

3 Suggested Experiments and Activities

Introduction

The Pre-U chemistry course should be at least 20% practical work. Practical work is important if each student is to develop the necessary skills for the Practical exam and the next phase of their education at University. It should be viewed as an enrichment activity to enhance and support the theory teaching and to foster students' enjoyment of the subject. Teachers should try to remember that when they do a suggested practical it might be the first time the student has seen a particular experiment and this should be a stimulating experience where questions are to be encouraged. Teachers will be able to select a range of practicals from those suggested as there simply isn't time to do them all. The age of pupils, time and budgetary constraints within a school/college will determine which suggested practicals are done as demonstrations and which are carried out as whole class experiments.

References

Some online references are given for material written specifically for this chemistry Pre-U course and from university chemistry departments. Weblinks have been chosen that have been around and stable for at least five years and which are worth students investigating.

Safety

CIE accepts no responsibility for the safety of these experiments and it is the responsibility of teachers to carry out a full risk assessment for each experiment undertaken. Hazard data sheets should be available from your suppliers. Sources of chemical safety information can be found in chapter 11, Resources.

Syllabus reference	Suggested Practical Work / Activities
Physical Chemistry	
A1.1 Atomic Structure	
A1.1(c)	It is possible to buy molymods of the various s, p, and d orbitals which are useful models for appreciating their shapes relative to the Cartesian coordinates.
A1.1(d)	There are no experiments but students would benefit from investigating the following weblinks. http://winter.group.shef.ac.uk/orbitron/ http://www.orbitals.com/orb/index.html http://www.btinternet.com/~chemistry.diagrams/electron_order.htm http://www.btinternet.com/~chemistry.diagrams/aufbau_animated.htm
A1.2 Chemical Forces	
	The gallium spoon is an excellent demonstration to show the unusual property of a low melting point solid metal. Using a teaspoon-mould a gallium spoon is made which can be shown to melt in hot water. www.disappearingspoons.com The metal can be recovered and recycled for further demonstrations.

A1.2(g)	VSEPR theory can be demonstrated by twisting together three different coloured and inflated long thin magician's balloons. The static on the balloons leads to maximum repulsion of the six lobes and the formation of an octahedral shape. By carefully popping one lobe at a time all the shapes from octahedral to linear can be achieved.
A1.2(i)	Deflection of a polar liquid, e.g. propanone, ethanol, and water can be achieved by running these liquids through separate burettes and bringing a freshly rubbed polythene rod close to the stream as it falls into a beaker below. The experiment works best when there is low humidity and if the polythene rods have been thoroughly dried with a hair drier prior to use.
A1.2(k)	<p>Investigate relative densities by adding ice to ethanol and then ice to water. Perhaps surprisingly the ice sinks in ethanol. Students enjoy varying the proportions of water and ethanol until the ice 'floats' in the middle of the liquid in its container.</p> <p>To get a paper clip to float on water place it on top of a thin piece of tissue paper and then lay it carefully on the water's surface. Then sink the tissue paper leaving the floating paper clip. The paper clip can be made to sink by changing the surface tension of the water by addition of a few drops of a washing up liquid/detergent.</p>
A1.2(j)	A model of graphite shows clearly the location of Van der Waals forces between layers. Writing on a piece of paper with pure graphite as a mineral reinforces the theory of layers which can peel away when a force is exerted. An electrical circuit can be completed by placing two electrodes at either end of a thick line drawn with graphite.
A1.3 Energy Change	
A1.3(a)	<p>There are many experiments which lend themselves to showing the temperature changes associated with exothermic and endothermic processes. A good exothermic practical is to add water dropwise to c.H₂SO₄ and record the initial and final temperature. A good endothermic practical is to mix together solid ammonium chloride and solid barium hydroxide and record the initial and final temperature. One trick when doing this experiment as a demonstration is to freeze the beaker onto a block of wet wood.</p> <p>http://www.practicalchemistry.org/experiments/endothermic-solid-solid-reactions,277,EX.html</p> <p>An endothermic reaction which looks exothermic as the liquid appears to be boiling is the addition of pellets of iron(III) chloride to thionyl chloride in a fume cupboard.</p>
A1.3(b)	<p>Energy changes can be measured using a flame calorimeter. Combust 1 cm³ of a fuel (ethanol or methanol) in a crucible and use the energy released to heat 50 cm³ of water in an aluminium can supported above the crucible whilst recording the highest temperature reached. Calculate the temperature change (ΔT). If spirit burners are available they can also be used.</p> <p>Energy changes can also be measured using a simple calorimeter. Mix reactants in a polystyrene cup and calculate ΔT. Reactants which work well are Mg(s) and H₂SO₄, NH₄Cl(s) and H₂O(l), 2.0 mol dm⁻³ NaOH and 2.0 mol dm⁻³ HCl. It is helpful to put the polystyrene cup inside a beaker for support and a cardboard lid with a hole cut out for the thermometer.</p>

