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ADVANCED TEACHING & LEARNING PACKAGES MICROCHEMISTRY EXPERIENCES

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Portable Document Files for Distribution via the Internet

The UNESCO-Associated Centre for Microscience Experiments
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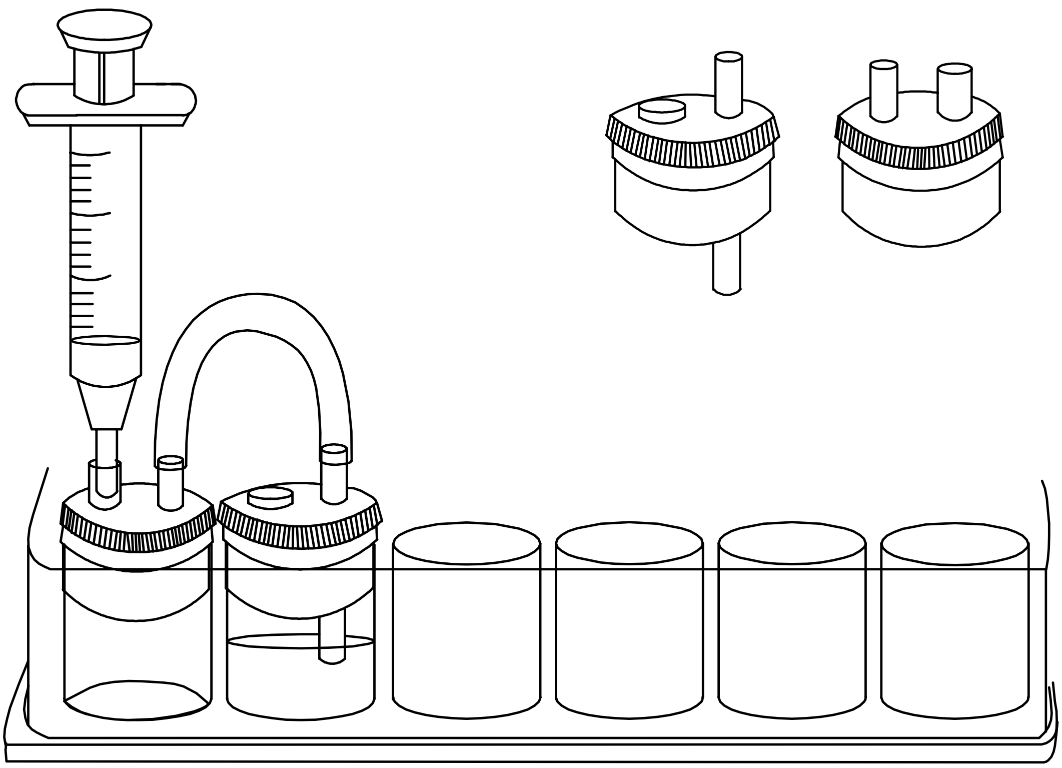


DECOMPOSITION OF MERCURY(II) OXIDE

TEACHER GUIDE

1. Chemicals
All of the required chemicals are listed in the requirements table preceding the experiment. Tap water is also needed.

2. Equipment
Most of the apparatus required can be found in a RADMASTE Advanced Microchemistry Kit. A plastic cup and prestik are also needed.

3. Hints
Tap the fusion tube gently on the work surface so that all of the mercury(II) oxide ($HgO(s)$) powder is deposited on the base of the tube.

Older versions of the kits contain PVC tubes (with a U-bend). This rigid plastic may be difficult to manipulate. It is suggested that the unbent end of the PVC tube be made wet with a little water so as to provide some lubrication. The open end of the fusion tube must then be gently pushed into the PVC tube. **Do not force the fusion tube into the PVC tube as the glass tube may break in your hand.** The new versions of the kits contain flexible silicone tubing with a U-bend, and there should not be any problems while attaching the fusion tube.

If the arms of the microstand do not fit securely between wells E3 and F3, they can be held in place using prestik as shown in the diagram on the worksheet.

Hold the microburner directly under the fusion tube in such a way that the tip of the flame touches that part of the tube which contains the HgO(s). This will ensure the maximum rate of oxygen gas production. (It should be noted that the appearance of oxygen bubbles does not occur immediately upon heating of the HgO(s). After a short length of time bubbles appear in the water in the cup, and continue to be formed steadily thereafter.)

It may happen that the HgO(s) has not been compacted tightly enough at the base of the fusion tube. During heating, the powder may begin to move along the fusion tube. If this happens, move the flame from side to side so that the HgO(s) is heated evenly.

When removing the gas collecting tube from the set-up, you do not need to **screw** the tube into the lid. **Push** the tube firmly into the lid and then gently lift the sealed tube out of the plastic cup. The lid does not adhere to the prestik in the vial if the procedure is carried out correctly.

The steps with the glowing splint (toothpick) must be performed quickly, otherwise the splint will be completely extinguished before it is inserted into the gas collecting tube.

Unlike macroscale testing for oxygen, the glowing splint may not burst into flame when in contact with the oxygen. However, the glowing tip definitely glows brighter when it is held inside the gas collecting tube. If the match has just been extinguished and the tip appears black, it will begin to glow if it is quickly inserted into the tube. Show learners the mercury droplets in the fusion tube. This will help them to conclude that oxygen must have been produced if the original compound is mercury(II) oxide.

The U-bend of the PVC (or silicone) tube must be pulled out of the water in the plastic cup at the end of the experiment to prevent suck-back.

Sometimes the mercury cannot be removed from the fusion tube after the experiment. Adding a drop or two of nitric acid will dissolve the mercury.

4. Cautions
Please remember the following cautions and inform your students of all safety hazards:

Do not allow anyone to bring a flame near the comboplate® or gas collecting tube. These are plastic and will melt.

Never allow the learners to play with matches, and do not allow anyone to touch the hot fusion tube. Treat any burn with cold running water or ice, and seek medical assistance where necessary.

The methylated spirits used in the microburner is poisonous. Do not inhale the vapour or drink the liquid.

Mercury is extremely poisonous! The PVC (or silicone) tube must be thoroughly sealed around the fusion tube, and the bent end of the tube must be completely immersed in water, to prevent escape of mercury vapour.

5. Model Answers to Questions in the Worksheet

It is recommended that learners write down all of the questions and answers in their workbooks. If this is done, then the answers to questions do not have to be in full sentences. If the learners do not copy the questions into their workbooks, then answers should be written in full sentences. Note that some of the questions can only be answered by learners in higher grades. Word equations can be written instead of chemical equations where required.

Q1. What happens to the mercury(II) oxide powder as it is heated ?
A1. As the powder is initially heated it changes from an orange-red colour to a blackish colour.

Q2. What do you observe on the wall of the fusion tube ?
A2. Droplets with a metallic appearance form on the walls of the fusion tube.

Q3. What is the name of the substance formed on the wall of the fusion tube ?
A3. Mercury.

Q4. Why is it necessary to let a few bubbles emerge from the U-tube before putting the gas collecting tube in place?
A4. The first few bubbles will be air which is in the tubes and which expands on heating. A gaseous product from the heating of mercury(II) oxide also has to push remaining air out of the system before it emerges.

Q5. What do you observe when the glowing end of the match or splint is held inside the mouth of the gas collecting tube?
A5. The match or splint glows brighter (or bursts into flame).

Q6. What is the name of the gas that you collected ?
A6. Oxygen (O_2(g)).

Q7. How do you know that it was this gas that you collected ?
A7. One test for oxygen (O_2(g)) is to place a glowing splint into the gas. The splint should glow brighter than before or burst into flames if the gas is oxygen (O_2(g)).

Q8. What has happened to the mercury(II) oxide ? Try to write down a word equation or chemical equation to show what happened.
A8. Most of the mercury(II) oxide powder has decomposed and produced mercury and oxygen. This decomposition is represented by the chemical equation:

$$2HgO(s) \rightarrow 2Hg(\ell) + O_2(g)$$

Q9. From your answer to Question 8, would you say that mercury(II) oxide is a compound, an element or a mixture?
A9. Mercury(II) oxide is a compound as it is decomposed on heating into two elements.

Q10. What do you observe in the fusion tube after it has cooled ?
A10. Initially there appears to be no more mercury(II) oxide powder but as the fusion tube cools down a very small quantity of a fine orange-red powder can be seen in some parts of the fusion tube.

Q11. Why do you think that the mercury(II) oxide has changed in appearance again ?
A11. Two possible events could be occurring to cause the observation of a small quantity of orange-red powder (probably mercury(II) oxide) in the fusion tube. Firstly a small quantity of gaseous oxygen, still remaining in the tube reacts with gaseous mercury to form solid mercury(II) oxide on cooling. Secondly small mercury droplets could, while still hot, be reacting with remaining gaseous oxygen to form mercury(II) oxide.

ELECTROLYSIS OF WATER

TEACHER GUIDE

1. Chemicals
All of the required chemicals are listed in the worksheet. Tap water is also needed.

2. Equipment
Most of the equipment required can be found in a RADMASTE Advanced Microchemistry Kit. A 9V battery is required. A ruler and permanent marking pen are needed to mark the electrodes into 1 cm units. If the teacher wants the electrolysis to proceed quickly, then the LED can be disconnected from the electrodes and battery after the glowing light has been observed. The electrodes will then need to be connected directly to the battery. This will require extra connecting wires which are not provided in the kit.

3. Hints
A sodium hydroxide pellet is added to the water in the sample vial to increase the conductivity of the water.

The 9V battery is a source of potential difference in the electrical circuit. It must be explained to the learner that the battery does not make the LED glow on its own. If the conducting wires are not placed in some electrolyte solution, the LED will not glow. It may be important to state this so as to avoid the misconception that the battery makes the LED glow, whether a conducting solution is present or not.

If the LED does not glow at first, check that the connections to the battery are secure.

The ends of the electrodes in the water must not touch, otherwise the circuit will be completed and the LED will glow brightly, although no electrolysis is occurring. This may be misleading.

Once the current indicator has been disconnected, the continued appearance of tiny bubbles of gas at the electrodes will indicate that a current is still flowing through the water. If no bubbles are evident, check that the connections to the battery and the electrodes are secure.

4. Cautions
Please remember the following cautions and inform your students of all safety hazards:

Sodium hydroxide is a corrosive base. If any base is spilt on the skin, rinse thoroughly with water.

Never point a propette or a syringe containing acid or base upwards. A momentary lapse of concentration can result in a nasty accident. If any acid or base is squirted into the eye, immediately rinse the eye out under running water. In the case of an acid, always have a dilute solution of sodium hydrogencarbonate (household baking soda), or milk close by to apply to the injury. In the case of a base, apply a dilute boric acid solution to the injury. These substances will help neutralise the acid or base in the eye. The patient should be referred to a doctor.

Never allow the learners to play with matches. Treat any burn with cold running water or ice, and seek medical assistance where necessary.

5. Model Answers to Questions in the Worksheet
It is recommended that learners write down all of the questions and answers in their workbooks. If this is done, then the answers to questions do not have to be in full sentences. If the learners do not copy the questions into their workbooks, then answers should be written in full sentences. Note that some of the questions can only be answered by learners in higher grades. Word equations can be written instead of chemical equations where required.

Q1. What effect is there on the current indicator when the battery is connected to the electrodes ?
A1. The LED in the current indicator glows.

Q2. What is the reason for your observation in question 1 ?
A2. The LED glows because there is an electric current through the circuit.

Q3. What do you observe at the different electrodes ?
A3. Electrode 1: Gas bubbles are being generated at the surface of the electrode.
Electrode 2: Gas is also generated at this electrode surface but less than at electrode 1.

Q4. When electrode 1 is full of substance A, how much of substance B is there in electrode 2 ?
A4. Electrode 2 is approximately half full of substance B when electrode 1 is full of substance A.

Q5. What happens when substance A is exposed to the flame ?
A5. When substance A is exposed to the flame a popping sound can be heard as the gas ignites.

Q6. What is the name given to substance A ?
A6. This explosion is characteristic of gaseous hydrogen ($H_2(g)$). Thus substance A is hydrogen ($H_2(g)$).

Q7. What is the name of substance B ?

A7. If substance A is gaseous hydrogen ($H_2(g)$) then the water ($H_2O(\ell)$) must have decomposed. Substance B is therefore probably oxygen ($O_2(g)$).

Q8. What test would you do to prove substance B is what you say it is ?

A8. The gaseous oxygen ($O_2(g)$) could be collected until electrode 2 has been filled. A glowing splint could be brought near to the outlet of the electrode. By squeezing the electrode the gas therein could be forced out onto the splint, which should light up brightly as it comes into contact with the gaseous oxygen ($O_2(g)$).

Q9. Why was a greater volume of substance A produced than of substance B ?

A9. Every molecule of water (H_2O) is composed of two atoms of hydrogen and one atom of oxygen chemically bonded together. Thus, when water (H_2O) is decomposed twice as many hydrogen molecules (H_2) as oxygen molecules (O_2) are generated. This means that the volume of hydrogen should be twice the volume of oxygen.

Q10. Write a summary of what happens when water is electrolysed.

A10. When an electric current is passed through tap water it decomposes into gaseous hydrogen ($H_2(g)$) and gaseous oxygen ($O_2(g)$).

Q11. From question 10, would you say that tap water is a compound, an element or a mixture ? Explain your answer.

A11. Water is a compound since when supplied with electrical energy it decomposes into two elements. The proportions in which the two elements, hydrogen and oxygen, are formed is consistent with the formula H_2O for water.

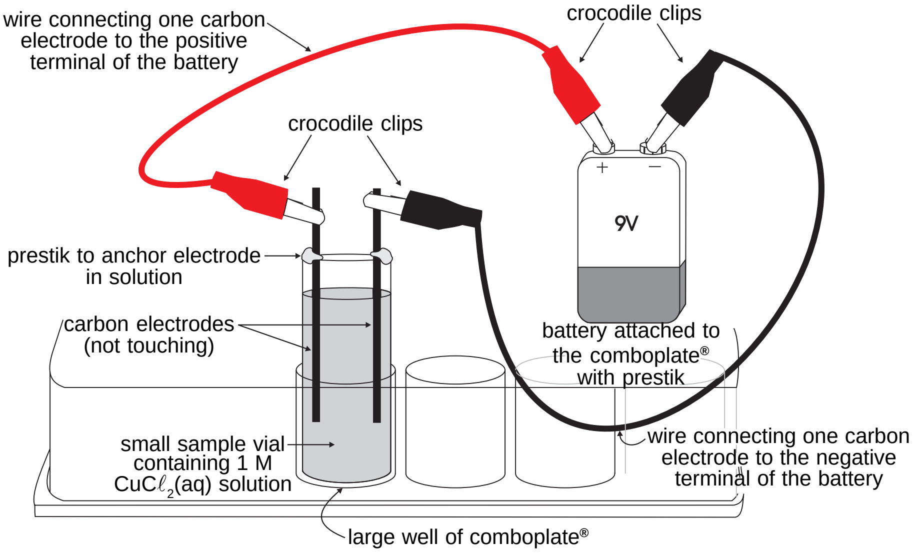
THE ELECTROLYSIS OF A COPPER(II) CHLORIDE SOLUTION

TEACHER GUIDE

1. Chemicals
All of the required chemicals are listed in the worksheet. Tap water is also required.

2. Equipment
Most of the apparatus required can be found in a RADMASTE Basic or Advanced Microchemistry Kit. Learners will also need a 9V battery, aluminium foil to make two connectors, an ordinary writing ("lead") pencil or two graphite rods, and prestik. Plastic coated paper clips are optional and are used to secure the foil connectors to the ends of each electrode. If connecting wires with crocodile clips are available, these can be used in place of aluminium foil strips to connect the electrodes to the terminals of the battery.

This experiment makes use of a large well of the comboplate® to replace the beaker in the conventional electrolysis of aqueous copper(II) chloride. However, the copper(II) chloride solution may also be electrolysed in the small sample vial in the kit. Users of the Basic Microchemistry Kit can clean and use the sample vial that forms part of the microburner in the kit. Users of the Advanced Microchemistry Kit will already have an extra small sample vial available in the kit, and therefore do not need to use the vial of the microburner. The method that uses the sample vial will require more of the copper(II) chloride solution, but the products of the electrolysis are easier to observe. A diagram of this alternative method appears below.



3. Hints
The 9 V battery is heavy in comparison with the other equipment used in the experiment. It tends to pull the connectors away from the carbon electrodes when it is moved or falls over onto its side. To prevent this, it is suggested that the battery be anchored in a suitable position on the comboplate® with prestik. This position can be altered during the experiment to ensure that the aluminium foil connectors reach the terminals of the battery.

Aluminium foil is an inexpensive material that can be used to construct connectors for the circuit. It is suggested in the procedure that a strip of foil about 3 cm in width and 15 cm in length be used. The strip must then be folded three or four times along the 3 cm edge so that the connector is thick enough to maintain electrical contact without tearing. One end of each foil connector must be attached to a terminal of the battery. Sometimes it is good enough to push the ends of the connectors into the battery terminals. However, it often occurs that the connectors are not in direct contact with the relevant battery terminals and it is therefore recommended that prestik be used to keep the ends of the connectors in place. Similarly, the connectors can slip off the carbon electrodes during the experiment. To prevent this, a plastic-coated paper clip can be gently pushed over the foil where it makes contact with the carbon electrode. If the learners find that electrolysis is not taking place, or that bubbling suddenly stops, they should always check the connections at the battery and at the electrodes to rectify the problem.

Connecting wires with crocodile clips at both ends are also very suitable for maintaining good electrical contact between the electrodes and the battery. Using such wires also enables the learners to identify which electrode is connected to the positive terminal of the battery, and which is connected to the negative terminal. This is necessary for the learners to establish whether an electrode is the cathode or anode, and to determine which products are formed at the different electrodes. The crocodile clips should be as small as possible so that they do not move the electrodes in the solution. Users of the Advanced kits can use the LED because it has connectors with crocodile clips. The bulb also glows when a current is flowing through the solution. However, the LED has a high internal resistance and electrolysis occurs at a much slower rate when the LED forms part of the circuit. It is better to connect the electrodes directly to the battery.

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"Lead" or graphite pencils can yield up to four carbon electrodes if the pencil is carefully broken open to remove the central, long carbon rod used for writing. It is important to find pencils that are relatively new or which have not been dropped, otherwise the graphite rod is usually broken at several places within the wooden casing. As an alternative to breaking open a pencil, learners can use the refills for propelling pencils available at stationery stores. The refills need to be approximately 2 mm in diameter so that they do not break when handled. This option is more expensive than breaking open an ordinary pencil. The electrodes should be approximately 5 cm in length to facilitate easy handling during the experiment.

The electrodes must not touch during the experiment as this will result in a completed electrical circuit which excludes the copper(II) chloride solution. If crocodile clips are used they are often heavier than the electrodes and therefore move the electrodes in the solution, sometimes causing the electrodes to touch. Learners should be advised to shift the connectors around until the crocodile clips no longer pull on the electrodes. The well should not be sealed as is sometimes done with the conventional electrolysis of copper(II) chloride. This is because the worksheet allows for the bleaching effect of chlorine to be tested. If the well is sealed, the chlorine gas may not escape from the well and the indicator paper may not be bleached.

The electrolysis begins as soon as the electrodes have been connected to the battery. The production of chlorine gas at the anode is immediate, as shown by vigorous bubbling around the electrode in the solution. The pungent odour of the gas is evident after about one or two minutes from the start of the electrolysis. The bleaching effect of the chlorine on moistened indicator paper can be observed soon after.

The detection of copper metal on the cathode may sometimes be obscured by the deep blue colour of the copper(II) chloride solution. Learners can be encouraged to lift the comboplate® to see the red-brown solid depositing on the electrode. After approximately 5 to 10 minutes, there should be enough copper on the cathode to allow the electrolysis to be stopped. The appearance of the copper deposit varies from scattered granules on the electrode to a fine layer of the metal, which coats the portion of the electrode which has been in contact with the solution. The colour is red-brown in all cases, making for easy identification of the metal.

Early on in the experiment, the learners are asked to identify which electrode is connected to the positive terminal of the battery (Question 3) and which is connected to the negative terminal of the battery (Question 4). Questions 10, 12, 13, 15 and 16 are intended to help learners understand that the electrodes have special names related to the ions in solution which migrate towards them during electrolysis. Learners in the lower grades are not expected to answer the questions on redox reactions.

It is a good idea to allow one or two learners to continue their electrolysis experiments for a longer period of time. They could perhaps leave their comboplate®s overnight in the classroom, or for a few more hours until the school day has ended. Learners will then be able to see a change in the appearance of the copper(II) chloride solution. It is usually pale blue in comparison with the untouched solution in the bottle. The deposit of copper at the cathode is large. Granules of copper fall off the electrode and collect at the bottom of the well.

4. Cautions

Please remember the following cautions and inform your students of all safety hazards:

Chlorine gas is a toxic, pungent gas. The fumes should not be inhaled directly. The experiment should preferably be performed in a ventilated room.

Copper(II) chloride is toxic if ingested. Wash hands thoroughly after the experiment has been completed.

5. Model Answers to Questions in the Worksheet

It is recommended that learners write down all of the questions and answers in their workbooks. If this is done, then the answers to questions do not have to be in full sentences. If the learners do not copy the questions into their workbooks, then answers should be written in full sentences. Note that some of the questions can only be answered by learners in higher grades. Word equations can be written instead of chemical equations where required.

Q1. What do you notice as soon as the battery has been connected to the electrodes?
A1. Vigorous bubbling takes place at one of the electrodes.

Q2. Describe the odour coming from the well.
A2. The odour escaping from the well smells like chlorine. (Learners may refer to familiar products like bleach, or the smell associated with swimming pool water.)

Q3. What happens to the section of the indicator paper that is held close to the electrode at which bubbling takes place? Is this electrode connected to the positive or negative terminal of the battery?
A3. The indicator paper is bleached (i.e it loses its colour and becomes white in appearance.)
The electrode at which bubbling occurs is connected to the positive terminal of the battery.

Q4. Describe the change in appearance of the other electrode (i.e the electrode where no bubbling occurs). Is this electrode connected to the positive or negative terminal of the battery?
A4. A red-brown solid is beginning to deposit on the other electrode. (Learners may not be able to detect the colour of the solid early in the experiment as the blue colour of the copper(II) chloride solution sometimes obscures the red-brown colour of the copper deposit.)
This electrode is connected to the negative terminal of the battery.

Q5. What has happened to the electrode after the electrolysis of the copper(II) chloride solution has been allowed to continue for 5 to 10 more minutes?
A5. More of the red-brown solid has deposited on the electrode.

Q6. What was happening at the electrode where you saw bubbling taking place? Use your answers to Questions 2 and 3 to support your explanation.
A6. Bubbles of chlorine gas were formed at the electrode connected to the positive terminal of the battery. This was shown by the smell of chlorine coming from the sample vial, as well as the bleaching effect of the chlorine on the indicator paper.

Q7. What was happening at the electrode where no bubbles were observed?
A7. Copper metal was formed at the electrode where no bubbling took place. This was seen as the red-brown solid coating the electrode.

Q8. Describe the appearance of the copper(II) chloride before electrolysis took place. Do the products formed at each electrode have the same properties as the original solution? Explain your answer by referring to observations made during the experiment.
A8. The copper(II) chloride is a blue solution prior to electrolysis. The products formed at each electrode do not have the same properties as the blue solution. Chlorine is a gas, observed as bubbles during the electrolysis. Copper metal is a solid, seen as red-brown granules on one electrode during and after electrolysis.

Q9. From your answer to Question 8, describe the effect of an electric current on a copper(II) chloride solution.
A9. An electric current causes the copper(II) chloride solution to decompose (or "break down") into copper metal and chlorine gas. (This is an example of a compound being decomposed into its elements by electrolysis.)

Q10. The carbon rods or electrodes are required for carrying current into and out of the copper(II) chloride solution. Each electrode has a special name. The electrode connected to the positive terminal of the battery is called the anode, while the electrode connected to the negative terminal of the battery is called the cathode.
i. At which electrode did chlorine gas form? (See your answer to Question 3)
ii. At which electrode did copper metal deposit? (See your answer to Question 4)
A10. i. Chlorine gas formed at the anode.
ii. Copper metal deposited at the cathode.

Q11. An electric current can only flow if the solution contains charged particles that are able to move through the solution. Write down the formulae of the charged particles which exist in a copper(II) chloride solution. Name the charged particles.
A11. $Cu^{2+}(aq)$ and $C\ell^-(aq)$. The charged particles or ions are aqueous copper(II) ions and aqueous chloride ions. There are two $C\ell^-(aq)$ ions for every one $Cu^{2+}(aq)$ ion, so the solution is neutral.

Q12. Recall what you observed at the anode. Which charged particles in the copper(II) chloride solution moved towards the anode?
A12. Bubbles of chlorine gas were observed at the anode. This means that the chloride ions in solution moved towards the anode.

Q13. Which charged particles moved towards the cathode? Explain by referring to the product you observed at this electrode.
A13. The copper(II) ions moved towards the cathode because this is the electrode where copper metal was deposited.

Q14. Write down a balanced equation to show the reaction taking place in the well during electrolysis. What type of reaction is this? Explain your answer with reference to the observations made at each electrode.
A14. The reaction taking place during electrolysis can be represented as: $CuC\ell_2(aq) \rightarrow C\ell_2(g) + Cu(s)$. This is a redox reaction. The charge on the chloride ion in $CuC\ell_2(aq)$ is -1. The charge on the chlorine atoms in $C\ell_2(g)$ is 0. Chloride ions have therefore lost electrons and have been oxidised to chlorine atoms. The charge on the copper ion in $CuC\ell_2(aq)$ is +2. The charge on the copper atom in Cu(s) is 0. Copper ions have therefore gained electrons and have been reduced to copper atoms.

Q15. What kind of half-reaction occurs at the anode? Write an equation for this half-reaction. (See your answers to Q10i and Q14)
A15. Oxidation occurs at the anode because chloride ions lost electrons at this electrode and were oxidised to chlorine atoms. The oxidation half reaction occurring at the anode is: $2C\ell^-(aq) \rightarrow C\ell_2(g) + 2e^-$

Q16. What kind of half-reaction occurs at the cathode? Write an equation for this half-reaction. (See your answers to Q10ii and Q14)
A16. Reduction occurs at the cathode because this is the electrode at which copper(II) ions gained electrons and were reduced to copper atoms. The reduction half reaction occurring at the cathode is:
$Cu^{2+}(aq) + 2e^- \rightarrow Cu(s)$

SEPARATION TECHNIQUES –
PAPER CHROMATOGRAPHY

TEACHER GUIDE

1. Chemicals
All of the required chemicals are listed in the worksheet. Tap water is required in Part 2.

2. Equipment
Most of the apparatus required can be found in a RADMASTE Basic or Advanced Microchemistry Kit. A black permanent marking pen and a measuring ruler are also needed.

3. Hints
The permanent marking pen should preferably have a fine tip so that the area of the dot applied to the filter paper is small. If the dot is too large, the ink will spread sideways too much during the separation. If a broad tipped pen is used, it must be pressed lightly onto the paper to keep the ink dot as small as possible.

The solvent should not spill onto the sides of the sample vial, as this will affect the separation.

When the filter paper is placed into the sample vial, the ink dot on the paper must always be above the level of the solvent in the vial. If the dot is immersed in the solvent, all the components of the ink that are soluble in the solvent will be washed into it. When the solvent travels up the filter paper, no separation will be seen.

The filter paper should be as upright as possible in the vial, otherwise the solvent may travel unevenly up the filter paper and cause the ink to run off the side of the paper.

Black ink consists of different colours of ink. Commercial manufacturers use varying combinations of these colours to produce the black ink that they market. Therefore, depending upon the brand of the pen used, a variety of colours may be seen. Blue and red are particularly common. The ink used to compile the model answers also contained a green component.

In Part 2, the permanent ink will not separate into its component colours when water is the solvent but some outward smudging of the ink dot may occur.

It is a good idea to obtain a non-permanent marking pen with which to repeat Part 2 of the experiment. In this way it can be shown that the components of ink in this pen are soluble in water, and can be separated using water as the solvent.

4. Cautions
Please remember the following cautions and inform your students of all safety hazards:

Methanol is poisonous! If contact is made with the skin or eyes, rinse the affected areas with copious amounts of water. Methanol is extremely flammable and must be stored in a cool place away from sources of ignition. The container should remain closed at all times, as the fumes produced by the chemical can cause headaches and dizziness after prolonged or repeated inhalation. If students show breathing difficulties, they must be moved to an area with fresh air.

5. Model Answers to Questions in the Worksheet
It is recommended that learners write down all of the questions and answers in their workbooks. If this is done, then the answers to questions do not have to be in full sentences. If the learners do not copy the questions into their workbooks, then answers should be written in full sentences. Note that some of the questions can only be answered by learners in higher grades. Word equations can be written instead of chemical equations where required.

PART 1: Is the ink of a black permanent marking pen a mixture or a pure substance ?

Q1. What happens to the filter paper the moment it is inserted into the methanol in the sample vial ?
A1. The filter paper gets wet as the solvent (methanol) quickly travels up by capillary action.

Q2. Does the black ink dot remain 5 mm from the edge of the strip of filter paper after 2 minutes ?
A2. No. The ink dot starts to travel up the filter paper.

Q3. What can you see on the filter paper after about 10 – 15 minutes ?
A3. The black ink dot has separated into three different coloured components. There is a long streak of blue along most of the filter paper, followed by a red band. A green band can be seen right at the top of the paper.

Note **Black ink is made up of different colours. Depending upon the manufacturer of the pen used, varying colours may be seen. Blue and red are particularly common.)**

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Q4. Is the ink a mixture or a pure substance ?
A4. The black ink is a mixture, composed of three different components: blue, red and green.

Q5. Give a reason for your answer to question 4.
A5. If the ink were a pure substance, only one component would have been seen after 10 minutes. Since there are three components, this indicates that the ink is a mixture.

Q6. Which component in the black ink is most soluble in methanol ? Explain your answer.
A6. The green component, since it has moved further than both the blue and red components on the filter paper.

Q7. Which component in the black ink is least soluble in methanol ? Explain your answer.
A7. The blue component, since it has moved less far than the red and green components on the filter paper.

Q8. Is the black ink a homogeneous or heterogeneous mixture ? Explain your answer.
A8. Black ink is a homogeneous mixture. The components of the ink cannot be differentiated when looking at the mixture with the unaided eye.

PART 2: Can water be used as a solvent to separate black permanent ink into its components by paper chromatography?

Q1. Does the black ink on the filter paper remain 5 mm from the edge of the filter paper after 2 minutes ?
A1. Yes.

Q2. What happens to the dot of black ink after 10 minutes ?
A2. The black dot doesn't change position. (The dot may show smudging.)

Q3. Has the black ink dot separated into different components as in Part 1 (with methanol as the solvent) ?
A3. No.

Q4. Can water be used to separate the components of black ink ?
A4. No.

Q5. Give a reason for your answer to question 4.
A5. The forces of attraction between the solvent molecules (water) and the molecules of the components in the black ink are weak. Hence the components in the ink did not travel up the filter paper with the water.

Q6. Why is this black ink described as "permanent" ?
A6. It is insoluble in water. Hence when used to mark clothing or other material, the black writing is not washed out.

SEPARATION OF TWO DYES BY COLUMN CHROMATOGRAPHY

TEACHER GUIDE

1. Chemicals

All of the required chemicals are listed in the worksheet. The dye mixture can be prepared using green and yellow food dyes and water. The food dyes can be obtained from grocery stores. The ratio of green to yellow dyes to water is 1:1:2. Tap water is also needed. Large volumes are not required since only a few drops are used for an experiment.

2. Equipment

Most of the apparatus required can be found in a RADMASTE Basic or Advanced Microchemistry Kit. A microfunnel can be used to transfer the silica gel and solvent mixture into the syringe to avoid spillage.

3. Hints

Prepare the butanol mixture in a large container for the whole class to use. Always ensure that the mixture is well mixed before it is used. Mixing is easily achieved by shaking.

The cotton wool can be taken in and out of the syringe with the use of an unwound paper clip.

The sand has a tendency of sticking on the walls of the syringe and it can be washed down with the use of the butanol mixture. The silica gel and butanol mixture do not form a solution and the container in which they were mixed can be washed with the butanol mixture. It is also important to stir the mixture in the sample vial before adding it into the syringe. A microfunnel can be used to add the silica gel mixture into the syringe.

After adding a drop of dye mixture, fill up the syringe with the butanol mixture and keep it that way throughout the experiment. This also helps speed up the movement of the dye components down the silica gel column.

