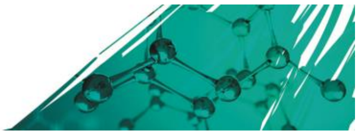


Unit 20: Applications of Physical Chemistry

Delivery guidance

This unit has three learning aims that deal with aspects of physical chemistry (thermodynamics, rate of reaction and chemical equilibrium). The fourth deals with how industry uses the concepts when operating chemical processes.

The thermodynamic factors will allow learners to identify whether or not reactions are feasible, but do not give an indication of the rate of the reactions. They will learn how to calculate the rates of chemical reactions from given data and to work out the relationship between the rate and the concentrations of the reactants. They will also carry out practical investigations of factors affecting the rate of reaction and explain these factors in terms of collision theory. Learners will also learn how to describe the characteristic features of equilibrium reactions and to calculate the equilibrium constant, exploring the effects on equilibrium of changes in concentration, pressure, temperature and catalysts. Finally learners will investigate how industrial chemical reactions may be controlled by using physical chemistry concepts.

A range of industries that employ scientists make use of these topics. For example, process operators and the technicians in the bulk chemical, polymer, agrochemical and pharmaceutical industries use the concepts learned in this unit to optimise production. The fundamental concepts introduced in this unit are extended in higher education courses involving chemistry and biology.

Approaching the unit

Learners will have encountered thermodynamics, chemical kinetics and chemical equilibrium in Units 2 and 6. In this unit they will further develop their knowledge of enthalpy changes and use data to calculate the enthalpy changes expected in reactions, as well as the other two functions of state, entropy and Gibbs energy. In relation to kinetics, learners will use measurements for rate of reaction to determine the rate equation and order of reaction. They will use data to perform calculations for the rate constant and activation energy. This will extend their knowledge of equilibrium to explore the relationship between equilibrium constant, temperature, enthalpy and entropy in showing the feasibility of reactions. Learners will have the opportunity to investigate how these physical concepts that have been looked at can be applied to controlling industrial reactions.

For **learning aim A,** learners should have the opportunity to revisit any definitions associated with thermodynamics. They will have the opportunity to develop their confidence in carrying out calculations using their own data and data from standard data books or the internet. They will measure and calculate enthalpy changes, including those that involve the rearrangement of equations. As in other units, you should encourage learners to identify specific and realistic error sources in experiments and to estimate the effect on the final, calculated result of changes to measurements. Learners will learn about entropy, Gibbs energy and how to predict whether a reaction is feasible under standard conditions.

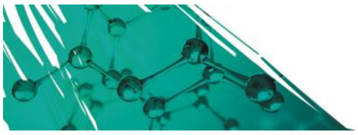
Learning aim B builds on the understanding regarding rate of reaction, factors affecting it and measurement of rate. All learners should be able to explain the factors affecting rate in the context of the reactions studied, in terms of collision theory, activation energy and the distribution of molecular energies. You will introduce learners to rate law expressions for calculating rate of reaction. Learners will understand not only why reaction rate increases with temperature, but will also be able to calculate activation energy for a reaction from the rate constants at different temperatures.

For **learning aim C**, learners will revisit aspects of chemical equilibrium that were dealt with previously. They can build on this by using different experimental methods to calculate K_c. For closed gaseous systems, they will write expressions for K_p and carry out calculations using partial pressures. Learners will carry out calculations for Gibbs free energy, equilibrium constant and temperature, and show that reactions that are feasible in terms of ΔG have large values for K_c and vice versa. They will analyse the relationship between equilibrium constant, temperature, enthalpy and entropy for a range of reactions, using a variety of equations in order to explore the links.

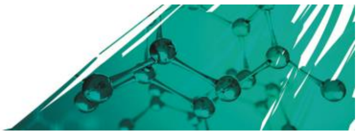
For **learning aim D**, learners will be given the opportunity to apply the knowledge gained from learning aims A, B and C. Reactions such as the Haber Process, Contact Process and sulphuric acid production, production of ethanol from ethene and synthesis of methanol are suitable industrial reactions on which to demonstrate how industry controls chemical reactions. All involve equilibrium processes, consideration of factors affecting rate and also thermodynamic factors. The Solvay process, production of nitric acid and phosphoric acid, and catalytic cracking of petroleum products may also be of relevance.