A1.3(c)	<p>Hess's Law experiments allow students to calculate energy changes for reactions that are difficult to measure experimentally such as the decomposition of limestone. ΔH can be calculated for the reaction between CaCO_3 & HCl, and the reaction between CaO & HCl.</p> <p>Determining ΔH for the hydration of MgSO_4 can be achieved by calculating the ΔH value for the reaction between MgSO_4 (3.00 g) and water (45 cm^3) and from the ΔH value for the reaction between $\text{MgSO}_4 \cdot 7\text{H}_2\text{O}$ (6.60 g) and water (45 cm^3).</p>
A1.3(e)	<p>A demonstration of the catalytic oxidation of ammonia. Bubble oxygen gas into c.NH_3 (aq) and lower in a red hot Pt gauze above the surface. Remove the gauze for a few seconds and return to the flask where it will re-glow. The experiment can also be done with an indicator, e.g. litmus in the ammonia solution to allow the change in pH to be observed.</p>
A1.3(f)	<p>Decomposition of 20 vol. H_2O_2 can be achieved in a number of ways, e.g. with enzymes found in vegetables (celery, potato, and peas), or using the enzyme catalase, or inorganic catalysts (MnO_2, ZnO & or CuO). If a few drops of detergent are added to the test tubes the height of the froth produced gives a qualitative indication of relative rates of reaction.</p> <p>A simple experiment to demonstrate catalysis is a comparison of the reaction of untreated zinc granules in $\text{c.H}_2\text{SO}_4$ with zinc granules treated by dipping them into CuSO_4 (aq).</p>
B1.4 Free Energy & Entropy	
B1.4(b)	<p>20 minutes is needed to demonstrate the reaction between c.NH_3 and c.HCl in a diffusion tube. Small pieces of cotton wool are dipped into the separate solutions. The cotton wool dipped into c.NH_3 is pushed into one end of the diffusion tube and stoppered. The cotton wool dipped into c.HCl is pushed into the other end of the diffusion tube and stoppered. The relative rates of diffusion can be related to the position that the white ring of ammonium chloride is formed.</p>
B1.5 Equilibrium	
B1.5(a)	<p>Nitrogen dioxide forms an equilibrium with dinitrogen tetraoxide in a closed system. Generation of red-brown NO_2 is possible by reacting copper turnings with c.HNO_3. Suck some of the red-brown gas into a syringe. Seal the syringe then compare the colour of the gas when it is dipped into hot water (darker) and ice-cooled water (lighter).</p> <p>A simple equilibrium practical is the equilibrium between yellow chromate(VI) and orange dichromate(VI). Take a yellow chromate(VI) solution and turn it orange by addition of acid. Take an orange dichromate(VI) solution and turn it yellow by addition of alkali.</p> <p>The "blue bottle" experiment where methylene blue changes from blue to colourless and back again with shaking is always a good lesson starter http://www.practicalchemistry.org/experiments/the-blue-bottle-experiment,269,EX.html .</p>
B1.5(b)	<p>Carbonic acid can be made by dissolving dry ice (solid carbon dioxide) in water. Add 2 cm^3 of universal indicator. The indicator goes from orange to yellow as the solution is warmed up.</p>
B1.5(c)	<p>Determination of an equilibrium constant K_c. Esterifications are good as</p>

	<p>they are kinetically slow. Reactions take place in sealed glass ampoules at room temperature over several days. The total volume of the chemicals in the ampoules is 10 cm^3, which includes 5 cm^3 of 3.0 mol dm^{-3} of HCl, and different volumes of ethanoic acid, ethanol, ethyl ethanoate and water.</p> <p>Do a titration of an acid vs. alkali recording the pH in the conical flask after the addition of 1 cm^3 of alkali from the burette and every 0.1 cm^3 around the end point. Students can then determine K_a from the half-neutralisation points in the titration curves. Ensure the pH probe is fully immersed in solutions and read pH to one decimal place. It is suggested that all solutions (HCl, H_3PO_4, CH_3COOH, vs. NaOH or NH_3) have the same concentration of $0.100 \text{ mol dm}^{-3}$.</p>
B1.5(f)	<p>Measure the pH of distilled water at different temperature to show how K_w is temperature dependent.</p> <p>Students often like to make a rack of test tubes with the colours of the rainbow and compare them to a coloured pH chart from 0-14. This can be achieved by providing them with acids and alkalis and universal indicator.</p> <p>One interesting experiment with data-logging potential is to show how the pH of milk varies over several hours. Typically it plummets after several hours becoming increasingly acidic once bacteria numbers grow and the lactose is converted into lactic acid.</p> <p>An experiment to help students overcome the confusion between strong and weak acids is to get them to measure the pH of a selection of strong and weak acids having different concentrations.</p>
B1.5(g)	<p>Get students to plot titration curves of strong (HCl, H_2SO_4) and weak acids (CH_3COOH, H_3PO_4) vs. strong (NaOH) and weak alkalis (NH_3) by measuring pH at regular intervals.</p> <p>It is important that pupils get practice with the colours of the familiar and less familiar indicators, e.g. litmus, methyl orange, phenolphthalein, bromophenol blue & bromothymol blue in neutral, acidic and alkaline conditions.</p>
B1.5(h)	<p>An acidic buffer can be made by dissolving solid sodium ethanoate to ethanoic acid. A basic buffer can be made by dissolving ammonium chloride in ammonia solution. Recipes for specific pH value solutions to calibrate pH meters can be found on CLEAPPS Hazcards (see chapter 11 Resources).</p> <p>A Faraday's Law experiment is the quantitative electrolysis of CuSO_4 (aq) for 30 minutes using a current of 0.5A. In this experiment the mass of the anode and cathode is recorded at the start and the end of the electrolysis. Washing electrodes needs care and can be done first with distilled water, and then with propanone which quickly air dries as it is so volatile.</p>
B1.5(k)	<p>One half cell can be made by dipping a piece of zinc into a 1 mol dm^{-3} solution of ZnSO_4 and another half cell can be made by dipping a piece of copper into a 1 mol dm^{-3} solution of CuSO_4. The two half-cells can be connected by a salt bridge. A salt bridge can be made by soaking a strip of filter paper into a saturated solution of KCl or KNO_3. When the two half cells are connected to a voltmeter the cell emf can be measured. A half cell can be measured against a standard hydrogen electrode.</p>
B1.5(o) B1.5(p)	<p>Students can investigate the effect of standard and non-standard conditions</p>

