reaction of Fe^{3+} with SCN^{-} to produce $[FeSCN]^{2+}$. This may be done by test tube comparisons of colour when conditions are varied or may be done quantitatively using colorimetry or spectroscopy. Learners should understand the significance of the equilibrium constant. In explaining the effect of concentration, temperature and pressure on equilibrium, interactive websites may be useful. The Fe^{3+}/SCN^{-} reaction is useful. Learners should understand why the yield of products reactions with a negative enthalpy change will be decreased when temperature is increased and understand the effect of temperature on equilibrium constant. Learners should understand the importance of the change in stoichiometric coefficient in gas reactions and how changes in pressure affect the position of the equilibrium. The effect of a catalyst can be quite complicated.

Explanation should be limited to lowering the activity of the forward and the backward reaction and therefore not altering the position of equilibrium. Maximising yield in the Haber and Contact processes by control of temperature and pressure should be introduced. More advanced learners should be able to calculate Kc from concentration data and to use this value of Kc to calculate concentrations after a change has been made to the concentration of a reactant or product.

The Bronsted-Lowry definition of acids and bases should be developed to explore the concepts of conjugate acids and bases and their associated acid dissociation constants. The size of acid dissociation constant will be related to the extent to which an acid is dissociated and to the concepts of strong and weak acids. pH should be calculated from $pH = -\log [H^+]$ for strong acids. The ionic product for water should be introduced to allow learners to calculate pH from strong alkalis. More able learners will be able to calculate pH for weak acid solutions and pH of buffer solutions. The use of buffer solutions in commercial products should be mentioned. The effect of adding small amounts of acid or alkali to buffer solutions may be explored in practice and by calculation. Learners could carry out pH titrations to see the position of the buffer zones and the end point of the titration. This could be extended to the pH range of where indicators change from conjugate acid to conjugate base and vice versa. Learners could measure Ka for weak acid. The importance of pH to solubility could be explored practically.

Electron transfer equilibria could be explored by carrying out displacement reactions. The reactivity of metals as one of the main factors determining E0 may be introduced and E0 defined in terms of standard conditions and the standard hydrogen electrode. The EMF of cells under standard conditions may be calculated using oxidation and reduction half equations. EMF for simple cells could be measured and the values compared to calculated values. Tendency to corrode may be related to the E0 of the metal (in a solution of its own ions at unit activity) and to the nature of any other metals with which it is connected. The non-standard nature of many industrial environments should be explored.

The concepts covered in the rest of the unit may be inter-related by considering how they may be applied industrially. For example, learners should be able to relate the heat given out by a reaction to an increase in temperature and a consequent increase in rate. Learners should be able to identify the need to use heat exchangers to remove excess heat energy in order to control the reaction; selection of the conditions needed for maximum yield may be incompatible with product being produced quickly; pH may need to be controlled carefully in order to prevent excessive corrosion. Learners should study at least two specific industrial processes, eg Haber and Contact processes, boiler systems with additives for controlling corrosion rate.

Outline learning plan

The outline learning plan has been included in this unit as guidance and can be used in conjunction with the programme of suggested assignments.

The outline learning plan demonstrates one way in planning the delivery and assessment of this unit.