Only one drop of dye mixture is sufficient to show the different colour components. However, to be able to collect the differently coloured samples, 4 drops can be used instead of one drop. These can be collected into sample vials or different wells of the comboplate®. This procedure, as mentioned in the worksheet, takes a longer time.

4. Cautions

Please remember the following cautions and inform your students of all safety hazards:

The butanol mixture has an odour which can cause slight headaches if inhaled continuously. It should always be kept in a closed container. Work in a well-ventilated area.

The butanol mixture easily comes out through the nozzle of the syringe. At all times, ensure that the nozzle of the syringe is above a clean, large well so that the butanol mixture can be collected and re-used. The level of the butanol mixture should always be slightly above the top solid layer (i.e. sand).

Ethanol and butanol are poisonous! If contact is made with the skin or eyes, rinse the affected areas with copious amounts of water. Both alcohols are extremely flammable and must be stored in a cool place away from sources of ignition. Their containers should remain closed at all times, as the fumes produced by the chemicals can cause headaches and dizziness after prolonged or repeated inhalation. If learners show breathing difficulties, they must be moved to an area with fresh air.

5. Model Answers to Questions in the Worksheet

It is recommended that learners write down all of the questions and answers in their workbooks. If this is done, then the answers to questions do not have to be in full sentences. If the learners do not copy the questions into their workbooks, then answers should be written in full sentences. Note that some of the questions can only be answered by learners in higher grades. Word equations can be written instead of chemical equations where required.

Q1. What is the function of the sand in the column ?
A1. The sand at the bottom improves the drainage of the entire system. At the top it protects the column of the silica gel from disturbance.

Q2. What colour is the dye mixture ?
A2. The dye mixture is deep green.

Q3. What colour(s) substances can be seen on the silica gel ?
A3. Blue, light green and yellow. The light green colour is a combination of blue and yellow.

Q4. Why do the different food dyes travel at different speeds down the silica gel column ?
A4. The dye molecules are attracted to the surface of the silica gel and also by the molecules of the solvent mixture. For different dyes the balance of forces is different. The dye molecules which have a relatively stronger attraction for the solvent molecules spend most of their time amongst these molecules, i.e. in solution in the butanol mixture. They then move down the column with the solvent most quickly.

Q5. Suggest why the dye mixture cannot be separated using filtration.

A5. Filtration can be used only to separate heterogeneous mixtures. The dye mixture is homogeneous.

Q6. Suggest an alternative method that can be used to separate the dye mixture. Explain the basis of this separation method.

A6. The dye mixture can be separated using paper chromatography. The principle is mostly the same as column chromatography. A suitable paper is used with a drop of the dye mixture near to one end. This end of the paper is then immersed in a suitable solvent which then moves up the paper with the different dye components at different speeds.

COMPOUNDS, ELEMENTS, PURE SUBSTANCES AND MIXTURES – MODELLING THE ATOMS AND MOLECULES

TEACHER GUIDE

1. Chemicals
No chemicals are required for this experiment.

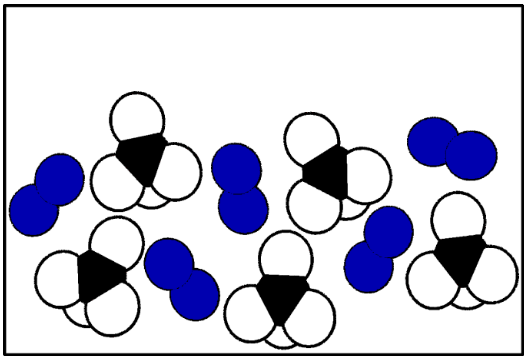
2. Equipment
Two different coloured balls of plasticine or modelling clay are supplied for this experiment in the RADMASTE Advanced Microchemistry Kit.

3. Hints
This practical is designed to address the most common misconceptions concerning compounds, elements and mixtures. It may best be performed by students working in groups and discussing the questions together (please refer groups to the diagrams supplied to simplify the experiment). After general consensus has been reached within the groups, a feedback session could be held where different groups present some of their answers and the reasons for these answers. In this way, common misconceptions could be identified and addressed.

Note that figures 1 to 7 supplied depict liquid substances; i.e. substances A and B (figures 1 to 4) are elements in the liquid state, substance C (figure 5) is a heterogeneous mixture of two different liquids, substance D (figure 6) is a homogeneous mixture of two different liquids and substance E (figure 7) is a liquid compound.

Although substance D (figure 6) shows that a homogeneous mixture consists of molecules of two different kinds of **elements**, it should be explained to students that **element/compound** mixtures are also mixtures. For example, the diagram below shows an homogeneous mixture of two different liquids, one an element (eg. bromine) and the other a compound (eg. carbon tetrachloride).

Stress to your learners that they must not mix up the different coloured plasticine, otherwise they will not be able to re-use it.



4. Model Answers to Questions in the Worksheet
It is recommended that learners write down all of the questions and answers in their workbooks. If this is done, then the answers to questions do not have to be in full sentences. If the learners do not copy the questions into their workbooks, then answers should be written in full sentences. Note that some of the questions can only be answered by learners in higher grades. Word equations can be written instead of chemical equations where required.

ACTIVITY 1

Q1. Is substance A a compound, a homogeneous or a heterogeneous mixture, or an element ? Give a reason for your answer. *(See Figure 1)*

A1. Substance A is an element because it is composed of one kind of atom. At this stage the model shows individual (separate) atoms. The only elements that exist in this form are the noble gases.

Q2. What criterion at the microscopic level is used to decide if a substance X is a pure substance ?

A2. A pure substance is one which is composed of one kind of atom or molecule. It is therefore possible for a pure substance to be a compound (composed of two or more different kinds of atoms chemically bonded together) or an element (composed of individual atoms of the same kind or two or more atoms of the same kind chemically bonded together). Example formulae of pure substances are:

Ne (Element), O_2 (Element), CO_2 (Compound).

Q3. Using the criterion in Question 2 above, is substance A a pure substance ?

A3. Yes. Substance A is a pure substance because it is composed of only one kind of atom.

Q4. What is the name given to the combination of the two atoms of substance A *(See Figure 2)* ?

A4. Diatomic molecule.

Q5. Is substance A now a compound, a homogeneous or a heterogeneous mixture, or an element ? Explain your answer.
A5. Although substance A is now composed of diatomic molecules it is still an element since it is composed of atoms of the same kind chemically bonded together.

ACTIVITY 2

Q1. Is substance B a compound, a homogeneous or a heterogeneous mixture, or an element ? Give a reason for your answer. *(See Figure 4)*
A1. Substance B is an element because it is composed of only one kind of atom.

Q2. What is the name given to the combination of the two atoms of substance B ?
A2. Diatomic molecule.

Q3. Is substance C a compound, a homogeneous or a heterogeneous mixture, or an element ? Give a reason for your answer.
A3. Substance C is a heterogeneous mixture because it is not uniform throughout. Thus two different layers would be seen macroscopically.

Q4. If the two collections of paired atoms in substance C, were to be moved apart from each other, would this represent a physical or a chemical change ? Give a reason for your answer.
A4. This change would be a physical one since there are no chemical bonds changed. Weaker intermolecular forces would need to be overcome to separate the two kinds of molecules from each other.

Q5. What is the name given to the process in question 4 ?
A5. Separation.

Q6. Is substance D a compound, a homogeneous or a heterogeneous mixture, or an element ? Give a reason for your answer.
A6. Substance D is a homogeneous mixture since it is approximately uniform. Although there are two different kinds of molecules these are intermixed, and at a macroscopic level two different components will not be seen.

Q7. If the two collections of paired atoms in substance D were to be moved apart from each other, would this represent a physical or a chemical change ? Give a reason for your answer.
A7. This change would also be a physical change since no chemical bonds need to be broken in order to separate the two different kinds of molecules.

Q8. What is the name given to the process in question 7 ?
A8. Separation.

Q9. Propose a method to perform the process mentioned in question 8 above, with real substances.
A9. An example of a homogeneous mixture would be a mixture of ethanol and water. The two substances could be separated by distillation, where the alcohol would be distilled off first.

ACTIVITY 3

Q1. Is substance E a compound, a homogeneous or a heterogeneous mixture or an element ? Give a reason for your answer. *(See Figure 7)*
A1. Substance E is a compound since it is composed of molecules which have two different kinds of atoms chemically bonded together.

Q2. How does substance E differ from substance D ?
A2. Substance E is a compound while substance D is a homogeneous mixture. Thus chemical bonds were broken and formed to produce substance E from substances A and B. This was not the case when substance D was produced from substances A and B.

Q3. If the paired atoms in substance E were to be rearranged into paired atoms as in substance D would this represent a physical or a chemical change ? Give a reason for your answer.
A3. This change would be a chemical change since chemical bonds would need to be broken and the new ones formed in order for substance E to be changed to substance D (a mixture of substances A and B).

Q4. What is the name of the process in question 3 ?
A4. Decomposition.

Q5. How does the energy required to change substance E into substance D compare with the energy required to change substance D to substance C ?
A5. Chemical bonds (intramolecular forces) are stronger than intermolecular forces and therefore more energy is required to break the former. For this reason the energy required to change substance D to substance C is less than that required to change substance E to substance D.

Q6. Propose a method to perform the change mentioned previously in question 4.
A6. Electrolysis (the decomposition of a compound by means of an electric current) could be used. For example water (H_2O) could be decomposed into hydrogen (H_2) and oxygen (O_2). Heating can also be used, as when mercury(II) oxide (HgO) is decomposed to mercury (Hg) and oxygen (O_2).

DO DISSOLVED SUBSTANCES SPREAD ?

TEACHER GUIDE

1. Chemicals
All of the required chemicals are listed in the worksheet.

2. Equipment
Most of the apparatus required can be found in a RADMASTE Basic or Advanced Microchemistry Kit.

3. Hints
Teachers can encourage learners to look at the vial and its contents regularly throughout the lesson during which they set up the vials. In this way learners will soon notice that nothing much seems to happen to the copper sulphate over such a short time, and that they may need to monitor its appearance perhaps only during each science lesson for a couple of weeks.

When learners are making drawings of the vial on different days, they can be encouraged to record the uppermost position of the blue colour and the sharpness of the boundary between the copper sulphate solution and the water. In this way they can begin to recognise that with time, the boundary becomes less distinct because more of the copper sulphate solution is diffusing.

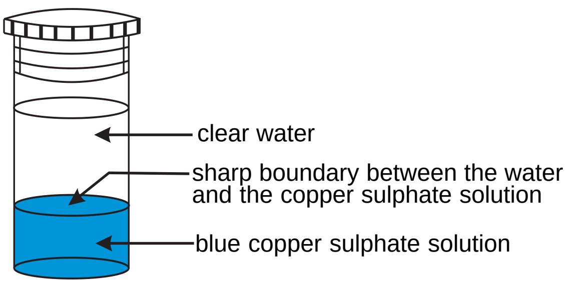
Learners may initially not be able to understand that the particles of copper sulphate are moving. The teacher can explain that the movement of the blue colour of the copper sulphate solution is an indication that the particles of copper sulphate are also moving.

4. Cautions
Please remember the following cautions and inform your students of all safety hazards:

Saturated copper sulphate solution is harmful if swallowed or absorbed through the skin. It can also cause eye and skin irritation. It can damage mucous membranes if ingested. If contact is made with the skin, rinse the affected area with copious amounts of water.

5. Model Answers to Questions in the Worksheet
It is recommended that learners write down all of the questions and answers in their workbooks. If this is done, then the answers to questions do not have to be in full sentences. If the learners do not copy the questions into their workbooks, then answers should be written in full sentences. Note that some of the questions can only be answered by learners in higher grades. Word equations can be written instead of chemical equations where required.

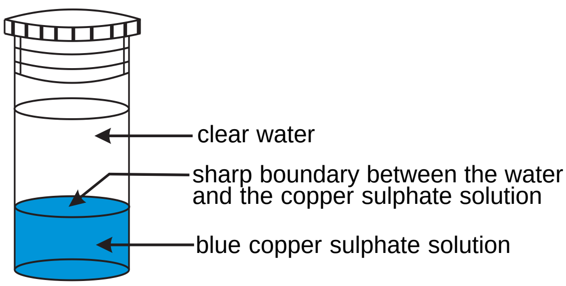
Q1. Make a drawing to show the appearance of the vial. Use a blue crayon if possible to colour in, to make your drawing easier to understand.



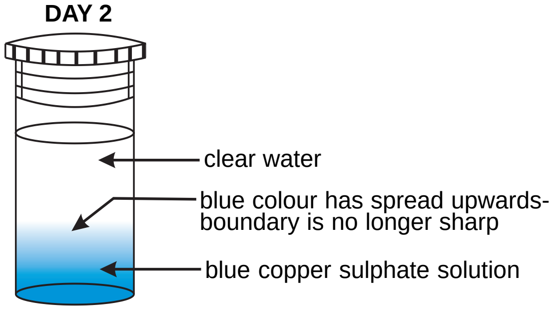
Q2. Put the vial in a safe place and observe its contents each day for a whole week if possible. Each day make a drawing.

A2. Hopefully learners will record both the uppermost position of the blue colour in the vial and the sharpness of the boundary between the copper sulphate solution and the water. A suitable format for the recording of the observations is shown below: By Day 7, the blue colour is uniformly spread throughout the vial.

DAY 1



DAY 2



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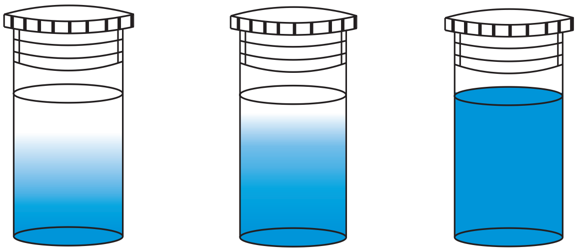
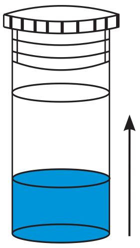


Q3. Why do you think that the vial containing the layer of copper sulphate solution and the water should be closed?
A3. The vial should be closed to prevent evaporation of water and to keep out draughts as both may have an effect on the behaviour of the copper sulphate solution.

Q4. Direction of movement of the dissolved copper sulphate particles in the vial
a Draw an arrow on one of your diagrams to show the direction in which the dissolved copper sulphate spreads in the vial.



b Describe the direction in which the dissolved copper sulphate in the vial spreads after a few days.
The dissolved copper sulphate spreads to the top of the vial. (This is a very restrictive way of describing the direction in which diffusion takes place.)

c Where is the concentration of the copper sulphate solution in the vial highest at the beginning of the activity ?
Learners may have difficulty with the concept of concentration. If this is the case, help them by rephrasing the question. A suggestion follows:

Where in the vial do you find most copper sulphate in the smallest volume of water at the beginning of the activity? Copper sulphate solution has the highest concentration at the bottom of the vial at the beginning of the activity.

d Where is the concentration of the copper sulphate solution in the vial lowest at the beginning of the activity ?
Copper sulphate solution has the lowest concentration at the top of the vial at the start of the activity. Its concentration at the top of the vial is zero.

e Describe the direction in which the dissolved copper sulphate spreads in the vial. Use concentration in your description.
The dissolved copper sulphate spreads from a place where its concentration is highest to a place where its concentration is lower.

Q5. We call the spreading and mixing of substances diffusion. Use your findings from this activity to write a sentence or two to explain clearly what diffusion is.
A5. Diffusion is the spreading of a substance from a place where its concentration is high to a place where its concentration is lower. This spreading happens on its own, without shaking or stirring.

Learners can be expected to include the notion of spontaneity (spreading happens on its own) in their description but are unlikely to include either the cause of diffusion (random motion of particles) or when the mixing results in no further change (when the concentration is the same everywhere).

Q6. This activity shows that dissolved copper sulphate particles spread throughout the water in the vial. Explain this spreading using the Particle Theory.
A6. The Particle Theory tells us that matter is made from particles. These particles move at different speeds in all directions. The particles change direction only when they bump into other particles. It is the motion of the dissolved copper sulphate particles which causes the copper sulphate solution to spread.

Q7. Why do you think diffusion takes place more slowly through water than through air at the same temperature ? Use your knowledge of particles to answer.
A7. It seems to be easier for substances to move through air than through liquids. This must mean that there is more space between particles in the gas phase than there is between particles in the liquid phase.

Q8. What difference would you expect to observe if you use hot copper sulphate solution in the syringe and hot water in the vial ?
A8. Learners may predict intuitively that the blue colour will spread more quickly. Particles move faster at higher temperature.

COLLIDING CLOUDS OF COLOUR

TEACHER GUIDE

1. Chemicals

All of the required chemicals are listed in the worksheet. Red and green food colouring can be obtained from the kitchen or the supermarket. Other food colours can be used. Hot and cold water are also required. Cold water from the refrigerator should be used i.e. the water should be ice-cold.

2. Equipment

Most of the apparatus required can be found in a RADMASTE Basic or Advanced Microchemistry Kit. If only Basic Kits are available, then the learners working in each pair will need to use the microburner vials from two kits. If Advanced Kits are used, only one kit will be required because there is a microburner vial and an additional vial in the kit. A marking pen is needed to write on the vials.

3. Hints

Learners are advised to work in pairs so that one learner can add the drops of food colouring to the hot water at exactly the same time as the other learner adds the food colouring to the cold water. If this is not done, it will be difficult for learners to compare the rates at which the food colouring diffuses through the hot and cold water respectively.

Care must be taken not to drop the food colouring onto the walls of the vials, as the drops will adhere to the walls and impede or slow down the movement of the food colouring through the water.

4. Model Answers to Questions in the Worksheet

It is recommended that learners write down all of the questions and answers in their workbooks. If this is done, then the answers to questions do not have to be in full sentences. If the learners do not copy the questions into their workbooks, then answers should be written in full sentences. Note that some of the questions can only be answered by learners in higher grades. Word equations can be written instead of chemical equations where required.

Q1. Why does the food colouring sink to the bottom of the water in both vials ?
A1. Food colouring is denser than water and so sinks in water.

Q2. How do you think the temperature of the drops of food colouring changes when they are put into the hot and cold water ?
A2. The food colouring is initially at room temperature. When put into the hot water, the food colouring will quickly become warmer – its temperature will increase. When put into the cold water the food colouring will cool down – its temperature will decrease.

Q3. What difference do you see when the food colouring sinks in the hot and the cold water ?
A3. As the food colouring sinks in the hot water, it spreads out much more than in the cold water.

Q4. What happens to the food colouring when it settles on the bottom of the vials ?
A4. It forms a layer at the bottom and then starts to spread upwards and sideways.

Q5. Describe any differences in appearance of the mixture in the two vials after about 10 minutes.
A5. After about 10 minutes, the red and green food colouring are completely mixed in the hot water. The mixture is yellow-green in colour. In the cold water, the two colours spread but after 10 minutes they have not mixed. There is a boundary between the two colours.

Q6. What substances do you see diffusing in this activity ?
A6. Red and green food colouring diffuse.

Q7. In this activity, you saw the effect of temperature on the speed at which liquids diffuse. What is this effect ?
A7. The hotter a liquid, the faster that liquid diffuses.

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LEAKING BALLOONS ? ? ?

TEACHER GUIDE

1. Chemicals

All of the required chemicals are listed in the worksheet. Concentrated ammonia solution is needed. Household ammonia solution may be used as a substitute for concentrated ammonia solution, but the activity will take longer.

2. Equipment

Most of the apparatus required can be found in a RADMASTE Basic or Advanced Microchemistry Kit. An elastic band, a pair of scissors, an old balloon, *prestik* and a piece of white paper are required.

3. Hints

It is preferable for teachers to use old balloons as these tend to be more porous than new balloons. If old balloons are not available, the teacher should blow up a new balloon and leave it to stretch for a few days to enhance its porosity. White balloons rather than coloured ones allow for better observation of the colour change of phenolphthalein from colourless to pink in the vial.

It is important for learners to stretch the piece of balloon as tightly as possible over the mouth of the microburner vial. This is because the spaces between the rubber particles are then likely to be larger than if the balloon is not stretched tightly. These large spaces will allow the diffusion of ammonia gas to take place without hindrance. If the rubber is not stretched tightly enough, the ammonia will take a long time to diffuse and the colour change in the phenolphthalein solution may not be seen within one lesson.

The learners should ensure that there is no leakage of phenolphthalein solution from the vial when it is turned upside down, otherwise the indicator solution will mix with the ammonia solution in the well of the comboplate®. A colour change will occur in the well, and learners may be confused.

If the day is cool or cold, the comboplate® can be floated on hot water to increase the rate of diffusion of gaseous ammonia.

4. Cautions

Please remember the following cautions and inform your students of all safety hazards:

Ammonia solution is a corrosive base. If any base is spilt on the skin, rinse the affected area with copious amounts of water.

Never point a propette or a syringe containing a base upwards. A momentary lapse of concentration can result in a nasty accident. If any base is squirted into the eye, immediately rinse the eye out under running water. Use a dilute boric acid solution for injuries involving a base. This solution will help neutralise the base in the eye. The patient should be referred to a doctor.

Ammonia fumes are toxic. Avoid inhaling the fumes from the bottle and the well containing the ammonia solution. Make sure the experiment is performed in a well ventilated room.

5. Model Answers to Questions in the Worksheet

It is recommended that learners write down all of the questions and answers in their workbooks. If this is done, then the answers to questions do not have to be in full sentences. If the learners do not copy the questions into their workbooks, then answers should be written in full sentences. Note that some of the questions can only be answered by learners in higher grades. Word equations can be written instead of chemical equations where required.

Q1. What do you observe when the phenolphthalein and ammonia solutions mix ?

A1. Phenolphthalein solution is colourless. When the phenolphthalein solution is mixed with the ammonia solution, it changes to bright pink.

Q2. Describe what happens to the phenolphthalein solution in the vial. In your description include

- colour changes
- where these colour changes happen
- how long it takes the colour changes to happen.

A2. The phenolphthalein solution changes from colourless to very pale pink. The pink colour first appears at the bottom of the vial where the phenolphthalein touches the balloon. The colour of the phenolphthalein solution starts changing a few minutes after the vial is turned upside down over well F1. The pink colour slowly becomes darker. The pink colour spreads upwards until, after about an hour, all the phenolphthalein solution is pink. The pink colour then darkens slowly.

Q3. What do your observations in Question 2 above tell you about the way the rubber particles are arranged in the piece of rubber ?

A3. The rubber particles must have spaces between them. The spaces must be large enough for ammonia molecules to move through into the phenolphthalein solution.

Q4. Describe the direction of diffusion of ammonia gas in this activity.

A4. Technically, the spreading of a gas through tiny openings is called effusion, rather than diffusion. However, it is unnecessary for pupils to make the distinction between diffusion and effusion.

In the light of knowledge gained in earlier activities, pupils can be expected to answer in terms of differences in ammonia concentration. An appropriate answer would then be:
Ammonia gas diffuses from a region of high concentration (above the ammonia solution in the well) to a region of lower (zero) concentration (the phenolphthalein solution in the vial).

Q5. Ivy complains bitterly to her friends that she saw nothing happening in her vial. Phoka is sure that she didn't stretch the rubber enough. Explain the difference between the way the particles are arranged in stretched and unstretched rubber.

A5. This question tries to make pupils explain macroscopic observations (thickness of rubber) in a microscopic (particle) framework.

In an unstretched piece of rubber there are likely to be many more layers of particles than there are in a stretched piece of rubber of the same area. In the unstretched rubber, these particles are likely to be more closely packed and the spaces between the particles are likely to be smaller than in the stretched piece of rubber. The spaces may often be blocked by other particles.

HOW FAST DOES GASEOUS AMMONIA DIFFUSE ?

TEACHER GUIDE

1. Chemicals
All of the required chemicals are listed in the worksheet. Concentrated ammonia solution is required.

2. Equipment
Most of the apparatus required can be found in a RADMASTE Basic or Advanced Microchemistry Kit. A sewing needle, piece of white cotton thread, a ruler, a piece of white paper, prestik, a pair of scissors and a stopwatch/ watch are also required. Sewing items are readily available in the haberdashery section of most supermarkets, while the other stationery should already be in use in the classroom.

3. Hints
Learners must be careful not to allow the thread to touch the cotton wool. If this happens, the ammonia solution placed on the cotton wool will immediately wet the thread. This will cause the phenolphthalein solution on the thread to turn pink immediately and the experiment will need to be restarted, because learners need to observe and measure the diffusion rate of gaseous ammonia – not ammonia solution.

Learners need to start timing as soon as the gaseous ammonia reaches the end of the thread which is ~ 1.5 cm away from the cotton wool. They will know when to begin timing because the tip of the thread will begin to turn pink.

Learners must stop timing when the ammonia has diffused to the end of the thread inside the tube i.e the end of the thread at the piece of prestik, not the end of the thread protruding from the combustion tube.

If time permits, learners can be encouraged to repeat the activity. Alternatively, the results from the class can be pooled to get an average rate of diffusion.

If learners find using a piece of cotton thread too finicky, a thin strip of white paper can be used instead. The paper should be about 1 mm wide and the length of the combustion tube. After being dipped in phenolphthalein solution, the paper may lose its rigidity. A needle or microspatula can then be used to push it into the tube.

4. Cautions
Please remember the following cautions and inform your students of all safety hazards:

Concentrated ammonia solution is extremely corrosive. If contact is made with the skin, the affected area should be rinsed with copious amounts of water.

The ammonia fumes are toxic. Avoid inhaling the fumes and ensure that the activity is performed in a well ventilated area.

5. Model Answers to Questions in the Worksheet
It is recommended that learners write down all of the questions and answers in their workbooks. If this is done, then the answers to questions do not have to be in full sentences. If the learners do not copy the questions into their workbooks, then answers should be written in full sentences. Note that some of the questions can only be answered by learners in higher grades. Word equations can be written instead of chemical equations where required.

Q1. What do you observe when the phenolphthalein and ammonia solutions mix ?
A1. Phenolphthalein solution is a colourless liquid. When phenolphthalein solution comes into contact with ammonia solution in well A12, it changes to bright pink.

Q2. Describe what happens in the combustion tube.
A2. The piece of cotton thread starts changing colour. It becomes faintly pink and gradually the colour becomes more intense. The cotton thread starts changing colour at the end closer to the propette.

Q3. What was the time from start to stop ?
A3. 248 seconds. (Time will vary with temperature.)

Q4. What is the length of thread inside the tube ?
A4. 4.0 cm.

Q5. Work out the speed at which ammonia diffuses in air at room temperature. Show your working.

A5. Learners can use the equation below:

$$\textbf{speed} = \frac{\textbf{distance}}{\textbf{time}} = \frac{\textbf{4.0 cm}}{\textbf{248 seconds}} = \textbf{0.016 cm / s}$$

Learners can use the following reasoning if they are unable to give / use a formula:

In 248 s the ammonia travels 4.0 cm.

Therefore, in 1 s the ammonia will travel $\frac{\textbf{4.0 cm}}{\textbf{248 seconds}} = \textbf{0.016 cm/s}$ **at room temperature.**

The results above were measured at 21 ^{0}C.

PREPARATION AND TESTING OF OXYGEN

TEACHER GUIDE

1. Chemicals

All of the required chemicals are listed in the worksheet.

2. Equipment

All of the apparatus required can be found in a RADMASTE Basic or Advanced Microchemistry Kit.

3. Hints

Hydrogen peroxide solutions ($H_2O_2(aq)$) decompose easily. It is therefore recommended that a fresh solution of 10% $H_2O_2(aq)$ be used each time this experiment is performed. Prior to carrying out the experiment with learners, the teacher can assess whether the hydrogen peroxide solution is suitable by adding a few drops of the solution to a level microspatula of manganese dioxide in a large well of the comboplate®. If the solution bubbles vigorously, the hydrogen peroxide is concentrated enough to rapidly produce an adequate volume of oxygen gas for testing.

The instructions in the worksheet suggest that the silicone tube is fitted at a slant onto the tube connector of lid 1. This is easily done by placing the silicone tube securely onto the connector and then pushing the bottom end of the tube closest to the syringe inlet slightly upwards, while the rest of the tube remains firmly at the base of the connector. When the glass tube is attached to the silicone tube, it will also be at a slant away from the syringe. This prevents the syringe from obstructing the splint when it is held in the oxygen escaping from the glass tube. There is also no danger of the syringe being melted by a flame. (The idea of attaching the glass tube to the silicone tube is to prevent the silicone tube from burning when the splint ignites in the oxygen.)

The toothpick splints contained in the gas collecting tube of the Microchemistry kits burn relatively slowly. Learners should therefore be able to add the hydrogen peroxide solution slowly to the manganese dioxide powder in the well, while the top end of the splint is burning. If the hydrogen peroxide is added too quickly, some of the solution may be forced upwards through the silicone and glass tubes. The experiment will have to be redone after the lid and tubes have been cleaned and dried thoroughly.

Learners need to ensure that there is a glowing portion of the splint remaining after they have put out the flame on the splint. Only a glowing splint will ignite in the oxygen escaping from the end of the glass tube. If the splint has already become ash-grey in appearance, then holding it at the open end of the glass tube may only produce a red glow without ignition. To ensure that learners see the splint igniting, they may have to relight the splint in the microburner flame or choose a new splint to test for the oxygen. It is essential to work quickly if the splint needs to be lit again, because the evolution of oxygen in the well slows down with time so that the volume of gas escaping from the glass tube is not sufficient to cause a glowing splint to ignite.

Once the splint has ignited in the oxygen, the flame can be put out gently to leave another glowing portion. This portion can then be held in the oxygen again, so that learners can observe the splint ignite once more. This practice can be continued for as long as a good flow of oxygen through the glass tube is maintained, or until most of the splint has burned.

4. Cautions

Please remember the following cautions and inform your students of all safety hazards:

Hydrogen peroxide is corrosive. If any $H_2O_2(aq)$ is spilt on the skin, the affected area must immediately be rinsed with copious amounts of water.

Never point a propette or a syringe containing $H_2O_2(aq)$ upwards. A momentary lapse of concentration can result in a nasty accident. If any peroxide is squirted into the eye, immediately rinse the eye out under running water.

Do not allow anyone to bring a flame near the comboplate® or syringe. These are plastic and will melt.

Never allow the students to play with matches. Treat any burn with cold running water or ice, and seek medical assistance where necessary.

The methylated spirits used in the microburner is poisonous. Do not inhale the vapour or drink the liquid.

5. Model Answers to Questions in the Worksheet

It is recommended that learners write down all of the questions and answers in their workbooks. If this is done, then the answers to questions do not have to be in full sentences. If the learners do not copy the questions into their workbooks, then answers should be written in full sentences. Note that some of the questions can only be answered by learners in higher grades. Word equations can be written instead of chemical equations where required.

Q1. What do you observe each time that the glowing splint is held above the open end of the glass tube ?
A1. The glowing splint ignites or "bursts" into flame.

Q2. What do you conclude from your observation of the glowing splint ?
A2. Oxygen gas escaped through the glass tube and caused the glowing splint to ignite. This is the test for oxygen.

Q3. What do you see happening in the well containing the hydrogen peroxide ?
A3. The hydrogen peroxide solution is bubbling vigorously in the well.

Q4. What do you conclude from your observation of the well ?
A4. The hydrogen peroxide is reacting in the well to form a gas, which has been shown to be oxygen by the glowing splint test.

Q5. Write a balanced chemical equation to represent the reaction occurring in the well.
A5. $H_2O_2(aq) \rightarrow H_2O(\ell) + O_2(g)$
(Word Equation: hydrogen peroxide solution → water + oxygen gas)

Q6. What is the role of the manganese dioxide in this experiment ?
A6. It is a catalyst. (It speeds up the decomposition of the hydrogen peroxide so that we see the vigorous bubbling, but it is not used up in the reaction.)

Q7. Suggest an alternative method (using the kit) for collecting the gas formed by the decomposition of hydrogen peroxide.
A7. The oxygen could be collected by the downward displacement of water, using the gas collecting tube. A glowing splint could then be inserted into the tube containing the oxygen. The splint should ignite in the oxygen.

Q8. Oxygen is often stored in large tanks for use in places like laboratories and hospitals. Why do you think these tanks have warnings for people not to smoke near them ?
A8. If oxygen escapes from a storage tank when a cigarette is burning near it, the glowing portion of the cigarette will ignite in the oxygen. The smoker may get burnt.

THE PREPARATION AND TESTING FOR HYDROGEN

TEACHER GUIDE

1. Chemicals

All of the required chemicals are listed in the worksheet. Tap water is also needed.

