3.1.8 Thermodynamics

The further study of thermodynamics builds on the Energetics section and is important in understanding the stability of compounds and why chemical reactions occur. Enthalpy change is linked with entropy change enabling the free-energy change to be calculated.

Prior knowledge:

AS Chemistry
- 3.1.4 – Energetics.

3.1.8.1 Born-Haber Cycles

Learning objective	Time taken	Learning Outcome	Learning activity with opportunity to develop skills	Assessment opportunities	Resources
Definitions of enthalpy changes used in Born–Haber and solution enthalpy cycles. Using Born–Haber cycles for ionic compounds. Considering covalent character of ionic compounds. Using solution enthalpy cycles for ionic compounds.	1.5 weeks	**Students should be able to:** • define lattice enthalpy (formation and dissociation), enthalpy of formation, ionisation enthalpy, enthalpy of atomisation, bond enthalpy, electron affinity, enthalpy of solution, hydration enthalpy • draw and use Born–Haber cycles to find missing values of enthalpy changes • comment on the covalent character of an ionic compounds by comparing lattice enthalpies found using Born–Haber cycles with those calculated	• Write equations to represent enthalpy changes (AO2 - Apply knowledge and understanding). • Construct Born-Haber cycles and use them to calculate missing enthalpy change values (AO2 - Apply knowledge and understanding; MS2.2 Change the subject of an equation). • Compare and comment on values of enthalpy changes from Born–Haber cycles with those calculated theoretically using the perfect ionic model (AO3 - Analyse, interpret and evaluate data to make judgements). • Construct and use cycles involving the solution of ionic compounds in water to find missing enthalpy change values (AO2 - Apply knowledge and understanding	• June 2013 Unit 5 Question 1 (QS13.5.01) • June 2013 Unit 5 Question 2 (QS13.5.02) • January 2013 Unit 5 Question 2 (QW13.5.02) • June 2011 Unit 5 Question 1 (QS11.5.01) • January 2010 Unit 5 Question 4 (QW10.5.04)	Nuffield Science Data Book (free download): http://www.nationalstemcentre.org.uk/elibrary/resource/3402/nuffield-advanced-science-book-of-data-second-edition Chemistry Data Book (Starck, Wallace, McGlashan) ISBN: 9780719539510 Many suitable calculations can be found at http://www.docbrown.info/ and http://www.chemsheets.co.uk/ (subscription required)

		theoretically using the perfect ionic model.	MS2.2 Change the subject of an equation). • Rich question – predict the relative magnitude of the lattice enthalpy of the following compounds: aluminium oxide, potassium oxide, sodium chloride, sodium oxide. • Rich question – for an ionic compound with covalent character, deduce whether the lattice enthalpy will have a greater or smaller magnitude than that calculated theoretically from the perfect ionic model.		