Topic and suggested assignments/activities and/assessment
Introduction of unit and assignment programme.
Learning outcome 1 – Enthalpy changes Introduction with test tube processes – measure temperature changes – relate the temperature changes to exothermic and endothermic reactions/processes and reaction profiles. Introduce standard states. Introduce a range of standard enthalpy changes. Provide a list of definitions, sheet with definitions and blank spaces, on which to paste examples of processes. Supply data tables – match data to processes. Make conclusions about the relative sizes and signs of enthalpy changes. Estimate enthalpy of formation from average bond enthalpy values. Measure enthalpy of solution – perform calculations. Measure enthalpy of neutralisation – perform calculations. Measure enthalpy of combustion – perform calculations. Calculate enthalpy of combustion from enthalpy of formation of reactants. Discuss the problems posed by exothermic reactions in industry – research control mechanisms using material found by tutor. **Assignment 1 – Enthalpy (P1, M1, D1)**
Learning outcome 2 – Rates of reaction Discussion about what is meant by rate – concentration versus time graph – initial rate – calculation of initial rate and rate constant from drawing tangents at zero concentration – extension to order if appropriate to learners. Revision from Key Stage 4 of factors affecting rate – concentration, particle size (surface area), temperature and use of a catalyst. Concentration and rate experiment – draw concentration/time graphs; work out initial rates and relate to initial concentration. Particle size and rate experiment – draw concentration/time graphs; work out initial rates and relate to particle size. Reaction profiles and activation energy; diagrams showing distribution of energies of molecules at a fixed temperature and how that changes when the temperature changes. Temperature and rate experiment – draw initial rate/time graphs – for very advanced groups draw graphs of ln(rate constant) versus 1/T. Experiments with heterogeneous catalyst(s) and homogeneous catalyst(s). Discussion about control of rate of reaction industrially – has to be as fast as possible for economic reasons but also has to be manageable. Calculation involving orders of reaction. **Assignment 2 – Rates of Reaction (P2, M2, D2)**

Topic and suggested assignments/activities and/assessment
Learning outcome 3 – Equilibrium reactions
Internet animations showing how concentrations of reactants and products vary with time in equilibrium reactions.
Definition of what is true about equilibrium reactions.
Equilibrium constant K_c – write equilibrium constants for a selection of reactions; units of equilibrium constant.
Experiment measuring K_c for a reaction – eg formation of $[FeSCN]^{2+}$ complex from Fe^{3+} and SCN^- using a colorimeter – use of appropriate software to calculate K_c.
Show K_c remains constant throughout and illustrate how initial and final concentrations of reactants and product vary. More advanced learners calculate K_c from concentrations at equilibrium and concentrations when the concentration of a reactant or product is varied.
Effect of pressure on position of equilibrium – explanation plus demonstration with gas syringe containing NO_2 (in a fume cupboard) in equilibrium with N_2O_4.
Demonstration of $2NO_2 \rightleftharpoons N_2O_4$ equilibrium and temperature.
Prediction of effect of pressure and temperature for different reactions.
Assignment 3 – Equilibrium (P3, M3, D3)
Learning outcome 3 – pH
Definition of pH in terms of $[H^+]$. Calculation of pH for strong acids.
Introduce ionic product for water. Calculate pH of strong bases.
Introduce K_a. The stronger the acid, the larger K_a. Calculation of pH of weak acid solutions.
Conjugate acids and bases.
pH titrations. Suitable indicators for those titrations.
Definition of a buffer solution. Calculation of pH of buffer solutions. Calculation of the effects of adding small quantities of acid and alkali to buffer solutions for the more able.
Discussion of the importance of constant pH for certain reactions, including biological ones. Changing pH to alter solubility.
Assignment 4 – pH Control (P4, M4, D4)
Learning outcome 3 – Electron transfer
Simple displacement reactions to illustrate electron transfer reactions.
Half equations for oxidation and reduction and overall redox reactions.
Definition of standard reduction potential and relationship to the displacement reactions.
Measuring the EMF of electrochemical cells. Calculation of the EMF of electrochemical cells. Discuss the terms oxidising agent and reducing agent.
Tendency for corrosion related to standard reduction potentials; ways of protecting against corrosion; problems of corrosion; present learners with a real situation where conditions are non-standard, eg industrial boiler; oil-platform and discuss whether the tendency to corrosion would be the same under these conditions.
Assignment 5 – Corrosion (P5, M5, D5)
Learning outcome 4 – Industrial processes
Discussions and research on industrial equilibrium reactions eg Haber and Contact processes. Choosing the optimum temperature and pressure. Isolating products to drive the forward reaction.
Recap industrial issues related to enthalpy change, rate, equilibrium, pH and electron transfer.
Assignment 6 – Application of Concepts to Industrial Processes (P6, M6)
Review of unit and programme of assignments.