2. Equipment

Most of the apparatus required can be found in a RADMASTE Advanced Microchemistry Kit. A plastic cup and prestik are also needed.

3. Hints

A plastic cup has been used here, but other suitable containers can be used into which the inverted gas collecting tube can be placed.

Add the 5.5 M hydrochloric acid ($HC\ell(aq)$) slowly to the zinc powder ($Zn(s)$), otherwise the vigorous bubbling in well F1 may force the solution up through the silicone tube (pvc in older kits) with the U-bend. Add 0,2 mℓ of the acid first to purge the system of air. Thereafter, place the gas collecting tube over the outlet of the U-tube in the plastic cup, and add the remaining acid slowly.

When removing the gas collecting tube from the set-up, push the tube firmly into the lid at the bottom of the plastic cup. You do not need to screw the tube into the lid. Gently lift the tube with the lid out of the cup. The lid does not adhere to the prestik at the bottom of the cup if the procedure is carried out correctly.

4. Cautions

Please remember the following cautions and inform your students of all safety hazards:

Hydrochloric acid is corrosive. If any acid is spilt on the skin, the affected area must immediately be rinsed with copious amounts of water. Severe burns must receive medical attention.

Never point a propette or a syringe containing acid upwards. A momentary lapse of concentration can result in a nasty accident. If any acid is squirted into the eye, immediately rinse the eye out under running water. Always have a dilute solution of sodium hydrogencarbonate (household baking soda), or milk close by to apply to the injury. These substances will help neutralise the acid in the eye. The patient should be referred to a doctor.

Do not allow anyone to bring a flame near the comboplate®. The hydrogen gas generated in well F1 is highly explosive. Ensure that the comboplate® is moved away from all sources of flames before the test for hydrogen is completed.

Never allow the learners to play with matches. Treat any burn with cold running water or ice, and seek medical assistance where necessary.

5. Model Answers to Questions in the Worksheet

It is recommended that learners write down all of the questions and answers in their workbooks. If this is done, then the answers to questions do not have to be in full sentences. If the learners do not copy the questions into their workbooks, then answers should be written in full sentences. Note that some of the questions can only be answered by learners in higher grades. Word equations can be written instead of chemical equations where required.

Q1. What do you observe in well F1 when the hydrochloric acid is added to the zinc powder ?
A1. Bubbles are given off vigorously as a gas is produced.

Q2. Why is it necessary to let a few bubbles emerge from the U-tube before collecting the gas in the gas collecting tube ?
A2. Before the reaction occurred, the silicone tube was filled with air. The first few bubbles which emerged were therefore air.

Q3. What happens to the water in the gas collecting tube as the bubbles of gas enter the tube ?
A3. The water is pushed out of the gas collecting tube.

Q4. What is the term used to describe what happens to the water in Question 3 ?
A4. The downward displacement of water.

Q5. What happens when the flame of the match is held inside the mouth of the gas collecting tube ?
A5. A popping sound is heard as the gas in the tube ignites explosively.

Q6. Can you see anything on the inner rim of the gas collecting tube where the reaction occurred ?
A6. Yes, a clear liquid has formed.

Q7. Is there a change in the appearance of the white copper sulphate ?
A7. Yes, the white copper sulphate becomes blue.

Q8. Write down a word equation for the chemical reaction in well F1 between hydrochloric acid and zinc.
A8. zinc(s) + hydrochloric acid(aq) → hydrogen(g) + zinc chloride(aq)

Q9. What property of the gas collected made it necessary to hold the gas collecting tube upside down ?
A9. Hydrogen is less dense than air. By holding the tube upside down, the gas was less likely to escape.

Q10. Why was there a “pop” sound when the lighted match was brought to the mouth of the gas collecting tube ?
A10. Hydrogen reacts explosively with the oxygen in the air when ignited.

Q11. What product was formed by the chemical reaction mentioned in Question 10 ? Give a reason for your answer.
A11. Water. This was shown when the white copper sulphate crystals became blue in the liquid formed on the inner rim of the gas collecting tube.

Q12. Write down a word equation for the chemical reaction referred to in Questions 10 and 11.
A12. hydrogen(g) + oxygen(g) → water(ℓ)

Q13. What does the term “anhydrous” mean ?
A13. “Anhydrous” means “without water”.

Q14. Why did the white copper sulphate change colour and what is the name of the product formed ?
A14. The white copper sulphate reacted with water and formed blue copper sulphate pentahydrate.

Q15. Write down the balanced chemical equation for the reaction occurring in well F1 between zinc and hydrochloric acid.
A15. $Zn(s) + 2HC\ell(aq) \rightarrow ZnC\ell_2(aq) + H_2(g)$

Q16. Write down the balanced chemical equation for the reaction occurring in the gas collecting tube when the gas produced was tested with the lighted match.
A16. $2H_2(g) + O_2(g) \rightarrow 2H_2O(\ell)$

Q17. Write down the balanced chemical equation for the reaction of the anhydrous copper sulphate with the clear liquid produced in the gas collecting tube.
A17. $CuSO_4(s) + 5H_2O(\ell) \rightarrow CuSO_4.5H_2O(s)$

Q18. Write down the name of the other product formed when zinc reacts with hydrochloric acid.
A18. Zinc chloride.

PREPARATION AND PROPERTIES OF CARBON DIOXIDE

TEACHER GUIDE

1. Chemicals

All of the required chemicals are listed in the worksheet. In Part 3 tap water is also needed.

2. Equipment

Most of the apparatus required can be found in a RADMASTE Basic or Advanced Microchemistry Kit. In Part 2 a drinking straw is also required. The ordinary, long drinking straws may be cut in half for this exercise.

3. Hints

Add the 5.5 M hydrochloric acid ($HC\ell(aq)$) slowly to the calcium carbonate ($CaCO_3(s)$), otherwise the vigorous bubbling in well F1 may force the solution through the silicone tube into well F2.

In Part 2, it is important to remember to blow gently through the drinking straw into the clear limewater. If there is vigorous blowing, the limewater will spill out of well F3 and no effect will be seen.

In Part 4, a burning match must be brought near the opening in lid 1. Make sure that the flame does not touch the lid or the syringe, because these will melt. Make sure that you are holding the flame in position before adding the hydrochloric acid to the calcium carbonate, otherwise all of the carbon dioxide will escape from well F1 before the extinguishing effect of this gas is observed.

4. Cautions

Please remember the following cautions and inform your students of all safety hazards:

Hydrochloric acid is corrosive. If any acid is spilt on the skin, the affected area must immediately be rinsed with copious amounts of water. Severe burns must receive medical attention.

Never point a propette or a syringe containing acid upwards. A momentary lapse of concentration can result in a nasty accident. If any acid is squirted into the eye, immediately rinse the eye out under running water. Always have a dilute solution of sodium hydrogencarbonate (household baking soda), or milk close by to apply to the injury. These substances will help neutralise the acid in the eye. The patient should be referred to a doctor.

Never allow the learners to play with matches. Treat any burn with cold running water or ice, and seek medical assistance where necessary.

5. Model Answers to Questions in the Worksheet

It is recommended that learners write down all of the questions and answers in their workbooks. If this is done, then the answers to questions do not have to be in full sentences. If the learners do not copy the questions into their workbooks, then answers should be written in full sentences. Note that some of the questions can only be answered by learners in higher grades. Word equations can be written instead of chemical equations where required.

PART 1: The Preparation of Carbon Dioxide

Q1. What do you observe in well F1 when hydrochloric acid is added to the calcium carbonate ?
A1. Gas bubbles are vigorously released and a "hissing" sound is heard. This is called <u>effervescence</u>.

Q2. What do you see in well F2 that shows you a gas is being produced ?
A2. Bubbles appear rapidly in the limewater.

Q3. What happens to the clear lime water in well F2 after the gas from well F1 has been bubbled through it ?
A3. The clear limewater becomes milky.

Q4. What must the gas be that was produced by the chemical reaction in well F1 ?
A4. Carbon dioxide.

Q5. Write down a word equation for the reaction that occurred between the hydrochloric acid and calcium carbonate.
A5. Hydrochloric acid(aq) + calcium carbonate(s) → carbon dioxide(g) + water(ℓ) + calcium chloride(aq)

Q6. Write down the chemical equation for the reaction occurring in well F1, but this time use chemical formulae. Balance the chemical equation.
A6. $CaCO_3(s) + 2HC\ell(aq) \rightarrow CO_2(g) + H_2O(\ell) + CaC\ell_2(s)$

Q7. Clear limewater is an aqueous solution of calcium hydroxide ($Ca(OH)_2(aq)$). When carbon dioxide reacts with the limewater, insoluble calcium carbonate and water are formed. Write down a word equation for the reaction of carbon dioxide with limewater.
A7. carbon dioxide(g) + calcium hydroxide(aq) → calcium carbonate(s) + water(ℓ)

Q8. Write down the balanced chemical equation for the reaction described in question 7.
A8. $CO_2(g) + Ca(OH)_2(aq) \rightarrow CaCO_3(s) + H_2O(\ell)$

Q9. From your answer to question 8, identify the substance that caused the milkiness when carbon dioxide was tested with clear limewater. Explain why the limewater became milky.
A9. Calcium carbonate ($CaCO_3(s)$). The calcium carbonate is a white, insoluble solid. The formation of tiny particles of this white solid causes the solution to appear cloudy or milky.

PART 2: The Production of Carbon Dioxide During Respiration

Q1. What happens to the clear limewater when you blow into it ?
A1. The clear limewater turns milky.

Q2. Explain why there is a change in the appearance of the limewater.
A2. There was carbon dioxide in the breath that was exhaled into the clear limewater. The insoluble, white calcium carbonate was produced and caused the solution to appear milky.

Q3. What happens to the clear limewater when air is bubbled through it ?
A3. It slowly turns milky.

Q4. Explain how the experiment shows that carbon dioxide is produced when you respire ("breathe").
A4. The limewater turns milky more quickly when you exhale through it than when air is bubbled through it.

PART 3: Dissolving Carbon Dioxide in Water

Q1. What is the colour of the universal indicator in the tap water in well F2 ?
A1. Green.

Q2. What does this tell you about the pH of the water ? (Look at the pH colour strip in your kit if you are unsure.)
A2. The pH is near to 7. (The water is neutral.)

Q3. What happens in well F2 when the carbon dioxide is bubbled through the water ?
A3. The colour of the universal indicator changes from green to pink/orange.

Q4. What does the colour of the indicator in well F2 tell you about the pH of the water after the $CO_2(g)$ has been bubbled through it ?
A4. The solution is now acidic (pH = 2 to 4).

Q5. What has the $CO_2(g)$ done to make the indicator change colour ?
A5. The carbon dioxide must have dissolved in the water to form an acid.

Q6. When carbon dioxide dissolves in water, some of it reacts with water to form an acid. Write down the word equation for the reaction.
A6. carbon dioxide(g) + water(ℓ) $\rightarrow$ carbonic acid(aq)

Q7. Write down the balanced chemical equation for this reaction.
A7. $CO_2(g) + H_2O(\ell) \rightarrow H_2CO_3(aq)$

Q8. Under pressure, more carbon dioxide dissolves in water to produce a solution called soda water. Can you explain why small gas bubbles are seen and a "fizzing" sound is heard when a bottle of soda water is opened ?
A8. When a bottle of soda water is opened, the pressure inside the bottle is suddenly reduced. The carbon dioxide gas escapes from the water, producing the small bubbles and the "fizzing".

PART 4: The Effect of Carbon Dioxide on Combustion

Q1. What happens to the flame of the match when it is held above the opening of the lid on well F1 ?
A1. The flame is extinguished ("put out").

Q2. Explain your observations in question 1.
A2. The carbon dioxide produced in well F1 escaped from the opening on the lid of well F1 and "put out" the flame.

Q3. Write a statement describing the effect of carbon dioxide on combustion.
A3. Carbon dioxide does not support combustion (i.e. of wood, candle, etc.).

Q4. Carbon dioxide ($CO_2(g)$) is a more dense gas than oxygen ($O_2(g)$). Describe how this property of CO_2, together with the results of this experiment can be used to fight fires. Name one example of fire-fighting apparatus where these two properties of CO_2 have been put to use.
A4. During a fire, the combustion is supported by oxygen in the air. When carbon dioxide is used to fight fires, the carbon dioxide forms a gaseous "blanket" over the burning substances because it is denser than the oxygen. Oxygen is thus prevented from reaching the fire. The carbon dioxide itself does not support combustion. Carbon dioxide is used in fire extinguishers.

THE REACTION OF CARBON WITH OXYGEN

TEACHER GUIDE

1. Chemicals
All of the required chemicals are listed in the worksheet. Tap water is also needed.

2. Equipment
All of the apparatus required can be found in a RADMASTE Basic or Advanced Microchemistry Kit.

3. Hints
Hydrogen peroxide solutions (H_2O_2(aq)) decompose easily. It is therefore recommended that a fresh solution of 10% H_2O_2(aq) be used each time this experiment is performed, otherwise the results may not be as described in the model answers.

Limewater solutions absorb carbon dioxide from the air to form calcium carbonate.

$$Ca(OH)_2(aq) + CO_2(g) \rightarrow CaCO_3(s) + H_2O(\ell)$$

For this reason it is necessary to use fresh limewater in well F6. If you find that the limewater takes a long time to turn cloudy whilst burning the carbon, the solution will have to be replaced.

The inside of the glass tube must be made wet with the cotton wool so as to cause the carbon powder to adhere to the tube. If the tube is dry inside, the oxygen produced in well F1 may blow the carbon along the glass tube and into well F6.

The H_2O_2(aq) must be added slowly to the manganese dioxide (MnO_2(s)) in well F1, because the vigorous evolution of oxygen may cause the solution to shoot up through the silicone tube into the glass tube. At the beginning of the experiment, the carbon should only be heated when a steady stream of bubbles (of oxygen) is observed in the limewater in well F6. During the heating stage, a stream of bubbles must be maintained in well F6. As soon as the bubbles cease, more H_2O_2(aq) must be added to the MnO_2(s) to produce more oxygen. (The addition of 0,2 mℓ increments of H_2O_2(aq) works well.)

When heating the carbon, do not move the microburner from side to side. If the flame is held directly beneath the carbon in the tube, the required reaction temperature will be reached sooner and the limewater will become cloudy within a short time. The carbon does not "burn" as it does when the experiment is performed on a macroscale level. In other words, it does not glow red or catch fire. However, the same reaction as that observed on a macroscale still takes place. The reaction is much slower and as a result, the carbon does not heat up enough to glow.

The carbon is heated further after the limewater has become cloudy to show that, as heating continues, the quantity of carbon becomes less.

4. Cautions
Please remember the following cautions and inform your students of all safety hazards:

Hydrogen peroxide is corrosive. If any H_2O_2(aq) is spilt on the skin, the affected area must immediately be rinsed with copious amounts of water.

Never point a propette or a syringe containing H_2O_2(aq) upwards. A momentary lapse of concentration can result in a nasty accident. If any peroxide is squirted into the eye, immediately rinse the eye out under running water.

Do not allow anyone to bring a flame near the comboplate® or gas collecting tube. These are plastic and will melt.

Never allow the learners to play with matches. Treat any burn with cold running water or ice, and seek medical assistance where necessary.

The methylated spirits used in the microburner is poisonous. Do not inhale the vapour or drink the liquid.

5. Model Answers to Questions in the Worksheet
It is recommended that learners write down all of the questions and answers in their workbooks. If this is done, then the answers to questions do not have to be in full sentences. If the learners do not copy the questions into their workbooks, then answers should be written in full sentences. Note that some of the questions can only be answered by learners in higher grades. Word equations can be written instead of chemical equations where required.

Q1. Describe the appearance of the limewater.
A1. It is clear and colourless.

Q2. Describe the appearance of the limewater in well F6 after about 2 minutes.
A2. The limewater is cloudy.

Q3. What difference is there between the quantity of carbon powder added at the beginning of the experiment, and that left in the tube after heating ?
A3. There is less carbon powder after heating.

Q4. What do you think has happened to the carbon powder in the glass tube during heating ?
A4. The carbon has reacted with the oxygen produced in well F1 to form a new product.

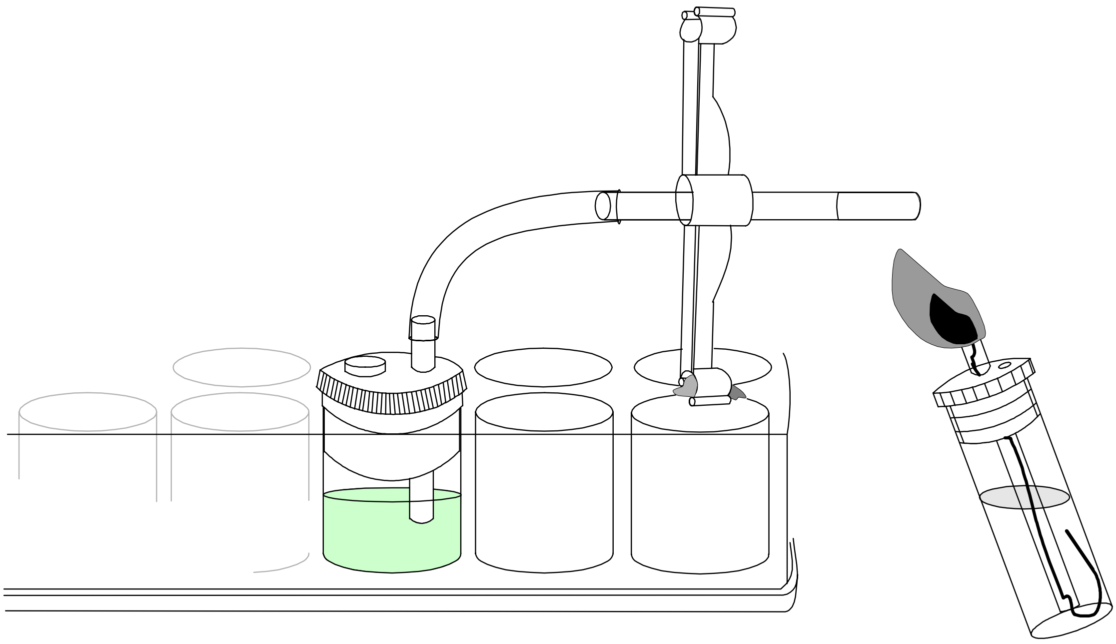
Q5. What caused the change in appearance of the limewater ?
A5. The product formed when carbon burns in oxygen is carbon dioxide gas. We know this because the gas bubbles that formed in well F6 caused the limewater to become milky.

Q6. How do you know that the gas bubbles that caused the limewater to change were not oxygen bubbles formed in well F1 ?
A6. Only carbon dioxide causes limewater to become milky. This is the positive test for carbon dioxide. (The oxygen test involves placing a glowing splint into a gas and observing if the splint bursts into flame. If it does, then the gas is oxygen.)

Q7. Write a word equation for the combustion of carbon in oxygen.
A7. oxygen(g) + carbon(s) → carbon dioxide(g)

Q8. Write a balanced chemical equation for the combustion of carbon in oxygen.
A8. $O_2(g) + C(s) \rightarrow CO_2(g)$

MICROCHEMISTRY
CHAPTER II



REACTION OF COPPER WITH OXYGEN

TEACHER GUIDE

1. Chemicals
All of the required chemicals are listed in the worksheet. Tap water is also needed.

2. Equipment
All of the apparatus required can be found in a RADMASTE Basic or Advanced Microchemistry Kit.

3. Hints
Hydrogen peroxide solutions (H_2O_2(aq)) decompose easily. It is therefore recommended that a fresh solution of 10% H_2O_2(aq) be used each time this experiment is performed. If this is not possible, the teacher should try the experiment before introducing it to the learners so as to determine whether more than 0,5 mℓ of H_2O_2(aq) is required at step 6. It may be necessary to obtain a fresh solution of hydrogen peroxide if the rate of oxygen production is too low.

Use the narrow end of the plastic spatula to place only a small quantity of copper powder into the glass tube. Do not heap the powder onto the spatula.

When heating the copper, do not move the microburner from side to side. Ensure that the lids are placed securely on the appropriate wells, otherwise the H_2O_2(aq) may be forced through the glass tube and the experiment will need to be repeated.

If the rate at which the bubbles of oxygen appear in the water in well F1 is low, more than 0,5 mℓ of the H_2O_2(aq) is required. However, **the syringe must not be removed from the syringe inlet on lid 1 until the oxygen bubbles in well F1 are no longer detected, as this will cause water in well F1 to be sucked back through the glass tube.** When the bubbles have stopped appearing, the syringe may be removed and refilled to repeat the experiment.

4. Cautions
Please remember the following cautions and inform your students of all safety hazards:

Hydrogen peroxide is corrosive. If any H_2O_2(aq) is spilt on the skin, the affected area must immediately be rinsed with copious amounts of water.

Never point a propette or a syringe containing H_2O_2(aq) upwards. A momentary lapse of concentration can result in a nasty accident. If any peroxide is squirted into the eye, immediately rinse the eye out under running water.

Do not allow anyone to bring a flame near the comboplate® or gas collecting tube. These are plastic and will melt.

Never allow the learners to play with matches. Treat any burn with cold running water or ice, and seek medical assistance where necessary.

The methylated spirits used in the microburner is poisonous. Do not inhale the vapour or drink the liquid.

5. Model Answers to Questions in the Worksheet
It is recommended that learners write down all of the questions and answers in their workbooks. If this is done, then the answers to questions do not have to be in full sentences. If the learners do not copy the questions into their workbooks, then answers should be written in full sentences. Note that some of the questions can only be answered by learners in higher grades. Word equations can be written instead of chemical equations where required.

Q1. Describe the appearance of the copper powder.
A1. It has a red-brown colour.

Q2. What happens when 10% hydrogen peroxide solution is added to well F6 ?
A2. Bubbling occurs as the hydrogen peroxide is decomposed into oxygen and water.

Q3. Why was it necessary to wait for the first few bubbles to come through before heating the glass tube ?
A3. This is to purge the glass tube of the air inside. This is to observe what effect the oxygen alone has on the copper powder.

Q4. What is happening to the copper powder during heating ? Describe any other changes in the glass tube.
A4. The powder changes colour. No other changes can be seen.

Q5. From your observations of the powder in the glass tube, would you say a chemical reaction occurred ? Explain your answer.

A5. Yes. The copper powder changed colour when heated in the presence of oxygen. When the heating stopped the black colour remained.

Q6. What product is formed when copper burns in oxygen ?

A6. Copper oxide or copper(II) oxide.

Q7. Write a word equation for the combustion of copper in oxygen.

A7. copper(s) + oxygen(g) → copper(II) oxide(s)

Q8. Write a balanced chemical equation for the combustion of copper in oxygen.

A8. $2Cu(s) + O_2(g) \rightarrow 2CuO(s)$

Q9. How would you try to prove that the product formed in this experiment is indeed copper(II) oxide ? Suggest an experimental set-up to perform this experiment.

A9. Copper(II) oxide powder is black. The product produced in this experiment is also black. When copper(II) oxide is heated in the presence of hydrogen (in the same experimental set-up as before), then the following reaction occurs:

$$CuO(s) + H_2(g) \rightarrow Cu(s) + H_2O(\ell)$$

The colour of the powder changes to reddish-brown and water vapour condenses further along the glass tube. The presence of this water could be confirmed by testing it with white anhydrous copper sulphate which should turn blue when hydrated.

If the black product produced here was reacted with hydrogen, as mentioned above, and underwent the same colour change as the copper(II) oxide powder did and produced water, then this would be evidence that the black product was indeed copper(II) oxide.

THE REACTION OF SULPHUR WITH OXYGEN

TEACHER GUIDE

1. Chemicals
All of the required chemicals are listed in the worksheet. Tap water is also needed.

2. Equipment
All of the apparatus required can be found in a RADMASTE Basic or Advanced Microchemistry Kit.

3. Hints
Hydrogen peroxide solutions (H_2O_2(aq)) decompose easily. It is therefore recommended that a fresh solution of 10% H_2O_2(aq) be used each time this experiment is performed, otherwise the results may not be as described in the model answers.

The H_2O_2(aq) must be added slowly to the manganese dioxide (MnO_2(s)) in well F1, because the vigorous evolution of oxygen may cause the solution to shoot up through the silicone tube into the glass tube. At the beginning of the experiment, the sulphur should only be heated when a steady stream of bubbles (of oxygen) is observed in the water in well F6. During the heating stage, a stream of bubbles must be maintained in well F6. Sulphur burns in air with a blue flame; you must ensure that oxygen is flowing over the sulphur during heating otherwise **no blue flame will be seen.** As soon as the bubbles cease, more H_2O_2(aq) must be added to the MnO_2(s) to produce more oxygen.(The addition of 0,2 mℓ increments of H_2O_2(aq) works well.)

Sometimes, the sulphur vapour that forms in the tube will catch fire. A blue flame will shoot across the tube with a sharp “popping” sound (almost like lightening!).

When heating the sulphur, do not move the microburner from side to side. If the flame is held directly beneath the sulphur in the tube, the required reaction temperature will be reached sooner and the indicator solution in well F6 will change colour within a short time.

4. Cautions
Please remember the following cautions and inform your students of all safety hazards:

Hydrogen peroxide is corrosive. If any H_2O_2(aq) is spilt on the skin, the affected area must immediately be rinsed with copious amounts of water.

Never point a propette or a syringe containing H_2O_2(aq) upwards. A momentary lapse of concentration can result in a nasty accident. If any peroxide is squirted into the eye, immediately rinse the eye out under running water.

Do not allow anyone to bring a flame near the comboplate® or gas collecting tube. These are plastic and will melt.

Never allow the learners to play with matches. Treat any burn with cold running water or ice, and seek medical assistance where necessary.

The methylated spirits used in the microburner is poisonous. Do not inhale the vapour or drink the liquid.

Sulphur dioxide fumes are poisonous and choking. Make sure that learners do not inhale the vapour directly.

5. Model Answers to Questions in the Worksheet
It is recommended that learners write down all of the questions and answers in their workbooks. If this is done, then the answers to questions do not have to be in full sentences. If the learners do not copy the questions into their workbooks, then answers should be written in full sentences. Note that some of the questions can only be answered by learners in higher grades. Word equations can be written instead of chemical equations where required.

Q1 Write down the colour of the indicator in the tap water. Describe the water as acidic, basic or neutral.
A1. The indicator is green. The tap water is neutral.

Q2. What do you observe in the glass tube while heating the sulphur ?
A2. The yellow powder changed into a yellow liquid. The yellow liquid then became a red-orange colour. Eventually, all the liquid disappeared and a yellow-white vapour moved along the tube. The sulphur burned with a blue flame.

Q3. Describe the smell that comes from the vent in well F6.
A3. A strong, choking smell.

Q4. What is the colour of the indicator solution in well F6 after the experiment ?
A4. Red/pink.

Q5. Why did the indicator change colour ?

A5. The gaseous product dissolved in the water, causing it to become acidic. The indicator became red, because this is the colour of the indicator in acidic solution.

Q6. Write a word equation for the combustion of sulphur in oxygen.

A6. oxygen(g) + sulphur(s) $\rightarrow$ sulphur dioxide(g)

Q7. Some carbon fuels, such as coal, contain sulphur as an impurity. When these fuels burn they form sulphur dioxide. Using the observations in the above experiment with the universal indicator, explain how the burning of sulphur in the environment can contribute to the problem of acid rain.

A7. When the sulphur dioxide formed in the above reaction dissolved in the water in well F6, the water became acidic. Similarly, sulphur dioxide arising from the burning of sulphur in the environment can dissolve in falling rain to form an acid. This "acid rain" has detrimental effects on plant and animal life.

THE REACTION OF MAGNESIUM WITH OXYGEN

TEACHER GUIDE

1. Chemicals
All of the required chemicals are listed in the worksheet. Tap water is also needed.

2. Equipment
All of the apparatus required can be found in a RADMASTE Basic or Advanced Microchemistry Kit.

3. Hints
Hydrogen peroxide solutions (H_2O_2(aq)) decompose easily. It is therefore recommended that a fresh solution of 10% H_2O_2(aq) be used each time this experiment is performed, otherwise the results may not be as described in the model answers.

The H_2O_2(aq) must be added slowly to the manganese dioxide (MnO_2(s)) in well F1, because the vigorous evolution of oxygen may cause the solution to shoot up through the silicone tube into the glass tube. During the heating stage, a steady stream of bubbles must be maintained in well F6. As soon as the bubbles cease, more H_2O_2(aq) must be added to the MnO_2(s) to produce more oxygen. (The addition of 0,2 mℓ increments of H_2O_2(aq) works well.)

When heating the magnesium, do not move the microburner from side to side. If the flame is held directly beneath the magnesium in the tube, the required reaction temperature will be reached sooner and the brilliant white light will be seen within a short time.

The brilliant white flame with which magnesium burns does not blind one, as is the case with the macroscale version of the experiment. Learners can therefore observe the contents of the glass tube without looking away.

When the solid, white magnesium oxide is mixed with water, it does not dissolve immediately. For this reason, the universal indicator solution appears green when first added to well E3. The MgO(s) dissolves slowly in the water, causing the indicator to change to a purple or violet colour as basic magnesium hydroxide is formed.

$$MgO(s) + H_2O(\ell) \rightarrow Mg(OH)_2(aq)$$

4. Cautions
Please remember the following cautions and inform your students of all safety hazards:

Hydrogen peroxide is corrosive. If any H_2O_2(aq) is spilt on the skin, the affected area must immediately be rinsed with copious amounts of water.

Never point a propette or a syringe containing H_2O_2(aq) upwards. A momentary lapse of concentration can result in a nasty accident. If any peroxide is squirted into the eye, immediately rinse the eye out under running water.

Do not allow anyone to bring a flame near the comboplate® or gas collecting tube. These are plastic and will melt.

Never allow the students to play with matches. Treat any burn with cold running water or ice, and seek medical assistance where necessary.

The methylated spirits used in the microburner is poisonous. Do not inhale the vapour or drink the liquid.

5. Model Answers to Questions in the Worksheet
It is recommended that learners write down all of the questions and answers in their workbooks. If this is done, then the answers to questions do not have to be in full sentences. If the learners do not copy the questions into their workbooks, then answers should be written in full sentences. Note that some of the questions can only be answered by learners in higher grades. Word equations can be written instead of chemical equations where required.

Q1. Describe the appearance of the magnesium powder.
A1. It is silvery-grey.

Q2. What did you observe in the glass tube while heating the magnesium in oxygen ?
A2. The silver-grey powder began to darken. The powder then burst into flame. The flame was brilliant white in colour. With continued heating, white sparks were given off. A white cloud formed in the tube. (This may not be easily detected as the cloud quickly deposits as a white solid on the glass.)

Q3. What do you see inside the glass tube after heating ? (Note: it is usual for a black residue to form at the bottom of the glass tube where the microburner was held, but this is not part of the product.)

A3. There is a white powder in the glass tube where the magnesium was originally placed. The wall of the glass tube surrounding the powder has a solid, white deposit which makes it appear cloudy.

Q4. What is the colour of the universal indicator solution in well E3 ?

A4. Green.

Q5. What is the colour of the indicator solution in well E3 after about 5 minutes ?

A5. Purple or violet.

Q6. Is the solution of the product acidic or basic ?

A6. Basic.

Q7. What product is formed when magnesium burns in oxygen ?

A7. Magnesium oxide.

Q8. Why did the indicator in well E3 change colour ?

A8. The solid product dissolved slowly in the water, causing it to become basic. The indicator turned purple, because this is the colour of the indicator in basic solution.

Q9. Write a word equation for the combustion of magnesium in oxygen.

A9. oxygen(g) + magnesium(s) → magnesium oxide(s)

Q10. Write a balanced chemical equation for the combustion of magnesium in oxygen.

A10. $O_2(g) + 2Mg(s) \rightarrow 2MgO(s)$

DECOMPOSITION OF COPPER CARBONATE

TEACHER GUIDE

1. Chemicals

All of the required chemicals are listed in the worksheet. For the test in step 2, most acids of various concentrations can be used. The copper(II) carbonate, however, does not react with dilute hydrochloric acid. It does react with dilute sulphuric acid.

2. Equipment

All of the apparatus required can be found in a RADMASTE Advanced Microchemistry Kit.

3. Hints

The copper carbonate decomposes at high temperatures. It is, therefore, important to concentrate on heating the copper carbonate and avoid heating and then melting the silicone tube.