3.1.8.2 Gibbs free-energy change ΔG and entropy change ΔS

Learning objective	Time taken	Learning Outcome	Learning activity with opportunity to develop skills	Assessment opportunities	Resources
To calculate entropy changes for reactions To calculate Gibbs free-energy changes and determine whether reactions are feasible at various temperatures	1.5 weeks	**Students should be able to:** • describe entropy in terms of disorder • predict whether reactions have an increase or decrease in entropy • calculate the entropy change for a reaction • calculate the Gibbs free-energy change for a reaction at a given temperature • determine whether a reaction is feasible at a given temperature • calculate the temperature at which a reaction becomes feasible • use entropy changes to explain why some endothermic reactions are feasible.	• Rank given substances in terms of entropy (AO2 - Apply knowledge and understanding). • Use entropy values to calculate the entropy change for a reaction (AO2 - Apply knowledge and understanding MS2.2 Change the subject of an equation; MS2.3 Substitute numerical values into algebraic equations). • Predict, where possible, whether reactions have an increase or decrease in entropy (AO2 - Apply knowledge and understanding). • Use the equation $\Delta G = \Delta H - T\Delta S$ to determine whether reactions are feasible at given temperatures, and determine the temperature at which reactions become feasible (AO2 - Apply knowledge and understanding; MS2.2 - Change the subject of an equation; MS2.3 - Substitute numerical values into algebraic equations using appropriate units for physical quantities). • Plot graphs of ΔG versus T to determine ΔH and ΔS (MS3.3 - Determine the slope and intercept of a linear graph). • Forecast how temperature affects the feasibility of reactions given the sign of the enthalpy and entropy	• June 2013 Unit 5 Question 3 (QS13.5.03) • January 2012 Unit 5 Question 2 (QW12.5.02) • June 2011 Unit 5 Question 2 (QS11.5.02) • June 2010 Unit 5 Question 6 (QS10.5.06)	Nuffield Science Data Book (free download): http://www.nationalstemcentre.org.uk/elibrary/resource/3402/nuffield-advanced-science-book-of-data-second-edition Chemistry Data Book (Starck, Wallace, McGlashan) ISBN: 9780719539510 RSC Classic Chemical Demonstrations - ΔH and ΔS for the vaporization of water using a kettle http://media.rsc.org/Classic%20Chem%20Demos/CCD-57.pdf Many suitable calculations can be found at http://www.docbrown.info/ and http://www.chemsheets.co.uk/ (subscription required)

			changes (AO2 - Apply knowledge and understanding). • Apply the equation $\Delta G = \Delta H - T\Delta S$ to state changes to find ΔH, ΔS, melting and/or boiling points (AO2 - Apply knowledge and understanding; MS2.2 - Change the subject of an equation; MS2.3 - Substitute numerical values into algebraic equations using appropriate units for physical quantities). • Determine ΔH and ΔS for the vaporization of water using a kettle (PS 3.2 - Process and analyse data using appropriate mathematical skills as exemplified in the mathematical appendix for each science).		

3.1.9 Rate Equations

In rate equations, the mathematical relationship between rate of reaction and concentration gives information about the mechanism of a reaction that may occur in several steps

Prior knowledge:

AS Chemistry
- 3.1.5 – Kinetics.

3.1.9.1 Rate Equations

Learning objective	Time taken	Learning Outcome	Learning activity with opportunity to develop skills	Assessment opportunities	Resources
Understand rate equations and order of reaction. Deduce order of reaction, rate equations and rate constants from rate data. Describe how the rate constant changes with temperature. Use the Arrhenius equation.	0.5 week	**Students should be able to:** • define the terms order of reaction and rate constant • describe how changing concentration of a reagent affects the rate when the order with respect that reagent is 0, 1 or 2 • determine the values and units for rate constants given appropriate data • describe how rate constants change with temperature • perform calculations using the Arrhenius equation • plot straight line graphs of ln k versus 1/T to determine the activation energy of a reaction.	• Describe how changes in concentration will affect reaction rates given the rate equation (AO2 - Apply knowledge and understanding). • Use rate equations to determine reaction rates or rate constants (with units) using initial rate data (AO2 - Apply knowledge and understanding; MS0.0 - Recognise and make use of appropriate units in calculation; MS2.3 – substitute numerical values into algebraic equations; MS2.4 - Solve algebraic equations). • Students use a graph of concentration–time and calculate the rate constant of a zero-order reaction by determination of the gradient. (AO2 - Apply knowledge and understanding; MS3.3 - Determine the slope of a linear graph; MS3.4 -	• June 2006 Unit 4 Question 5a and 5b (QS06.4.05) • June 2003 Unit 4 Question 1 (QS03.4.01)	Calculations in AS / A Level Chemistry (Clark) ISBN 9780582411272 *Chemistry Review* article: Establishing a rate equation (Volume 14, edition 2) Many suitable calculations can be found at http://www.docbrown.info/ and http://www.chemsheets.co.uk/ Advanced Practical Chemistry (ILPAC) ISBN 0719575079

			Calculate rate of change from a graph showing a linear relationship). • Students can measure the activation energy for the catalysed and uncatalysed reaction of iodine with peroxodisulphate(VI) ions by experiment and plotting graphs (AO2 - Apply knowledge and understanding; MS3.3 - Determine the slope of a linear graph).		