Assessment model

Learning aim	Key content areas	Recommended assessment approach
A Investigate chemical thermodynamics in order to understand spontaneous reactions	**A1** Enthalpy changes **A2** Entropy and Gibbs energy	A report explaining standard enthalpy changes and entropy, with examples of reactions. Practical report of determination of enthalpies of reactions, with accurate measurements and techniques, calculations and discussion of the assumptions and sources of error. Worksheets containing calculations, involving enthalpy changes, entropy changes and Gibbs energy, and assessment of the feasibility of reactions.
B Investigate rate equations and activation energy to understand the chemical kinetics of reactions	**B1** Rate of reaction	Practical report of the effect of concentration of different reactants, temperature and catalysis on rates of reaction, with accurate measurements and techniques, calculations and conclusions, and discussion of the assumptions and sources of error. Worksheets showing reasoning and calculation to determine rate equations and activation energy. Analysis of rate equations and activation energy for reactions to consider the mechanism of the reaction.



Learning aim	Key content areas	Recommended assessment approach
C Investigate chemical equilibrium in order to understand the extent to which reactions go to completion	**C1** Chemical equilibrium	A report explaining the features of equilibrium and the effect of changing conditions, with examples of reactions. Practical report to determine the equilibrium constant for reactions using different methods, with accurate measurements and techniques, calculations and conclusions, and discussion of the assumptions and sources of error. Worksheets showing calculations and graph work involving the equilibrium constant (K_p or K_c), mole quantities, pressure, Gibbs energy, temperature, enthalpy and entropy, commenting on the feasibility and extent of the reaction where appropriate.
D Understand physical chemistry concepts and how industry controls chemical reactions	**D1** Industrial application of physical chemistry concepts	An explanation of the reason for three specified features of the operation of an industrial process. An explanation of three further factors that may be altered on the basis of physical chemistry concepts. Analysis of other industrial processes in terms of the physical chemistry concepts involved.



Assessment guidance

This unit is internally assessed via a number of independent tasks. Learners must produce individual evidence that is original and can be authenticated.

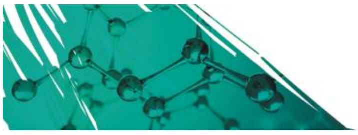
Learners should attempt assignments only once they have all the skills and knowledge that they will need to achieve the criteria, of which they are capable

For learning aim A, learners are required to produce a report/portfolio explaining standard enthalpy changes and write equations for reactions showing the associated enthalpy changes. Learners should be able to demonstrate how they have carried out practical work, applying accurate measurements and techniques to determine enthalpy change for two types of reaction (displacement, neutralisation or combustion). The report should show the relevant calculations and discuss the assumptions and sources of error. There should be an explanation of entropy and its significance for different chemical processes, with examples of how it can be calculated for different reactions. The report should include worksheets which enable learners to perform more complex calculations involving enthalpy changes, using a range of data and involving the rearrangement of equations. It should examine how Gibbs free energy and entropy are used to assess the spontaneity and feasibility of reactions, citing the limitations involved with such predictions.

Learning aim B requires learners to produce a practical report/portfolio on investigations into the factors that affect rate of reaction. This should include concentration of different reactants (at least two experiments), temperature (at least one experiment) and catalysis (at least one experiment) on rates of reaction, with accurate measurements and techniques, graphs/plots, calculations and conclusions. There should also be discussion of the assumptions and sources of error. The report should include worksheets showing reasoning and calculation to determine rate equations, order of reaction and activation energy (some of this could follow from the practical investigation). There should be an analysis of rate equations and activation energy for reactions to consider the mechanism of the reaction.

For learning aim C, learners must produce a report/portfolio explaining the features of equilibrium and the effect of changing conditions, with examples of reactions. This should detail how they have used experimental methods to determine the equilibrium constant for at least two reactions using different methods (e.g. titration and colorimetry), with accurate measurements, techniques, calculations and conclusions, and discussion of the assumptions and sources of error. Learners should explain the relevance of K_p for closed heterogeneous gaseous systems, write expressions using partial pressure and perform calculations from supplied data. This can be achieved through the use of worksheets which show calculations and graph work involving the equilibrium constant (K_p or K_c), mole quantities, pressure, Gibbs energy, temperature, enthalpy and entropy. There should be an analysis of the relationship between K_c, temperature, enthalpy and entropy for a range of reactions, commenting on the feasibility and extent of the reaction where appropriate.