When heating the copper(II) carbonate, carbon dioxide gas is released and this tends to push copper(II) carbonate solid into the silicone tube. That is why you are advised to leave space above the solid to allow the gas released to move in the space created, towards the microwell through the silicone tube. Care should be taken that the space is available by consistently tapping the glass tube containing the copper(II) carbonate.

The first few bubbles that come out in well F4 are not carbon dioxide yet. They contain air that was trapped in the silicone tube as well as the glass tube.

Once heating is completed/discontinued, the limewater in well F4 moves up the silicone tube as the gas in the fusion tube contracts on cooling. As it does so the limewater absorbs the carbon dioxide in the tube, thus further reducing the volume of gas. The limewater moves up and absorbs more carbon dioxide. If the silicone tube is not disconnected from the glass tube at the right moment, the limewater may eventually move through to the glass tube. The glass tube might break if it is still hot.

When the silicone tube is disconnected, the limewater flows back into well F4. It can then be easily seen that it has become milky.

4. Cautions

Please remember the following cautions and inform your students of all safety hazards:

Sulphuric acid is corrosive. If any acid is spilt on the skin, the affected area must immediately be rinsed with copious amounts of water. Severe burns must receive medical attention.

Never point a propette or a syringe containing acid upwards. A momentary lapse of concentration can result in a nasty accident. If any acid is squirted into the eye, immediately rinse the eye out under running water. Always have a dilute solution of sodium hydrogencarbonate (household baking soda), or milk close by to apply to the injury. These substances will help neutralise the acid in the eye. The patient should be referred to a doctor.

Never allow the learners to play with matches. Treat any burn with cold running water or ice, and seek medical assistance where necessary.

5. Model Answers to Questions in the Worksheet

It is recommended that learners write down all of the questions and answers in their workbooks. If this is done, then the answers to questions do not have to be in full sentences. If the learners do not copy the questions into their workbooks, then answers should be written in full sentences. Note that some of the questions can only be answered by learners in higher grades. Word equations can be written instead of chemical equations where required.

Q1. What colour is $CuCO_3$(s) ?
A1. Pale green.

Q2. What happens in well A1 ? Explain your observation.
A2. There is bubbling, which suggests that a gas is produced. A greenish-yellow solid remains.

Q3. What do you observe in well F4 ?
A3. Bubbles are given off.

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Q4. What colour is the solid remaining in the fusion tube ?
A4. Black.

Q5. What happens in well F4 ?
A5. The limewater turns cloudy as the liquid goes back into the well.

Q6. What is responsible for your observation in well F4 ?
A6. Carbon dioxide turns limewater milky (this is a test for carbon dioxide).

Q7. What happens in well A2 ?
A7. Nothing happens.

Q8. What is the name of the solid remaining in the fusion tube after heating ?
A8. Copper(II) oxide.

Q9. Explain why your observation in Q7 is different from your observation in Q2.
A9. In Q2 sulphuric acid reacted with the solid copper(II) carbonate to form carbon dioxide gas as one of the products, which was given off. In Q7 no gas was given off. The copper carbonate decomposed on heating: carbon dioxide was given off during heating. The black colour of the residue suggests it is copper oxide. This does not react with the acid.

Q10. Write a word equation for the reaction that took place in this experiment. Beneath each substance write the colour.
A10. copper(II) carbonate(s) → copper(II) oxide(s) + carbon dioxide(g)
Pale green black colourless

Q11. Write a chemical formula equation for the reaction in Q10 above.
A11. $CuCO_3(s) \rightarrow CuO(s) + CO_2(g)$

DECOMPOSITION OF AMMONIUM CARBONATE

TEACHER GUIDE

1. Chemicals
All of the required chemicals are listed in the worksheet. Any other indicator whose pH range is known, can be used in this experiment.

2. Equipment
All of the apparatus required can be found in a RADMASTE Advanced Microchemistry Kit.

3. Hints
Learners can be asked to smell the ammonium carbonate in its container. Care should be taken when smelling the ammonium carbonate that the vapour is not inhaled in large quantities. One can smell by waving a hand above an open container towards the nose. The odour can be discussed at the end of the experiment or even be referred to at a later stage. It is the smell of ammonia. It smells because ammonium carbonate decomposes even at low temperatures into ammonia and carbon dioxide. The learners can be told to remember the smell for the identification of ammonia.

When heating the ammonium carbonate in the fusion tube, try heating from the bottom of the tube. Heating the tube close to the mouth might melt the silicone tube and/or the microstand arms into which the silicone tube is placed.

When heating is completed and/or stopped, the water in well F4 tends to rise up the silicone tube. Do not let the water go into the fusion tube as the fusion tube might break if it is still hot.

4. Cautions
Please remember the following cautions and inform your students of all safety hazards:

Ammonia produced from the decomposition of ammonium carbonate, is a toxic gas. Avoid inhaling large quantities of the fumes. Make sure the experiment is performed in a well ventilated room.

Never allow the learners to play with matches. Treat any burn with cold running water or ice, and seek medical assistance where necessary.

5. Model Answers to Questions in the Worksheet
It is recommended that learners write down all of the questions and answers in their workbooks. If this is done, then the answers to questions do not have to be in full sentences. If the learners do not copy the questions into their workbooks, then answers should be written in full sentences. Note that some of the questions can only be answered by learners in higher grades. Word equations can be written instead of chemical equations where required.

Q1. What colour is the universal indicator before adding it to water ?
A1. Orange.

Q2. What colour is the universal indicator after adding it to water ?
A2. Green.

Q3. What happens in well F4 as heating is continued ?
A3. Bubbles can be seen.

Q4. What happens in the fusion tube as heating is continued ?
A4. Bubbling and presence of a liquid in the fusion tube which could suggest that a gas and some water are produced.

Q5. What colour is the mixture in well F4 ?
A5. Purple.

Q6. Is the mixture in well F4 acidic or basic after heating ?
A6. Basic.

Q7. Why did the mixture in well F4 go basic ?
A7. The gas that bubbled through it is basic.

Q8. What do you smell ?
A8. Ammonia.

Q9. What remains in the fusion tube ?
A9. Nothing remains in the fusion tube.

Q10. Write a formula equation for the reaction in this experiment.
A10. $(NH_4)_2CO_3(s) \rightarrow 2NH_3(g) + CO_2(g) + H_2O(\ell)$

REDUCTION OF COPPER(II) OXIDE

TEACHER GUIDE

1. Chemicals

All of the required chemicals are listed in the worksheet. Tap water is also needed. Note that in an older version of the worksheet, a zinc or galvanised iron coil was reacted with the hydrochloric acid. The coil has now been replaced with zinc powder.

2. Equipment

All of the apparatus required can be found in a RADMASTE Basic or Advanced Microchemistry Kit.

3. Hints

Make sure that the glass tube containing the copper oxide powder (CuO(s)) is held in a horizontal position when connecting it to the silicone tubes. If the glass tube is tilted, the CuO(s) will spill into well F1 or well F6, making it necessary to restart the experiment.

Add the 5.5 M $HC\ell(aq)$ slowly to the zinc in well F1, otherwise the vigorous bubbling in well F1 may force the solution up through the silicone tube and over the CuO(s) in the glass tube. Ensure that the lids are securely placed on wells F1 and F6 to prevent acid spillage, as well as hydrogen gas leaking from well F1.

Do not move the microburner from side to side when heating. Keeping the flame at one position allows the CuO powder to reach the required reaction temperature quickly. For this reason, it is also not necessary to use a large quantity of powder in the glass tube.

As soon as the glass tube has cooled, take the apparatus apart and thoroughly rinse the comboplate® with water.

Most of the copper that adheres to the inner walls of the glass tube can be scraped off with a toothpick, match or piece of wire. Stubborn deposits in the glass tube may need to be removed with concentrated hydrochloric acid or nitric acid. If the copper has interacted with the glass in such a way that it cannot be removed, the tube will have to be replaced.

4. Cautions

Please remember the following cautions and inform your students of all safety hazards:

Hydrochloric acid is corrosive. If any acid is spilt on the skin, the affected area must immediately be rinsed with copious amounts of water. Severe burns must receive medical attention.

Never point a propette or a syringe containing acid upwards. A momentary lapse of concentration can result in a nasty accident. If any acid is squirted into the eye, immediately rinse the eye out under running water. Always have a dilute solution of sodium hydrogencarbonate (household baking soda), or milk close by to apply to the injury. These substances will help neutralise the acid in the eye. The patient should be referred to a doctor.

Do not allow anyone to bring a flame near the vent in well F1. The hydrogen gas generated in well F1 is highly explosive. Ensure that the comboplate® is moved away from all sources of flames after the copper has formed.

Never allow the learners to play with matches. Treat any burn with cold running water or ice, and seek medical assistance where necessary.

The methylated spirits used in the microburner is poisonous. Do not inhale the vapour or drink the liquid.

5. Model Answers to Questions in the Worksheet

It is recommended that learners write down all of the questions and answers in their workbooks. If this is done, then the answers to questions do not have to be in full sentences. If the learners do not copy the questions into their workbooks, then answers should be written in full sentences. Note that some of the questions can only be answered by learners in higher grades. Word equations can be written instead of chemical equations where required.

Q1. What happens when 5.5 M $HC\ell(aq)$ is added to well F1 ?
A1. Bubbles can be seen in the solution.

Q2. Why was it necessary to wait for the first few bubbles to come through before heating the glass tube ?
A2. So that all the air is purged (pushed out) from the system.

Q3. What has happened to the CuO(s) ?
A3. The black copper oxide (CuO(s)) changed colour to brown.

Q4. Describe any other changes in the glass tube.
A4. Some colourless liquid can be seen near the silicone tube connected to lid 2 on well F6.

Q5. From your observations of the solid in the glass tube, would you say a chemical reaction occurred ? Explain your answer.
A5. Yes, because the black solid changed to a brown solid.

Q6. What do you think the products of this reaction are ?
A6. The brown solid may be copper. Some colourless liquid forms in a cooler part of the tube. This liquid may be water.

Q7. Write down the equation for the chemical reaction in which hydrogen was formed, starting with Zn(s) and HCℓ(aq).
A7. $Zn(s) + 2HC\ell(aq) \rightarrow ZnC\ell_2(aq) + H_2(g)$

Q8. How could we test if hydrogen gas ($H_2(g)$) is really being produced ?
A8. We could trap the gas which does come off and burn it in air. If this gas is hydrogen, then a characteristic popping sound will be made.

Q9. Write down the chemical equation for the reaction of copper oxide (CuO(s)) which you think occurred.
A9. $CuO(s) + H_2(g) \rightarrow Cu(s) + H_2O(\ell)$

Q10. Suggest how you could prove that water is a product of the reaction.
A10. To test if water was being produced, one should firstly eliminate the possibility of water being present in the hydrogen generated from the Zn/HCℓ mixture. To do this, the hydrogen must be passed through sulphuric acid to "dry" it. The dry hydrogen can then be passed into the one end of the glass tube containing the copper oxide (CuO(s)).

Anhydrous copper sulphate ($CuSO_4(s)$), which has a grey-white colour, could be added near the other end of the glass tube. Any water produced by the reduction of copper oxide (CuO(s)) to copper (Cu(s)), would then react with this anhydrous copper sulphate ($CuSO_4(s)$) and form the familiar blue hydrated copper sulphate ($CuSO_4.5H_2O(s)$).

ACID/BASE TITRATION – AN INTRODUCTION

TEACHER GUIDE

1. Chemicals
All of the required chemicals are listed in the worksheet. Tap water is required.

2. Equipment
All of the apparatus required can be found in a RADMASTE Basic or Advanced Microchemistry Kit.

3. Hints
The acids required for this experiment are 0.10 M hydrochloric acid and 0.10 M sulphuric acid. Hydrochloric acid ($HC\ell$) is a monoprotic acid and sulphuric acid (H_2SO_4) is diprotic. The students must deduce this from their results. It is therefore suggested that the teacher decants the 0.1 M $HC\ell$(aq) and 0.1 M H_2SO_4(aq) into clean bottles labelled “Acid A” and “Acid B” respectively. Alternatively, the existing labels on the acid bottles could be replaced with “Acid A” and “Acid B” labels.

The narrow end of the plastic microspatula must be used to stir the solutions during the titrations. This will allow the end point to be determined more accurately, otherwise more drops of sodium hydroxide (NaOH(aq)) than necessary will be added to the acid before the indicator changes colour. Make sure that the microspatula is cleaned before stirring a different solution.

4. Cautions
Please remember the following cautions and inform your students of all safety hazards:

Hydrochloric acid and sulphuric acid are corrosive. If any acid is spilt on the skin, the affected area must immediately be rinsed with copious amounts of water.

Sodium hydroxide is a corrosive base and any spills on the skin must be treated by rinsing with water.

Never point a propette or a syringe containing acid or base upwards. A momentary lapse of concentration can result in a nasty accident. If any acid or base is squirted into the eye, immediately rinse the eye out under running water. In the case of acids, always have a dilute solution of sodium hydrogencarbonate (household baking soda), or milk close by to apply to the injury. These substances will help neutralise the acid in the eye. The patient should be referred to a doctor.

5. Model Answers to Questions in the Worksheet
It is recommended that learners write down all of the questions and answers in their workbooks. If this is done, then the answers to questions do not have to be in full sentences. If the learners do not copy the questions into their workbooks, then answers should be written in full sentences. Note that some of the questions can only be answered by learners in higher grades. Word equations can be written instead of chemical equations where required.

Q1. Note the colour of the solution in well A1.
A1. Yellow/Orange.

Q2. Note the colour of the solution in well A2.
A2. Red.

Q3. Prepare a table like Table 1 below, and enter the number of drops.
A3. TABLE 1.

Acid Used	Number of Drops of Acid A	Number of Drops of NaOH	Average No. of Drops NaOH
A	5 5 5	**5** **5** **5**	**5**

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Q4. Prepare a table like Table 2 below, and enter the number of drops.

A4. TABLE 2.

Acid Used	Number of Drops of Acid B	Number of Drops of NaOH	Average No. of Drops of NaOH
B	5 5 5	**10** **10** **10**	**10**

Q5. What is the volume ratio of NaOH/acid A in the titration of 0.10 M acid A ?

A5. 1:1.

Q6. What is the volume ratio of NaOH/acid B in the titration of 0.10 M acid B ?

A6. 2:1.

Q7. Compare your answers to questions 5 and 6 above and then explain these results.

A7. The volume of the 0.10 M sodium hydroxide solution required to titrate acid B was twice that required for acid A. Since the volume and concentration of both acids is the same, this indicates that every molecule of acid A is a source of one hydrogen ion or proton (monoprotic) while every molecule of acid B is a source of two hydrogen ions or protons (diprotic). Examples of formulae of two such possible acids are: $HC\ell$ and H_2SO_4.

THE EFFECT OF DILUTE ACIDS AND ALKALIS ON INDICATORS

TEACHER GUIDE

1. Chemicals
All of the required chemicals are listed in the worksheet. Tap water is also needed.

2. Equipment
All of the apparatus required can be found in a RADMASTE Basic or Advanced Microchemistry Kit. A sheet of white paper is required onto which the comboplate® is placed to allow for the indicator colours to be observed clearly.

3. Hints
Learners must take care not to drop any of the acids or base into the other wells, as this will cause misleading colour changes with the indicator solutions and indicator paper used.

4. Cautions
Please remember the following cautions and inform your students of all safety hazards:

Hydrochloric acid and sulphuric acid are corrosive. If any acid is spilt on the skin, the affected area must immediately be rinsed with copious amounts of water. Severe burns must receive medical attention.

Sodium hydroxide is a corrosive base and any spills on the skin must be treated by rinsing with water.

Never point a propette or a syringe containing acid or base upwards. A momentary lapse of concentration can result in a nasty accident. If any acid or base is squirted into the eye, immediately rinse the eye out under running water. In the case of acids, always have a dilute solution of sodium hydrogencarbonate (household baking soda), or milk close by to apply to the injury. These substances will help neutralise the acid in the eye. The patient should be referred to a doctor.

5. Model Answers to Questions in the Worksheet
It is recommended that learners write down all of the questions and answers in their workbooks. If this is done, then the answers to questions do not have to be in full sentences. If the learners do not copy the questions into their workbooks, then answers should be written in full sentences. Note that some of the questions can only be answered by learners in higher grades. Word equations can be written instead of chemical equations where required.

Q1. Prepare a table like the one shown below.
A1. See Table 1.

Q2. Complete the table.
A2. Table 1

	In $HC\ell(aq)$	In $H_2SO_4(aq)$	In NaOH(aq)	In Tap Water
Colour of Universal Indicator	**red**	**red**	**blue**	**green**
Colour of Methyl Orange	**red**	**red**	**orange-yellow**	**orange**
Colour of Universal Indicator Paper	**red**	**red**	**blue**	**orange**

Q3. What did you see happen in this experiment ?
A3. The indicators changed colour in the different solutions.

Q4. Use the information on the pH indicator strip to classify the substances as “acidic”, “neutral” or “alkaline”.
A4. Acidic: hydrochloric acid and sulphuric acid
Neutral: tap water
Alkaline: sodium hydroxide solution

Q5. Discuss in your group: What do the words “indicator” and “to indicate” mean in everyday use ? Think of some everyday examples of where we use the words.
A5. The words “to indicate” mean “to show”: the car’s left indicator light is on — this shows that it is going to turn left.

Q6. Discuss in your group: Based on the experiment you have completed, formulate a definition for an indicator.
A6. An indicator is .... **a chemical substance that changes colour to show whether a substance it is in contact with is acidic, alkaline or neutral.**

THE REACTION OF SULPHURIC ACID WITH COPPER(II) OXIDE

TEACHER GUIDE

1. Chemicals
All of the required chemicals are listed in the worksheet. Tap water is also needed.

2. Equipment
Most of the apparatus required can be found in a RADMASTE Basic or Advanced Microchemistry Kit.

3. Hints
The end of the glass rod must be gently heated in the flame of the microburner by moving it through the flame a few times. The rod must not be left in the flame too long as the end will get so hot that the solution in well F1 boils. This may result in loss of the dissolved copper sulphate as some of the solution splashes out of the well.

4. Cautions
Please remember the following cautions and inform your students of all safety hazards:

Sulphuric acid is corrosive. If any acid is spilt on the skin, the affected area must immediately be rinsed with copious amounts of water. Severe burns must receive medical attention.

Never point a propette or a syringe containing acid upwards. A momentary lapse of concentration can result in a nasty accident. If any acid is squirted into the eye, immediately rinse the eye out under running water. Always have a dilute solution of sodium hydrogencarbonate (household baking soda), or milk close by to apply to the injury. These substances will help neutralise the acid in the eye. The patient should be referred to a doctor.

Never allow the learners to play with matches. Treat any burn with cold running water or ice, and seek medical assistance where necessary.

5. Model Answers to Questions in the Worksheet
It is recommended that learners write down all of the questions and answers in their workbooks. If this is done, then the answers to questions do not have to be in full sentences. If the learners do not copy the questions into their workbooks, then answers should be written in full sentences. Note that some of the questions can only be answered by learners in higher grades. Word equations can be written instead of chemical equations where required.

Q1. What is the colour of the copper(II) oxide **?**
A1. Black.

Q2. What happens in well F1 after some time ?
A2. The colour of the solution changes to blue.

Q3. What ions give this colour to the solution ?
A3. Cu^{2+} ions.

Q4. What do you notice in well F1 after leaving the comboplate® overnight ?
A4. Blue crystals formed.

Q5. What is this substance in F1 ?
A5. Copper sulphate crystals ($CuSO_4$(s)). (NB: Actually, they are copper sulphate pentahydrate crystals, $CuSO_4.5H_2O$. However teachers may wish to use the simpler name and formula.)

Q6. The other product of the reaction in F1 evaporated when you heated the solution and left the comboplate® overnight. What could this possibly be ?
A6. Water.

Q7. Write a word equation for the chemical reaction that took place in well F1.
A7. Sulphuric acid(aq) + copper(II) oxide(s) $\rightarrow$ copper sulphate(aq) + water(ℓ)

Q8. Look at the name of the crystals that formed in this reaction. It is called a SALT. This salt was prepared by the reaction between an acid and a metal oxide. What part of the name of the salt comes from the metal oxide ?
A8. The "copper" part of the name copper sulphate.

Q9. What part of the name of the salt comes from the acid used in the reaction ?
A9. The "sulphate" part of the name comes from the sulphuric acid used in the reaction.

Q10. What difference would it make if you used hydrochloric acid instead of sulphuric acid in the reaction ?
A10. The salt formed would be copper chloride.

THE REACTION OF ACIDS WITH SODIUM HYDROXIDE

TEACHER GUIDE

1. Chemicals
All of the required chemicals are listed in the worksheet. Tap water is also needed.

2. Equipment
Most of the apparatus required can be found in a RADMASTE Basic or Advanced Microchemistry Kit. A sheet of paper is needed, onto which the comboplate® can be placed to show up colour changes better.

3. Hints
Learners must ensure that they do not contaminate the sulphuric acid solution. The syringe should be rinsed with tap water and dried thoroughly after hydrochloric acid is added to well F3.

It is essential to add the sodium hydroxide solution drop by drop at steps 8 and 9 in the procedure, and to stir between each drop added. It is often the case that the acid solution in a well only changes colour at the point where the drop of sodium hydroxide has been added. If the solution is not stirred to allow for mixing of the sodium hydroxide with the acid, the learner may add too many drops of the sodium hydroxide solution to wells F3 and F4 before realising that the solution in the well has already changed colour.

4. Cautions
Please remember the following cautions and inform your students of all safety hazards:

Hydrochloric acid and sulphuric acid are corrosive. If any acid is spilt on the skin, the affected area must immediately be rinsed with copious amounts of water. Severe burns must receive medical attention.

Sodium hydroxide is a corrosive base and any spills on the skin must be treated by rinsing with water.

Never point a propette or a syringe containing acid or base upwards. A momentary lapse of concentration can result in a nasty accident. If any acid or base is squirted into the eye, immediately rinse the eye out under running water. In the case of acids, always have a dilute solution of sodium hydrogencarbonate (household baking soda), or milk close by to apply to the injury. These substances will help neutralise the acid in the eye. The patient should be referred to a doctor.

5. Model Answers to Questions in the Worksheet
It is recommended that learners write down all of the questions and answers in their workbooks. If this is done, then the answers to questions do not have to be in full sentences. If the learners do not copy the questions into their workbooks, then answers should be written in full sentences. Note that some of the questions can only be answered by learners in higher grades. Word equations can be written instead of chemical equations where required.

Q1. What chemical substance is in well F1 ?
A1. Tap water.

Q2. What is the colour of the universal indicator in well F1 **?**
A2. Green.

Q3. Use the pH indicator strip to explain the meaning of the colour of the solution in well F1.
A3. Tap water is neutral.

Q4. Write down the name of the chemical substance, the colour of the universal indicator, and the meaning of the colour in well F2.
A4. Sodium hydroxide. Blue. Alkaline solution.

Q5. What was the colour of the indicator in the dilute sulphuric acid and hydrochloric acid in wells F3 and F4 before you started adding the sodium hydroxide solution ? Use the pH indicator strip to explain the meaning of this colour.
A5. Red. The solutions are acidic.

Q6. What happens when you add the sodium hydroxide to the acidic solutions ?
A6. The colours in wells F3 and F4 change from red to green.

Q7. Explain in your own words what this means.
A7. Adding an alkaline solution (sodium hydroxide) to the acidic solutions (sulphuric acid and hydrochloric acid) neutralised the acidic solution. In the reaction between the acid and the alkali a neutral product is formed.

Q8. A wasp sting injects an alkaline chemical into the skin. What household chemical could be used to relieve the pain from the wasp sting ? Explain why.

A8. A household acid like vinegar or lemon juice would bring some relief. The acid neutralises the alkali in the wasp sting.

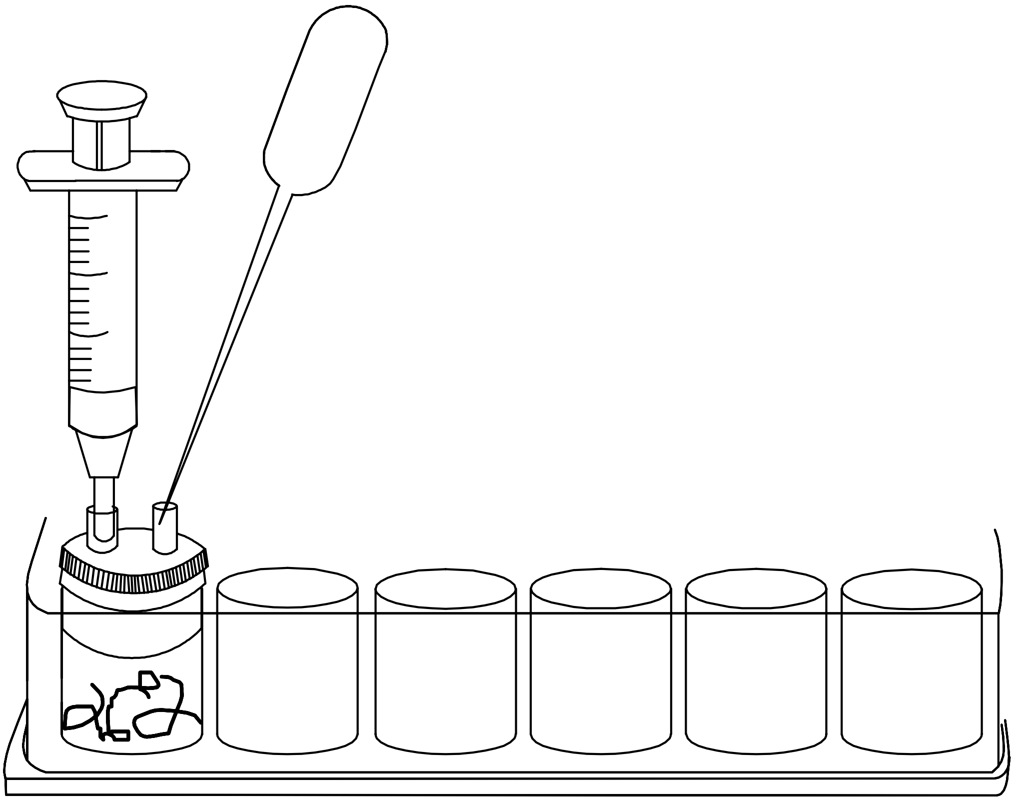
Q9. A solution of bicarbonate of soda brings some relief when it is applied to a bee sting on the skin. Explain why this is so.

A9. Bee stings inject an acid into the skin. Bicarbonate of soda forms an alkaline solution in water that can neutralise the acid in the bee sting.

Q10. Why does “Milk of Magnesia” relieve indigestion ?

A10. Indigestion is sometimes caused when the stomach forms excess acid during the digestion process. “Milk of Magnesia” is an alkaline solution and will neutralise some of the excess stomach acid.

MICROCHEMISTRY
CHAPTER III



THE REACTION OF GROUP 1 AND 2 METALS WITH WATER

TEACHER GUIDE

1. Chemicals
All of the required chemicals are listed in the worksheet. Tap water is also needed.

2. Equipment
Most of the apparatus required can be found in a RADMASTE Basic or Advanced Microchemistry Kit. A knife and paper clip are required in Part 1.

3. Hints

PART 1: The Reaction of the Group 1 Metals – Sodium and Potassium – with Water

Potassium and sodium form oxides when exposed to the air. For this reason, these metals are stored in stoppered bottles under liquid paraffin. Use the knife or other suitable utensil to remove the pieces of metal from the storage bottles.

Even though the metals are stored under liquid paraffin, there may still be a layer of white oxide surrounding each piece of metal. The oxide partially protects the metal from any further oxidation, and a reaction will not be easily seen if the oxide layer is not removed. Scrape the white oxide layer off the metal with the knife after you have used the paper clip to hold the metal firmly in position.

Try to keep the sizes of the pieces of potassium and sodium as close as possible, so that good comparisons of the rates of reaction of these metals with water can be made.

PART 2: The Reaction of the Group 2 Metals – Magnesium and Calcium – with Water

Magnesium ribbon required in Part 2 will also form an oxide coating if exposed to the air. This oxide coating causes the ribbon to appear dull, and the ribbon must be scraped with some sandpaper until it is shiny, otherwise no reaction will be seen.

When calcium metal reacts with water a white solid, calcium hydroxide ($Ca(OH)_2(s)$), is formed. Since well F2 contains universal indicator, the solution becomes purple when the calcium reacts with the water and it may be difficult to see the white solid. In this instance, the observation of a milky, purple mixture in well F2 should be regarded as indicating the presence of the white solid and the alkaline solution. You can lift the comboplate® above eye-level later on to view the solid calcium hydroxide which has settled.

PART 3: What Gas is Produced when a Group 1 or Group 2 Metal Reacts with Water ?

In Part 3, a test for hydrogen must be carried out by holding a flame over well F1. The presence of hydrogen in this experiment is not indicated by the characteristic squeaky popping sound, but rather by a series of miniature explosions as the oxygen in the vicinity of the flame reacts with the hydrogen escaping from the well.

4. Cautions
Please remember the following cautions and inform your students of all safety hazards.

Do not touch the potassium and sodium metals with your hands. They are corrosive and will burn the skin. If the metals or liquid paraffin make contact with the skin, rinse the affected area thoroughly under water.

Never allow anyone to place large pieces of sodium or potassium metal into water. The explosion may be so large as to cause serious damage. Limit the pieces of each metal to approximately 2 mm x 2 mm. If the piece of metal is too large, the comboplate® might crack.

5. Model Answers to Questions in the Worksheet
It is recommended that learners write down all of the questions and answers in their workbooks. If this is done, then the answers to questions do not have to be in full sentences. If the learners do not copy the questions into their workbooks, then answers should be written in full sentences. Note that some of the questions can only be answered by learners in higher grades. Word equations can be written instead of chemical equations where required.

PART 1: The Reaction of the Group 1 Metals – Sodium and Potassium – with Water

Q1. What is the colour of the solution in each well ? What is their pH ?
A1. well F1: green, pH ~7 well F2: green, pH ~7.

Q2. What happens to the sodium when it is added to the water ?
A2. The sodium darts about in the water and a "fizzing" sound is heard.

Q3. Does the pH of the solution in well F1 change ? Explain.
A3. Yes, the colour of the solution changes from green to purple, indicating a pH change from ~7 to ~12/13. The sodium has reacted with the water to form an alkaline solution.

Q4. Write a balanced chemical equation which represents the reaction which took place in well F1.
A4. $2Na(s) + 2H_2O(\ell) \rightarrow 2NaOH(aq) + H_2(g)$

Q5. What happens to the potassium when it is added to water ?
A5. The K(s) darts about vigorously in the water until it has all reacted. A "fizzing" sound is heard and some sparks are seen.

Q6. Does the pH of the solution in well F2 change ? Explain.
A6. Yes, the colour of the solution changes from green to purple, indicating a change in pH from ~7 to ~12/13. The potassium has reacted with water to form an alkaline solution.

Q7. Write a balanced chemical equation which represents the reaction which took place in well F2.
A7. $2K(s) + 2H_2O(\ell) \rightarrow 2KOH(aq) + H_2(g)$

Q8. Compare the rates of reaction of sodium and potassium with water.
A8. The rate of reaction of potassium with water is greater than that of sodium with water.

PART 2: The Reaction of the Group 2 Metals – Magnesium and Calcium – with Water

Q1. Observe the colour of the solutions in each well and deduce their pH values.
A1. well F1: pH ~7
well F2: pH ~ 7

Q2. What happens to the magnesium when it is added to water ?
A2. The Mg(s) reacts very slowly with the water. Bubbles of gas are given off slowly and a white solid forms.

Q3. Does the pH of the solution in well F1 change ? (Explain).
A3. Yes, the colour of the solution changes from green to dark blue, indicating a pH change from ~7 to ~11/ 12. The reaction between magnesium and water has produced an alkaline solution.

Q4. Write a balanced chemical equation which represents the reaction which took place in well F1.
A4. $Mg(s) + 2H_2O(\ell) \rightarrow Mg(OH)_2(aq) + H_2(g)$

Q5. What happens to the calcium when it is added to the water ?
A5. The calcium reacts with the water, releasing bubbles of gas and forming a white solid that sinks to the bottom of the well.

Q6. Does the pH of the solution in well F2 change ? (Explain).
A6. Yes, the colour of the solution changes from green to purple, indicating a pH change from ~7 to ~12/13. The reaction between the calcium and water has produced an alkaline solution.