3.1.9.2 Determination of rate equation

Learning objective	Time taken	Learning Outcome	Learning activity with opportunity to develop skills	Assessment opportunities	Resources
Understand that rate equations have to be determined by experiment. Link rate equations to mechanisms. Determine rate using concentration-time graphs. Use rate-concentration graphs to deduce order for a reagent. **Required practical 7** Measure the rate of a reaction by an initial rate method, and a continuous monitoring method. Students could research the method. Students could also do practical 3 here and use Arrhenius equation.	2.0 weeks	**Students should be able to:** • explain that rate equations can only be determined by experiment • use concentration-time graphs to find rates (including initial rates) • use initial rate data to determine rate equations • use rate-concentration data/graphs to find orders of reaction with respect to a reagent • link rate equations to mechanism and determine rate determining steps.	• Determine rate equations, rate constants (with units) using initial rate data (AO2 - Apply knowledge and understanding; MS0.0 - Recognise and make use of appropriate units in calculation; MS2.3 – substitute numerical values into algebraic equations; MS2.4 - Solve algebraic equations). • Students do the iodine clock reaction and determine the order of reaction for a reactant (AO2 - Apply knowledge and understanding; PS 2.4 - Identify variables including those that must be controlled; PS 3.1 - Plot and interpret graphs; PS 3.2 - Process and analyse data using appropriate mathematical skills; MS3.1 - Translate information between graphical, numerical and algebraic forms; MS3.2 - Plot two variables from experimental or other data; MS3.3 - Determine the slope and intercept of a linear graph AT a, k, l). • Students can react calcium carbonate or magnesium with acid of different concentrations and plot volume of gas formed against time for continuous monitoring. Initial rates could be found from these plots and compared (AO2 - Apply knowledge and understanding; PS	• SAMs A-level paper 2 (set 1) Q2 • June 2013 Unit 4 Question 1 (QS13.4.01) • January 2013 Unit 4 Question 1 (QW13.4.01) • January 2011 Unit 4 Question 1 (QW11.4.01) • January 2010 Unit 4 Question 3 (QW10.4.03) • January 2006 Unit 4 Question 1 (QW06.4.01) • January 2003 Unit 4 Question 1 (QW03.4.01)	Calculations in AS / A Level Chemistry (Clark) ISBN 9780582411272 *Chemistry Review* article: Establishing a rate equation (Volume 14, edition 2) ILPAC Unit P5: Chemical Kinetics (free download from www.nationalstemcentre.org.uk) Avogadro web site on rate equations: http://www.avogadro.co.uk/kinetics/rate_equation.htm

			2.4 - Identify variables including those that must be controlled; PS 3.1 - Plot and interpret graphs; PS 3.2 - Process and analyse data using appropriate mathematical skills; MS3.1 - Translate information between graphical, numerical and algebraic forms; MS3.2 - Plot two variables from experimental or other data; MS3.3 - Determine the slope and intercept of a linear graph; MS3.4 - Calculate rate of change from a graph showing a linear relationship; MS3.5 - Draw and use the slope of a tangent to a curve as a measure of rate of change; AT a, k, l). • Students can use colorimetry for continuous monitoring experiments (eg bromine + methanoic acid; propanone + iodine) to determine order (AO2 - Apply knowledge and understanding; PS 3.1 - Plot and interpret graphs; PS 3.2 - Process and analyse data using appropriate mathematical skills; MS3.1 - Translate information between graphical, numerical and algebraic forms; MS3.2 - Plot two variables from experimental or other data; MS3.3 - Determine the slope and intercept of a linear graph; MS3.4 - Calculate rate of change from a graph showing a linear relationship; MS3.5 - Draw and use the slope of a tangent to a curve as a measure of rate of change; AT a, k, l).		