Assessment

For P1, learners need to measure the enthalpy changes in at least two different reactions, eg neutralisation, solution, combustion, and compare the values with given reference values. The comparison should involve conclusions about the size of the difference.

For M1, learners will use standard enthalpy changes in tables, eg enthalpy of formation, enthalpy of vaporisation, enthalpy of hydration, lattice enthalpy, to calculate other standard enthalpy changes. This should be related to P1 where possible. The practical work will have inherent errors. Using enthalpy of combustion (where the reaction is not likely to be in contact with the water absorbing the heat) as well as carrying out another reaction (where the reaction is occurring in the water which absorbs or loses heat) will provide opportunities for evaluation in addition to the errors associated with measurement and lack of familiarity with the technique. For D1, learners are expected to identify errors, specific to the techniques involved.

To achieve P2, learners should carry out a range of investigations on the effect of rate of concentration, particle size, temperature and presence of a catalyst. Learners should plot graphs and describe trends to 'establish' how the factors influence the rates of reaction. The emphasis is on the correct use of scientific and mathematical language in the description of trends. It is not sufficient to state that as the concentration or temperature increases, the rate increases. For M2, learners must explain the theoretical background to the measurements. Learners are expected to use collision theory in explanations and consider the number of collisions per unit time in relation to concentration and to surface area. Learners should show clear understanding of the relationship between surface area and particle size. Learners should be able to use the reaction profile and the associated activation energy in conjunction with the distribution of energy of particles at a particular temperature when explaining the effects of temperature and presence of a catalyst. For D2, learners should demonstrate an understanding of what is meant by initial rate as the gradient of the concentration/time graph at zero concentration. Order of reaction, rate constants and rate equations should be part of the analysis of rate of reaction in relation to concentration.

To achieve P3, learners should explain equilibrium in terms of its dynamic nature, the constancy of concentrations of reactants and products at equilibrium and the fact that an equilibrium constant may be written for the reaction. To achieve M3, learners should explain whether the forward or backward reaction is initially speeded up by given concentration changes and what the overall effect on the balance of product and reactants will be, given that the equilibrium constant will be the same after equilibrium is re-established. Learners should relate the enthalpy change for the forward reaction to the effect on equilibrium of increasing or decreasing temperature for a given reaction. They should be able to state whether the equilibrium constant will increase or decrease with temperature. Learners should changes in pressure to the yield of reactions involving gases, in terms of the change in stoichiometric coefficient for the forward or backward reaction. Learners should explain that the activation energy for the forward and backward reaction would be unchanged in the presence of a catalyst and that its presence should have no effect on the position of equilibrium. For D3, learners should not only calculate Kc from concentration data but also calculate the effects of a change in concentration on the equilibrium concentrations of a simple equilibrium reaction, like the decomposition of N_2O_4 to NO_2.

To achieve P4, learners should explain what is meant by a strong acid and a weak acid and a weak base in terms of the acid dissociation constant, Ka. This will involve writing the equilibrium expression for the dissociation. For M4, learners should demonstrate understanding of how pH is related to Ka by calculating pH of strong acids, strong alkalis, weak acids and buffer solutions. For D4, learners should explain how pH of a buffer will remain relatively unchanged on addition of small quantities of acid or alkali. This should involve a clear explanation in relation to the Henderson-Hasselbach equation or appropriate calculations of pH based on this equation.

For P5, learners must explain what is meant by standard reduction potential and explain that reactivity of a metal in terms of its tendency to lose electrons is important in relation to the value and sign of standard reduction potential. Learners must explain that corrosion tendency is related to the reactivity of the metal. To achieve M5, learners should must use ion/electron half equations and appropriate standard reduction potentials to calculate the voltage for at least two cells under standard conditions. For D5, learners should analyse how conditions which are likely to be present in a given industrial situation differ from ideal conditions and are likely to affect predictions of corrosion tendency, based on standard reduction potentials. The volume of assessment work produced for this set of related criteria should be relatively small.