Q7. Write a balanced chemical equation which represents the reaction which took place in well F2.
A7. $Ca(s) + 2H_2O(\ell) \rightarrow Ca(OH)_2(aq) + H_2(g)$

Q8. Compare the rates of reaction of calcium and magnesium with water.
A8. The rate of reaction of calcium with water is greater than that of magnesium with water.

Q9. Recall your observations from parts 1 and 2 for the reactions of sodium and magnesium with water. Which metal reacts faster with water: sodium or magnesium ?
A9. Sodium.

Q10. Recall your observations from parts 1 and 2 for the reactions of potassium and calcium with water. Which metal reacts faster with water: potassium or calcium ?
A10. Potassium.

Q11. Does the reactivity of Group 1 and 2 metals increase or decrease with increasing atomic number in the group ?
A11. Increase.

Q12. Does the reactivity of Group 1 and 2 metals increase or decrease with increasing atomic number in a period ?
A12. Decrease.

Q13. Predict whether aluminium would react faster or slower than magnesium with water.
A13. Slower.

Q14. Predict whether beryllium would react faster or slower than magnesium with water.
A14. Slower.

Q15. What gas was produced when each of the Group 1 and 2 metals investigated, reacted with water ?
A15. Hydrogen.

Q16. How would you test for this gas without collecting it ?
A16. A burning match held over one of the wells in which a metal is reacting with water, should produce a pop sound when the hydrogen reacts with the oxygen in the air.

PART 3: What Gas is Produced when a Group 1 or Group 2 Metal Reacts with Water ?

Q1. What happens while the match is being held over well F1 ?
A1. A series of popping sounds is heard. The more vigorous the bubbling in well F1, the louder the popping.

Q2. What is the name of the gas produced ?
A2. Hydrogen.

Q3. Use your knowledge of the reactivity of the Group 1 and 2 metals with water to explain why sodium, potassium and magnesium were not used in the test for hydrogen.
A3. The sodium and potassium react too quickly with the water. The magnesium reacts too slowly.

REACTIONS OF METALS WITH METAL SALT SOLUTIONS

TEACHER GUIDE

1. Chemicals

All of the required chemicals are listed in the worksheet. The procedure requires that 1 M iron(II) sulphate solution be used. This solution is normally pale green in colour, but it is easily oxidised by the air to iron(III) sulphate which is brown in colour. If your solution of $FeSO_4$(aq) is brown or brown-green in colour, it should be discarded and a fresh solution prepared.

2. Equipment

All of the apparatus required can be found in a RADMASTE Basic or Advanced Microchemistry Kit.

3. Hints

When adding the metal powders to the small wells, care must be taken to ensure that none of the powder spills into adjacent wells. This may result in a reaction being observed where there is no reaction.

The comboplate® should be viewed from above and from the side when making observations. Characteristics of reactions, such as bubbling, are best seen from above whereas changes in colours of solutions and/or metal powders are revealed from the side.

It is important to make final observations after about 3 minutes since some reactions are slower than others, eg. zinc reacts with iron(II) sulphate after ~ 2 minutes. Colour changes also occur after a period of time.

A metal will not react with its own metal salt solution.

4. Cautions

Please remember the following cautions and inform your students of all safety hazards:

Metal sulphate solutions are harmful if swallowed or absorbed through the skin. They are skin and eye irritants.

Make sure that learners wash their hands thoroughly after completing the experiment.

5. Model Answers to Questions in the Worksheet

It is recommended that learners write down all of the questions and answers in their workbooks. If this is done, then the answers to questions do not have to be in full sentences. If the learners do not copy the questions into their workbooks, then answers should be written in full sentences. Note that some of the questions can only be answered by learners in higher grades. Word equations can be written instead of chemical equations where required.

Q1. Record your observations in a table like Table 1 below. Describe what you see; if no change is detected, indicate this also.

A1. Table 1

	$CuSO_4$(aq)	$FeSO_4$(aq)	$ZnSO_4$(aq)
Cu(s)	**X**	**X**	**X**
Fe(s)	**The iron filings become copper coloured. The solution changes from dark blue to a lighter blue.**	**X**	**X**
Zn(s)	**The zinc powder becomes copper coloured, and small bubbles form around the powder. The copper sulphate solution changes from dark blue to a lighter blue.**		**X**

Q2. Of the three metals investigated above, which metal showed the greatest tendency to react with the aqueous solutions of metal salts ? Give a reason for your answer.

A2. Zinc, because it reacted with all the metal salt solutions, except for the zinc sulphate solution.

Q3. Which metal showed the least tendency to react with the aqueous solutions of metal salts ? (see Table) Give a reason for your answer.

A3. Copper, because it did not react with any of the metal salt solutions.

Q4. Write down a reactivity series for the metals, from the most reactive to the least reactive.

A4. From the reactions of the three metals tested, it can be deduced that zinc is the most reactive followed by iron and lastly copper i.e:

$$Zn(s) > Fe(s) > Cu(s)$$

ARE METAL OXIDES ACIDIC OR BASIC OXIDES?

TEACHER GUIDE

1. Chemicals
All of the required chemicals are listed in the worksheet. For sodium oxide, sodium peroxide ($Na_2O_2(s)$) is used. This is because it is easily available. Oxides of metals that are more reactive are the ones that work better. Other metal oxides like lead(II) oxide and copper(II) oxide do not give a positive test because they do not react with water. The chosen metal oxides are the ones that are more reactive and the test results can be visible within a short space of time. Tap water is needed in this experiment. Universal indicator solution is used in this experiment since it is available in the chemicals kit, although any indicators whose pH ranges are known can be used.

2. Equipment
All of the apparatus required can be found in a RADMASTE Basic or Advanced Microchemistry Kit.

3. Hints
When sodium oxide is added, the colour of the water does not change to violet. There is however a change in colour from olive to a darker green. The learners should be able to observe this change in the shade of green and therefore an increase in pH towards the basic side (pH between 7.5 and 9.5). This change in pH can also be seen when comparing the mixture containing sodium oxide with the one that has water only.

The pH of tap water is not necessarily 7 in all places depending on the origin of the water and chemicals used to clean it: please note this when filling in Table 1.

It is important to use a clean microspatula to transfer each metal oxide into the A wells so that there is no contamination between the wells.

4. Cautions
Please remember the following cautions and inform your students of all safety hazards:

Calcium oxide is a strong base. It forms a corrosive alkali with water. If the powder makes contact with the skin, wash the affected area thoroughly with copious amounts of water.

5. Model Answers to Questions in the Worksheet
It is recommended that learners write down all of the questions and answers in their workbooks. If this is done, then the answers to questions do not have to be in full sentences. If the learners do not copy the questions into their workbooks, then answers should be written in full sentences. Note that some of the questions can only be answered by learners in higher grades. Word equations can be written instead of chemical equations where required.

Q1. Prepare a table like Table 1 below in your workbook.
A1. Table 1.

Well	Colour of Indicator	pH	Acid/Base	Substance Added	Colour of Mixture	pH	Acid/Base
A1	**green/olive**	**7**	**neutral**	**sodium oxide**	**dark green**	**7.5 - 9.5**	**base**
A2	**green/olive**	**7**	**neutral**	**calcium oxide**	**violet**	**9.5 - 14**	**base**
A3	**green/olive**	**7**	**neutral**	**magnesium oxide**	**greenish violet**	**9.5 - 14**	**base**
A4	**green/olive**	**7**	**neutral**	**nothing**	**green/olive**	**6.5 - 7.5**	**neutral**

Q2. Observe and record the colour of the indicator in the water in each well in the second column of Table 1.
A2. See Table 1.

Q3. Observe and record the colour of the indicator in the mixture in wells A1, A2 and A3 in the sixth column of Table 1.
A3. See Table 1.

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Q4. Use the universal indicator colour chart in the kit to deduce the pH corresponding to each colour recorded in your table.

A4. See the third and seventh columns of Table 1.

Q5. From the pH values, record whether each solution is acid, base or neutral.

A5. See final column of Table 1.

Q6. Are metal oxides acidic or basic oxides?

A6. Metal oxides are basic oxides.

REACTIVITY OF GROUP 7 ELEMENTS

TEACHER GUIDE

1. Chemicals
All of the required chemicals are listed in the worksheet.

2. Equipment
Most of the apparatus required can be found in a RADMASTE Basic or Advanced Microchemistry Kit.

3. Hints
The solutions must be stirred thoroughly for the colour change to be observed reliably.

It may sometimes happen that the expected colour changes are not observed. This may lead to the perception that the experiment does not work. However, the halogen solutions deteriorate with time. In particular, the chlorine solution loses gaseous chlorine quite rapidly. If colour changes are not observed, the teacher should perform the experiment with fresh halogen solutions.

4. Cautions
Please remember the following cautions and inform your students of all safety hazards:

Bromine has a high vapour pressure and the vapour above the solution will expand with an increase in temperature. It must therefore be kept in a cool, dark place in a well stoppered bottle.

The halogens are corrosive. Avoid dropping the bromine, iodine and chlorine solutions onto fabrics and skin. Wash hands thoroughly if any of the solutions make contact with the skin.

The bromine, iodine and chlorine solutions form toxic fumes. Avoid inhaling these fumes and make sure the experiment is performed in a well ventilated room.

Halogen and halide solutions have been known to cause gastrointestinal, endocrine, behavioural and respiratory complaints. The sodium iodide and sodium bromide solutions must also therefore be handled with care.

5. Model Answers to Questions in the Worksheet
It is recommended that learners write down all of the questions and answers in their workbooks. If this is done, then the answers to questions do not have to be in full sentences. If the learners do not copy the questions into their workbooks, then answers should be written in full sentences. Note that some of the questions can only be answered by learners in higher grades. Word equations can be written instead of chemical equations where required.

Q1. Did the colours of the solutions in wells B1 to B3 change ? If so, what are the colour changes ?

A1. Well B1: No colour change.
Well B2: The colour changed to yellow-brown.
Well B3: The colour changed to dark brown.

Q2. Explain your answers to question 1, with chemical equations.

A2. Well B1: No reaction occurs
Well B2: $C\ell_2(aq) + 2NaBr(aq) \rightarrow 2NaC\ell(aq) + Br_2(aq)$
Well B3: $C\ell_2(aq) + 2NaI(aq) \rightarrow 2NaC\ell(aq) + I_2(aq)$

Q3. Did the colours of the solutions in wells B4 to B6 change ? If so, what are the colour changes ?

A3. Well B4: No colour change.
Well B5: No colour change.
Well B6: The colour changed to dark brown.

Q4. Explain your answers to question 3 with chemical equations.

A4. Well B4: No reaction occurs
Well B5: No reaction occurs
Well B6: $Br_2(aq) + 2NaI(aq) \rightarrow 2NaBr(aq) + I_2(aq)$

Q5. Did the colours of the solutions in wells B7 to B9 change ? If so what are the colour changes ?

A5. In wells B7 to B9, there was no colour change.

Q6. Explain your answers to question 5 with chemical equations.

A6. Well B7: No reaction occurs.
Well B8: No reaction occurs.
Well B9: No reaction occurs.

Q7. Which halogen was the most reactive towards halide ions ?

A7. Chlorine.

Q8. Which halogen was the least reactive towards halide ions ?

A8. Iodine.

Q 9. Examine a periodic table. How does the order of the halogens in Group 7 compare with the reactivity of these halogens ?

A9. The reactivity of these halogens decreases down the group.

Q10. Predict the reactivity of F_2(g) and give reasons.

A10. Since the reactivity decreases down Group 7, F_2(g) is predicted to be the most reactive of all the halogens because it is at the top of the group.

PREPARATION OF IRON(III) CHLORIDE

TEACHER GUIDE

1. Chemicals

All the required chemicals are listed in the worksheet. Tap water is also needed. The procedure requires that 5.5 M hydrochloric acid ($HC\ell$(aq)) be diluted to 2.75 M. Remember to always add the acid to the water and not the other way around. **If you add 5.5 M hydrochloric acid to the potassium permanganate, you will damage the well of the comboplate®.**

2. Equipment

Most of the apparatus required can be found in a RADMASTE Basic or Advanced Microchemistry Kit.

3. Hints

When diluting the 5.5 M hydrochloric acid ($HC\ell$(aq)), make sure that the syringe does not contain water. If it does, the concentration of the $HC\ell$(aq) prepared in well E6 will be less than 2.75 M. This may affect the preparation of the desired product as the rate of chlorine gas liberation from well F1 will be low.

Add the 2.75 M $HC\ell$(aq) slowly to the potassium permanganate ($KMnO_4$(s)), otherwise the vigorous bubbling in well F1 may force the solution up through the silicone tube and over the iron in the glass tube, making it necessary to restart the experiment.

Before heating the iron in the glass tube, make sure that the chlorine bubbles passing into the water in well F6 appear at a steady rate. If the rate of bubble production is low, it means that chlorine gas is not being produced quickly enough in well F1 and this could result in the preparation of iron(II) chloride instead of iron(III) chloride. Iron(II) chloride, when dissolved in water, will produce a green precipitate with 2 M ammonia solution.

Iron(II) chloride may also result if the flame temperature used for heating is not high enough. Try to always keep the microburner filled with methylated spirits to ensure an intense flame. Do not move the microburner from side to side when heating. Keeping the flame at one position allows for the iron powder to reach the required reaction temperature quickly. For this reason, it is also not necessary to use a large amount of iron powder in the glass tube.

As soon as the glass tube has cooled, take the apparatus apart and thoroughly rinse the comboplate® with water. Fill well F1 with 10 % hydrogen peroxide solution, otherwise the well will be stained brown. This solution effectively removes most of the brown stain, and also reacts with any remaining $KMnO_4$(s) in the well to produce a clear solution. The latter can then be removed from the well with a propette and used many times over to clean the stained wells of other learners' comboplates®.

The tap water in certain areas may have a high chloride content; therefore, depending on the area in which the experiment is performed, a white silver chloride ($AgC\ell$(s)) precipitate may be obtained when the tap water is tested with silver nitrate ($AgNO_3$(aq)) solution. This is usually not a problem, as the silver chloride precipitate obtained after the production of the iron(III) chloride ($FeC\ell_3$(aq)) is of a greater quantity, and thus much more evident, than that due to the chloride content of the tap water.

Most of the iron(III) chloride that adheres to the inner walls of the glass tube after the ion tests, can be scraped off with a toothpick, match or piece of wire. Stubborn deposits in the glass tube may need to be removed with aqua regia (a solution consisting of 2 parts conc. hydrochloric acid to 1 part conc. nitric acid). If the iron chloride has interacted with the glass in such a way that it cannot be removed, the tube will have to be replaced.

4. Cautions

Please remember the following cautions and inform your students of all safety hazards:

Hydrochloric acid, sulphuric acid and nitric acid (HNO_3(aq)) are corrosive. If any acid is spilt on the skin, the affected area must immediately be rinsed with copious amounts of water. Severe burns must receive medical attention.

Ammonia (NH_3(aq)) is a base. If any base is spilt on the skin, treat as described above for acid burns.

Never point a propette or a syringe containing acid or base upwards. A momentary lapse of concentration can result in a nasty accident. If any acid or base is squirted into the eye, immediately rinse the eye out under running water. In the case of an acid injury, always have a dilute solution of sodium hydrogencarbonate (household baking soda), or milk close by to apply to the injury. These substances will help neutralise the acid in the eye. The patient should be referred to a doctor.

Chlorine is a pungent, toxic gas. Do not inhale the fumes. Make sure the experiment is performed in a well ventilated room.

Potassium permanganate is poisonous. Rinse your hands thoroughly if any crystals make contact with the skin.

The chlorine water formed in well F6 during the experiment is corrosive. Rinse your hands well after the experiment and do not allow the solution in well F6 to make contact with any fabrics, as it is a bleach.

Silver is an expensive metal. Solutions of silver nitrate are also expensive and should not be wasted!

5. Model Answers to Questions in the Worksheet

It is recommended that learners write down all of the questions and answers in their workbooks. If this is done, then the answers to questions do not have to be in full sentences. If the learners do not copy the questions into their workbooks, then answers should be written in full sentences. Note that some of the questions can only be answered by learners in higher grades. Word equations can be written instead of chemical equations where required.

Q1. What happens inside the glass tube ?
A1. A yellow-orange vapour appears, which moves towards the cooler ends of the glass tube and forms a red-orange solid deposit.

Q2. What is the colour of the solution in well A1 ?
A2. Pale orange.

Q3. What happens in well A1 when the ammonia solution is added ?
A3. A brown precipitate forms.

Q4. What happens in well A3 when the silver nitrate solution is added ?
A4. The solution turns milky and a white precipitate settles.

Q5. What do you deduce from testing the solution in well A1 with 2 M ammonia solution ? Justify your answer.
A5. The solution contains iron(III), since iron(III) hydroxide is a brown solid insoluble in water.

Q6. What do you deduce from testing the solution in well A3 with nitric acid and silver nitrate solution ? Justify your answer.
A6. The solution contains chloride, since silver chloride is a white solid insoluble in water.

Q7. Explain how your answers to questions 5 and 6 suggest that iron(III) chloride was produced by the reaction of iron and chlorine.
A7. The product of the reaction gave a positive test for iron(III) and for $C\ell^-$.

Q8. Write down the balanced chemical equation for the reaction occurring in the glass tube between the Fe(s) and $C\ell_2$(g).
A8. $2Fe(s) + 3C\ell_2(g) \rightarrow 2FeC\ell_3(s)$

Q9. What type of reaction is this ? Justify your answer by using suitable chemical equations.
A9. Redox. The reductant is iron (Fe(s)). The loss of electrons from Fe atoms is represented by the oxidation half-reaction equation as:

$$Fe \rightarrow Fe^{3+} + 3e^-$$

The oxidant is chlorine ($C\ell_2$(g)). The chlorine atoms accept electrons as represented by the reduction half-reaction equation:

$$C\ell_2 + 2e^- \rightarrow 2C\ell^-$$

PREPARATION OF COPPER(II) CHLORIDE

TEACHER GUIDE

1. Chemicals

All of the required chemicals are listed in the worksheet. Tap water is also needed. The procedure requires that 5.5 M hydrochloric acid ($HC\ell(aq)$) be diluted to 2.75 M. Remember to always add the acid to the water and not the other way around. **If you add 5.5 M hydrochloric acid to the potassium permanganate, you will damage the well of the comboplate®.**

2. Equipment

Most of the apparatus required can be found in a RADMASTE Basic or Advanced Microchemistry Kit.

3. Hints

Add the 2.75 M hydrochloric acid ($HC\ell(aq)$) slowly to the potassium permanganate ($KMnO_4(s)$), otherwise the vigorous bubbling in well F1 may force the solution up through the silicone tube and over the copper in the glass tube, making it necessary to restart the experiment.

As soon as the glass tube has cooled, take the apparatus apart and thoroughly rinse the comboplate® with water. Fill well F1 with 10 % hydrogen peroxide solution, otherwise the well will be stained brown.

The tap water in certain areas may have a high chloride content; therefore, depending on the area in which the experiment is performed, a white silver chloride ($AgC\ell(s)$) precipitate may be obtained when the tap water is tested with silver nitrate ($AgNO_3(aq)$) solution. This is usually not a problem, as the silver chloride precipitate obtained after the production of the copper(II) chloride ($CuC\ell_2(aq)$) is of a greater quantity, and thus much more evident, than that due to the chloride content of the tap water.

Most of the copper(II) chloride that adheres to the inner walls of the glass tube after the ion tests, can be scraped off with a toothpick, match or piece of wire. Stubborn deposits in the glass tube may need to be removed with aqua regia (a solution consisting of 2 parts conc. hydrochloric acid to 1 part conc. nitric acid). If the copper chloride has interacted with the glass in such a way that it cannot be removed, the tube will have to be replaced.

4. Cautions

Please remember the following cautions and inform your students of all safety hazards:

Hydrochloric acid, sulphuric acid and nitric acid ($HNO_3(aq)$) are corrosive. If any acid is spilt on the skin, the affected area must immediately be rinsed with copious amounts of water. Severe burns must receive medical attention.

Ammonia ($NH_3(aq)$) is a base. If any base is spilt on the skin, treat as for acid burns.

Never point a propette or a syringe containing acid or base upwards. A momentary lapse of concentration can result in a nasty accident. If any acid or base is squirted into the eye, immediately rinse the eye out under running water. In the case of an acid injury, always have a dilute solution of sodium hydrogencarbonate (household baking soda), or milk close by to apply to the injury. These substances will help neutralise the acid in the eye. The patient should be referred to a doctor.

Chlorine is a pungent, toxic gas. Do not inhale the fumes. Make sure the experiment is performed in a well ventilated room.

Potassium permanganate is poisonous. Rinse your hands thoroughly if any crystals make contact with the skin.

The chlorine water formed in well F6 during the experiment is corrosive. Rinse your hands well after the experiment and do not allow the solution in well F6 to make contact with any fabrics, as it is a bleach.

Silver is an expensive metal. Solutions of silver nitrate are also expensive and should not be wasted!

5. Model Answers to Questions in the Worksheet

It is recommended that learners write down all of the questions and answers in their workbooks. If this is done, then the answers to questions do not have to be in full sentences. If the learners do not copy the questions into their workbooks, then answers should be written in full sentences. Note that some of the questions can only be answered by learners in higher grades. Word equations can be written instead of chemical equations where required.

Q1. Note what happens inside the glass tube.
A1. The copper powder inside the tube begins to bubble. With further heating, a yellow-orange deposit can be seen near one or both ends of the glass tube. Blue-black droplets can be seen on the glass immediately above the heated copper. In some cases, if one looks closely enough, a yellow-green solid is visible inside the tube.

Q2. What remains in the glass tube after cooling ?
A2. There is now a yellow deposit on the inside of the cooled glass tube where the blue-black droplets were observed on the hot glass.

Q3. What do you think this compound could be ? Give a reason for your answer.
A3. This yellow product is copper(II) chloride ($CuC\ell_2(s)$). Before the heating took place, there was only copper (Cu(s)) powder inside the glass tube. A stream of chlorine ($C\ell_2(g)$) flowed over the copper from the chlorine generator in well F1. The new yellow product must therefore have resulted from the combination of the Cu(s) and $C\ell_2(g)$ in the heated environment.

Q4. What is the colour of the solution ?
A4. Pale blue.

Q5. What happens in well A1 ?
A5. The solution becomes deep blue.

Q6. What happens in well A3 ?
A6. The solution turns milky and a white precipitate forms.

Q7. What do you deduce from testing the solution in well A1 with aqueous ammonia solution ? Justify your answer and write a balanced chemical equation for the reaction you observed.
A7. The solution contains copper(II). Blue $Cu^{2+}(aq)$ ions form deep-blue ($Cu(NH_3)_4^{2+}(aq)$) ions with ammonia.

$$Cu^{2+}(aq) + 4NH_3(aq) \rightarrow Cu(NH_3)_4^{2+}(aq)$$

Q8. What do you deduce from testing the solution in well A3 with nitric acid and silver nitrate solution ? Justify your answer.
A8. The solution contains chloride, since silver chloride is a white solid insoluble in water.

Q9. What compound has been formed by reaction of copper with chlorine ?
A9. Copper(II) chloride ($CuC\ell_2(s)$).

Q10. Write a balanced chemical equation for the reaction which you think occurred between chlorine and copper.
A10. $Cu(s) + C\ell_2(g) \rightarrow CuC\ell_2(s)$

ACID-BASE – INDICATORS

TEACHER GUIDE

1. Chemicals

All of the required chemicals are listed in the worksheet. Tap water is required, also Part 2 lists white vinegar, Sprite and soapy water as possible items for testing, but other domestic solutions may be used.

2. Equipment

Most of the apparatus required can be found in a RADMASTE Basic or Advanced Microchemistry Kit.

3. Hints

Steps 3 and 7 in the procedure make use of a mixing propette. This is an empty propette which is used to suck up the contents of a well and mix them. Learners must be reminded to rinse the mixing propette after step 3, otherwise some acidic solution left behind in the propette will be mixed with a basic solution at step 7.

The pH values and colours of universal indicator in Table 2 of the model answers were obtained with samples of water and solutions of universal indicator in our laboratory. There are different concentrations of the indicator available, and water samples in your area may also vary in pH. As a result, it is possible that your learners may get colours with universal indicator that differ slightly from those presented in Table 2. Note that the answers serve as a guide only and that “proposed” pH values are given for the solutions prepared in wells A1 to A7.

The narrow end of the plastic microspatula can be used to stir the solutions in each well after the addition of indicator. This will allow the colour to be observed better. Make sure that the microspatula is cleaned before stirring a different solution.

Sprite, white vinegar and soapy water are not the only items that can be used in Part 2. Examples of other items that can be tested are: salt water, sugar water, soapy water made with washing powder, soapy water made with Handy Andy, lemon juice etc. Learners can be encouraged to bring different water samples from their homes. The worksheets can then be easily modified to include these items.

4. Cautions

Please remember the following cautions and inform your students of all safety hazards:

Hydrochloric acid is corrosive. If any acid is spilt on the skin, the affected area must immediately be rinsed with copious amounts of water.

Sodium hydroxide is a corrosive base and any spills on the skin must be treated by rinsing with water.

Never point a propette or a syringe containing acid or base upwards. A momentary lapse of concentration can result in a nasty accident. If any acid or base is squirted into the eye, immediately rinse the eye out under running water. In the case of acids, always have a dilute solution of sodium hydrogencarbonate (household baking soda), or milk close by to apply to the injury. These substances will help neutralise the acid in the eye. The patient should be referred to a doctor.

5. Model Answers to Questions in the Worksheet

It is recommended that learners write down all of the questions and answers in their workbooks. If this is done, then the answers to questions do not have to be in full sentences. If the learners do not copy the questions into their workbooks, then answers should be written in full sentences. Note that some of the questions can only be answered by learners in higher grades. Word equations can be written instead of chemical equations where required.

PART 1: In what pH range do Methyl Orange and Phenolphthalein change colour ?

Q1. Note the colour of the solution in each well and write this down in a table like Table 2. Use Table 1 to determine the pH from the colour of each solution in wells A1 to A7. Write down each pH value in your table.

A1. Table 2

Table 2

Well Number	Colour of solution	proposed pH
A1	**Dark red**	**1**
A2	**Dark red/ Light red**	**1 or 2**
A3	**Orange/ Light orange**	**4 or 5**
A4	**Dark green/ Light green**	**7 or 8**
A5	**Blue/ Dark blue**	**10 - 11**
A6	**Purple/ Dark purple**	**12 - 13**
A7	**Dark purple**	**13**

Q2. When a hypothetical indicator HX is placed in a colourless solution of pH 2 the colour of the solution appears red. When the same quantity of indicator HX is added to a colourless solution of pH 10 the solution appears green. Why were the colours different for the same indicator?

A2. Indicator HX is a weak acid which has different colours for HX and X^-. The colour of a solution of indicator HX is dependent on the concentration of hydrogen ions or hydroxide ions in the solution. Thus HX is red in solution, while X^- is green.

For example: methyl orange (call it HMeth) is a complex organic dye which is red when as HMeth and yellow as $Meth^-$. These species are in equilibrium:

$$\underset{}{H_2O} + \underset{\text{(red)}}{\text{HMeth}} \rightleftharpoons \underset{\text{(yellow)}}{\text{Meth}^-} + H_3O^+$$

Q3. At which pH values was the colour of methyl orange in solution red **?**

A3. Methyl orange appeared red at pH 1 and pH 2.

Q4. At which pH values was the colour of methyl orange in solution yellow/orange ?

A4. Methyl orange appeared yellow/orange in solution at pH's 4, 7, 11, 12 and 13.

Q5. At which pH values was phenolphthalein colourless in solution **?**

A5. Phenolphthalein appeared colourless in solution at pH's 1, 2, 4 and 7.

Q6. At which pH values was phenolphthalein pink in solution **?**

A6. Phenolphthalein appeared pink in solution at pH's 10 – 11, 12 and 13.

Q7. What is the pH range in which (a) methyl orange, and (b) phenolphthalein change colour **?**

A7. Methyl orange changes colour in the pH range from 2 to 4, while phenolphthalein changes colour in the pH range from 7 to 10.

PART 2: What is the pH of vinegar, Sprite and soapy water ?

Q1. Note the colour of the solution in each well and write this down in a table like Table 2 in Part 1.

A1. See Table 3.

Q2. Use Table 1 (Part 1) to determine the pH from the colour of each solution in wells A1 to A3. Write down the pH of each solution in your table.

A2. See Table 3.

Table 3

Well Number	Colour of solution	proposed pH
A1	**orange**	**4**
A2	**orange**	**4**
A3	**green**	**7**

PROPERTIES OF ACIDS AND ALKALIS

TEACHER GUIDE

1. Chemicals
All of the required chemicals are listed in the worksheet. Tap water is also needed. The vinegar, lemon juice and bicarbonate of soda can be obtained from a grocery store.

2. Equipment
Most of the apparatus required can be found in a RADMASTE Basic or Advanced Microchemistry Kit. A sheet of white paper is needed, onto which the comboplate® can be placed for better observation of colour changes in the relevant wells.

3. Hints
The teacher must ensure that learners practise caution when tasting chemicals. Only the household substances must be tasted. Vinegar is a clear, colourless solution and should not be mistaken for the hydrochloric acid.

4. Cautions
Please remember the following cautions and inform your students of all safety hazards:

Be very careful when tasting household chemicals. DO NOT TASTE ANY CHEMICAL SUBSTANCE IN THE LABORATORY UNLESS SPECIFICALLY INSTRUCTED TO DO SO.

Hydrochloric acid and sodium hydroxide are corrosive. If any acid or alkali is spilt on the skin, the affected area must immediately be rinsed with copious amounts of water.

Sodium hydroxide is a corrosive base and any spills on the skin must be treated by rinsing with water.

Never point a propette or a syringe containing acid or base upwards. A momentary lapse of concentration can result in a nasty accident. If any acid or base is squirted into the eye, immediately rinse the eye out under running water. In the case of acids, always have a dilute solution of sodium hydrogencarbonate (household baking soda), or milk close by to apply to the injury. These substances will help neutralise the acid in the eye. The patient should be referred to a doctor.

5. Model Answers to Questions in the Worksheet
It is recommended that learners write down all of the questions and answers in their workbooks. If this is done, then the answers to questions do not have to be in full sentences. If the learners do not copy the questions into their workbooks, then answers should be written in full sentences. Note that some of the questions can only be answered by learners in higher grades. Word equations can be written instead of chemical equations where required.

Q1. What did you notice about the taste of lemon juice and vinegar ?
A1. Both have a sharp, sour taste.

Q2. Describe the taste of the bicarbonate of soda.
A2. Bitter.

Q3. What did you notice when you rubbed the sodium hydroxide between your fingers **?**
A3. It has a soapy feel.

Q4. Do you think taste is an effective way to distinguish between different chemicals ? Explain your answer.
A4. No. Most laboratory chemicals are toxic.

Q5. Prepare a table like the one shown below.
A5. See the table.

Q6. Enter your observations in your table.

A6.

	In Vinegar	**In Lemon Juice**	**In HCℓ(aq)**	**In Bicarbonate of Soda**	**In NaOH(aq)**
Colour of Universal Indicator	**red**	**red**	**red**	**green-blue**	**blue**
Colour of Methyl Orange	**red**	**red**	**red**	**orange-yellow**	**orange-yellow**
Colour of Universal Indicator Paper	**red**	**red**	**red**	**green-blue**	**blue**

Q7. Use the information on the pH indicator strip to classify the substances as “acidic”, “neutral” or “alkaline”.

A7. Acidic: vinegar, lemon juice and hydrochloric acid.
Alkaline: sodium hydroxide solution, bicarbonate of soda solution.

Q8. Design a table and use the results of this experiment to summarise some of the properties of acids and alkalis.

A8.

	Properties	**Examples**
Acids	**1. Sour taste** **2. Change the colour of universal indicator and methyl orange to red**	**Lemon juice, vinegar, hydrochloric acid**
Alkalis	**1. Bitter taste** **2. Change the colour of universal indicator to blue, and that of methyl orange to yellow-orange**	**Bicarbonate of soda, sodium hydroxide**

A THERMOCHEMICAL DETERMINATION OF THE STOICHIOMETRY OF ACID–BASE REACTIONS

TEACHER GUIDE

1. Chemicals
All of the required chemicals are listed in the worksheet.

2. Equipment
Most of the apparatus required can be found in a RADMASTE Basic or Advanced Microchemistry Kit. A thermometer is required to measure temperature changes.