			• Students could be given data to plot and interpret in terms of order with respect to a reactant. Alternatively, students could just be given appropriate graphs and asked to derive order(s) (AO2 - Apply knowledge and understanding; MS3.1 - Translate information between graphical, numerical and algebraic forms; MS3.2 - Plot two variables from experimental or other data; MS3.3 - Determine the slope and intercept of a linear graph; MS3.4 - Calculate rate of change from a graph showing a linear relationship; MS3.5 - Draw and use the slope of a tangent to a curve as a measure of rate of change). • Students calculate the rate constant of a zero-order reaction by determining the gradient of a concentration–time graph (MS3.3 - Determine the slope and intercept of a linear graph; MS3.4 - Calculate rate of change from a graph showing a linear relationship). • Students plot concentration–time graphs from collected or supplied data and draw an appropriate best-fit curve. Students draw tangents to such curves to deduce rates at different times (MS3.5 - Draw and use the slope of a tangent to a curve as a measure of rate of change).		

3.1.10 Equilibrium constant K_p for homogeneous systems

The further study of equilibria considers how the mathematical expression for the equilibrium constant K_p enables us to calculate how an equilibrium yield will be influenced by the partial pressures of reactants and products. This has important consequences for many industrial processes.

Prior knowledge:

AS Chemistry
- 3.1.6 – Chemical equilibria, Le Châtelier's principle and K_c

Learning objective	Time taken	Learning Outcome	Learning activity with opportunity to develop skills	Assessment opportunities	Resources
Understand the concept of and calculate partial pressures using mole fractions. Write expressions for and calculate K_p including units. Perform calculations involving K_p. Predict how changes in conditions affect the position of an equilibrium and the value of K_p. The effect of a catalyst affects an equilibrium and K_p.	2.0 weeks	**Students should be able to:** • calculate equilibrium quantities, mole fractions and partial pressures for equilibrium mixtures • write an expression for K_p for a reaction and calculate the value of K_p with units • predict and justify how changes in temperature and pressure affect the position of an equilibrium, and how this may or may not affect the value of K_p • understand how a catalyst affects an equilibrium and the value of K_p.	• Given initial amounts of substances and one substance at equilibrium, find the quantity of each reagent at equilibrium (AO2 - Apply knowledge and understanding). • Calculate mole fractions and then partial pressures in order to determine K_p, with units (AO2 - Apply knowledge and understanding; MS2.3 - Substitute numerical values into algebraic equations using appropriate units for physical quantities). • For given equilibria with enthalpy change data, predict the effect on the position of an equilibrium and the value of K_p (AO2 - Apply knowledge and understanding).	• January 2007 Unit 4 Question 2 (QW04.4.02) • June 2007 Unit 4 Question 1 (QS07.4.01) • January 2008 Unit 4 Question 3 (QW08.4.03) • June 2008 Unit 4 Question 3 (QS08.4.03) • January 2009 Unit 4 Question 3 (QW09.4.03) • June 2009 Unit 4 Question 2 (QS09.4.02)	Calculations for A level Chemistry (Ramsden) ISBN 9780748758395 Many suitable calculations can be found at http://www.docbrown.info/ and http://www.chemsheets.co.uk/ (subscription required)

3.1.11 Electrode potential and electrochemical cells

Redox reactions take place in electrochemical cells where electrons are transferred from the reducing agent to the oxidising agent indirectly via an external circuit. A potential difference is created that can drive an electric current to do work. Electrochemical cells have very important commercial applications as a portable supply of electricity to power electronic devices such as mobile phones, tablets and laptops. On a larger scale, they can provide energy to power a vehicle.

Prior knowledge:

AS Chemistry

- 3.1.7 – Oxidation, reduction and redox equations.