B1.5(q)	<p>on the cell emf, by using dilute or more concentrated solutions or by changing the temperature.</p> <p>A simulation of a hydrogen fuel cell is the electrolysis of acidified water (dilute H_2SO_4) using platinum electrodes in a Hoffmann voltameter. Weblinks of fuel cell diagrams are worth students investigating, e.g. http://www.btinternet.com/~chemistry.diagrams/Fuel_cell.htm .</p>
B1.6 Gases & kinetics	
B1.6(a)	Demonstrate kinetic theory using diffusion of bromine in a gas jar and by looking at a drop of water containing lycopodium powder on a microscope slide.
B1.6(b)	<p>Boyles Law: Measure the volume of gas in a syringe with different weights placed on the end of the clamped syringe.</p> <p>When a marshmallow is placed in a round bottomed flask and the air is removed by connecting to a vacuum pump the marshmallow gets much larger. This demonstrates how for a constant mass the volume increases as the pressure is reduced. http://dwb.unl.edu/Chemistry/MicroScale/MScale11.html</p> <p>Charles' Law: Measure the volume of gas in a syringe in a beaker of water at different temperatures http://dwb.unl.edu/Chemistry/MicroScale/MScale12.html</p> <p>Experiment to determine M_r of CO_2: weigh a dry and stoppered empty volumetric flask, pass CO_2 (g) from a cylinder into the flask for 1 minute and re-stopper and reweigh. Weigh the volumetric flask when it is full of water to calculate its true volume. This is possible from the mass of water as it has a density of 1 g/cm^3. Record the room temperature and atmospheric pressure. Calculate M_r from mRT/PV.</p>
B1.6(d)	Experiment to calculate E_a for the reaction between $0.020 \text{ mol dm}^{-3}$ of $\text{S}_2\text{O}_8^{2-}$ (10 cm^3) and 0.50 mol dm^{-3} of I^- (5 cm^3) in the presence of $0.010 \text{ mol dm}^{-3}$ of $\text{S}_2\text{O}_3^{2-}$ (5 cm^3) and starch solution (2.5 cm^3). The time recorded at different temperatures (20°C , 30°C , 40°C , 50°C) is the time (t) for the blue-black colour to appear. A graph of $\log_e (1/t)$ versus $1/T$ can be used to calculate E_a .
B1.6(f)	Disappearing cross experiment: The reaction between 0.1 moldm^{-3} $\text{Na}_2\text{S}_2\text{O}_3$ & 0.2 moldm^{-3} HCl which produces yellow sulfur which obscures a cross written on a white tile placed underneath a conical flask. Change the concentration of the individual reactants to see how rate is affected to solve the rate equation. This experiment works well also using a colorimeter. Rate is the reciprocal of the time taken to obscure the cross by the sulfur.
B1.6(h)	<p>Kinetics of iodination of propanone: Propanone (2.0 mol dm^{-3}), iodine ($0.020 \text{ mol dm}^{-3}$) and hydrochloric acid (2.0 mol dm^{-3}) follow by colorimetry (reference Expt 9.5 p.148 ILPAC Second Edition, John Murray, ISBN 0-7195-7507-9)</p> <p>Kinetics of Harcourt-Esson experiment, <i>i.e.</i> the reaction between hydrogen peroxide and iodide in the presence of acid. Start the stopwatch when 10 cm^3 of KI (0.10 moldm^{-3}) and 25 cm^3 of H_2SO_4 (0.25 moldm^{-3}) are poured into a conical flask containing 5 cm^3 of $\text{Na}_2\text{S}_2\text{O}_3$ (0.01 mol dm^{-3}), 5 cm^3 of H_2O_2 (0.10 mol dm^{-3}), water (20 cm^3) and 1 cm^3 of 1% starch solution. The time is taken when the blue-black colour appears. In one set of experiments keep the total volume of H_2O_2 and water at 25 cm^3 and vary their proportions. This experiment might be more familiar as the iodine clock</p>