Learning aim D requires learners to apply their knowledge of thermodynamic factors, factors affecting rate of reaction and equilibrium processes to the industrial control of chemical reactions. This should entail a report that provides an explanation of the reason for three specified features of the operation of an industrial process. It should then identify and discuss three potential measures for a different industrial process, which may be used to control or affect the operation of the process. There should be an analysis of other industrial processes in terms of the physical chemistry concepts involved.



Getting started

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

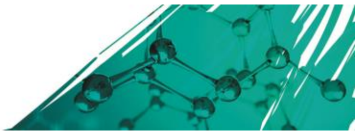
Unit 20: Applications of Physical Chemistry

Introduction

Introduce the unit by showing learners a presentation involving photographs and videos of chemical plants relevant to the work. Explain the need to take notes in a personally useful style from the start of the unit. Mention aspects of all learning aims briefly. Learners should have the opportunity to carry out brief research or have discussions on selected topics throughout. Give them a quiz or examination-style questions to test and gauge their existing knowledge and understanding with regard to thermodynamics, kinetics and equilibrium.

Learning aim A – Investigate chemical thermodynamics in order to understand spontaneous reactions

- Learning aim A is primarily concerned with three areas: enthalpy changes, entropy and Gibbs energy. Learners will have encountered enthalpy in Unit 6 and should be able to define terms, carry out measurements and calculate energy changes. They will perform more complex calculations, including those that involve the rearrangement equations. Learners will learn about entropy, Gibbs energy and how to predict whether a reaction is feasible under standard conditions.
- Give learners a worksheet where they are required to define a range of standard enthalpy changes, including combustion, formation, solution, hydration, neutralisation, bond dissociation, ionisation, electron affinity, atomisation, lattice, sublimation, fusion and vaporisation. The worksheet can also contain examples of chemical reactions with literature values for enthalpy, which they use to interpret whether the reaction is endothermic or exothermic, and the extent.
- Have learners do a differentiated worksheet based on heat (Q) = mcΔT. Give learners a value of the standard enthalpy change for displacing copper (II) ions by iron (II) ions. Lead them through the planning of an experiment to measure the above enthalpy change by the addition of excess iron filings to a known volume copper (II) sulphate in solution. They should then carry out the practical work for the Cu^{2+}(aq) + Fe experiment. Ask the learners to plot temperature against time for the reaction, extrapolating back to zero time to get the accurate highest temperature on which to base their value of ΔT. The enthalpy change per mole for their experiment should be calculated and results presented clearly. A class discussion can follow on the strengths and weaknesses of each other's presentation and then each can improve their own presentation of calculations. They should also discuss how well results agree within the class and with the standard value, supplied by you, and comment on sources of error.
- Learners will understand the applications of the law of conservation of energy to calculate enthalpy changes, including Hess' Law. They should use standard enthalpy of formation data to calculate the standard enthalpy changes for a range of reactions. They could also calculate the standard enthalpy of formation for a substance, given the enthalpy change for a reaction and the enthalpies of formation for the other substances. Ensure that



learners are using a clear and appropriate way of presenting their work. You should prepare a differentiated worksheet for calculations, which the learners will find useful when carrying out their assignment work.

- Review average bond enthalpies and how to calculate enthalpy of formation from these values. Discuss the reliability of these values with the learners. Learners should practise the above calculations by working through a differentiated worksheet. Examples that are more complex may involve values for the enthalpy of vaporisation and comparisons with literature values, or could involve finding a value of average bond enthalpy value where the enthalpy of formation was one of the pieces of supplied data.
- The focus of teaching can now shift to entropy, and you should explain that this is a measure of disorder. Show learners how to calculate the standard molar entropy changes from values of standard molar entropy for individual substances. Lead learners to relate the values for the entropy for reactions to the degree of disorder in the reactants and products in a reaction equation. They should carry out some calculations involving ΔS^0reaction = ΣS^0products – ΣS^0reactants.
- Introduce Gibbs energy and how change in Gibbs energy is related to changes in enthalpy and entropy. You could demonstrate a reaction which, although endothermic, is spontaneous, e.g. barium hydroxide and ammonium chloride or sodium hydrogen carbonate with dilute hydrochloric acid. Explain the condition for a feasible reaction as a negative change in Gibbs energy, and how to calculate ΔG^0 from ΔH^0 and ΔS^0. You will need a good source of thermodynamic data. Learners should work through a differentiated worksheet based on the equation $\Delta G^0 = \Delta H^0 - T\,\Delta S^0$, including rearrangement of the equation and calculation of the temperature at which a reaction may become feasible if ΔH and ΔS do not vary much with temperature.