3.1.11.1 Electrode potentials and cells

Learning objective	Time taken	Learning Outcome	Learning activity with opportunity to develop skills	Assessment opportunities	Resources
The idea of a cell that has a potential difference being made by combining two half cells (electrodes). How potentials are measured relative to the Standard Hydrogen Electrode and under standard conditions. Use the electrochemical series to calculate the EMF of cells and predict the direction of simple redox reactions. **Required practical 8** Measuring the EMF of an electrochemical cell.	1. 0 week	**Students should be able to:** • understand that there is a potential difference between two half cells (electrodes) that are joined • use cell notation to represent cells • understand that potentials are measured relative to the Standard Hydrogen Electrode • understand that the potential of an electrode is affected by conditions • know the standard conditions under which potentials are measured • know that electrode potential are listed in order in the electrochemical series	• Students make simple cells and use them to measure EMF and unknown electrode potentials (AO2 - Apply knowledge and understanding; PS 1.1 - Solve problems set in practical contexts; AT j - Set up electrochemical cells and measuring voltages). • Students write the standard cell notation for cells (AO2 - Apply knowledge and understanding). • Students predict how changes in conditions will affect EMF (AO2 - Apply knowledge and understanding). • Students could be asked to plan and carry out an experiment to investigate the effect of changing conditions, such as concentration or temperature, in a voltaic cell such as $Zn\|Zn^{2+}\|\|Cu^{2+}\| Cu$ (AO2 - Apply knowledge and understanding; PS 1.1 - Solve problems set in practical contexts; PS 2.4 - Identify variables	• January 2013 Unit 5 Question 7 (QW13.5.07) • January 2012 Unit 5 Question 4 (QW12.5.04) • June 2006 Unit 5 Question 5 (QS06.5.05) • January 2004 Unit 5 Question 4 (QW04.5.04)	Nuffield Science Data Book (free download): http://www.nationalstemcentre.org.uk/elibrary/resource/3402/nuffield-advanced-science-book-of-data-second-edition Chemistry Data Book (Starck, Wallace, McGlashan) ISBN: 9780719539510 *Chemistry Review* articles: Understanding electrode potentials (Volume 12, edition 1) Electrode potentials (Volume 15, edition 3) Some suitable problems can be found at http://www.docbrown.info/

Students to research method of making an electrochemical cell		• use the electrochemical series to predict the direction of simple redox reactions.	including those that must be controlled; AT j). • Students could use *E* values to predict the direction of simple redox reactions, then test these predictions by simple test-tube reactions (AO2 - Apply knowledge and understanding).		and http://www.chemsheets.co.uk/ (subscription required)

3.1.11.2 Commercial applications of electrochemical cells

Learning objective	Time taken	Learning Outcome	Learning activity with opportunity to develop skills	Assessment opportunities	Resources
That cells can be used as a source of energy. That cells can be non-rechargeable or rechargeable. That fuel cells can be used to generate an electric current. That there are benefits and risks associated with using these cells.	1.0 week	**Students should be able to:** • understand that there is a potential difference between two half cells (electrodes) that are joined • use cell notation to represent cells • understand that potentials are measured relative to the Standard Hydrogen Electrode • understand that the potential of an electrode is affected by conditions • know the standard conditions under which potentials are measured • know that electrode potential are listed in order in the electrochemical series • use the electrochemical series to predict the direction of simple redox reactions.	• Students make simple cells and use them to measure EMF and unknown electrode potentials (AO2 - Apply knowledge and understanding; PS 1.1 - Solve problems set in practical contexts). • Students write the standard cell notation for cells (AO2 - Apply knowledge and understanding). • Students predict how changes in conditions will affect EMF (AO2 - Apply knowledge and understanding). • Students could be asked to plan and carry out an experiment to investigate the effect of changing conditions, such as concentration or temperature, in a voltaic cell such as $Zn\|Zn^{2+}\|\|Cu^{2+}\|\ Cu$ (AO2 - Apply knowledge and understanding; PS 1.1 - Solve problems set in practical contexts; PS 2.4 - Identify variables including those that must be controlled). • Students could use *E* values to predict the direction of simple redox reactions, then test these predictions by simple test-tube reactions (AO2 - Apply knowledge and understanding).	• June 2013 Unit 5 Question 5 (QS13.5.05) • June 2012 Unit 5 Question 5 (QS12.5.05) • January 2011 Unit 5 Question 5 (QW11.5.05)	Nuffield Science Data Book (free download): http://www.nationalstemcentre.org.uk/elibrary/resource/3402/nuffield-advanced-science-book-of-data-second-edition Chemistry Data Book (Starck, Wallace, McGlashan) ISBN: 9780719539510 *Chemistry Review* articles: Understanding electrode potentials (Volume 12, edition 1) Electrode potentials (Volume 15, edition 3) Some suitable problems can be found at http://www.docbrown.info/ and http://www.chemsheets.co.uk/ (subscription required)