B1.6(i)	<p>experiment. http://www.practicalchemistry.org/experiments/iodine-clock-reaction,55,EX.html or http://dwb.unl.edu/Chemistry/MicroScale/MScale37.html. In another set of experiments keep the total volume of KI and water at 25 cm³ and vary their proportions. Plot graphs of log₁₀ 1/t vs. log₁₀ [H₂O₂] or log₁₀ [KI].</p> <p>Initial rates method is where the initial rate is calculated from the slope of a graph of volume of gas evolved <i>versus</i> time. Suitable experiments include the reaction between magnesium and different concentrations of HCl, and the decomposition of H₂O₂ having different concentrations (20 vol or 100 vol).</p>
B1.7 Chemical Models & Evidence	
No suggestions for this section.	
Inorganic Chemistry	
A2.1 Periodic Table	
A2.1(a)	Shapes of simple molecules, e.g. H ₂ , O ₂ , O ₃ , N ₂ , Cl ₂ , P ₄ , S ₈ and H ₂ O ₂ and the types of bonds (single, double and triple) are often best taught through the use of molymods.
A2.1(e)	<p>Reaction of period 3 elements (Na, Mg, S) with oxygen can easily be achieved by igniting the element on the end of a combustion spoon which is then placed in a gas jar of oxygen.</p> <p>If white phosphorus is available react it with oxygen in a large flask and a darkened room for the best effect. Place sand in the bottom of a large pyrex or glass flask. Then fill the flask with oxygen and stopper it. Put a small piece of white phosphorus in a crucible and lower it onto the bed of sand. Ignite the phosphorus by touching it with the hot end of a heated glass rod and then seal the flask. Pulling down the blinds or turning off the lights makes for a more spectacular reaction which emits a large amount of bright white light. On cooling add 200 cm³ of distilled water followed by universal indicator. The red colour indicates the formation of an acid from the non-metallic oxides of phosphorus.</p> <p>The poor reactivity of aluminium is unexpected from its position in the reactivity series. The protective oxide layer of Al₂O₃ can be removed from aluminium by an aqueous solution of mercury(II) chloride. This experiment is described in the inspiring book called Uncle Tungsten by Oliver Sacks http://www.oliversacks.com/books/uncle-tungsten/ (chapter 4).</p>
A2.1(f)	<p>Reaction of Period 3 elements with water.</p> <p>React sodium in a small trough on top of an OHP with a few drops of phenolphthalein. Place a 10 cm strip of magnesium ribbon under a funnel in cold water with blue tac and collect the H₂(g) in an inverted boiling tube over several weeks. A safe method to react magnesium with steam is to hold a piece of ribbon using tongs above a conical flask (protected with a ceramic wool heatproof collar) containing boiling water.</p>
A2.1(g)	'Reaction' of Period 3 oxides (Na ₂ O, MgO, Al ₂ O ₃ , SiO ₂ , P ₂ O ₅) with water; measure the pH of any resulting solutions. SO ₂ can be made by burning sulfur on a combustion spoon and placing it into a gas jar. Adding water and adding universal indicator give a red acidic solution.
A2.1(h)	Reaction of Period 3 chlorides (NaCl, MgCl ₂ , AlCl ₃) with water. Measure the pH and test fumes of HCl (g) with moist blue litmus paper.
A2.2 Main Group Chemistry	

A2.2(a)	Thermal decomposition of MgCO_3 and CaCO_3 . Heat these carbonates in crucibles to constant mass. Record masses to at least three decimal places.
A2.2(d)	<p>The high solubility of ammonia can be illustrated by demonstration of the ammonia fountain experiment. A dry round bottomed flask (fitted with a glass tube in its neck) is filled ammonia gas followed by addition of a few drops of litmus are added. The flask is then inverted and clamped and the glass tube is lowered into a trough of water.</p> <p>Hold a piece of red litmus paper near the neck of a recently unstoppered bottle of ammonia solution.</p> <p>To show the reaction of ammonia with an acid dip a glass rod into c.HCl and bring it near a bottle of c.NH₃ which has had its stopper removed.</p> <p>If you want students to make ammonia they can easily do this by stirring two solids together (NH₄Cl & Ca(OH)₂).</p>
A2.2 (f)	<p>The chemistry of hydrogen peroxide is familiar in terms of its decomposition. To follow the rate of this decomposition collect the evolved oxygen gas in a syringe or by downward displacement using different concentrations of H₂O₂ (10, 20, 50, 100 vol) with MnO₂ as the catalyst (see also A1.3(f)).</p> <p>A demo to test for the presence of H₂O₂ is the qualitative test by adding acidified K₂Cr₂O₇ and extracting with diethyl ether. A positive test is indicated by a blue colour for Cr₂O₅.</p> <p>Cleaning of silver coins is possible with hydrogen peroxide as the surface will be coated with silver(I) oxide. http://metaldetectingworld.com/cleaning_coin_p12_peroxide.shtml</p>
A2.2(h)	<p>Test H₂SO₄ for sulfate ion with BaCl₂ (aq). Leave beaker of c. H₂SO₄ in a fume cupboard and mark the surface changing level of several months. Make plaster of paris by adding water to CaSO₄.0.5H₂O (s).</p> <p>Dehydration experiments using c.H₂SO₄. To 20 g of sucrose in a small beaker add 5 cm³ of water and stir with a glass rod. Continue stirring whilst adding 10 cm³ of c.H₂SO₄ until the mixture turns black. An even more impressive dehydration can be achieved by dehydrating 4-nitroacetanilide (10g) with 10 cm³ of c.H₂SO₄ and heating the mixture in a crucible.</p>
A2.2(j)	<p>Test tube reactions of c.H₂SO₄ with small amounts of solid Group 1 halides, e.g. NaCl, NaBr, NaI.</p> <p>Reactions of c.H₂SO₄ with small pieces of Mg, Zn, Fe and Cu and testing the evolved SO₂ (g) with filter paper soaked in orange dichromate paper.</p>
A2.2(m)	Titration of 0.05 mol dm ⁻³ I ₂ solution with 0.10 mol dm ⁻³ Na ₂ S ₂ O ₃ using 1% starch solution as indicator.
B2.3 Group 14	
B2.3(a)	<p>A simple conductivity experiment is to place samples of Group 14 elements (carbon as graphite, Si, Ge, Sn & Pb.) in turn into a circuit with a lamp to observe which conducts electricity and completes the circuit.</p> <p>Students would benefit from researching these weblinks when considering the structures of the recently discovered allotropes of carbon</p>