For P6, learners should examine how two or more of the concepts of enthalpy change, rate of reaction, equilibrium reactions, pH and corrosion may be important in at least two industrial contexts. Learners could be presented with specific contexts or discuss the interrelation of the concepts in general in two or more hypothetical situations. For M6, learners should be given an assessment scenario involving a specific industrial process. Learners should analyse how the operating conditions for the process should be optimised to maximum yield in relation to two or more physical chemistry concepts. The Haber and Contact processes are useful processes to consider in relation to this assessment criterion.

Programme of suggested assignments

The table below shows a programme of suggested assignments that cover the pass, merit and distinction criteria in the assessment and grading grid. This is for guidance and it is recommended that centres either write their own assignments or adapt any Edexcel assignments to meet local needs and resources.

Criteria covered	Assignment title	Scenario	Assessment method
P1, M1, D1	Enthalpy	As a technician at a large chemical plant, Eureka Chemicals, you have been asked to demonstrate two practical methods to explain to plant operators that some of the reactions on the plant are exothermic.	Measure two enthalpy changes following given methods. Compare results to literature values and to values that may be calculated from tables of enthalpy data.
P2, M2, D2	Rates of Reaction	As a respected technician at Eureka Chemicals, you have been asked to give a presentation at a technicians' conference on how experimental work can be used to explain how various factors influence reaction rate – which is important in the process industry.	Create a presentation and associated notes explaining the experiments that you have carried out on rates of reaction.
P3, M3, D3	Equilibrium	Eureka Chemicals operates a chemical process (eg Haber process) which involves chemical equilibrium. To help the process operators better understand the process, you have been asked to write some notes on equilibrium.	Explain the features of equilibrium reactions and how they are affected by changes in temperature, concentration and presence of a catalyst, giving worked mathematical examples where relevant.

Criteria covered	Assignment title	Scenario	Assessment method
P4, M4, D4	pH Control	As a scientific journalist, you have been asked to write an article about factors that determine pH for a magazine produced for chemical process technicians.	You should explain the concept of pH and how it may be calculated in a range of situations. You must also explain what a buffer solution is and how it works.
P5, M5, D5	Corrosion	You are a consultant chemist, working for a company which supplies additives for industrial metal boilers to stop them corroding. You have been asked to produce a leaflet explaining the background to corrosion to customers, in terms of standard reduction potentials.	You should analyse, using suitable examples and equations, how standard reduction potentials, E^{θ}, and calculation of cell EMFs may be used to explain the tendency of metals to corrode. Consider whether E^{θ} values alone are sufficient to explain the tendency of boilers to corrode.
P6, M6	Application of Concepts to Industrial Processes	The process operators at Eureka Chemicals found your explanation of equilibrium so useful that they have asked you to write them notes on other aspects of process control.	Explain the relationship between enthalpy changes, rate and use of heat exchange. Analyse why the company operates an equilibrium process under non-standard conditions and why that is relevant to maximising yield.

Links to National Occupational Standards, other BTEC units, other BTEC qualifications and other relevant units and qualifications

This unit forms part of the *BTEC Applied Science sector* suite. This unit has particular links with the units shown below in the BTEC Applied Science suite of qualifications:

Level 1	Level 2	Level 3
	Chemistry and Our Earth	Chemical Periodicity and its Applications
	Applications of Chemical Substances	Chemistry for Biology Technicians

Essential resources

Learners should have access to laboratory facilities and data on enthalpy changes. They also need internet access and/or access to textbooks. Learners should have access to computers for producing graphs where possible.

Employer engagement and vocational contexts

Learners should visit a plant, operating a chemical process, have a speaker from such a plant or have access to virtual resources related to such a plant.