3.1.12 Acids and bases

Acids and bases are important in domestic, environmental and industrial contexts. Acidity in aqueous solutions is caused by hydrogen ions and a logarithmic scale, pH, has been devised to measure acidity. Buffer solutions, which can be made from partially neutralised weak acids, resist changes in pH and find many important industrial and biological applications.

Prior knowledge:

AS Chemistry
- 3.1.6 – Chemical equilibria, Le Châtelier's principle and K_c

3.1.12.1 Brønsted–Lowry acid-base equilibria in aqueous solutions

Learning objective	Time taken	Learning Outcome	Learning activity with opportunity to develop skills	Assessment opportunities	Resources
The idea of acids as proton donors and bases as proton acceptors.	0.2 weeks	**Students should be able to:** • define Brønsted–Lowry acids and bases • identify species as Brønsted–Lowry acids or bases in proton transfer reactions.	• Identify which species acts as the acid and which as the base in Brønsted-Lowry acid-base reactions (AO2 - Apply knowledge and understanding).	• June 2012 Unit 4 Question 3a and 3b (QS12.4.03)	Theory of acids history websites: http://www.bbc.co.uk/dna/ptop/plain/A708257 http://pubs.acs.org/subscribe/archive/tcaw/12/i03/pdf/303chronicles.pdf RSC acid-base simulator: http://www.rsc.org/learn-chemistry/resource/res00001457/acid-base-solutions-rsc-funded

3.1.12.2 Definition and determination of pH

Learning objective	Time taken	Learning Outcome	Learning activity with opportunity to develop skills	Assessment opportunities	Resources

Calculate the pH of strong acids from concentration and vice versa.	0.4 weeks	**Students should be able to:** • calculate pH of a strong acid from its concentration • calculate the concentration of a strong acid from its pH • calculate the pH of when a strong acid is diluted.	• Identify acids as being strong or weak and monoprotic or diprotic (AO2 - Apply knowledge and understanding). • Calculate the pH of strong acids from the acid concentration, including examples where the acids are diluted (AO2 - Apply knowledge and understanding; MS0.4 - Use calculators to find and use power, exponential and logarithmic functions; MS2.5 - Use logarithms in relation to quantities that range over several orders of magnitude). • Calculate the concentration of strong acids from the pH (AO2 - Apply knowledge and understanding; MS0.4 - Use calculators to find and use power, exponential and logarithmic functions; MS2.5 - Use logarithms in relation to quantities that range over several orders of magnitude).	• June 2009 Unit 4 Question 3a (QS09.4.03)	RSC pH simulator: http://www.rsc.org/learn-chemistry/resource/res00001458/ph-scale-simulation-rsc-funded Some suitable problems can be found at http://www.docbrown.info/ and http://www.chemsheets.co.uk/ (subscription required)
Extension					Estimate the number of H^+ ions in a drop of water http://www.rsc.org/learn-chemistry/resource/res00000665/h-ions-in-water

3.1.12.3 The ionic product of water K_w

Learning objective	Time taken	Learning Outcome	Learning activity with opportunity to develop skills	Assessment opportunities	Resources
Use K_w to calculate the pH of strong bases.	0.3 weeks	**Students should be able to:** • show that $K_w = [H^+][OH^-]$	• Derive the expression $K_w = [H^+][OH^-]$ (AO1 - Demonstrate knowledge and understanding).	• January 2013 Unit 4 Question 2a (QW13.4.02)	RSC pH simulator: http://www.rsc.org/learn-chemistry/resource/res00