B2.3(c)	<p>http://www.creative-science.org.uk/c60model.html http://www.btinternet.com/~chemistry.diagrams/bucky.htm http://www.btinternet.com/~chemistry.diagrams/C70.htm</p> <p>Use a scalpel to cut a 10p sized hollow into a block of charcoal. Into the hole place a spatula of yellow litharge (PbO) and a spatula of carbon powder and mix these reactants. Hold a Bunsen burner on a blue flame across the top of the reaction mixture and blow air into the hollow from a blowpipe. After about 5 minutes small globules of lead should be visible.</p> <p>Make insoluble lead compounds by reacting $\text{Pb}^{2+}(\text{aq})$ with $\text{SO}_4^{2-}(\text{aq})$, $\text{Cl}(\text{aq})$, $\text{I}^{-}(\text{aq})$ and $\text{CrO}_4^{2-}(\text{aq})$. The last example is how they get the yellow colour in road markings.</p>
B2.4 Transition Elements	
B2.4(c)	<p>To illustrate a range of colours shown by transition metals of varying oxidation states get students to make a series of aqueous solutions in test tubes, e.g. FeSO_4, CuSO_4, $\text{Fe}_2(\text{SO}_4)_3$, CoCl_2, KMnO_4 and show them a selection of coloured compounds in sample jars, e.g. yellow (K_2CrO_4), green ($\text{NiCl}_2 \cdot 6\text{H}_2\text{O}$), blue $\text{CuSO}_4 \cdot 5\text{H}_2\text{O}$, VOSO_4 (blue), $\text{FeSO}_4 \cdot 7\text{H}_2\text{O}$ (green), $\text{ZnSO}_4 \cdot 7\text{H}_2\text{O}$ (white).</p>
B2.4(e)	<p>The structure of the hexadentate ligand EDTA takes time to learn and can be speeded up by getting students to make its structure using molymods</p>
B2.4(e)	<p>Molymods of geometric isomers, e.g. <i>cis</i>-platin and <i>trans</i>-platin and optical isomers, e.g. $[\text{CrCl}_2(\text{en})_2]^{+}$. Students find it helpful to have mirrors available so they can check that mirror images are non-superimposable.</p>
B2.4(g)	<p>A simple experiment to show that different oxidation states for a transition metal have different colours is the reduction of vanadium from 5+ through all its oxidation states to 2+. This can be achieved by dissolving a spatula of ammonium vanadate(V) in 20 cm³ of dil. HCl, followed by the addition of zinc granules and warming the mixture gently in a Bunsen flame.</p> <p>Titration between 0.1 mol dm⁻³ solutions of $\text{Ni}^{2+}(\text{aq})$ or $\text{Cr}^{3+}(\text{aq})$ & $[\text{EDTA}]^{4-}$ or 1,2-diaminoethane (en) to work out the formula of complexes using a colorimeter. The filter in the colorimeter is chosen as the complementary colour to the complex. Ensure the metal ions and ligands have the same concentrations and mix them in varying proportions keeping the overall volume constant. The test tube containing the mixture with the maximum or minimum absorbance corresponds to the formula of the complex.</p>
B2.4(h)	<p>To improve students laboratory technique why not get them to prepare the greenish coloured complex salt potassium trioxalatoferrate(III). This can be done by dissolving 3.6 g of iron(II) ethanedioate in water (20 cm³) and 5.5 g of potassium ethanedioate at a temperature below 50°C. Add 20 cm³ of 20 vol. H_2O_2 from a burette in 1 cm³ portions. Filter and add ethanol (20 cm³) to the filtrate, cool in an ice-water bath and filter the complex via Buchner filtration.</p>
B2.4(i)	<p>Ligand exchanges and colour changes, e.g. Cu^{2+} reacting with these ligands dil. NH_3, c.NH_3, Cl^{-}, OH^{-} and Fe^{3+} with KSCN to form the blood red complex.</p> <p>There are plenty of redox titrations to choose from for example $\text{Fe}^{2+}/\text{Fe}^{3+}$ or</p>

	<p>$\text{Cu}^+/\text{Cu}^{2+}$ vs. $\text{MnO}_4^-/\text{Mn}^{2+}$ or $\text{Cr}_2\text{O}_7^{2-}/\text{Cr}^{3+}$ and Fe^{2+} vs. Cl^- or H_2O_2 or $(\text{CO}_2\text{H})_2$</p> <p>Example of a disproportionation by warming red Cu_2O (s) with c.H_2SO_4. Take a spatula of red copper(I) oxide and add c.H_2SO_4 and warm in a test tube for a few minutes. Blue Cu^{2+} and copper metal will be evident.</p>
B2.5 Crystallography	
B2.5(a)	<p>There are no experiments directly involving crystals but students would benefit from investigating the following weblinks.</p> <p>http://chemistry.about.com/od/growingcrystals/ht/purplecrystal.htm</p> <p>http://www-teach.ch.cam.ac.uk/links/3Dindex.html</p> <p>Students will get the idea about efficient and inefficient packing and the two major crystal types (hexagonal close packing and cubic close packing) by being given polystyrene balls and blue tac or glue.</p> <p>Print off the nett on the following weblink http://www.btinternet.com/~chemistry.diagrams/crystals_unit_cells.htm Photocopy enough netts so that each student has eight. Colour in the circles, semi circles and part circles on the nett. Make eight cubes from the netts so that each fraction of an atom/ion's contribution to each cube (unit cell) can be worked out.</p>
Organic Chemistry	
A3.1 Organic Chemistry Preliminaries	
A3.1(c)	<p>There are no experiments but students would benefit from visiting this weblink each month.</p> <p>http://www.chm.bris.ac.uk/motm/motm.htm</p>
A3.1(d)	<p>Making simple organic with molymods will allow students to appreciate the realistic zig-zag, explore functional group isomers (aldehydes/ketones, alcohols/ethers, esters/carboxylic acids), geometric isomers (<i>cis</i> and <i>trans</i>), optical isomers (with four different groups attached to a tetrahedral carbon atom).</p>
A3.2 Functional Group Level	
A3.2(a)	<p>Reaction of 5 cm³ of cyclohexane with 2 cm³ of bromine water under a UV lamp. Reaction of 5 cm³ of cyclohexene with 2 cm³ of bromine water.</p>
A3.2(c)	<p>Preparation of cyclohexene by the dehydration of cyclohexanol (20 cm³) using c.H_3PO_4 (8 cm³) as the dehydrating agent. Collect the fraction that distils <95°C. Treat the distillate with a saturated solution of NaCl (4 cm³). Separate the two layers and dry the upper layer with CaCl_2 and filter. The product can be tested for unsaturation with bromine water.</p>
A3.2(d)	<p>Make use of molymods to illustrate the concept of primary, secondary and tertiary with molymods of alcohols, amines, and halogenoalkanes.</p> <p>Natural product extractions are possible in school laboratories, e.g. steam distillation of limonene from orange/lemon peel or extraction of eugenol from cloves http://www.westfield.ma.edu/cmasi/organic_lab/organic1_lab/isolation_of_eugenol.pdf</p> <p>Oxidation of propan-2-ol with acidified dichromate(VI) by heating under reflux to form propanone with its characteristic smell.</p>