Learning aim B – Investigate rate equations and activation energy to understand the chemical kinetics of reactions

- Learning aim B is solely concerned with the rate of reaction and chemical kinetics. In Unit 6, learners will have been introduced to collision theory, investigated the factors affecting it and carried out measurement to determine the rate of reactions. They will determine the order of reaction from experimental measurements and use rate law expressions for calculating rate of reaction. They will also be able to calculate activation energy for a reaction from the rate constants at different temperatures.
- Give learners a worksheet where they can define the rate of reaction for a range of chemical reactions and measure it from the gradients of plots of, for example, concentration against time, and how it will be measured. Then ask them to plan investigations into factors that affect rate of reaction, such as concentration, temperature or application of a catalyst.
- They should then carry out the practical work for their investigation. Learners should use their results to calculate rate and initial rate of reaction from concentration/time graphs. Lead them to deduce the units of rate of reaction. Present learners with tables showing direct proportion between initial rate and concentration (first order), proportion between initial rate and concentration squared (second order) and constant initial rate, no matter what the concentration is (zero order). Deduce the units of the first, second and zero order rate constants from the rate expression – for example, Rate = k[A] for a first order reaction where k has units of s^{-1}. Present a straightforward example of initial rate for reactions involving two or three reactants, where you work out the order with respect to each reagent, the overall order, the rate expression and then calculate rate constant.

- Learners should work through a differentiated worksheet with straightforward and more complex examples of the type of problem described above. They should understand that the rate equation and order of reaction will enable determination of the mechanism of a reaction. Examples could include the reaction of hydrogen and chlorine as a zero order, the decomposition of hydrogen peroxide as a first order and the reaction of nitrogen (IV) oxide with carbon monoxide (to produce nitrogen (II) oxide and carbon dioxide) as a second order.
- Working in pairs, learners should complete a worksheet that recaps the effect of particle size, concentration, temperature and presence of a catalyst on the rate of reaction. For example you could ask, '2 mol dm^{-3} hydrochloric acid is added to marble chips of average width 2 mm and 5 mm. Which will react faster? How could you prove this?'
- Explain collision theory in general terms and then go through each of the four factors, using collision theory, reaction profiles and the spread of energies of reacting particles (re. Maxwell-Boltzman distribution) to explain the effects of the factors on rate. Learners should be led through the explanations and involved throughout. For example, if you explained the effect of decrease in particle size, get the learners to give an explanation of increase in particle size.
- Explain the basis of the Arrhenius equation in both the exponential and logarithmic forms. Describe the graphical relationship between ln(k) and 1/T. Demonstrate calculations to obtain the activation energy. Learners can then work through examples, calculating activation energy. This could also include examples of finding rate constant and temperature. They should be able to observe that when the rate is lower the activation energy will be higher and vice versa. This could include comparing the catalysed and non-catalysed version of a particular reaction (e.g. the decomposition of hydrogen peroxide) and certain reactions (e.g. reaction of calcium carbonate with hydrochloric acid) where the temperature is increased by, say, 10°C at a time.

Learning aim C – Investigate chemical equilibrium in order to understand the extent to which reactions go to completion

- Learning aim C is solely concerned with chemical equilibrium. In Unit 6, learners will have been introduced to the topic and should be able to explain dynamic equilibrium, factors affecting it, the equilibrium constant K_c and how it is affected by changes. They will now carry out experimental methods to calculate K_c and be introduced to Gibb's free energy and entropy. They will understand the relationship between equilibrium constant, temperature, enthalpy and entropy for different reactions.
- You could revisit the concept of equilibrium with a game involving coloured sticky notes. Yellow and pink together is the product of reaction of separate yellow and pink notes stuck to a whiteboard. You can begin with the separate notes. One person will be responsible for combining them, another for separating them. An equilibrium will be established. At equilibrium, there will be separate reactants and products in the mixture at any time. The rate of making the compound will be the same as for breaking it up. The reaction will continue to happen.
- Use videos and animations to illustrate what happens to the concentration of reactants and products – starting with products or starting with reactants. Learners should make notes about the characteristics of equilibrium reactions. Recap equilibrium constant and how to

write the expressions for K_c. Learners should then complete a differentiated worksheet where they write expressions for finding K_c and deduce units and substitute values for concentration into the expressions. This should include more complex examples where learners may have the total volume of the reaction vessel or solution and the number of moles of each reagent. Learners should then be asked to plan experimental investigations for determining K_c, e.g. ethyl ethanoate-water/ethanoic acid-ethanol using acid-base titration. They should then carry out the practical work for their investigation. Learners should calculate K_c from the concentration values obtained from the investigation.