		• use K_w to find the pH of strong bases from its concentration, and vice versa • calculate the pH of water at different temperatures	• Calculate the pH of strong bases from the base concentration and vice versa, including dilutions (AO2 - Apply knowledge and understanding; MS0.4 - Use calculators to find and use power, exponential and logarithmic functions; MS2.5 - Use logarithms in relation to quantities that range over several orders of magnitude). • Calculate the pH of water at different temperatures (AO2 - Apply knowledge and understanding; MS0.4 - Use calculators to find and use power, exponential and logarithmic functions; MS2.5 - Use logarithms in relation to quantities that range over several orders of magnitude). • Explain how the pH and neutrality of water is or is not affected by changes in temperature (AO2 - Apply knowledge and understanding).	• June 2011 Unit 4 Question 2a (QS11.4.02) • June 2010 Unit 4 Question 5a and 5b (QS10.4.05)	001458/ph-scale-simulation-rsc-funded Some suitable problems can be found at http://www.docbrown.info/ and http://www.chemsheets.co.uk/ (subscription required)

3.1.12.4 Weak acids and bases; K_a for weak acids

Learning objective	Time taken	Learning Outcome	Learning activity with opportunity to develop skills	Assessment opportunities	Resources
Understand the term *weak* in relation to acids and bases. Use K_a to find the pH of weak acids from the concentration and vice versa. Relate K_a to pK_a	0.3 weeks	**Students should be able to:** • write expressions for K_a for stated weak acids • perform calculations linking K_a to concentration and pH • convert K_a values to pK_a and vice versa • calculate the pH of water at different temperatures.	• Explain the difference between strong and weak acids and bases (AO1 - Demonstrate knowledge and understanding). • Derive expressions for K_a for stated acids (AO1 - Demonstrate knowledge and understanding). • Perform calculations linking K_a to concentration and pH (AO2 - Apply knowledge and understanding; MS0.4 - Use calculators to find and use power, exponential and logarithmic functions; MS2.5 - Use logarithms in relation to quantities that range over several orders of magnitude). • Convert K_a values to pK_a and vice versa, and use these values to rank acids in order of strength (AO2 - Apply knowledge and understanding; MS0.4 - Use calculators to find and use power, exponential and logarithmic functions; MS2.5 - Use logarithms in relation to quantities that range over several orders of magnitude). • Measure K_a of a weak acid by measuring pH at half neutralisation (AO2 - Apply knowledge and understanding; AT c - Measure pH using pH charts, or pH meter, or pH probe on a data logger; PS 4.1 - Know and understand how to use a	• January 2012 Unit 4 Question 4b (QW12.4.04) • January 2006 Unit 4 Question 2a and 2b (QW06.4.02)	RSC acid-base simulator: http://www.rsc.org/learn-chemistry/resource/res00001457/acid-base-solutions-rsc-funded RSC pH simulator: http://www.rsc.org/learn-chemistry/resource/res00001458/ph-scale-simulation-rsc-funded Creative problem solving in Chemistry – weak acids: http://www.rsc.org/learn-chemistry/resource/res00000677/a-weak-acid Some suitable problems can be found at http://www.docbrown.info/ and http://www.chemsheets.co.uk/ (subscription required)

			wide range of experimental and practical instruments, equipment and techniques; AT d).		