A3.3 Alcohol Level	
A3.3(a)	Hydrolysis of liquid halogenoalkanes can be carried out on in a water-bath at 50°C. Just 5 drops of each halogenoalkane is added to a mixture of ethanol (1 cm ³) and silver nitrate (1 cm ³) in a test tube clamped in the water bath. Rate = 1/time for the precipitate to appear (see also A4.1(d)).
A3.3(b)	<p>1°, 2° & 3° alcohols can be distinguished at room temperature using the Lucas test, where 2 cm³ of alcohol are added to 1 cm³ of c.HCl and 1 cm³ of ZnCl₂ (aq). 3° alcohols rapidly give a cloudy mixture and 2° alcohols give a cloudy mixture after 5 minutes.</p> <p>Bromoethane can be prepared by reacting ethanol (6 cm³) with c.H₂SO₄ (6 cm³) and 6 g of solid sodium bromide. This method results in the <i>in situ</i> generation of HBr (g) The fraction that distils between 38-40°C is collected by distilling into a test tube held in an ice-bath. To purify the product add 4 cm³ of saturated NaHCO₃ (aq) to the distillate. Using a separating funnel the organic layer is separated from the aqueous layer and then dried with anhydrous MgSO₄.</p>
A3.4 Carbonyl Level	
A3.4(a)	A suggested introduction to the carbonyl level can be giving students a selection of carbonyl compounds to smell. Aldehyde examples include vanillin, benzaldehyde, and cinnamaldehyde. Ketone examples include caraway seeds (S-carvone) and spearmint (R-carvone) and nail varnish remover (propanone).
A3.4(c)	<p>A very quick practical is making use of sodium bisulfite (NaHSO₃) to purify simple aldehydes such as ethanal. Addition of a saturated bisulfite solution to ethanal leads to white crystals which can be filtered. Hydrolysis of the addition product using dilute HCl (aq) will return the aldehyde.</p> <p>Distillation of ethanol from a mixture of c.H₂SO₄ and Na₂Cr₂O₇ will yield ethanal and refluxing ethanol with a mixture of c.H₂SO₄ and Na₂Cr₂O₇ will yield ethanoic acid. The reaction is quite exothermic so gentle heating is recommended.</p> <p>Tollens' reagent (silver mirror test) is made by adding 1 drop of dilute NaOH (aq) to 2 cm³ of AgNO₃ (aq) and adding ~10 drops of dilute NH₃ (aq) until the brown ppt of Ag₂O just dissolves. To get a positive test (silver mirror) add 1 cm³ of aldehyde to the Tollens' reagent. Adding a spatula of glucose to Tollens' reagent gives consistently good silver mirrors. A recipe for a giant silver mirror useful for demonstration purposes can be found by investigating this weblink http://www.rsc.org/images/mirror_tcm18-188809.pdf</p>
A3.4(d)	To dry (remove water) from a solvent such as diethyl ether which may be needed for some reactions, e.g. when using LiAlH ₄ or in preparing Grignard reagents, add small pieces of sodium or sodium wire extruded through a hole.
A3.5 Addition & Elimination Reactions	
A3.5(b)	Decolorisation of alkenes by bromine water, e.g. cyclohexene, butter, margarine, by simply shaking the unsaturated chemical in a stoppered test tube.
A3.5(c)	It is possible to make polystyrene from styrene using a peroxide initiator http://www.terrificscience.org/lessonpdfs/PolymerLab13.pdf
A3.5(d)	Dehydration of an ethanol soaked in mineral wool using Al ₂ O ₃ catalyst. Collect the ethene produced under water and test with bromine water.