3. Hints
To make recording of temperature changes easier and more accurate, it is better to supply thermometers that are graduated in 0.1°C intervals. If this is not possible, the student will have to rely upon personal judgement of the level of mercury in the thermometer.

When measuring temperatures of solutions, wait a few seconds before recording values. Make sure that the bulb of the thermometer is adequately covered with solution. You may need to tilt the comboplate® slightly to achieve this, if the thermometer has a long bulb.

In order for reliable temperature changes to be obtained, the initial temperatures of the acid and base solutions must be the same or as close as possible. It is therefore necessary to check the temperatures of all the solutions prior to performing the experiment. If the temperatures of the solutions differ, the solution at the higher temperature must be allowed to cool to that of the solution at the lower temperature before the students attempt the exercise. If this is not done, the average initial temperature of the solutions, when mixed, will be dependent on the proportions in which they are added at their individual initial temperatures. The temperature changes recorded will not be reliable and an incorrect volume ratio will be obtained from the graph.

Make sure that the syringe is thoroughly dry inside before it is used to dispense a different solution, otherwise water in the syringe will dilute the acid/base and introduce errors into the results.

The acid and base solutions provided by chemical suppliers are often not standardised. In other words, the exact concentration of the acid or base is not known. For example, the hydrochloric acid may be labelled as a 1.0 M solution but it may have an exact concentration of 0.98 M or 1.1 M. In this case the expected mole ratio of acid:

base will not be obtained. The mole ratio may be close to that expected, but the result obtained may be confusing to learners who are encountering such concepts for the first time. For example, as a teacher you may recognise that a mole ratio of 0.98 for HCℓ:NaOH indicates that the acid reacts with the base in a ratio of 1:1, but a learner may not understand this.

Unless you are using standardised solutions of NaOH and HCℓ(aq) in this experiment, you will have to establish the exact concentrations of the acid or base by titration before allowing the learners to perform the experiment. This can be done using traditional scale glassware by titrating 10,0 mℓ sodium hydroxide solution with the hydrochloric acid. The expected volume ratio of acid:base is 1 i.e you should require 10,0 mℓ hydrochloric acid to neutralise the sodium hydroxide. If you are using the microburette, which is also available in the microscience system, then you will need volumes which are only 10 % of those mentioned: 1,00 mℓ NaOH and about 1,00 mℓ HCℓ. Microscale titration will give sufficiently accurate results. If you find that the volume ratio is greater than 1 you will need to adjust the concentration of the base by dilution. If the volume ratio is less than 1, the acid will need dilution. Another titration should be carried out to confirm that the acid and base react in a volume ratio of 1:1.

4. Cautions
Please remember the following cautions and inform your students of all safety hazards:

Hydrochloric and sulphuric acids are corrosive. If any acid is spilt on the skin, the affected area must immediately be rinsed with copious amounts of water. Severe burns must receive medical attention.

Sodium hydroxide is a corrosive base. If any base is spilt on the skin, treat as for acid burns described above.

Never point a propette or a syringe containing acid or base upwards. A momentary lapse of concentration can result in a nasty accident. If any acid or base is squirted into the eye, immediately rinse the eye out under running water. In the case of an acid, always have a dilute solution of sodium hydrogencarbonate (household baking soda), or milk close by to apply to the injury. These substances will help neutralise the acid in the eye. The patient should be referred to a doctor.

Mercury is an expensive, poisonous metal. Be careful not to drop the thermometers!

5. Model Answers to Questions in the Worksheet

It is recommended that learners write down all of the questions and answers in their workbooks. If this is done, then the answers to questions do not have to be in full sentences. If the learners do not copy the questions into their workbooks, then answers should be written in full sentences. Note that some of the questions can only be answered by learners in higher grades. Word equations can be written instead of chemical equations where required.

Q1. What is the initial temperature of the sodium hydroxide solution ?
A1. 26.00 ^{0}C. (Note: This, and other temperatures quoted, are examples only.)

Q2. What is the initial temperature of HCℓ(aq) ?
A2. 26.00 ^{0}C.

Q3. What is the average initial temperature of the two reactants ?*
A3. 26.00 ^{0}C.

Q 4. Prepare a table like Table 1 below.

Table 1

Well	Volume of NaOH(aq) /mℓ	Volume of HCℓ(aq) /mℓ	Maximum Temperature/ °C	Change in Temp.** of mixture/ °C
	2.0	0.0	**26.00**	**0.00**
E1	1.6	0.4	**28.30**	**2.30**
E2	1.4	0.6	**29.00**	**3.00**
E3	1.2	0.8	**30.00**	**4.00**
E4	1.1	0.9	**30.20**	**4.20**
E5	1.0	1.0	**31.00**	**5.00**
E6	0.9	1.1	**30.80**	**4.80**
F1	0.7	1.3	**30.30**	**4.30**
F2	0.4	1.6	**29.00**	**3.00**
	0.0	2.0	**26.00**	**0.00**

* **Average initial temp. = (initial temp. of NaOH(aq) + initial temp of HCℓ(aq)) ÷ 2**
** **Change in temperature = Maximum temp. – Average initial temp.**

Q5. Record the maximum temperature for the mixture in well E1 in your table.
A5. See Table 1.

Q6. Record the maximum temperature for each mixture in your table.
A6. See Table 1.

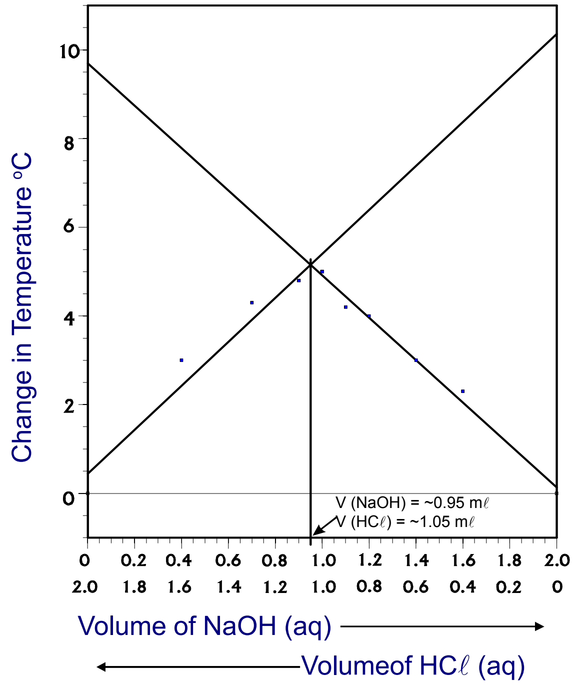
Q7. Calculate the change in temperature of the reaction mixture in each well and record the values in your table.
A7. See Table 1.

Q8. Prepare a graph with the change in temperature on the Y axis. On the X axis put the volume of sodium hydroxide solution (from 0.0 mℓ to 2.0 mℓ at 0.2 mℓ intervals), as well as the volume of hydrochloric acid (from 2.0 mℓ to 0.0 mℓ at intervals of 0.2 mℓ).
On the X axis, let 0,5 cm represent 0.1 mℓ of solution. On the Y axis, let 1,0 cm represent a 1.0°C temperature change.

Note

From Table 1, it can be seen that the total volume of solutions added to each well is 2 mℓ. Therefore the X axis can serve as an axis for the volumes of both NaOH(aq) and HCℓ(aq). At each volume of NaOH(aq), the volume of HCℓ(aq) is (2 mℓ – V(NaOH)). For example, on the X axis a scale mark could be 1.7 mℓ sodium hydroxide solution and 0.3 mℓ hydrochloric acid.

CHANGE IN TEMPERATURE vs VOLUME OF NaOH(aq)/HCℓ(aq)



Q 9. The scientific method used for finding the volume ratio with a graph like that which you have prepared, is to draw the best straight line through the set of points showing a positive slope, and another straight line through the set of points which displays a negative slope.Therefore, draw the best straight line through the set of points between 0.0 mℓ and the volume of sodium hydroxide at which the maximum change of temperature was observed. Now, draw the best straight line through the set of points between this volume that gave the maximum temperature change and 2.0 mℓ sodium hydroxide. Where the two lines intersect is the true maximum point on the curve (i.e where the highest change in temperature occurs). Drop a perpendicular from this point onto the X axis and record the volumes of NaOH(aq) and HCℓ(aq) where the perpendicular touches the axis.

Q9. V(NaOH) = 0.95 mℓ. V(HCℓ) = 1.05 mℓ

Q10. Why is there a temperature change when hydrochloric acid and sodium hydroxide solution are mixed ?

A10. When hydrochloric acid and sodium hydroxide solution are mixed, a chemical reaction occurs. In a chemical reaction bonds are broken within the reactants, and at the same time, bonds are formed to produce products. This results in either a decrease or increase in total energy of the system, shown by the temperature change.

Q11. In Table 1, you should notice that a temperature change of 0°C has been recorded for the sodium hydroxide volumes of 2.0 mℓ and 0.0 mℓ. Although you have not tested these volumes, why do you think the temperature change is O°C ?

A11. The total volume of solution tested in each well is 2 mℓ. At a volume of 2.0 mℓ NaOH(aq) therefore, there would be 0,0 mℓ HCℓ(aq). There would be no reaction taking place and therefore no change in temperature. Similarly, at a volume of 0,0 mℓ NaOH(aq), there would only be HCℓ(aq) in the well and once again no reaction.

Q12. Why is the temperature change different when different volume ratios of hydrochloric acid and sodium hydroxide solution are used ?

A12. Different volume ratios of reactants result in different amounts of products being formed, and therefore the temperature change must be different.

Q13. Use the volumes of hydrochloric acid and sodium hydroxide solution from your graph to calculate the volume ratio of HCℓ:NaOH that corresponds to the maximum temperature increase.

A13. The volume of hydrochloric acid is ~1,05 mℓ and that of sodium hydroxide solution is ~0,95 mℓ. The volume ratio is 1,05 mℓ HCℓ: 0,95 mℓ NaOH or 1,2:1. Within experimental error, this may be taken to indicate a volume ratio of approximately 1:1.

Q14. What do you deduce from your answer to question 13 about the mole ratio in which hydrochloric acid and sodium hydroxide react ?

A14. The mole ratio is 1:1, because both the HCℓ(aq) and NaOH(aq) are 1.0 M.

Q15. Justify your answer to question 14.

A15. This is the mole ratio giving the largest temperature increase. Hence the greatest amount of reaction occurred at this mole ratio.

Q16. Write down a balanced chemical equation to represent the chemical reaction between hydrochloric acid and sodium hydroxide solution.

A16. $HC\ell(aq) + NaOH(aq) \rightarrow NaC\ell(aq) + H_2O(\ell)$

PREPARATION OF A SALT: THE REACTION BETWEEN AN ACID AND A METAL CARBONATE

TEACHER GUIDE

1. Chemicals
All of the required chemicals are listed in the worksheet.

2. Equipment
Most of the apparatus required can be found in a RADMASTE Basic or Advanced Microchemistry Kit.

3. Hints
The hydrochloric acid must be added slowly to the calcium carbonate in well F1. If it is added too quickly, the vigorous bubbling in the well may force the solution through the silicone tube into the limewater in well F3.

The end of the glass rod should be gently heated by waving it four or five times through the flame of the microburner. It should not be allowed to become so hot that the reaction mixture boils violently, as this may result in loss of some of the dissolved calcium chloride.

4. Cautions
Please remember the following cautions and inform your students of all safety hazards:

Hydrochloric acid is corrosive. If any acid is spilt on the skin, the affected area must immediately be rinsed with copious amounts of water. Severe burns must receive medical attention.

Never point a propette or a syringe containing acid upwards. A momentary lapse of concentration can result in a nasty accident. If any acid is squirted into the eye, immediately rinse the eye out under running water. Always have a dilute solution of sodium hydrogencarbonate (household baking soda), or milk close by to apply to the injury. These substances will help neutralise the acid in the eye. The patient should be referred to a doctor.

Never allow the learners to play with matches. Treat any burn with cold running water or ice, and seek medical assistance where necessary.

5. Model Answers to Questions in the Worksheet
It is recommended that learners write down all of the questions and answers in their workbooks. If this is done, then the answers to questions do not have to be in full sentences. If the learners do not copy the questions into their workbooks, then answers should be written in full sentences. Note that some of the questions can only be answered by learners in higher grades. Word equations can be written instead of chemical equations where required.

Q1. What do you see happening in well F1 when you add the acid ?
A1. There is a "hissing" sound, and gas bubbles form.

Q2. What do you see happening in well F3 after a short while **?**
A2. The clear limewater becomes milky.

Q3. What does this tell us about the gas that formed in the reaction in well F1 ?
A3. Carbon dioxide gas was one of the products of the reaction between hydrochloric acid and calcium carbonate.

Read the following information carefully. Use this to answer Q4–Q6. Clear lime water is an aqueous solution of calcium hydroxide. When carbon dioxide reacts with the limewater, insoluble calcium carbonate and water are formed.

Q4. Write down a word equation for the reaction between carbon dioxide and limewater.
A4. Carbon dioxide(g) + calcium hydroxide(aq) $\rightarrow$ calcium carbonate(s) + water(ℓ)

Q5. Write down a balanced chemical equation for the reaction between carbon dioxide and limewater.
A5. $CO_2(g) + Ca(OH)_2(aq) \rightarrow CaCO_3(s) + H_2O(\ell)$

Q6. Use the equation above to identify the substance that caused the clear limewater to become milky. Explain your answer.
A6. Calcium carbonate ($CaCO_3(s)$). This is a white insoluble solid. Small particles of this white insoluble solid would cause the milkiness.

Q7. What do you notice in well F1 after leaving the comboplate® overnight ?
A7. White crystals formed.

Q8. What is this substance in F1 ?
A8. Calcium chloride crystals ($CaC\ell_2(s)$).

Q9. The other product in this reaction evaporated when you heated the solution and left the comboplate® overnight. What could this possibly be ?
A9. Water.

Q10. Write a word equation for the chemical reaction that took place in well F1.
A10. Hydrochloric acid(aq) + calcium carbonate(s) → calcium chloride(s) + water(ℓ) + carbon dioxide(g)

Q11. Write a balanced chemical equation for this reaction in well F1.
A11. $2HC\ell(aq) + CaCO_3(s) \rightarrow CaC\ell_2(s) + H_2O(\ell) + CO_2(g)$

Q12. Look at the name of the crystals that formed in this reaction. It is called a SALT. This salt was prepared by the reaction between an acid and a metal carbonate. What part of the name of the salt comes from the metal carbonate?
A12. The "calcium" part of the name calcium chloride.

Q13. What part of the name of the salt comes from the acid used in the reaction ?
A13. The "chloride" part of the name comes from the hydrochloric acid used in the reaction.

Q14. What difference would it make if you had used nitric acid instead of hydrochloric acid in the reaction ?
A14. The salt formed would have been calcium nitrate.

Q15. What chemicals would you use to prepare sodium chloride from the reaction between an acid and a carbonate ?
A15. Sodium carbonate and hydrochloric acid.

Q16. Write a balanced chemical equation for the reaction in your answer to Q15.
A16. $Na_2CO_3(s) + 2HC\ell(aq) \rightarrow 2NaC\ell(s) + H_2O(\ell) + CO_2(g)$

Q17. In this experiment you looked at the reaction between hydrochloric acid and calcium carbonate. Complete the general chemical equation:
A17. acid + metal carbonate → salt + water + carbon dioxide

PREPARATION OF A SALT:
THE REACTION OF AN ACID WITH A METAL

TEACHER GUIDE

1. Chemicals
All of the required chemicals are listed in the worksheet. Tap water is also needed.

2. Equipment
Most of the apparatus required can be found in a RADMASTE Basic or Advanced Microchemistry Kit.

3. Hints
When first adding the acid to the zinc in well F1, only about half of the acid must carefully be injected into the well. If all of the acid is added too quickly, the vigorous bubbling in the well may force the solution upwards and out of the silicone tube. This will prevent collection of any hydrogen gas formed.

The gas collecting tube must not be tilted or turned the right way up when it is being removed from the set-up. Hydrogen is less dense than air and will escape from the tube if it is not kept in an inverted position.

Once the open end of the gas collecting tube has been sealed with a finger, the tube can be turned the right way up. The finger must not be removed from the mouth of the tube until a lighted match is held in place to test for the hydrogen gas. It is recommended that learners work in pairs or groups to carry out the test for hydrogen because it is difficult for one learner to light a match whilst also holding the gas collecting tube.

4. Cautions
Please remember the following cautions and inform your students of all safety hazards:

Hydrochloric acid is corrosive. If any acid is spilt on the skin, the affected area must immediately be rinsed with copious amounts of water. Severe burns must receive medical attention.

Never point a propette or a syringe containing acid upwards. A momentary lapse of concentration can result in a nasty accident. If any acid is squirted into the eye, immediately rinse the eye out under running water. Always have a dilute solution of sodium hydrogencarbonate (household baking soda), or milk close by to apply to the injury. These substances will help neutralise the acid in the eye. The patient should be referred to a doctor.

Do not allow anyone to bring a flame near the comboplate®. The hydrogen gas generated in well F1 is highly explosive. Ensure that the comboplate® is moved away from all sources of flames.

Never allow the learners to play with matches. Treat any burn with cold running water or ice, and seek medical assistance where necessary.

5. Model Answers to Questions in the Worksheet
It is recommended that learners write down all of the questions and answers in their workbooks. If this is done, then the answers to questions do not have to be in full sentences. If the learners do not copy the questions into their workbooks, then answers should be written in full sentences. Note that some of the questions can only be answered by learners in higher grades. Word equations can be written instead of chemical equations where required.

Q1. What happens in well F1 when the acid is added ?
A1. Gas bubbles form in the well.

Q2. What does this tell us about one of the products of the reaction ?
A2. One of the products of the reaction between an acid and a metal is a gas.

Q3. What, if anything, is in the gas collecting tube at the start of the experiment ?
A3. Air.

Q4. What, if anything, collects in the gas collecting tube as the reaction takes place in well F1 ?
A4. The gas that formed as a result of the reaction between the acid and the metal.

Q5. Why does the gas not escape from the upside-down gas collecting tube ?
A5. The gas that formed is less dense than air.

Q6. Describe what happens when you remove your finger from the open end of the gas collecting tube with the burning match in place.
A6. A loud popping noise can be heard.

Q7. Explain your answer to Q6.
A7. As soon as the gas in the tube mixed with the oxygen in the air it formed an explosive mix which ignited with the burning match.

Q8. What gas was formed during the reaction ?
A8. Hydrogen gas. We know this because hydrogen gas characteristically forms an explosive mix with oxygen in the air, and gives the "popping" sound when a small amount of hydrogen gas is ignited in air.

Q9. Explain why it was necessary to move the comboplate® away from any open flames.
A9. The reaction mixtures in the wells continue to produce hydrogen gas for some time. If any flames had been brought near the comboplate®, the hydrogen gas escaping may have reacted with the oxygen in the air around it.

Q10. What do you see in the microwell after leaving the comboplate® overnight ?
A10. White crystals.

Q11. Explain your observation.
A11. One of the products of the reaction between the acid and the metal was in solution, and crystallised when left overnight and the water evaporated.

Q12. What were the reactants in well F1 ?
A12. Hydrochloric acid and zinc powder.

Q13. What were the products of the reaction in well F1 ?
A13. Hydrogen gas and zinc chloride.

Q14. Write a word equation for the reaction that occurred in well F1.
A14. Hydrochloric acid(aq) + zinc(s) → hydrogen gas(g) + zinc chloride(aq)

Q15. Write down a balanced chemical equation for the reaction that occurred in well F1.
A15. $2HC\ell(aq) + Zn(s) \rightarrow H_2(g) + ZnC\ell_2(aq)$

Q16. What chemicals would you use to prepare magnesium sulphate using a similar procedure ?
A16. Sulphuric acid and magnesium.

Q17. Write down a balanced chemical equation for the reaction that you propose in question 16.
A17. $H_2SO_4(aq) + Mg(s) \rightarrow MgSO_4(s) + H_2(g)$

PREPARATION OF A SALT:
THE REACTION BETWEEN AN ACID AND A METAL OXIDE

TEACHER GUIDE

1. Chemicals
All of the required chemicals are listed in the worksheet. Tap water is also needed.

2. Equipment
Most of the apparatus required can be found in a RADMASTE Basic or Advanced Microchemistry Kit.

3. Hints
The end of the glass rod must be gently heated in the flame of the microburner by moving it through the flame a few times. The rod must not be left in the flame too long as the end will get so hot that the solution in well F1 boils. This may result in loss of the dissolved copper sulphate as some of the solution splashes out of the well.

4. Cautions
Please remember the following cautions and inform your students of all safety hazards:

Sulphuric acid is corrosive. If any acid is spilt on the skin, the affected area must immediately be rinsed with copious amounts of water. Severe burns must receive medical attention.

Never point a propette or a syringe containing acid upwards. A momentary lapse of concentration can result in a nasty accident. If any acid is squirted into the eye, immediately rinse the eye out under running water. Always have a dilute solution of sodium hydrogencarbonate (household baking soda), or milk close by to apply to the injury. These substances will help neutralise the acid in the eye. The patient should be referred to a doctor.

Never allow the learners to play with matches. Treat any burn with cold running water or ice, and seek medical assistance where necessary.

5. Model Answers to Questions in the Worksheet
It is recommended that learners write down all of the questions and answers in their workbooks. If this is done, then the answers to questions do not have to be in full sentences. If the learners do not copy the questions into their workbooks, then answers should be written in full sentences. Note that some of the questions can only be answered by learners in higher grades. Word equations can be written instead of chemical equations where required.

Q1. What is the colour of the copper(II) oxide ?
A1. Black.

Q2. What happens in well F1 after some time ?
A2. The colour of the solution changes to blue.

Q3. What ions give this colour to the solution ?
A3. Cu^{2+} ions.

Q4. What do you notice in well F1 after leaving the comboplate® overnight ?
A4. Blue crystals formed.

Q5. What is this substance in F1 ?
A5. Copper sulphate crystals ($CuSO_4$(s)).

(NB: Actually, they are copper sulphate pentahydrate crystals, $CuSO_4.5H_2O$. However teachers may wish to use the simpler name and formula.)

Q6. The other product in this reaction evaporated when you heated the solution and left the comboplate® overnight. What could this possibly be ?
A6. Water.

Q7. Write a word equation for the chemical reaction that took place in well F1.
A7. Sulphuric acid(aq) + copper(II) oxide(s) → copper sulphate(aq) + water(ℓ)

Q8. Write a balanced chemical equation for this reaction in well F1.
A8. $H_2SO_4(aq) + CuO(s) \rightarrow CuSO_4(aq) + H_2O(\ell)$

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Q8. Write a balanced chemical equation for this reaction in well F1.

A8. $H_2SO_4(aq) + CuO(s) \rightarrow CuSO_4(aq) + H_2O(\ell)$

Q9. Look at the name of the crystals that formed in this reaction. It is called a SALT. This salt was prepared by the reaction between an acid and a metal oxide. What part of the name of the salt comes from the metal oxide ?

A9. The "copper" part of the name copper sulphate.

Q10. What part of the name of the salt comes from the acid used in the reaction ?

A10. The "sulphate" part of the name comes from the sulphuric acid used in the reaction.

Q11. What difference would it make if you used hydrochloric acid instead of sulphuric acid in the reaction ?

A11. The salt formed would be copper chloride.

Q12. What chemicals would you use to prepare magnesium sulphate using the reaction between an acid and a metal oxide ?

A12. Sulphuric acid and magnesium oxide.

THE CONDUCTIVITY AND pH OF SOLUTIONS OF ACIDS AND BASES

TEACHER GUIDE

1. Chemicals
All of the required chemicals are listed in the worksheet. Tap water is also needed.

2. Equipment
Most of the apparatus required can be found in a RADMASTE Advanced Microchemistry Kit. A 9V battery and 2 pencil leads are also required.

3. Hints
The 9V battery is a source of potential difference in the electrical circuit. It must be explained to the student that the battery does not make the LED glow on its own. If the conducting wires are not placed in some electrolyte solution, the LED will not glow. It may be important to state this so as to avoid the misconception that the battery makes the LED glow, whether a conducting solution is present or not.

If the LED does not glow when the pencil leads are immersed in the acidic/basic solution, check that the electrical connections are secure.

The experiment is best performed in a dull lit room, as this makes it easier to assess and compare the intensity (brightness) with which the LED is glowing. Alternatively, the student can cup one hand around the apparatus to darken the area around the LED.

The pencil leads in the test solution must not touch, otherwise the circuit will be completed and the LED will glow brightly. This will give a false result, especially if a solution of low conductivity is being tested.

Universal indicator solutions provided by different manufacturers may have different pH values of their own. Tap water samples used to dilute the acid and base solutions may also have varying pH values. As a result, the colour and pH obtained by the student with a particular indicator solution may vary slightly from that given in Tables 1 and 2 of the model answers.

The colours produced by indicator solutions often represent a pH range rather than a specific pH value. This may make it difficult for a single pH value to be assigned to a particular solution. Nevertheless, the aim of the experiment is still achieved since it will be shown that the NaOH(aq) solution of higher concentration and higher pH has a greater conductivity than that with a lower concentration and lower pH. Similarly, the $HC\ell(aq)$ of higher concentration and lower pH has a greater conductivity than that with a lower concentration and higher pH.

The syringe must be thoroughly dry inside before dispensing a new solution, otherwise the acid/base will be more dilute than intended. This will lead to confusion during pH testing.

The LED glows when the connecting wires are placed in tap water. This is because tap water contains other ions besides $H_3O^+(aq)$ and $OH^-(aq)$ ions. These ions increase the conductivity of the tap water and cause the LED to glow. Even distilled water produces a dull light from the LED, because it is not completely deionised. Only pure, deionised water will not have a high enough conductivity to cause the LED to glow.

4. Cautions
Please remember the following cautions and inform your students of all safety hazards:

Hydrochloric and acetic acids are corrosive. If any acid is spilt on the skin, the affected area must immediately be rinsed with copious amounts of water. Severe burns must receive medical attention.

Sodium hydroxide and ammonia are corrosive bases. If any base is spilt on the skin, treat as above for acid burns.

Never point a propette or a syringe containing acid or base upwards. A momentary lapse of concentration can result in a nasty accident. If any acid or base is squirted into the eye, immediately rinse the eye out under running water. In the case of an acid, always have a dilute solution of sodium hydrogencarbonate (household baking soda), or milk close by to apply to the injury. These substances will help neutralise the acid in the eye. The patient should be referred to a doctor.

5. Model Answers to Questions in the Worksheet

It is recommended that learners write down all of the questions and answers in their workbooks. If this is done, then the answers to questions do not have to be in full sentences. If the learners do not copy the questions into their workbooks, then answers should be written in full sentences. Note that some of the questions can only be answered by learners in higher grades. Word equations can be written instead of chemical equations where required.

PART 1: What is the effect of the concentration of a basic or acidic solution on its conductivity and pH ?

Table 1. Experimental observations (contains answers for questions 1 to 6)

Well	Concentration NaOH(aq)/M	LED glow: dull, bright?	pH of solution
E1	**0.005**	**bright**	**~ 11 - 12**
E2	**0.00025**	**dull**	**~ 10 - 11**
Well	Concentration HCℓ(aq)/M	LED glow: dull, bright?	pH of solution
F1	**0.005**	**bright**	**~ 2 - 3**
F2	**0.00025**	**dull**	**~ 4 - 6**

Q7. Which wells had the higher concentration of sodium hydroxide solution and hydrochloric acid and what were the pH values of the solutions in these wells?

A7. Sodium hydroxide: Well E1 – pH~11-12
Hydrochloric acid: Well F1 – pH~2-3

Q8. Which wells had the lower concentration of sodium hydroxide solution and hydrochloric acid and what were the pH values of the solutions in these wells ?

A8. Sodium hydroxide: Well E2 – pH~10-11
Hydrochloric acid: Well F2 – pH~4-6

Q9. What causes the current indicator to glow ?

A9. Ions in the solution are necessary for the existence of an electric current in the circuit. The higher the concentration of these ions the brighter the current indicator should glow.

Q10. The current indicator used in this experiment will not glow if the wires are immersed in pure (deionised) water. If pure water contains H_3O^+(aq) and OH^-(aq) ions, why will the current indicator not glow ?

A10. The concentration of the hydronium ions (H_3O^+(aq)) and the hydroxide ions (OH^-(aq)) in pure water is only 10^{-7} mol/l or 0.000 000 1 mol/l each. Thus the conductivity of pure water is very poor. This current indicator would not glow when the ion concentration is so low.

Q11. In which wells did the current indicator glow more brightly for the sodium hydroxide solution and hydrochloric acid and what were the pH values of the solutions in these wells ?

A11. Sodium hydroxide: Well E1 – pH~11-12
Hydrochloric acid: Well F1 – pH~2-3

Q12. In which wells did the current indicator glow less brightly for the sodium hydroxide solution and hydrochloric acid and what were the pH values of the solutions in these well ?

A12. Sodium hydroxide: Well E2 – pH~10-11
Hydrochloric acid: Well F2 – pH~4-6

Q13. What is the effect of the concentration of a basic or acidic solution on its conductivity and pH ?

A13. The experimental results have shown that the higher the concentration of an acid or a base, the greater the conductivity of the solution. This is because the higher the concentration of acid or base, the higher the concentration of ions. Similarly, the higher the concentration of base the higher the concentration of hydroxide ions, and the lower the concentration of hydronium ions; hence the higher the pH. Also the higher the concentration of acid, the higher the concentration of hydronium ions (H_3O^+(aq)) and therefore the lower the pH.

PART 2: Does the nature of a base or acid affect the conductivity and pH of its solution ?

Table 2. Experimental observations (contains answers for questions 1 to 3)

Well	Concentration /M	Solution Type	pH	LED glow: very dull, dull, bright, very bright ?
E1	1.0	Ammonia	**~ 13**	**Bright**
E2	0.1	Sodium Hydroxide	**~ 13**	**Very Bright**
F1	1.0	Acetic Acid	**~ 1**	**Bright**
F2	0.1	Hydrochloric Acid	**~ 1**	**Very Bright**

Q4. Which of the solutions in wells E1 and E2 has the higher pH ?
A4. Neither. They are both pH~13.

Q5. Which of the solutions in wells E1 and E2 caused the current indicator to glow brighter ?
A5. The sodium hydroxide solution in well E2.

Q6. Which is a stronger base: ammonia or sodium hydroxide ? Explain.
(☺ **Hint:** See your answers to questions 4 and 5)
A6. Sodium hydroxide is a stronger base, since a 0.10 M solution of sodium hydroxide has the same pH and a higher conductivity than a 1.0 M solution of ammonia. The concentration of the ammonia solution is ten times greater than the solution of sodium hydroxide, yet the pH values of the two solutions are the same.

Q7. Which of the solutions in wells F1 and F2 has the lower pH ?
A7. Neither. They are both pH~1.

Q8. Which of the solutions in wells F1 and F2 caused the current indicator to glow brighter ?
A8. The hydrochloric acid in well F2.

Q9. Which is a stronger acid: acetic acid or hydrochloric acid ? Explain. (☺ **Hint:** See your answers to questions 7 and 8.)
A9. Hydrochloric acid is a stronger acid, since a 0.10 M solution of hydrochloric acid has the same pH and a higher conductivity than a 1.0 M solution of acetic acid. The concentration of acetic acid is ten times greater than the concentration of hydrochloric acid, yet the pH values of the solutions are the same.

Q10. How does the nature of a base or acid affect the conductivity and pH of its solutions ?
A10. The nature of a base or acid does affect the conductivity and pH of its solution. Solutions of ammonia and sodium hydroxide, for example, are both basic. Yet a solution of ammonia needs to be made ten times more concentrated than a solution of sodium hydroxide, for both solutions to have the same pH. Even at the higher concentration, ammonia has a slightly lower conductivity than the 0.10 M sodium hydroxide. Thus ammonia is called a weak base, while sodium hydroxide is a called a strong base. Similarly acetic acid is called a weak acid, while hydrochloric acid is called a strong acid.

THE STOICHIOMETRY OF PRECIPITATION REACTIONS

TEACHER GUIDE

1. Chemicals
All of the required chemicals are listed in the worksheet. Boiling water is needed to allow the precipitates to settle better, but the experiment will still work if it is not available.

2. Equipment
Most of the apparatus required can be found in a RADMASTE Basic or Advanced Microchemistry Kit. A ruler is required to measure the precipitate heights. A plastic container is needed for the boiling water.