Indicative reading for learners

Textbooks

Beavon R and Jarvis A – *Periodicity, Quantitative Equilibria and Functional Group Chemistry* (Nelson Thornes, 2001) ISBN 9780174482918

Chapman B and Jarvis A – *Organic Chemistry, Energetics, Kinetics and Equilibrium* (Nelson Thornes, 2003) ISBN 9780748776566

Ellis H, NCCT – *Book of Data (Nuffield Advanced Science – Revised Editions)* (Longman, 1984) ISBN 9780582354487

Facer G – *Make the Grade in AS and A2 Chemistry* (Nelson Thornes, 2003) ISBN 9780748772810

Facer G – *Edexcel AS Chemistry, 2nd Edition* (Hodder Education, 2008) ISBN 9780340957608

Facer G – *Edexcel A2 Chemistry, 2nd Edition* (Hodder Education, 2009) ISBN 9780340957615

Fullick A and Fullick P – *Chemistry: Evaluation Pack (Heinemann Advanced Science)* (Heinemann Educational Secondary Division, 2000) ISBN 0435570965

Heaton A – *Introduction to Industrial Chemistry, 3rd Edition* (Blackie Academic and Professional, 1996) ISBN 9780751492728

Hill G and Holman J – *Chemistry in Context, 5th Edition* (Nelson Thornes, 2000) ISBN 9780174482765

Hill G and Holman J – *Chemistry in Context: Laboratory Manual and Student Guide, 5th Edition* (Nelson Thornes, 2000) ISBN 9780174483076

Hill B and Hunt A – *Edexcel Chemistry for AS* (Hodder Murray, 2008) ISBN 9780340949085

Lewis E and Berry M – *AS and A Level Chemistry* (Longman, 2000) ISBN 9780582337336

Lewis R and Evans W – *Chemistry, 3rd Edition* (Palgrave Macmillan, 2006) ISBN 9780230000117

Lister T – *Industrial Chemistry Case Studies* (Royal Society of Chemistry, 1999) ISBN 9780854049257

Pearson Education – *Chemical Storylines AS, 3rd Edition* (Heinemann, 2008) ISBN 9780435631475

Ramsden E N – *A-level Chemistry: AND Answers Key* (Nelson Thornes, 2004) ISBN 9780748753017

Stark J G and Wallace H G – *Chemistry Data Book, 2nd Edition* (Murray, 1982) ISBN 9780719539510

Journals

Chemistry Review

Education in Chemistry

Royal Society of Chemistry

Websites

www.alevelchemistry.co.uk	Chemistry resources
www.bbc.co.uk/scotland/education/bitesize/higher/chemistry/reactions/index.shtml	Chemical reactions
www.chemguide.co.uk	Guide to chemistry
www.chemtopics.com/unit13/unit13f.htm	Chemistry resources
www.chm.davidson.edu/ronutt/che115/EquKin/EquKin.htm	Chemical equilibrium experiment
www.industry-animated.org/home.htm	How machinery in the chemical industry works
www.mhhe.com/physsci/chemistry/animations/chang_7e_esp/kim2s2_5.swf	Chemical equilibrium animation
www.rsc.org/ChemistryWorld	Chemistry news online
www.s-cool.co.uk/alevel/chemistry.html	Chemistry revision

Delivery of personal, learning and thinking skills

The table below identifies the opportunities for personal, learning and thinking skills (PLTS) that have been included within the pass assessment criteria of this unit.

Skill	When learners are …
Creative thinkers	[CT2,5] comparing measured enthalpy changes with standard enthalpy changes; examining how physical chemistry concepts may be applied to the control industrial processes
Reflective learners	[RL2,5] explaining chemical equilibrium in terms of the concentrations of reactants and products explaining the strength of acids and bases in terms of the acid dissociation constant explaining corrosion tendency in terms of standard reduction potential
Effective participators	[EP3] carrying out practical work to establish how various factors influence the rates of chemical reactions.