	Another alcohol you can dehydrate is 2-methylpropan-2-ol at 170°C by refluxing with c.H ₂ SO ₄ .
A3.6 Green Chemistry	
	No suggestions.
B3.7 Carboxylic Acid Level	
B3.7(a)	<p>The detection of the carboxylic acid group in aqueous solutions of ethanoic, propanoic and benzoic acid is achieved by adding either Na₂CO₃ (aq) or NaHCO₃ (aq). Both reactions lead to the release of a colourless gas (CO₂) which when bubbled into limewater turns it cloudy.</p> <p>It is a simple matter to compare the relative rates of reaction of a weak acid (CH₃COOH) and a strong acid (HCl) having identical concentrations by reacting 0.1 mol dm⁻³ solutions with 2 cm pieces of magnesium ribbon.</p> <p>Hydrolysis of 2 cm³ of ethanoyl chloride or benzoyl chloride by addition of 2 cm³ of water leads to the evolution of white fumes of HCl (g) which can be tested for with moist blue litmus paper.</p>
B3.7(b)	<p>Another carboxylic acid practical is the hydrolysis of oil of wintergreen (methyl salicylate). 0.003 mol of the ester is refluxed with 40 cm³ of 2.0 mol dm⁻³ hydrochloric acid for 15 minutes. Once the precipitate has disappeared the reaction mixture is filtered and then fractionally distilled. To precipitate the salicylic acid you add 20 cm³ of 2.0 mol dm⁻³ hydrochloric acid. The aspirin is collected by Buchner filtration and washed with a small quantity of distilled water.</p> <p>To find out which alcohols and carboxylic acids are needed to make fruity esters students should investigate this weblink http://www.chm.bris.ac.uk/motm/ethylacetate/smells.htm One simple method is to mix 1 cm³ of alcohol and 1 cm³ of carboxylic acid in a test tube with a few drops of the catalyst c.H₂SO₄ and warm the reaction mixture gently in a test tube for several minutes.</p>
B3.7(c)	<p>The nylon rope trick is a good example of a condensation polymerisation. The method involves adding 20 cm³ of a 5% solution of hexanedioyl chloride in iotoxane (a 'green' solvent) to a 5% aqueous solution of 1,6-diaminohexane (20 cm³). Using a pair of tweezers at the interface of the two immiscible liquids it is possible to pull out a thread of nylon and with practise several metres of polymer can be wrapped round a glass rod.</p> <p>It is possible to buy two ingredients which when mixed result in the formation of polyurethane foam by mixing in a recyclable plastic cup 10 cm³ of solution A and 10 cm³ of solution B. Useful weblinks include; http://video.google.com/videoplay?docid=-6367640639873461283# and http://www.cfsnet.co.uk/acatalog/CFS_Catalogue_2_Part_Polyurethane_Foam_Liquid_415.html</p>
B3.8 Carbon dioxide Level	
B3.8(a)	<p>There are no experiments but students would benefit from investigating the following weblinks.</p> <p>http://www.demochem.de/chembox_urease-e.htm http://www.seriaz.org/downloads/4-caffiene.pdf</p>
B3.9 Mechanisms	
B3.9(e)	<p>There are no experiments but students would benefit from investigating the following weblinks.</p> <p>http://www.btinternet.com/~chemistry.diagrams/Animations.htm http://www.rod.beavon.clara.net/slides.htm</p>
B3.10 Aromatic chemistry	

B3.10(a)	<p>A safer nitration is the nitration of the aromatic ester methylbenzoate. Dissolve the ester in equimolar mixtures of c.HNO₃ and c.H₂SO₄. Heat the mixture to 50°C for 30 minutes. Then pour the mixture onto iced-water and filter using Buchner filtration. Recrystallize the nitromethylbenzoate from a minimum volume of warm ethanol.</p> <p>Reaction of 1 cm³ of toluene, 1 cm³ of aqueous phenol solution, 1 cm³ of aniline with bromine water. Compare the rate of formation of the resultant white precipitate.</p> <p>To test for phenol dissolve 10 mg in warm water. Addition of FeCl₃ (aq) will result in a purple complex.</p> <p>Preparation of aspirin by reacting 5 g of 2-hydroxybenzoic acid with 7.0 cm³ of ethanoic anhydride in a conical flask. Add 3 drops of c.H₂SO₄ and swirl, then warm for 15 minutes at 50-60°C stirring with a thermometer. Cool and add cold water (70 cm³) and filter. Recrystallise the aspirin by dissolving in warm ethanol (15 cm³) and pouring onto cold water.</p>
B3.10(b)	
B3.10(c)	
B3.11 Acidity & Basicity	
B3.11(a)	In a boiling tube react 4 mm ³ of sodium with 20 cm ³ of ethanol in the presence of a few drops of phenolphthalein.
B3.11(b)	Prepare aqueous solutions of acidic and basic compounds and record their pH values, e.g. phenol, benzoic acid, ethanol, methylamine, ethylamine and aniline, ethanoic. Record the pH of chloroethanoic, dichloroethanoic and trichloroethanoic acid having the same concentrations and compare to ethanoic acid.
B3.12 Stereochemistry	
B3.12(b)	Dissolve 1 g of sucrose in 20 cm ³ of distilled water and record its optical rotation in a polarimeter. To the sucrose solution add 2 cm ³ of 2.0 mol dm ⁻³ HCl and record this new mixtures optical rotation every 5 minutes until it remains constant.
Analytical Chemistry	
A4.1 Qualitative & Quantitative Chemistry	
A4.1(a)	<p>This section covers all the qualitative tests found in the databooklet for the course. A lot of the tests can be carried out whilst teaching other parts of the course and where opportunities arise they are referenced to the appropriate section of the syllabus.</p> <p>Tests for cations (Al³⁺, Fe³⁺ (B2.4i), Cr³⁺, Ba²⁺ (A2.2j), Cu²⁺, Fe²⁺ (B2.4l), Pb²⁺ (B2.3), Mn²⁺ & Zn²⁺ (B2.4) & NH₄⁺)</p> <p>Tests for anions (SO₄²⁻ (A2.4h), CO₃²⁻, SO₃²⁻, NO₃⁻, NO₂⁻, Cl⁻, Br⁻, I⁻, gases (NH₃, CO₂, H₂, Cl₂ (A2.1h), SO₂ (A2.1a), O₂, HCl) and organic functional groups, e.g. alcohol (A3.3) and distinguish between 1°, 2° & 3°), halogenoalkane, carboxylic acid, aldehyde, ketone, phenol & alkene.</p>
A4.1(b)	Empirical formula of MgO by heating 2.43 g of magnesium in a crucible with a lid. Take care not to lose too much smoke as you lift the crucible's lid to let in more air for reaction.
A4.1(c)	<p>Volumetric analysis:</p> <p>Redox titrations (mostly using indicators), e.g. Fe²⁺ vs. MnO₄⁻ (B2.4i), Fe²⁺ vs. Cr₂O₇²⁻, I₂ vs. S₂O₃²⁻, Fe²⁺ vs. H₂O₂;</p> <p>Thermometric titrations (A1.3c), where you measure changes in</p>