3. Hints
The thin stemmed propettes used to dispense the potassium chromate (K_2CrO_4) and barium chloride ($BaC\ell_2$) solutions in Part 1, as well as those used to dispense the lead nitrate ($Pb(NO_3)_2$) and sodium iodide (NaI) solutions in Part 2, should be identical or matched as closely as possible. This is needed to ensure that the drop sizes of each solution delivered are very similar, otherwise misleading volume ratios may be obtained from the graphs.

The barium chromate ($BaCrO_4$) precipitates formed in Part 1 and the lead iodide (PbI_2) precipitates formed in Part 2, are placed in boiling water to allow them to settle better. However, the precipitates will still settle in the absence of boiling water. A 10 minute settling period is required. The volume ratios recorded from the graphs may not be as accurate as when the boiling stage is included in the procedure, but reasonable results are attainable.

The container into which the boiling water is poured should be large enough to accommodate the comboplate® e.g a 2 litre ice cream tub or similar. Ideally, each student should have their own container. If larger containers are available, a few students can share these at a time provided that the water bath does not become overcrowded with comboplates®. The water should not reach a depth of more than about 1.5 cm, otherwise the wells of the comboplate® may be flooded.

After the comboplates® have been removed from the water bath and allowed to stand for a further 5 minutes, there may be condensation on the plastic of the comboplate® which obscures the precipitates and makes measuring difficult. The condensation is simply removed by pushing some paper towel between the small wells and the front of the comboplate®.

Learners must be reminded that the points plotted on the graph must not be joined with a curve. In scientific practise, the best straight line is drawn through the points that show a positive slope and another straight line is drawn through the points that display a negative slope. The two lines will intersect at the true maximum point on the curve, which in this case will be the highest precipitate formed. This method allows for the most accurate volume ratio to be calculated, since the true maximum precipitate height given by the graph may not actually have been observed with the limited number of samples measured in the experiment.

PART 1: The Reaction of Potassium Chromate ((K_2CrO_4(aq)) and Barium Chloride ($BaC\ell_2$(aq))

In Part 1, the colours of the solutions above the $BaCrO_4$ precipitates help identify which reagent has been added in excess. The amount of precipitate obtained is limited by the reagent in the smaller quantity, leaving the excess of the other reagent unreacted. For this reason, when the yellow K_2CrO_4(aq) is added in excess, the solution above the $BaCrO_4$ precipitate is yellow.

If you are using your own solutions for either part of this experiment, make sure that the concentrations of the two solutions used are identical. If you prepare one of the required solutions at a higher (or lower) concentration, the mole ratios calculated will not be as given in the model answers. (e.g for Part 1, a 1:1 mole ratio for K_2CrO_4:$BaC\ell_2$ is expected. If the $BaC\ell_2$(aq) is prepared at a higher concentration than that of the K_2CrO_4(aq), then more drops of the chromate solution will be required for a complete reaction to occur. The highest precipitate measured will not be in the well containing 5 drops of each solution, but rather where there are more than 5 drops of chromate solution. The apparent mole ratio will therefore exceed 1:1.)

PART 2: The Reaction of Lead Nitrate ($Pb(NO_3)_2$(aq)) and Sodium Iodide (NaI(aq))

It is advisable to rinse out the PbI_2 precipitates as soon as Part 2 has been completed. If washing is delayed, some of the PbI_2(s) may adhere to the inside of the wells. If this happens, boiling water can be used to flush out the comboplate®. Any stubborn residues can then be removed with a little cotton wool that has been twirled around the end of a toothpick or wooden skewer.

4. Cautions

Please remember the following cautions and inform your students of all safety hazards:

Barium salts and chromates are poisonous. Avoid getting the reagents and mixtures into the mouth, eyes or on the skin. Wash affected areas with copious amounts of water. Treat spillages in the same way.

Lead solutions and lead salts are poisonous. Avoid contact with these, and dispose of the precipitates in a waste jar.

5. Model Answers to Questions in the Worksheet

It is recommended that learners write down all of the questions and answers in their workbooks. If this is done, then the answers to questions do not have to be in full sentences. If the learners do not copy the questions into their workbooks, then answers should be written in full sentences. Note that some of the questions can only be answered by learners in higher grades. Word equations can be written instead of chemical equations where required.

PART 1: The Reaction of Potassium Chromate ((K_2CrO_4(aq)) and Barium Chloride ($BaC\ell_2$(aq))

Q1. What is the colour of the barium chloride solution ?
A1. Colourless.

Q2. What is the colour of the potassium chromate solution ?
A2. Yellow.

Q3. What happens in well A1 after adding the drop of potassium chromate solution ?
A3. A milky yellow precipitate forms.

Q4. Prepare a table like Table 3 below.
A4. See Table 3.

Well	Drops of $BaC\ell_2$(aq) [0.50 M] / (V_1)	Drops of K_2CrO_4(aq) [0.50 M] / (V_2)	Height of precipitate / mm
	10	0	**0.0**
A1	9	1	**1.0**
A2	7	3	**2.7**
A3	5	5	**3.9**
A4	3	7	**3.0**
A5	1	9	**1.5**
	0	10	**0.0**

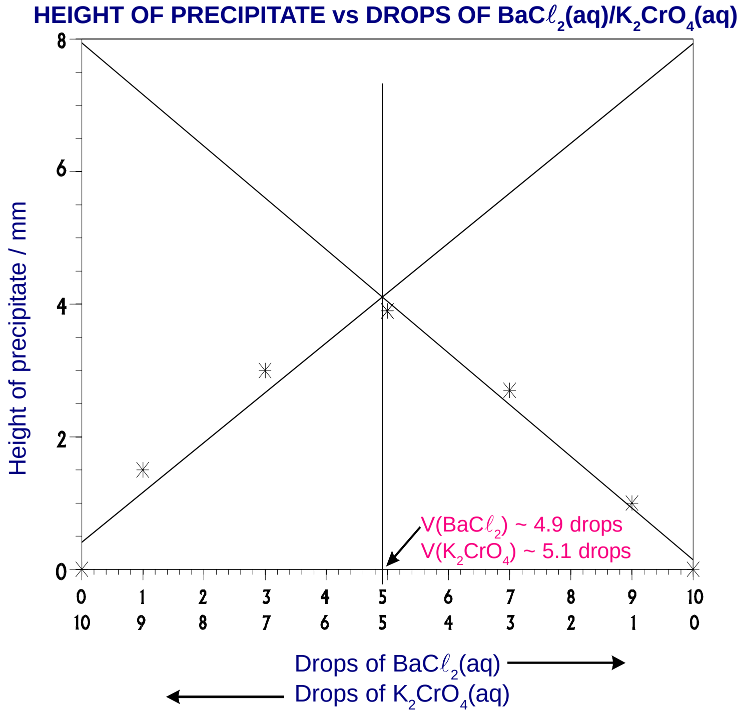
Q5. Complete your table.
A5. Table 3

Q6. Prepare a graph with the height of precipitate (mm) on the Y axis. On the X axis put the volume of barium chloride solution (from 0 drops to 10 drops at one drop intervals), as well as the volume of potassium chromate solution (from 10 drops to 0 drops at intervals of one drop).

Note

From Table 3, it can be seen that the total volume of solutions added to each well is 10 drops. Therefore the X axis can serve as an axis for the volumes of both $BaC\ell_2$(aq) and K_2CrO_4(aq). At each volume of $BaC\ell_2$(aq), the volume of K_2CrO_4(aq) is (10 drops – drops of $BaC\ell_2$(aq)). For example, on the X axis a scale mark could be 3 drops of barium chloride solution and 7 drops of potassium chromate solution.

A6.



Q7. The scientific method used for finding the volume ratio with a graph like that which you have prepared, is to draw the best straight line through the set of points showing a positive slope, and another straight line through the set of points which displays a negative slope.

Therefore, draw the best straight line through the set of points between 0 and the number of drops of barium chloride giving the maximum height of the precipitate. Now, draw the best straight line through the set of points between the number of drops for the maximum height and 10. The two lines will intersect at the true maximum point on the curve (i.e where the highest precipitate occurs).
Drop a perpendicular from this point onto the X axis and record the drops of $BaC\ell_2$(aq) and K_2CrO_4(aq) where the perpendicular touches the axis.

A7. Volume (V_1) of $BaC\ell_2$(aq) in drops: 4.9 drops
Volume (V_2) of K_2CrO_4(aq) in drops: 5.1 drops

Q8. What causes a precipitate to form, when barium chloride and potassium chromate solutions are mixed ?

A8. When barium chloride and potassium chromate solutions are mixed, a chemical reaction occurs resulting in the formation of barium chromate. Barium chromate is insoluble and therefore precipitates, leaving potassium chloride in solution.

Q9. You will notice in Table 3 that the height of the precipitate at 0 drops and 10 drops of barium chloride is given as 0 mm. Explain this.

A9. At 0 drops of $BaC\ell_2$(aq), there is only K_2CrO_4(aq) in the well. Therefore, no reaction occurs and no barium chromate precipitates. At 10 drops of $BaC\ell_2$(aq), there is no K_2CrO_4(aq) present and similarly no reaction occurs.

Q10. Why does the height of the precipitate change as the ratio of barium chloride:potassium chromate changes ?

A10. As the ratio of reactants added changes so does the amount of product, i.e barium chromate, which forms and precipitates.

Q11. Calculate the volume ratio (V_1/V_2) corresponding to the maximum height of precipitate.

A11.

$$\frac{V_1}{V_2} = \frac{4.9 \text{ drops}}{5.1 \text{ drops}} = 0.96$$

Within experimental error, this is equivalent to a volume ratio of 1.

Q12. What do you deduce from the volume ratio in question 11 about the mole ratio in which barium chloride and potassium chromate react ?

A12. The mole ratio is 1.0.

Q13. Justify your answer to question 12.

A13. A maximum precipitate is formed at the V_1/V_2 ratio of 1.0 (or 1:1). This means that the greatest amount of barium chromate formed when one volume of $BaC\ell_2$ reacted with one volume of K_2CrO_4. Since the concentrations of the $BaC\ell_2(aq)$ and $K_2CrO_4(aq)$ are the same, we can say that $BaC\ell_2$ reacted with K_2CrO_4 in the molar ratio of 1:1.

Q14. Write down a balanced chemical equation to represent the chemical reaction between barium chloride and potassium chromate.

A14. $BaC\ell_2(aq) + K_2CrO_4(aq) \rightarrow BaCrO_4(s) + 2KC\ell(aq)$

Q15. What would be the mole ratio (see question 12) if the concentrations of both the barium chloride and the potassium chromate solutions were doubled ? Give reasons for your answer.

A15. The mole ratio would remain 1.0. From the balanced equation it can be observed that 1 mole of barium chloride reacts completely with one mole of potassium chromate. Therefore the change in concentration will not affect the mole ratio.

Q16. What do you notice about the appearance of the solutions above the precipitates in wells A1 and A2 ?

A16. They are clear and colourless (if the comboplate® was placed in boiling water) or milky (if boiling water was not used).

Q17. What do you notice about the appearance of the solutions above the precipitates in wells A4 and A5 ?

A17. They are yellow.

Q18. Explain the observations made in questions 16 and 17. (Recall your observations of the colours of the $BaC\ell_2(aq)$ and the $K_2CrO_4(aq)$ at the beginning of the experiment.)

A18. The amount of barium chromate precipitate formed is determined by the reagent in the smaller volume, leaving the excess of the other reagent unreacted. In wells A1 and A2, there were more drops of $BaC\ell_2(aq)$ than $K_2CrO_4(aq)$. Since the reaction ratio of $BaC\ell_2$:K_2CrO_4 is 1.0, only 1 drop of $BaC\ell_2(aq)$ reacted with the 1 drop of $K_2CrO_4(aq)$ in well A1. The other 9 drops of $BaCl_2(aq)$ remained unreacted as the clear solution above the precipitate in well A1. Similarly in well A2, only 3 of the 7 drops of $BaC\ell_2(aq)$ reacted with the 3 drops of $K_2CrO_4(aq)$. In well A4, there were more drops of potassium chromate than barium chloride. Only 3 drops of $K_2CrO_4(aq)$ reacted with the 3 drops of $BaC\ell_2(aq)$. The other 7 drops of $K_2CrO_4(aq)$ remained unreacted as the yellow solution above the precipitate. Similarly, in well A5 only 1 out of 9 drops of $K_2CrO_4(aq)$ reacted with the 1 drop of $BaC\ell_2(aq)$.

PART 2: The Reaction of Lead Nitrate ($Pb(NO_3)_2(aq)$) and Sodium Iodide ($NaI(aq)$)

Q1. Prepare a table like Table 3.

A1. Table 3

Well	Drops of $Pb(NO_3)_2(aq)$ [0.50 M] / (V_1)	Drops of NaI(aq) [0.50 M] / (V_2)	Height of Precipitate / mm
	0	12	**0.0**
A1	2	10	**0.8**
A2	4	8	**2.0**
A3	7	5	**1.2**
A4	8	4	**1.0**
A5	10	2	**0.5**
	12	0	**0.0**

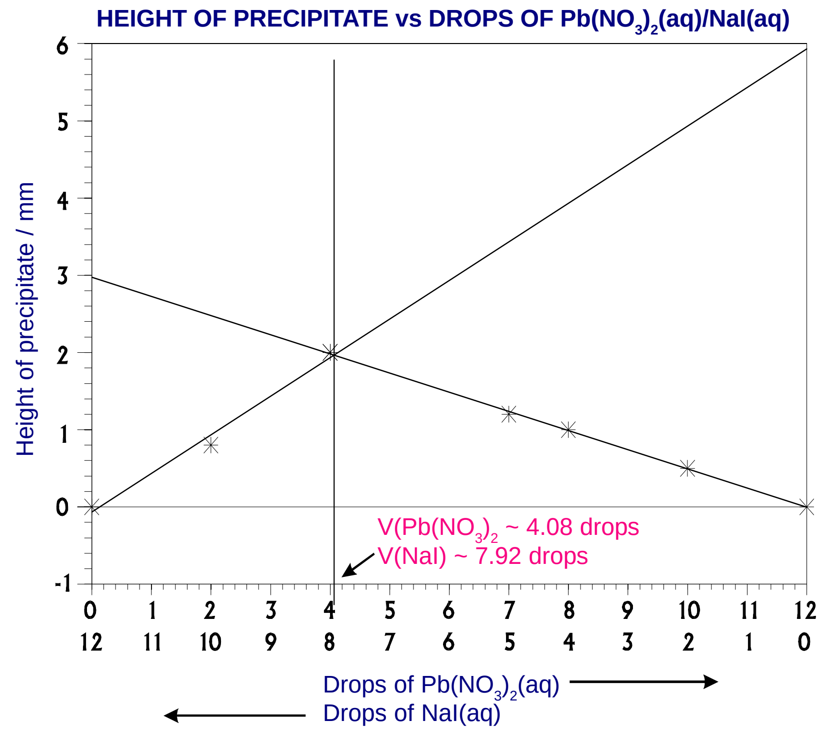
Q2. Record the heights of the precipitates in your table.

A2. See Table 3.

Q3. Prepare a graph with the height of precipitate (mm) on the Y axis. On the X axis put the volume of lead nitrate solution (from 0 drops to 12 drops at one drop intervals), as well as the volume of sodium iodide solution (from 12 drops to 0 drops at intervals of one drop).

Note **From Table 3, it can be seen that the total volume of solutions added to each well is 12 drops. Therefore the X axis can serve as an axis for the volumes of both $Pb(NO_3)_2(aq)$ and NaI(aq). At each volume of $Pb(NO_3)_2(aq)$, the volume of NaI(aq) is (12 drops – drops of $Pb(NO_3)_2(aq)$). For example, on the X axis a scale mark could be 3 drops of lead nitrate solution and 9 drops of sodium iodide solution.**

A3.



Q4. Draw the best straight line through the set of points between 0 and the number of drops of lead nitrate which gave the most precipitate. Now, draw the best straight line between the most precipitate and 12 drops of lead nitrate (i.e 0 drops of NaI(aq) and no reaction). The two lines will intersect at the true maximum point on the curve (i.e where the highest precipitate occurs). Drop a perpendicular from this point onto the X axis and record the volume (V_1) of $Pb(NO_3)_2$(aq) and volume (V_2) of NaI(aq) in drops, where the perpendicular touches the axis.

A4. Volume (V_1) of $Pb(NO_3)_2$(aq) in drops: 4.08 drops

Volume (V_2) of NaI(aq) in drops: 7.92 drops

Q5. What causes a precipitate to form, when lead nitrate and sodium iodide solutions are mixed ?

A5. When lead nitrate and sodium iodide solutions are mixed a chemical reaction occurs, which results in the formation of lead iodide. Lead iodide is insoluble in water and therefore precipitates. Sodium nitrate remains in solution.

Q6. Calculate the volume ratio (V_1/V_2) corresponding to the maximum height of precipitate.

A6. $$\frac{V_1}{V_2} = \frac{4.08 \text{ drops}}{7.92 \text{ drops}} = 0.52$$

Within experimental error, this is equivalent to a volume ratio of 0.5.

Q7. What do you deduce from the volume ratio in question 6 about the mole ratio in which lead nitrate and sodium iodide react ?

A7. The mole ratio is 0.5.

Q8. Justify your answer to question 7.

A8. A maximum precipitate is formed at the V_1/V_2 ratio of 0.5 (or 1:2). This means that the greatest amount of lead iodide formed when one volume of $Pb(NO_3)_2$ reacted with two volumes of NaI. Since the concentrations of the $Pb(NO_3)_2$(aq) and NaI(aq) are the same, we can say that $Pb(NO_3)_2$ reacted with NaI in the <u>molar ratio</u> of 1:2.

Q9. Write down a balanced chemical equation to represent the chemical reaction between lead nitrate and sodium iodide.

A9. $Pb(NO_3)_2(aq) + 2NaI(aq) \rightarrow PbI_2(s) + 2NaNO_3(aq)$

TESTING FOR IONS IN AQUEOUS SOLUTIONS

TEACHER GUIDE

1. Chemicals
All of the required chemicals are listed in the worksheet. Tap water is also needed in Part 1.

2. Equipment
Most of the apparatus required can be found in a RADMASTE Basic or Advanced Microchemistry Kit.

3. Cautions
Please remember the following cautions and inform your students of all safety hazards:

11 M hydrochloric acid is extremely corrosive. 1.0 M sulphuric acid and 2.0 M nitric acid are also dangerous if not handled safely. If any acid is spilt on the skin, the affected area must immediately be rinsed with copious amounts of water. Severe burns must receive medical attention.

Never point a propette or a syringe containing acid upwards. A momentary lapse of concentration can result in a nasty accident. If any acid is squirted into the eye, immediately rinse the eye out under running water. Always have a dilute solution of sodium hydrogencarbonate (household baking soda), or milk close by to apply to the injury. These substances will help neutralise the acid in the eye. The patient should be referred to a doctor.

Silver is an expensive metal. Solutions of silver nitrate are also expensive and should not be wasted!

4. Model Answers to Questions in the Worksheet
It is recommended that learners write down all of the questions and answers in their workbooks. If this is done, then the answers to questions do not have to be in full sentences. If the learners do not copy the questions into their workbooks, then answers should be written in full sentences. Note that some of the questions can only be answered by learners in higher grades. Word equations can be written instead of chemical equations where required.

PART 1: Testing for the Presence of Sulphate Ions

Q1. What do you observe when a solution of barium chloride is added to wells A1 to A4 ?
A1. Well A1: The solution remains clear.
Well A2: The solution turns milky.
Well A3: The solution turns milky.
Well A4: The solution remains clear.

Q2. In which well/s do you observe a precipitate ?
A2. Wells A2 and A3.

Q3. Write the chemical formula to represent any precipitate/s observed in wells A1 to A4.

HINT **Sodium chloride and zinc chloride are both soluble in water.**

A3. $BaSO_4$(s) in well A2 and $BaCO_3$(s) in well A3.

Q4. Can the addition of a solution of barium chloride (as in the above procedure) serve as a test for the presence of sulphates in aqueous solutions ? Give a reason for your answer.
A4. No. This is because the carbonate as well as the sulphate formed a white precipitate on addition of barium chloride solution.

Q5. What do you observe when 11 M hydrochloric acid is added to wells A1 to A4?
A5. Well A1: The solution remains clear.
Well A2: The solution remains milky.
Well A3: Bubbles can be seen. A clear solution forms.
Well A4: The solution remains clear.

Q6. In which well/s do you now observe a precipitate ?
A6. Well A2.

Q7. Write a chemical formula to represent any precipitate/s observed in the above wells, after the addition of $HC\ell(aq)$.
A7. $BaSO_4(s)$.

Q8. Explain any change observed in wells A1 to A4 on adding $HC\ell(aq)$.
A8. When hydrochloric acid is added to well A3 the barium carbonate precipitate reacts forming gaseous carbon dioxide ($CO_2(g)$), water and barium chloride. The barium chloride is soluble in water and so the precipitate is observed to "disappear".

Q9. On the basis of your observations, state how you would test for sulphate ions in solution.
A9. To test for sulphates in solution add hydrochloric acid followed by barium chloride. A white precipitate forms if sulphate is present.

Q10. How would you show by experiment that a solution contained both carbonate and sulphate ?
A10. Barium chloride solution could be added first. If a white precipitate forms it would indicate the presence of either carbonate or sulphate or both. Thereafter hydrochloric acid could be added. If the precipitate partly dissolves <u>and</u> bubbles of gas form, this indicates carbonate and sulphate.

PART 2: Testing for the Presence of Halide Ions

Q1. Prepare a table like Table 1 below.
A1. Table 1

Well	Halide Solution	Initial Appearance	Final Appearance
A1	**$NaC\ell(aq)$**	**colourless**	**white precipitate**
A2	**NaBr(aq)**	**colourless**	**light yellow precipitate**
A3	**NaI(aq)**	**colourless**	**yellow precipitate**

Q2. Record your observations in the table.
A2. See Table 1.

Q3. Did a chemical reaction occur in any of wells A1 to A3 ? Explain your answer.
A3. Yes. A precipitate was formed in each well. This is evidence that a chemical reaction occurred.

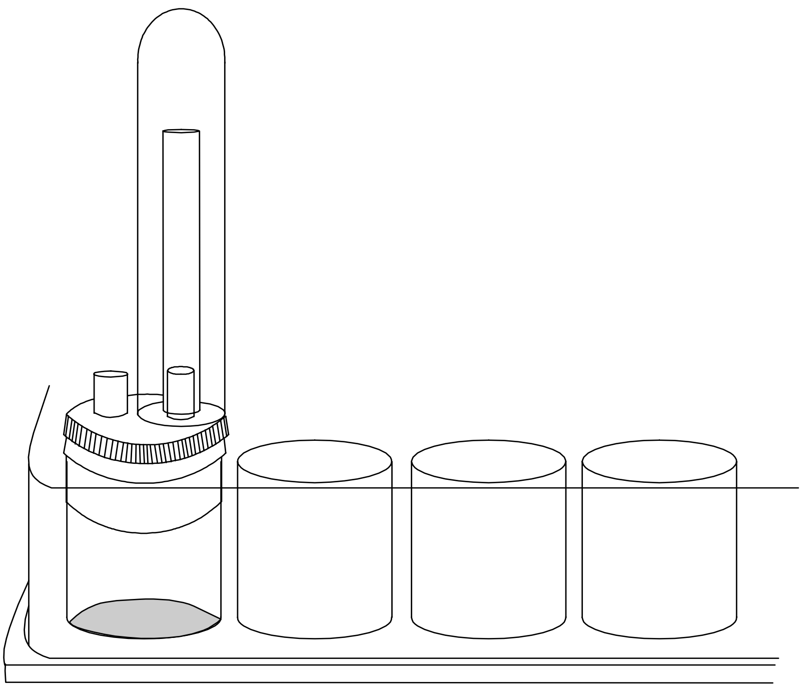
Q4. Write a balanced chemical equation to represent any reaction which occurred in wells A1 to A3.
A4. Well A1: $NaC\ell(aq) + AgNO_3(aq) \rightarrow AgC\ell(s) + NaNO_3(aq)$

Well A2: $NaBr(aq) + AgNO_3(aq) \rightarrow AgBr(s) + NaNO_3(aq)$

Well A3: $NaI(aq) + AgNO_3(aq) \rightarrow AgI(s) + NaNO_3(aq)$

Q5. From your observations is it possible to distinguish which halide was present in solution by adding silver nitrate ? Explain your answer.
A5. Yes. The precipitate that formed in each well had a different colour. Silver chloride is white, silver bromide is light yellow and silver iodide is deeper yellow.

MICROCHEMISTRY
CHAPTER IV



FLAME COLOURS

TEACHER GUIDE

1. Chemicals

All of the required chemicals are listed in the worksheet. Tap water is also needed.

2. Equipment

Most of the apparatus required can be found in a RADMASTE Basic or Advanced Microchemistry Kit. Paper towelling is needed to dry the glass rod between testing of the different solutions.

3. Hints

It is a good idea to perform this experiment in a room with subdued lighting because the flame colours are more easily observed in dim light. This can be achieved by drawing the curtains (or dropping blinds) in the classroom. If the room in which the experiment is performed does not have curtains or blinds, overhead lights can be switched off to darken the room.

Once the end of the glass rod has been immersed in a solution to be tested, it must immediately be placed in the flame of the microburner to ensure that the colour of the metal ion is observed.

It is important to rinse the glass rod with tap water and dry it before testing the next solution. It may happen that a residue forms at the end of the rod where it has been held in the flame. If this residue is not removed with rinsing and drying, the other solutions will become contaminated.

You may wish to extend the experiment by giving unknown solutions for learners to test. They can be asked to identify which metal ions (Ca^{2+}, Cu^{2+}, Na^{+} or K^{+}) are in the solution.

4. Cautions

Please remember the following cautions and inform your students of all safety hazards:

Nitric acid is corrosive. If any acid is spilt on the skin, the affected area must immediately be rinsed with copious amounts of water. Severe burns must receive medical attention.

Never point a propette or a syringe containing acid upwards. A momentary lapse of concentration can result in a nasty accident. If any acid is squirted

into the eye, immediately rinse the eye out under running water. Always have a dilute solution of sodium hydrogencarbonate (household baking soda), or milk close by to apply to the injury. These substances will help neutralise the acid in the eye. The patient should be referred to a doctor.

Never allow the learners to play with matches. Treat any burn with cold running water or ice, and seek medical assistance where necessary.

5. Model Answers to Questions in the Worksheet

It is recommended that learners write down all of the questions and answers in their workbooks. If this is done, then the answers to questions do not have to be in full sentences. If the learners do not copy the questions into their workbooks, then answers should be written in full sentences. Note that some of the questions can only be answered by learners in higher grades. Word equations can be written instead of chemical equations where required.

Q1. Draw up a table to summarise your observations in this experiment. Include in it the salt solution you used, the metal ions present in the solution and the flame colours.

A1.

Salt Solution	Metal Ions in Solution	Flame Colour
$Ca(NO_3)_2(aq)$	**$Ca^{2+}(aq)$**	**red**
$Cu(NO_3)_2(aq)$	**$Cu^{2+}(aq)$**	**green**
$NaC\ell(aq)$	**$Na^{+}(aq)$**	**yellow**
$KNO_3(aq)$	**$K^{+}(aq)$**	**purple**

Q2. Write a word equation for the reaction that took place in well F1.

A2. Calcium oxide(s) + nitric acid(aq) → calcium nitrate(aq) + water(ℓ)

Q3. Write a balanced chemical equation for the reaction that took place in well F1.

A3. $CaO(s) + 2HNO_3(aq) \rightarrow Ca(NO_3)_2(aq) + H_2O(\ell)$

THE PREPARATION AND PROPERTIES OF HYDROGEN SULPHIDE

TEACHER GUIDE

1. Chemicals
All of the required chemicals are listed in the worksheet. Tap water is required.

2. Equipment
Most of the apparatus required can be found in a RADMASTE Basic or Advanced Microchemistry Kit.

3. Hints
The hydrochloric acid must be added slowly to the iron sulphide in well F2, otherwise the vigorous bubbling may force the mixture up through the silicone tube into well F1. The lids must also be securely fitted into wells F1 and F2 to prevent leakage.

The experiment must be performed in a well ventilated area as the hydrogen sulphide fumes are noxious. Students must not inhale the fumes directly!

After testing the pH of the solution in well A2, the teacher should ensure that students do not take long to complete the remainder of the worksheet. The solution formed in well F1 is only weakly acidic and if there is too long a delay between testing of the dichromate and metal nitrate solutions in the A wells, the hydrogen sulphide gas may escape from the solution. The results obtained may not be convincing.

The yellow or white suspension that forms with the acidified dichromate solution may be better observed from underneath the comboplate®.

4. Cautions
Please remember the following cautions and inform your students of all safety hazards:

11 M hydrochloric acid is extremely corrosive. If any acid is spilt on the skin, the affected area must immediately be rinsed with copious amounts of water. Severe burns must receive medical attention.

Never point a propette or a syringe containing acid upwards. A momentary lapse of concentration can result in a nasty accident. If any acid is squirted into the eye, immediately rinse the eye out under running water. Always have a dilute solution of sodium hydrogencarbonate (household baking soda), or milk close by to apply to the injury. These substances will help neutralise the acid in the eye. The patient should be referred to a doctor.

Hydrogen sulphide fumes are extremely poisonous. The experiment must be performed in a well ventilated room. If this is not possible, the experiment should be avoided or performed outside of the venue. Persons with liver ailments should not perform the experiment! If anyone shows breathing difficulties, they should be moved into an area of fresh air. If breathing continues to be laboured, the patient should be given oxygen and referred to a physician.

Lead, zinc and copper nitrates are poisonous if ingested or absorbed by the skin. Thoroughly wash your hands with soap and water after handling these chemicals.

Potassium dichromate causes skin and eye irritation. Wash hands with soap and copious amounts of water after use.

The hydrogen sulphide solutions and iron sulphide residues should be diluted with water and discarded into a waste jar.

5. Model Answers to Questions in the Worksheet
It is recommended that learners write down all of the questions and answers in their workbooks. If this is done, then the answers to questions do not have to be in full sentences. If the learners do not copy the questions into their workbooks, then answers should be written in full sentences. Note that some of the questions can only be answered by learners in higher grades. Word equations can be written instead of chemical equations where required.

Q1. What do you observe happening in well F1 ?
A1. Bubbles of gas are coming through the water in F1.

Q2. Can you smell anything from the vent in well F1 ?
If so, what do you think this smell is due to ?
A2. Yes, there is a noxious smell from well F1. This is due to hydrogen sulphide.

Q3. Write down a chemical formula for the gas formed in well F2.
A3. The chemical formula for hydrogen sulphide is $H_2S(g)$.

Q4. Having observed the change in the indicator colour, what can you say about the solution ?

A4. The solution is acidic. Gaseous hydrogen sulphide ($H_2S(g)$) dissolved in the water in F1 to form a weak acid

$$(H_2S(g) + H_2O(\ell) \rightarrow HS^-(aq) + H_3O^+(aq)).$$

This caused the indicator in well A2 to change colour to red. By contrast the indicator in well A1 (containing tap water) is green.

Q5. Give a chemical equation to represent the reaction of hydrochloric acid (HCl(aq)) with iron sulphide (FeS(s)).

A5. $2HC\ell(aq) + FeS(s) \rightarrow H_2S(g) + FeC\ell_2(aq)$

Q6. What is the colour of the solution in wells A3 and A4 ?

A6. Well A3:The solution is orange.
Well A4:The solution appears green, and has a pale yellow or white suspension.

Q7. What evidence do you have that aqueous hydrogen sulphide $H_2S(aq)$ reacts with $K_2Cr_2O_7(aq)$?

A7. Wells A3 and A4 both contain hydrochloric acid ($HC\ell$), yet they are differently coloured. Therefore, the hydrogen sulphide (H_2S) in solution reacted with the potassium dichromate ($K_2Cr_2O_7$) and caused the solution in well A4 to turn green.

Q8. If the equation for the reaction is

$$3H_2S + 8HC\ell + K_2Cr_2O_7 \rightarrow 2CrC\ell_3 + 7H_2O + 3S + 2KC\ell,$$

Is the reaction a redox one ? Give a reason for your answer.

A8. Yes, this is a redox reaction. In this reaction chromium atoms in an oxidation state of +6 in $K_2Cr_2O_7$ are reduced to an oxidation state of +3 in $CrC\ell_3$ (green coloured solution). Sulphur atoms in an oxidation state of -2 in H_2S are oxidised to an oxidation state of 0 (zero) in S (the yellowy, white suspension). Chromium atoms received electrons, while sulphur atoms donated them.