- Introduce K_p for closed gaseous systems and ask learners to write expressions for it using partial pressures (p). They should understand the relationship between partial pressure of a gas (p), total pressure (p_T) and mole fraction (X) in a closed system: $p = Xp_T$. Learners should then complete a differentiated worksheet where they write expressions for finding K_p and calculate it with given values of partial pressure or the total pressure and mole fractions at equilibrium, and vice versa.
- Learners will have encountered Le Chatelier's principle in Unit 6 and will understand that equilibrium will re-establish following an imposed change in concentration, pressure and temperature. In other words, the equilibrium constant will stay the same if the concentration of either one of the reactants or one of the products is increased or decreased. If more of a reactant is added, it will react to form more product. If more of a product is added, it will react to give more 'reactants' (i.e. substances on lhs). You could further illustrate this with some examples, e.g. the Fe/H_2O = Fe_2O_3/O_2 reaction.
- From unit 6, learners will also understand that equilibrium constant stays the same at constant temperature. Adding reactants or taking product away means that the reaction is no longer in equilibrium. The forward reaction speeds up and the backward reaction speeds up and so on until equilibrium is re-established. The amounts of reactants and products will be different – but the equilibrium constant will still be the same. (It may be possible to illustrate this for buffer systems if the learners have done Unit 16. Adding hydroxide to a weak acid solution uses the small amount of hydrogen ions present due to dissociation of the acid. More acid dissociates as a result. It is possible to titrate a weak acid with hydroxide until effectively all the acid has dissociated.) You should guide learners about the level of detail/clarity expected in a description of the effect. Lead learners to deduce that removing product from an equilibrium reaction will cause more product to be made.
- Explain the effect of temperature in terms of the endothermic reaction (forward or backward) being favoured by increases in temperature. Learners could work through examples, describing increases or decreases in temperature of a range of reactions and predicting the change in equilibrium yield. They should explain mathematically why equilibrium constant increases for reactions whose forward reaction is endothermic, and decreases when the forward reaction is exothermic.
- Introduce the rule that the reaction that produces fewer molecules will be favoured by high pressure/the reaction which produces more molecules will be favoured by low pressure. Have learners work through a series of examples, predicting which reaction will be favoured (forward or backward) by an increase in pressure and whether increasing pressure will increase/decrease/have no effect on yield. Once that is understood, ask learners to consider examples where they have to predict the effects of either raising or decreasing the pressure.
- Explain the effect of catalyst on equilibrium – it has no effect but because a catalyst increases the rate of reaction, equilibrium will be established sooner.

- Learners should understand that reactions are often not run under equilibrium conditions in order to keep the reaction happening. (One of the products may be constantly removed.)
- Have learners research industrial equilibrium reactions where the conditions are altered to produce more product in a realistic time frame (Haber Process, Contact Process and hydration of ethene to produce ethanol).
- Show learners the equation that relates equilibrium constant to standard change in Gibbs energy: $\Delta G^0 = - RT$ in K, which means that $K = \exp(-\Delta G^0/RT)$. So a reaction that has a huge negative standard Gibbs energy will have a very large equilibrium constant, while a reaction with a huge positive standard Gibbs energy will have a very tiny equilibrium constant.

Learning aim D – Understand physical chemistry concepts and how industry controls chemical reactions

- Learning aim D gives learners the opportunity to apply the knowledge gained from thermodynamic factors, factors affecting rate of reaction and equilibrium processes to the industrial control of chemical reactions. Reactions including the Haber Process, Contact Process, sulphuric acid production, production of ethanol from ethene and synthesis of methanol will be investigated. Since this learning aim is assessed by learners applying their knowledge and understanding, you should try to find a balance between leading learners into how they may apply what they have learned without giving them too much evidence for the assessment criteria. It is likely that discussion and independent research will be the best way forward for this learning aim.
- You could explain areas that the learners may not be totally familiar with, e.g. the use of heat exchangers, hot spots and design of reaction vessels. Involve learners in discussions; videos are useful here. Have learners work through a worksheet that will allow them to understand the important concepts.
- Learners should research a list of industrial reactions, taking notes as they carry out the research. Introduce the idea of control of industrial reactions by posing questions that they can answer by carrying out research – give an example of:
    - particle size being altered
    - use of a catalyst
    - temperature being optimised
    - concentration being optimised
    - pressure being optimised
    - running reactions under non-equilibrium conditions.