3.1.12.5 pH curves, titrations and indicators

Learning objective	Time taken	Learning Outcome	Learning activity with opportunity to develop skills	Assessment opportunities	Resources
Calculate the pH of the solution formed when strong or weak acids react with strong bases. Sketch pH curves and choose suitable indicators for titrations. **Required practical 9** Investigate how pH changes when a weak acid reacts with a strong base and when a strong acid reacts with a weak base. Use of data logger and plot curve.	1.0 weeks	**Students should be able to:** • calculate pH of a mixture of a strong acid with a strong base • calculate the pH of a mixture of a weak acid with a strong base • sketch pH curves for titrations of strong/weak acids with strong/weak bases • choose a suitable indicator for acid-base titrations.	• Perform calculations to find the pH of mixtures of strong/weak acids with strong bases, with either excess acid or base (AO2 - Apply knowledge and understanding; MS0.4 - Use calculators to find and use power, exponential and logarithmic functions; MS2.5 - Use logarithms in relation to quantities that range over several orders of magnitude). • Produce pH curves by experiment (AO2 - Apply knowledge and understanding; AT c - Measure pH using pH charts, or pH meter, or pH probe on a data logger; AT d, k, a). • Sketch pH curves for given acid and base combinations, and choose a suitable indicator (AO2 - Apply knowledge and understanding).	• June 2013 Unit 4 Question 3 (QS13.4.03) • June 2011 Unit 4 Question 1 (QS11.4.01) • CHEM4 Specimen Paper Question 3 (QSP 4.03) • June 2005 Unit 4 Question 2 (QS05.4.02) • June 2005 Unit 5 Question 2 (QS05.5.02) • June 2003 Unit 4 Question 3 (QW03.4.03)	RSC pH simulator: http://www.rsc.org/learn-chemistry/resource/res00001458/ph-scale-simulation-rsc-funded pH curve simulators: http://chem-ilp.net/labTechniques/AcidBaseIdicatorSimulation.htm http://terpconnect.umd.edu/~toh/models/TitrationDemo.html Some suitable problems can be found at http://www.docbrown.info/ and http://www.chemsheets.co.uk/ (subscription required)
Extension			• Write spreadsheets to calculate the pH during a titration and to plot the pH curve (AO2 - Apply knowledge and understanding)		

3.1.12.6 Buffer action

Learning objective	Time taken	Learning Outcome	Learning activity with opportunity to develop skills	Assessment opportunities	Resources
Know what buffer solutions are, how they are made and what they are used for. Explain how acidic and basic buffer solutions work. Calculate the pH of acidic buffer solutions.	0.6 weeks	**Students should be able to:** • describe what a buffer solution is and how it is made • explain qualitatively how acidic/basic buffer solutions work • know some uses of buffer solutions • calculate the pH of a buffer solution.	• Describe how buffer solutions are made, how they work and what they are used for (AO2 - Apply knowledge and understanding). • Calculate the pH of a buffer solution given details about quantities of the reagents it is made from, and changes in pH when small amounts of acid/alkali are added to buffer solutions (AO2 - Apply knowledge and understanding; MS0.4 - Use calculators to find and use power, exponential and logarithmic functions; MS2.5 - Use logarithms in relation to quantities that range over several orders of magnitude). • Students could prepare a solution of a specific pH and then test the solution to check its pH and buffer action (AO2 - Apply knowledge and understanding; MS0.4 - Use calculators to find and use power, exponential and logarithmic functions; MS2.5 - Use logarithms in relation to quantities that range over several orders of magnitude; AT c - Measure pH using pH charts, or pH meter, or pH probe on a data logger; AT e - Use volumetric flask, including accurate technique for making up a standard solution; PS 1.1 - Solve problems set in practical contexts; PS 4.1 - Know and understand how to use a wide range of experimental	• January 2013 Unit 4 Question 2 (QW13.4.02) • January 2011 Unit 4 Question 2 (QW11.4.02) • CHEM4 Specimen Paper Question 4 (QSP 4.04) • January 2005 Unit 4 Question 8 (QW05.4.08) • January 2002 Unit 4 Question 3 (QW02.4.03)	Sandcastles & mudhuts – buffering action in blood (Hancock) ISBN 9780340543696 Some suitable problems can be found at http://www.docbrown.info/ and http://www.chemsheets.co.uk/ (subscription required)

			and practical instruments, equipment and techniques).		

3.2 Inorganic Chemistry

3.2.4 Properties of Period 3 elements and their oxides

The reactions of the Period 3 elements with oxygen are considered. The pH of the solutions formed when the oxides react with water illustrates further trends in properties across this period. Explanations of these reactions offer opportunities to develop an in-depth understanding of how and why these reactions occur.