Although PLTS are identified within this unit as an inherent part of the assessment criteria, there are further opportunities to develop a range of PLTS through various approaches to teaching and learning.

Skill	When learners are …
Creative thinkers	[CT1,3,5,6] analysing how physical chemistry concepts are applied to optimise the operation of a specific industrial process illustrating understanding of equilibrium principles by carrying out calculations involving kc and concentrations of reactants and products analysing the extent to which standard reduction potentials may predict the extent of corrosion in an industrial context
Reflective learners	[RL3,5,6] calculating the EMF of electrochemical cells using standard reduction potentials from oxidation/reduction half equations evaluating the sources of error in practical measurements analysing rates of reaction in terms of order with respect to concentration of reactants explaining how the ph of a buffer solution is affected by the addition of small quantities of acid and of alkali.

Functional Skills – Level 2

Skill	When learners are …
ICT – Use ICT systems	
Select, interact with and use ICT systems independently for a complex task to meet a variety of needs	recording rate of reaction data searching for data on industrial processes
Use ICT to effectively plan work and evaluate the effectiveness of the ICT system they have used	processing data relating to rate of reaction
Manage information storage to enable efficient retrieval	saving information in suitable files in suitable folders
Follow and understand the need for safety and security practices	keeping food and drink away from computers not using someone else's login explaining how safety is addressed in the context of the tasks explaining why the it usage policy forbids certain actions
Troubleshoot	carrying out checks to identify the source of a problem encountered, eg missing file of work
ICT – Find and select information	
Select and use a variety of sources of information independently for a complex task	obtaining information on industrial reactions from textbooks and websites
Access, search for, select and use ICT-based information and evaluate its fitness for purpose	carrying out multiple criteria searches, finding suitable websites and writing notes on the information on the sites
ICT – Develop, present and communicate information	
Enter, develop and format information independently to suit its meaning and purpose including: • text and tables • images • numbers • records	entering concentration time data, rate/temperature data into a spreadsheet in order to plot graphs and establish trends in data recording data in tables obtaining images of corrosion
Bring together information to suit content and purpose	collating information on rates of reaction, equilibrium processes and industrial reactions
Present information in ways that are fit for purpose and audience	producing word-processed documents like reports and notes about equilibrium and industrial processes preparing presentations, using appropriate software, on rate of reaction – in line with the assignment briefs
Evaluate the selection and use of ICT tools and facilities used to present information	reflecting on the ICT tools used
Select and use ICT to communicate and exchange information safely, responsibly and effectively including storage of messages and contact lists	sending emails to tutors with assignment work attached sending emails to classmates, comparing results of rate experiments

Skill	When learners are …
Mathematics	
Understand routine and non-routine problems in a wide range of familiar and unfamiliar contexts and situations	calculating enthalpy changes, rates of reactions, equilibrium constant, ph and EMF of cells
Identify the situation or problem and the mathematical methods needed to tackle it	identifying suitable ways of performing calculations to meet the requirements of assignment tasks
Select and apply a range of skills to find solutions	calculating enthalpy changes using standard formulae using gradients of graphs to obtain rate constants establishing trends in data relating to rate of reaction
Use appropriate checking procedures and evaluate their effectiveness at each stage	estimating answers to calculations; checking calculations done on a calculator or using appropriate software
Interpret and communicate solutions to practical problems in familiar and unfamiliar routine contexts and situations	writing reports in line with assignment criteria
Draw conclusions and provide mathematical justifications	discussing results of rates of reaction experiments
English	
Speaking and listening – make a range of contributions to discussions and make effective presentations in a wide range of contexts	making a presentation on rates of reaction listening to other people's ideas in class discussions
Reading – compare, select, read and understand texts and use them to gather information, ideas, arguments and opinions	reading information on corrosion and industrial reactions
Writing – write documents, including extended writing pieces, communicating information, ideas and opinions, effectively and persuasively	writing notes, reports and articles in line with assignment briefs.