A4.1(d)	<p>temperature, e.g. neutralisation of NaOH (aq) by adding 5 cm³ portions of HCl (aq) carried out in a polystyrene cup.</p> <p><i>Potentiometric titrations:</i> where you measure changes in conductivity, e.g. Fe²⁺ vs. Ce where you measure changes in conductivity</p> <p><i>Gravimetric analysis</i> for example thermal decompositions by heating carbonates to constant mass, e.g. MgCO₃, CaCO₃, NaHCO₃, Na₂CO₃; or by removing water or crystallisation of hydrates, e.g. Na₂CO₃.10H₂O, CaSO₄.2H₂O, FeSO₄.7H₂O, MgSO₄.7H₂O or BeCl₂.2H₂O.</p> <p><i>Precipitation reactions</i> for example mixing solutions of ; Pb(NO₃)₂ & KI, AgNO₃ & KCl or HCl, or BaCl₂ & H₂SO₄ (A2.2h). Mohr titration to determine purity of rock salt by chloride precipitation as silver chloride http://www.outreach.canterbury.ac.nz/chemistry/chloride_mohr.shtml using chromate as indicator.</p>
A4.2 Mass Spectrometry	
A4.2(a)	<p>There are no experiments but students would benefit from investigating the following weblinks.</p> <p>http://www.btinternet.com/~chemistry.diagrams/mass_spec6.swf</p> <p>http://www.btinternet.com/~chemistry.diagrams/electron_impact.htm</p> <p>http://riodb01.ibase.aist.go.jp/sdbs/cgi-bin/direct_frame_top.cgi</p> <p>http://www.btinternet.com/~chemistry.diagrams/Spectroscopy-1a.doc</p>
A4.3 Electronic Spectroscopy	
A4.3(a)	<p>Weblinks that students would benefit from investigating are;</p> <p>http://www.btinternet.com/~chemistry.diagrams/element_discharge.htm</p> <p>http://www.avogadro.co.uk/light/bohr/spectra.htm</p> <p>http://www.chemguide.co.uk/inorganic/group1/flametests.html</p> <p>http://www.btinternet.com/~chemistry.diagrams/Bohr_hydrogen_transitions.htm</p> <p>http://www.btinternet.com/~chemistry.diagrams/hydrogen_energy_states.htm</p> <p>http://www.btinternet.com/~chemistry.diagrams/Hspec_animation2.swf</p>
A4.3(c)	<p><i>Flame tests:</i> Make a small loop on the end of a nichrome or platinum wire. Dip the wire into c.HCl and use the moisture to stick small amounts of compounds onto the loop, e.g. chlorides of Li, Na, K, Ca, Ba, Cu & Pb. Hold the loop in the hottest part of a Bunsen flame and note the flame colour. If hand held spectrosopes are available look at the coloured flame through it, or alternately look at elements in discharge tubes. If your school is lucky enough to have a dark room make use of it for these experiments.</p> <p>Hold the back of a CD up to a light to see spectral lines which show mercury is present in fluorescent strip lighting.</p>

A4.4 Infra-red Spectroscopy	
A4.4(a)	<p>Weblinks that students would benefit from investigating are; http://www.btinternet.com/~chemistry.diagrams/aspirin.htm</p> <p>https://www.le.ac.uk/spectraschool/</p> <p>http://www.chem.ed.ac.uk/bunsen_learner/ir.html</p> <p>To model what happens to the resonance frequency of different bonds in IR spectroscopy stick different size polystyrene balls on one end of a series of springs.</p> <p>If your school does not have easy access to a local university or its own IR spectrometer then there is Spectroscopy in a suitcase Outreach provided by the Royal Society of Chemistry http://www.rsc.org/education/hestem/sias.asp</p>
A4.5 Carbon-13 nmr spectroscopy	
A4.5(a)	<p>There are no experiments but students would benefit from investigating the following weblinks.</p> <p>http://www.btinternet.com/~chemistry.diagrams/C13nmrshifts.htm</p> <p>http://www.chemguide.co.uk/analysis/nmr/backgroundc13.html</p> <p>http://riodb01.ibase.aist.go.jp/sdbs/cgi-bin/direct_frame_top.cgi</p>
A4.6 Nmr of other spin half nuclei	
A4.6(a)	<p>There are no experiments but students would benefit from investigating the following weblinks.</p> <p>http://www.cis.rit.edu/htbooks/mri/</p> <p>http://www.rod.beavon.clara.net/nmr2.htm</p> <p>http://www2.chemistry.msu.edu/faculty/reusch/VirtTxtJml/Spectrpy/nmr/nmr1.htm</p> <p>http://www.goldennumber.net/pascal.htm</p> <p>http://www.knockhardy.org.uk/sci_htm_files/nmr1.pdf</p> <p>http://www.rod.beavon.clara.net/spectra.htm</p>