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 6: Principles and Applications of Chemistry II
- Unit 16: Applications of Inorganic Chemistry
- Unit 21: Applications of Organic Chemistry.

Resources

In addition to the resources listed below, publishers are likely to produce Pearson-endorsed textbooks that support this unit of the BTEC International L3 Qualifications in Applied Science. Check the Pearson website (http://qualifications.pearson.com/endorsed-resources) for more information as titles achieve endorsement.

Textbooks

Clark, J – *Calculations in AS/A Level Chemistry* (Longman, 2000) ISBN 9780582411270

Ramsden, E – *Calculations for A-Level Chemistry* (Nelson Thornes, 2001) ISBN 9780748758399. These two books are both useful for helping learners carry out calculations related to chemistry concepts.

Curtis, C, Scott, D and Murgatroyd, J – *Edexcel AS/A Level Chemistry Student Book 2 + Activebook: Student Book 1* (Pearson, 2015) ISBN 9781447991168

Curtis, C, Scott, D and Murgatroyd, J – *Edexcel A Level Chemistry Student Book 2 + Activebook* (Pearson, 2015) ISBN 9781447991175. Both of these student books cover some of the topics in this unit.

Hill, G and Holman, J – *Chemistry in Context: Laboratory Manual*, 5th edition (Nelson Thornes, 2001) ISBN 9780174483076. This contains details of practical work that will be useful.

Hill, G and Holman, J – *Chemistry in Context*, 6th edition (Nelson Thornes, 2011) ISBN 9781408514962. Excellent reference for harder topics which need more detail and explanation.

Lister, T and Renshaw, J – *AQA Chemistry A Level Year 1*, 2nd edition (Oxford University Press, 2015) ISBN 9780198351825. Contains material on enthalpy changes and equilibrium.

Lister, T and Renshaw, J – *AQA Chemistry A Level Year 2*, 2nd edition (Oxford University Press, 2015) ISBN 9780198357711. Contains material on kinetics, equilibria and thermodynamics.

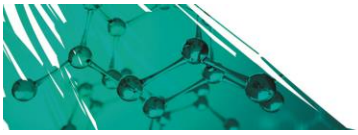
Journals

Chemistry World

Education in Chemistry

These can contain relevant articles that relate to physical chemistry concepts.

Videos



Visit Ineos.com, which has a series of videos about the operation of a company heavily involved in the chemical industry. Learners will get the chance to see the chemical plant that is featured in these videos.

‘Heat exchangers principles – Complete video’ – this is a good introduction to heat exchangers.

‘Fluidised bed technology: Generating options for tomorrow’ – this explains fluidised bed combustion.

‘Fluidized Bed Combustor’ – this video shows a fluidised bed combustor on a laboratory scale.

‘Industrial implementation of the ammonia synthesis – how does it work?’ – this video outlines ammonia production at a BASF plant.

‘The Haber Process’ – this video about an ammonia plant has many views of the plant, although it is quite old.

‘Mod-01 Lec-01 Thermodynamics and the Chemical Industry’ – this video presents an introduction to the use of thermodynamics in the chemical industry.

Websites

Visit the National STEM Centre and Nuffield Foundation website. The website has links to lots of science resources. This particular resource is a collection of standard thermochemical data which is very useful for learning aim A. Despite the standard state involving a pressure of 1 atmosphere rather than 1 bar, the data are self-consistent and useful.

Visit the Chemguide website. Although this website is aimed at AS and A level learners, it contains explanations of the topics that are broader than required for particular syllabi and thus targets the BTEC content effectively.

Visit the Chemistry LibreTexts website. This Open Access textbook environment supplants conventional paper-based books and has a wide-ranging collection of articles on most topics.

Visit The Essential Chemical Industry website from the University of York’s Chemistry Department. The central resource is a book about the chemical industry which is updated and is available online. This site explains how the material may be used and gives links to all the chapters (Introduction, Industrial Processes, Materials and Applications, Basic Chemicals, Polymers, Metals). It contains a great deal of material which learners will find relevant to the research for their assignments.

Visit the Royal Society of Chemistry website’s Resources page; this provides links to resources relevant to the topics in the unit.

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.