Q9. What is the colour of the mixture in wells A5 and A6 **?**

A9. Well A5: Blue solution.
Well A6: Black suspension, or a black precipitate and a colourless solution.

Q10. What is the colour of the mixture in wells A7 and A8 ?

A10. Well A7: Colourless solution.
Well A8: Black suspension, or black precipitate and a colourless solution.

Q11. What is the colour of the mixture in wells A9 and A10 ?

A11. Well A9: Colourless solution.
Well A10: White suspension, or white precipitate and a colourless solution.

Q12. Have the solutions in wells A6, A8 and A10 reacted with the metal salts that were added to them ?

A12. Yes, the hydrogen sulphide solution in A6, A8 and A10 has reacted with the copper nitrate, lead nitrate and zinc nitrate salts respectively.

Q13. Give the reason for your answer to question 12 and illustrate what you think has happened in each of these wells with a chemical equation.

A13. Well A6: The formation of a black precipitate indicates a chemical reaction.

$$H_2S(aq) + Cu(NO_3)_2(aq) \rightarrow CuS(s) + 2HNO_3(aq)$$

Well A8: The formation of a black precipitate indicates a chemical reaction.

$$H_2S(aq) + Pb(NO_3)_2(aq) \rightarrow PbS(s) + 2HNO_3(aq)$$

Well A10: The formation of a white precipitate indicates a chemical reaction.

$$H_2S(aq) + Zn(NO_3)_2(aq) \rightarrow ZnS(s) + 2HNO_3(aq)$$

Q14. Is aqueous hydrogen sulphide ($H_2S(aq)$) oxidised by any of the metal salts which have been used in wells A6, A8 and A10 ?

A14. No, aqueous hydrogen sulphide is not oxidised by the copper, lead and zinc nitrate salts.

Q15. Is aqueous hydrogen sulphide ($H_2S(aq)$) reduced by any of the metal salts which have been used in wells A6, A8 and A10 ?

A15. No, aqueous hydrogen sulphide is not reduced by the copper, lead and zinc nitrate salts.

Q16. Give the reason for your answers to questions 14 and 15 above.

A16. The oxidation state of the sulphur atoms in H_2S and in the metal sulphides (CuS, ZnS, PbS) is -2. Since there is no change in the oxidation state of the S atoms during these reactions, the S atoms cannot have been oxidised or reduced.

Q17. Write a statement describing the two different kinds of reaction that may occur when hydrogen sulphide reacts with metal salts in aqueous solution.

A17. When H_2S reacts with metal dichromate salts in acidic solution, a redox reaction occurs and the H_2S is oxidised as sulphur is formed. When H_2S reacts with aqueous solutions of metal nitrate salts, insoluble metal sulphides may be formed.

PREPARATION AND PROPERTIES OF SULPHUR DIOXIDE

TEACHER GUIDE

1. Chemicals

All of the required chemicals are listed in the worksheet. Tap water is required.

2. Equipment

Most of the apparatus required can be found in a RADMASTE Basic or Advanced Microchemistry Kit.

3. Hints

The hydrochloric acid (HCl(aq)) must be added slowly to the sodium sulphite in well F3, otherwise the initial bubbling may force the mixture up through the silicone tube into well F2.

After the HCl(aq) has been added, the comboplate® must be shaken to prevent water being sucked back from well F2 into well F3. Approximately two minutes is required for sufficient sulphur dioxide to form. During this time, one must ensure that learners shake the comboplate® as soon as any suck-back occurs.

The experiment must be performed in a well ventilated area as the sulphur dioxide fumes are noxious. Learners must not inhale the fumes directly!

4. Cautions

Please remember the following cautions and inform your students of all safety hazards:

Hydrochloric acid and sulphuric acid are corrosive. If any acid is spilt on the skin, the affected area must immediately be rinsed with copious amounts of water. Severe burns must receive medical attention.

Never point a propette or a syringe containing acid upwards. A momentary lapse of concentration can result in a nasty accident. If any acid is squirted into the eye, immediately rinse the eye out under running water. Always have a dilute solution of sodium hydrogencarbonate (household baking soda), or milk close by to apply to the injury. These substances will help neutralise the acid in the eye. The patient should be referred to a doctor.

Sulphur dioxide fumes are extremely poisonous. The experiment must be performed in a well ventilated room. If this is not possible, the experiment should be avoided or performed outside of the venue. Persons with liver ailments should not perform the experiment! If anyone shows breathing difficulties, they should be moved into an area of fresh air. If breathing continues to be laboured, the patient should be given oxygen and referred to a physician.

Potassium dichromate causes skin and eye irritation. Wash hands with soap and copious amounts of water after use.

The waste solutions should be diluted with water and discarded into a waste jar.

5. Model Answers to Questions in the Worksheet

It is recommended that learners write down all of the questions and answers in their workbooks. If this is done, then the answers to questions do not have to be in full sentences. If the learners do not copy the questions into their workbooks, then answers should be written in full sentences. Note that some of the questions can only be answered by learners in higher grades. Word equations can be written instead of chemical equations where required.

Q1. What is the colour of the indicator paper ? What is the pH of the water ?
A1. If blue litmus paper is used to test the water, it remains blue. If universal indicator paper is used, it changes colour to green. The pH of the water is ~ 7 (neutral).

Q2. What do you observe happening in well F3 ?
A2. The mixture in well F3 bubbles.

Q3. Can you smell anything from the vent in well F2 ? If so, what do you think the smell is due to ?
A3. Yes, there is a smell coming from well F2. This is due to the formation of gaseous sulphur dioxide.

Q4. What is the chemical formula of the gas formed in well F3 ?
A4. The chemical formula for sulphur dioxide is SO_2(g).

Q5. What is the colour of the indicator paper ? What do you deduce ?.

A5. Blue litmus paper becomes red or pink when immersed in the solution in F2. Universal indicator paper also changes colour to red/pink. The gaseous sulphur dioxide that formed in well F3 dissolved in the water in well F2 to form a weakly acidic solution, which caused the indicator paper to change colour to red/pink.

Q6. Give a chemical equation for the reaction of hydrochloric acid (HCl(aq)) and sodium sulphite (Na_2SO_3(s)).

A6. $Na_2SO_3(s) + 2HC\ell(aq) \rightarrow 2NaC\ell(aq) + SO_2(g) + H_2O(\ell)$

Q7. What is the colour in each well:

A7. Well F1: Orange. Well F2: Green.

Q8. What ions are responsible for the colour of the solution in well F1 ?

A8. The dichromate ions ($Cr_2O_7^{2-}$(aq)) in solution are responsible for the orange colour in F1.

Q9. Explain any colour difference between the solution in well F1 and well F2.

A9. The solution in well F1 is orange, while the solution in well F2 is green. The colour of chromium(III) ions in solution is green. The different colour of the solution in well F2 indicates that the orange dichromate ions have been reduced to green chromium(III) ions in acid solution.

Q10. Is sulphur dioxide oxidised or reduced by potassium dichromate in acid solution ?

A10. The aqueous sulphur dioxide is oxidised by potassium dichromate ($K_2Cr_2O_7$(aq)) in acid solution.

A chemical equation to represent the reaction would be:

$$H_2SO_4(aq) + K_2Cr_2O_7(aq) + 3SO_2(aq) \rightarrow Cr_2(SO_4)_3(aq) + H_2O(\ell) + K_2SO_4(aq)$$

THE REACTION OF SULPHUR DIOXIDE AND HYDROGEN SULPHIDE

TEACHER GUIDE

1. Chemicals
All of the required chemicals are listed in the worksheet. Tap water is required.

2. Equipment
Most of the apparatus required can be found in a RADMASTE Basic or Advanced Microchemistry Kit.

3. Hints
The hydrochloric acid (HCℓ(aq)) must be added slowly to the sodium sulphite in well F3, otherwise the initial bubbling may force the mixture up through the silicone tube into well F2.

After the HCℓ(aq) has been added, the comboplate® must be shaken to prevent water being sucked back from well F2 into well F3. Approximately two minutes is required for sufficient sulphur dioxide to form. During this time, one must ensure that learners shake the comboplate® as soon as any suck-back occurs.

The experiment must be performed in a well ventilated area as the sulphur dioxide and hydrogen sulphide fumes are noxious. Learners must not inhale the fumes directly!

The HCℓ(aq) must be added slowly to the iron sulphide to prevent the solution in well F1 from being forced into well F2.

The milky yellow appearance of the solution is due to the formation of sulphur (S(s)). The solid itself cannot be seen as it remains in suspension, making the water appear milky.

4. Cautions
Please remember the following cautions and inform your students of all safety hazards:

Hydrochloric acid and sulphuric acid are corrosive. If any acid is spilt on the skin, the affected area must immediately be rinsed with copious amounts of water. Severe burns must receive medical attention.

Never point a propette or a syringe containing acid upwards. A momentary lapse of concentration can result in a nasty accident. If any acid is squirted into the eye, immediately rinse the eye out under running water. Always have adilute solution of sodium hydrogencarbonate (household baking soda), or milk close by to apply to the injury. These substances will help neutralise the acid in the eye. The patient should be referred to a doctor.

Sulphur dioxide and hydrogen sulphide fumes are extremely poisonous. The experiment must be performed in a well ventilated room. If this is not possible, the experiment should be avoided or performed outside of the venue. Persons with liver ailments should not perform the experiment! If anyone shows breathing difficulties, they should be moved into an area of fresh air. If breathing continues to be laboured, the patient should be given oxygen and referred to a physician.

The solutions and iron sulphide residues should be diluted with water and discarded into a waste jar.

5. Model Answers to Questions in the Worksheet
It is recommended that learners write down all of the questions and answers in their workbooks. If this is done, then the answers to questions do not have to be in full sentences. If the learners do not copy the questions into their workbooks, then answers should be written in full sentences. Note that some of the questions can only be answered by learners in higher grades. Word equations can be written instead of chemical equations where required.

Q1. What do you observe in well F2 where the two gases generated in wells F1 and F3 mix in aqueous solution ?
A1. The clear water in F2 becomes milky yellow in colour.

Q2. Why do you think this has happened ? What is the substance found in well F2 ?
A2. The sulphur dioxide formed in well F3 and the hydrogen sulphide formed in well F1 have mixed in aqueous solution. Sulphur (a solid) has formed in well F2. The solid in suspension makes the water appear milky.

Q3. Write a chemical equation to represent the reaction between the two gases in aqueous solution.
A3. $SO_2(aq) + 2H_2S(aq) \rightarrow 3S(s) + 2H_2O(\ell)$

Q4. Is hydrogen sulphide oxidised or reduced when the two gases in aqueous solution mix ? Give a reason for your answer.
A4. The sulphur atom in H_2S has oxidation number -2. This changes to zero when the S atom is in solid sulphur. The H atoms do not change their oxidation number. Hence hydrogen sulphide is oxidised.

Q5. Is sulphur dioxide reduced or oxidised when the two gases in aqueous solution mix ? Give reasons for your answer.
A5. The sulphur atom in SO_2 has oxidation number +4. This changes to zero when the S atom is in solid sulphur. The O atoms do not change their oxidation number. Sulphur dioxide molecules gain electrons and are therefore reduced when the two gases mix in aqueous solution.

AIR POLLUTION BY SULPHUR DIOXIDE

TEACHER GUIDE

1. Chemicals
All of the required chemicals are listed in the worksheet. Tap water is required.

2. Equipment
Most of the apparatus required can be found in a RADMASTE Basic or Advanced Microchemistry Kit.

3. Hints

PART 1: Uncontrolled Emission of Sulphur Dioxide

When adding the hydrochloric acid ($HC\ell(aq)$) to the sodium sulphite in Part 1, do not push the nozzle of the syringe all the way into the vent of lid 2. The syringe may get stuck in the vent. Push in the plunger of the syringe slowly: the $HC\ell(aq)$ may collect on the underside of the lid if it is added all at once.

A waiting period of three to five minutes is recommended before observations are made (Parts 1, 2 and 3). If you wait longer than this, the results obtained may not be as described in the model answers because the acidification of the water in the small wells increases with time.

Note that any draughts in the room will influence the results as the sulphur dioxide gas ($SO_2(g)$) may reach the outermost wells of the comboplate®. This may be used to show the effect of wind in spreading air pollution, for example from an industrial area to a distant town. To eliminate draughts, the comboplate® can be placed in a shallow container such as an empty cardboard box.

PART 2: The Function of a Chimney in Dispersing Air Pollutants

In Part 2, the acid must be added slowly to well E3, otherwise the vigorous bubbling in the well may force acid out through the silicone tube.

The syringe inlet in lid 1 must be sealed as quickly as possible after the syringe is removed, otherwise sufficient $SO_2(g)$ may escape from well E3 to confuse the results.

PART 3: The Elimination of Emission by an Absorbing Substance

In Part 3, the calcium oxide must be packed as tightly as possible into the silicone tube so that it is not forced out when the $HC\ell(aq)$ is added to the well. The acid must also not be added too quickly, because this will cause an increase in pressure in the well that may force all of the calcium oxide out of the silicone tube.

As in Part 2, the syringe inlet in lid 1 must be sealed immediately after the syringe has been removed to prevent escaping $SO_2(g)$ from confusing the results.

4. Cautions
Please remember the following cautions and inform your students of all safety hazards:

Hydrochloric acid is corrosive. If any acid is spilt on the skin, the affected area must immediately be rinsed with copious amounts of water. Severe burns must receive medical attention.

Never point a propette or a syringe containing acid upwards. A momentary lapse of concentration can result in a nasty accident. If any acid is squirted into the eye, immediately rinse the eye out under running water. Always have a dilute solution of sodium hydrogencarbonate (household baking soda), or milk close by to apply to the injury. These substances will help neutralise the acid in the eye. The patient should be referred to a doctor.

Sulphur dioxide fumes are poisonous. The experiment must be performed in a well ventilated room. If this is not possible, the experiment should be avoided or performed outside of the venue. If anyone shows breathing difficulties, they should be moved into an area of fresh air. If breathing continues to be laboured, the patient should be given oxygen and referred to a physician.

5. Model Answers to Questions in the Worksheet

It is recommended that learners write down all of the questions and answers in their workbooks. If this is done, then the answers to questions do not have to be in full sentences. If the learners do not copy the questions into their workbooks, then answers should be written in full sentences. Note that some of the questions can only be answered by learners in higher grades. Word equations can be written instead of chemical equations where required.

PART 1: Uncontrolled Emission of Sulphur Dioxide

Q1. What is the colour and pH of the aqueous solution of universal indicator at the beginning of the experiment ?

A1. The colour of the indicator solution in the tap water in the small wells is green. The pH is therefore 7 (neutral).

Q2. What happens to the colour of the aqueous solution of universal indicator in the wells ? What is happening to the pH of this solution ?

A2. The colour of the indicator gradually changes from green to red at the surface of the water, in some of the wells. The pH is decreasing i.e. the solution is becoming acidic.

Q3. Explain your answer to question 2 using a chemical equation to represent the reaction that could be occurring.

A3. $SO_2(g) + H_2O(\ell) \rightarrow H_2SO_3(aq)$

Q4. Does the colour of the aqueous solution change uniformly:
a) across the surface area of the solution in each well,
b) from top to bottom in each well ?

A4. a) No the colour of the solution does not change uniformly across the surface area of the solution in each well. Some wells closer to the source of sulphur dioxide have their entire surface area coloured red. Other wells further away have only the outer edges of the surface coloured red, while the central surface regions are still green. Some wells do not change colour at all.

b) No, there is not a uniform colour change from the top to the bottom of each well. The colour of the solution at the surface is red, whilst the colour beneath this is green.

Q5. Suggest a reason for your answer to question 4.

A5. Gaseous sulphur dioxide has reacted with the top layer of the aqueous solution of universal indicator which it first came into contact with, causing this layer of solution to become acidic. The further away the wells were from the source of SO_2, the less the colour of the solution changed.

Q6. Is the acidification of the solution the same throughout all the small wells of the comboplate® ? Explain your answer.

A6. No, the acidification of the solution is not the same for all the small wells. The contents of the wells closest to the source of sulphur dioxide have been acidified the most, while those further away are less acidified. Some wells have not been acidified at all, as shown by the green colour of the solution.

Q7. In how many wells has the water been acidified ? (Answer this no longer than 5 minutes from the time you began the experiment.)

A7. The acidification will vary with conditions, but usually 40 – 45 wells become acidified within 5 minutes.

Q8. Would the number of wells showing water acidification be more or less if six microspatulas of sodium sulphite were added to well E3 instead of three, when the experiment began ? Explain your answer.

A8. The extent of water acidification would be more if six spatulas of sodium sulphite were used. The addition of more sodium sulphite in the reaction would result in an increase in the emission of gaseous sulphur dioxide, provided sufficient hydrochloric acid is used.

Q9. How has the distribution of the acidification changed from the first time you viewed the wells from beneath the comboplate® ? Explain your answer.

A9. The solutions in the wells closest to the source of $SO_2(g)$ are red from the top to the bottom of each well. The solutions in some other wells have a red layer at the surface, an orange layer beneath the red and green at the bottom of the well. Other wells at the outer edges of the comboplate® are red at the surface and green at the bottom of the well. The solutions in some wells are still green only.

PART 2: The Function of a Chimney in Dispersing Air Pollutants

Q1. Is the acidification of the solution the same throughout all the small wells of the comboplate®? Explain your answer.

A1. No, the acidification is not the same for all the small wells. The contents of the wells closest to the source of the sulphur dioxide are the most acidified. Some of the outer wells may show a little acidity, but only at the rims of the wells.

Q2. In how many wells has the water been acidified ? (Answer this no longer than 5 minutes from the time you began the experiment.)

A2. The acidification will vary with conditions, but usually between 12 and 25 wells are acidified within 5 minutes.

Q3. Compare your answer to question 2 above with your answer to question 7 in part 1. Is the number of wells showing water acidification greater or smaller when a chimney is present ?

A3. The number of wells showing acidification is smaller than in part 1. This shows that the function of a chimney is to push the air-pollutants higher up into the atmosphere to disperse them, thereby reducing the extent of water acidification in the region around the pollution source.

PART 3: The Elimination of Emission by an Absorbing Substance

Q1. In how many wells has the water been acidified ? (Answer this no longer than 5 minutes from the time you began the experiment.)

A1. 0 wells have been acidified.

Q2. Write down a balanced chemical equation to show the reaction between the SO_2(g) and the CaO(s) in the chimney.

A2. $SO_2(g) + CaO(s) \rightarrow CaSO_3(s)$

Q3. Write a statement describing the effect of calcium oxide on SO_2 emission.

A3. Calcium oxide eliminates SO_2 as an air pollutant. All the gaseous sulphur dioxide is converted into solid calcium sulphite.

PREPARATION AND TESTING FOR HYDROCHLORIC ACID

TEACHER GUIDE

1. Chemicals

All of the required chemicals are listed in the worksheet. Tap water and hot water are also required. You may have concentrated sulphuric acid ($H_2SO_4(aq)$) in your school laboratory. The concentration of this acid is 98% or approximately 18 M. **If you use 18 M sulphuric acid to perform this experiment, the comboplate® will be destroyed.** You will need to dilute the sulphuric acid from a concentration of 18 M to 13.5 M in the following way:

Fill a beaker with 25 mℓ of water. Carefully measure 75 mℓ of the 18 M sulphuric acid into a measuring cylinder or other suitable container. Add **small** volumes of the sulphuric acid to the water, and stir the solution constantly during each addition. **Do not add the water to the acid. The heat evolved when the water and the acid meet can cause the acid to splash up out of the beaker. Do not spill any of the acid onto your skin or clothing as it is highly corrosive! If any acid is spilt on the skin, immediately rinse the affected area with water and seek medical attention if necessary.**

2. Equipment

All of the apparatus required can be found in a RADMASTE Basic or Advanced Microchemistry Kit.

3. Hints

If possible, the sulphuric acid could be warmed before the learners begin the experiment. This will save some time.

The tap water in certain areas may have a high chloride content; therefore, depending on the area in which the experiment is performed, a white silver chloride ($AgC\ell(s)$) precipitate may be obtained when the tap water is tested with silver nitrate ($AgNO_3(aq)$) solution. This is usually not a problem, as the silver chloride precipitate obtained after the production of the hydrochloric acid ($HC\ell(aq)$) is of a greater quantity, and thus much more evident than that due to the chloride content of the tap water.

When adding the sulphuric acid to the sodium chloride ($NaC\ell(s)$) in well F1, the solution foams and large bubbles rise up in the well. For this reason the acid must be added **slowly**, otherwise the solution will bubble through the silicone tube into well F2, making it necessary to restart the experiment. Allow the bubbles to subside before adding another drop of the acid.

4. Cautions

Please remember the following cautions and inform your students of all safety hazards:

Sulphuric acid is very corrosive. If any acid is spilt on the skin, the affected area must immediately be rinsed with copious amounts of water. Severe burns must receive medical attention.

Never point a propette or a syringe containing acid upwards. A momentary lapse of concentration can result in a nasty accident. If any acid is squirted into the eye, immediately rinse the eye out under running water. Always have a dilute solution of sodium hydrogencarbonate (household baking soda), or milk close by to apply to the injury. These substances will help neutralise the acid in the eye. The patient should be referred to a doctor.

Silver is an expensive metal. Solutions of silver nitrate are also expensive and should not be wasted!

5. Model Answers to Questions in the Worksheet

It is recommended that learners write down all of the questions and answers in their workbooks. If this is done, then the answers to questions do not have to be in full sentences. If the learners do not copy the questions into their workbooks, then answers should be written in full sentences. Note that some of the questions can only be answered by learners in higher grades. Word equations can be written instead of chemical equations where required.

Q1. Note the colour of the indicator in the sample of tap water.
A1. The universal indicator is green in the sample of tap water.

Q2. What is the pH of the water ?
A2. The pH of the water is approximately 7.

Q3. What do you observe in well A4 ?
A3. There is no apparent reaction between the tap water and the silver nitrate solution in well A4.

Q4. What do you observe happening in well F1 ?
A4. The reaction mixture in well F1 foams as a gas is given off.

Q5. What happens in well F2 ?
A5. Bubbles of gas can be seen entering the water in well F2.

Q6. What is the colour of the indicator in well A2 ?
A6. The indicator colour is red in well A2.

Q7. Is this solution acidic, basic or neutral ?
A7. The solution is acidic.

Q8. What happens in well A5 ?
A8. The clear solution in well A5 immediately turns milky and a white precipitate settles.

Q9. Write a balanced chemical equation to represent the reaction occurring in well F1.
A9. $H_2SO_4(aq) + NaC\ell(s) \rightarrow HC\ell(g) + NaHSO_4(aq)$

Q10. What is the name of the gas that produced the bubbles in the water in well F2 ?
A10. Hydrogen chloride ($HC\ell(g)$) is the gas that produced bubbles in well F2.

Q11. Explain why the water in well F2 has changed in pH. What does this tell you about the gas produced in well F1 ?
A11. Hydrogen chloride is an acid gas, dissolving in water to form hydrochloric acid ($HC\ell(aq)$).

Q12. Write a balanced chemical equation to represent the reaction of the gas with the water in well F2. From the equation, identify the ions that caused the universal indicator to change colour.
A12. $HC\ell(g) + H_2O(\ell) \rightarrow H_3O^+(aq) + C\ell^-(aq)$

The hydronium ($H_3O^+(aq)$) ions gave the solution its acidic properties and caused the universal indicator to appear red.

Q13. What further evidence is there for your answers to questions 10 and 11 ? Write down the chemical equation of the precipitation reaction in well A5.
A13. The silver nitrate ($AgNO_3(aq)$) reacted with hydrochloric acid to form a white, silver chloride ($AgC\ell(s)$) precipitate. The precipitation reaction can be represented as either:

$$AgNO_3(aq) + HC\ell(aq) \rightarrow AgC\ell(s) + HNO_3(aq)$$

$$\text{or: } Ag^+(aq) + C\ell^-(aq) \rightarrow AgC\ell(s)$$

PREPARATION AND TESTING FOR NITRIC ACID

TEACHER GUIDE

1. Chemicals

All of the required chemicals are listed in the worksheet. Tap water is also required. You may have concentrated sulphuric acid ($H_2SO_4(aq)$) in your school laboratory. The concentration of this acid is 98% or approximately 18 M. **If you use 18 M sulphuric acid to perform this experiment, the comboplate® will be destroyed.** You will need to dilute the sulphuric acid from a concentration of 18 M to 9 M in the following way:

Fill a beaker with 50 mℓ of water. Carefully measure 50 mℓ of the 18 M sulphuric acid into a measuring cylinder or other suitable container. Add **small** volumes of the sulphuric acid to the water, and stir the solution constantly during each addition. **Do not add the water to the acid. The heat evolved when the water and the acid meet can cause the acid to splash up out of the beaker. Do not spill any of the acid onto the skin, eyes or clothing as it is highly corrosive! If any acid is spilt on the skin or in the eyes, immediately rinse the affected area with water and seek medical attention if necessary.**

2. Equipment

All of the apparatus required can be found in a RADMASTE Basic or Advanced Microchemistry Kit.

3. Hints

The first part of the experiment requires that nitric acid ($HNO_3(aq)$) be produced from sulphuric acid and potassium nitrate ($KNO_3(s)$). After the sulphuric acid has been added to the potassium nitrate, some of the grains of potassium nitrate will remain behind in well F1. This is because an excess of potassium nitrate has been used. It is therefore not necessary to spend time stirring the solution in well F1 to try and dissolve all of the potassium nitrate.

The second part of the experiment requires that the product formed in well F1 be tested to prove that nitric acid has indeed been formed. The solution from well F1 is added to copper turnings in well F3. This set-up is represented in the diagram provided, where a piece of prestik or plasticine is shown blocking the tube outlet of lid 1. **Do not block the outlet before the acid has been added to the copper turnings, otherwise the pressure created inside well F3 will force the lid off the well.** It is advised that the students read the procedure carefully and that they do not follow the diagram only.

If the brown nitrogen dioxide ($NO_2(g)$) gas forms shortly after adding the nitric acid to the copper turnings, it may not even be necessary to block the outlet of lid 1. However, once the nitrogen dioxide has escaped from well F3, blocking the outlet of lid 1 will result in more nitrogen dioxide gas forming above the blue copper nitrate solution in the well, and a brown colour will be seen.

4. Cautions

Please remember the following cautions and inform your students of all safety hazards:

Sulphuric acid is very corrosive. If any acid is spilt on the skin, the affected area must immediately be rinsed with copious amounts of water. Severe burns must receive medical attention.

Never point a propette or a syringe containing acid upwards. A momentary lapse of concentration can result in a nasty accident. If any acid is squirted into the eye, immediately rinse the eye out under running water. Always have a dilute solution of sodium hydrogencarbonate (household baking soda), or milk close by to apply to the injury. These substances will help neutralise the acid in the eye. The patient should be referred to a doctor.

Nitrogen dioxide is a pungent, toxic gas. Do not inhale the fumes. Make sure the experiment is performed in a well ventilated room.

5. Model Answers to Questions in the Worksheet

It is recommended that learners write down all of the questions and answers in their workbooks. If this is done, then the answers to questions do not have to be in full sentences. If the learners do not copy the questions into their workbooks, then answers should be written in full sentences. Note that some of the questions can only be answered by learners in higher grades. Word equations can be written instead of chemical equations where required.

Q1. What are the names of the aqueous products formed in the reaction ?

A1. The aqueous products formed in the reaction are nitric acid ($HNO_3(aq)$) and potassium hydrogensulphate ($KHSO_4(aq)$).

Q2. Write a balanced chemical equation to represent the reaction occurring in well F1 between sulphuric acid ($H_2SO_4(aq)$) and potassium nitrate ($KNO_3(s)$)).

A2. $H_2SO_4(aq) + KNO_3(s) \rightarrow HNO_3(aq) + KHSO_4(aq)$

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Q3. What happens in well F3 ?
A3. After a few seconds, bubbles can be seen rising from the surface of the copper turnings.

Q4. Do you notice any coloured gaseous products forming ?
A4. No, coloured gaseous products do not form immediately.

Q5. What is the colour of the solution in well F3 after 3 – 5 minutes ?
A5. The solution in F3 is light blue in colour.

Q6. What is the colour of the gas formed in well F3 ?
A6. The gas formed in F3 is brown in colour.

Q7. Identify the products and their respective colours that you observed in well F3.
A7. The products were the blue copper nitrate solution ($Cu(NO_3)_2(aq)$) and a gas, identified by the bubbles that rose to the surface of the blue solution as the copper reacted. This gas was colourless, so it could not be seen above the solution. We may guess that it was nitrogen monoxide (NO(g)).

Q8. Write a balanced chemical equation to represent the reaction occurring in well F3.
A8. $8HNO_3(aq) + 3Cu(s) \rightarrow 3Cu(NO_3)_2(aq) + 4H_2O(\ell) + 2NO(g)$

Q9. The gaseous product, nitrogen monoxide (NO), is colourless and cannot be seen. Why did the gas in well F3 appear brown after the well was blocked with plasticine for 5 minutes ? (*Hint: think of the reaction of NO(g) with the air in well F3.)
A9. After the lid was blocked, the nitrogen monoxide could no longer vent from the well and so it reacted with the gaseous oxygen ($O_2(g)$) in the air inside the well, to produce brown, gaseous nitrogen dioxide ($NO_2(g)$). The chemical equation representing the reaction of gaseous nitrogen monoxide with the oxygen in the air is:

$$2NO(g) + O_2(g) \rightarrow 2NO_2(g)$$

Q10. How does the chemical reaction in well F3 provide evidence for the production of nitric acid in well F1 ?
A10. The formation of $NO_2(g)$ by reaction with copper is characteristic of nitric acid. Apart from bromine, NO_2 is the only brown gas. The formation of a blue solution as the reaction occurs, shows the copper is dissolving and Cu^{2+} ions are being formed in the solution.

SOLUBILITY OF GROUP 2 METAL SULPHATES IN WATER

TEACHER GUIDE

1. Chemicals
All of the required chemicals are listed in the worksheet.

2. Equipment
Most of the apparatus required can be found in a RADMASTE Basic or Advanced Microchemistry Kit. A piece of white paper is needed on which to place the comboplate® for better observation.

3. Hints
If any of the precipitates formed are uneven, they can be stirred with a clean microspatula and allowed to resettle before a comparison of the precipitate heights is made.

The reaction involved when a sodium sulphate solution is added to many of the Group 2 metal nitrate solutions, can be represented by:

$$Na_2SO_4(aq) + M(NO_3)_2(aq) \rightarrow MSO_4(s) + 2NaNO_3(aq)$$

where M = Ca, Sr or Ba.

These metal sulphates are insoluble and sink to the bottom of the well. Magnesium sulphate (M = Mg), in contrast, is soluble in water and the $Mg^{2+}(aq)$ and $SO_4^{2-}(aq)$ ions remain in solution.

4. Cautions
Please remember the following cautions and inform your students of all safety hazards:

Sodium sulphate solution may be harmful if swallowed or absorbed by the skin. Make sure that you wash your hands thoroughly after the experiment.

The Group 2 nitrate solutions may be harmful if swallowed or absorbed by the skin. They are eye and skin irritants. If contact is made with the skin or eyes, the affected areas must be rinsed with copious amounts of water.

5. Model Answers to Questions in the Worksheet
It is recommended that learners write down all of the questions and answers in their workbooks. If this is done, then the answers to questions do not have to be in full sentences. If the learners do not copy the questions into their workbooks, then answers should be written in full sentences. Note that some of the questions can only be answered by learners in higher grades. Word equations can be written instead of chemical equations where required.

Q1. Prepare a table like Table 1 below.

Table 1. Experimental observations

	Most Precipitate	Second Most Precipitate	Third Most Precipitate	Least Precipitate
WELL	**A4**	**A3**	**A2**	**A1**
PRODUCT	**Barium Sulphate ($BaSO_4(s)$)**	**Strontium Sulphate ($SrSO_4(s)$)**	**Calcium Sulphate ($CaSO_4(s)$)**	**Magnesium Sulphate ($MgSO_4(s)$)**

Q2. Observe the heights of the precipitates formed in each well and record in your table which wells had the most through to the least precipitate.
A2. See Table 1. (Note that there is no precipitate in well A1.)

Q3. Give the name and formula of the product which formed in each well. Record this in your table.
A3. See Table 1.

Q4. What is the order of solubility of the sulphates of the Group 2 elements – Mg, Ca, Sr and Ba **?**
A4. Mg > Ca > Sr > Ba

PREPARATION OF AMMONIA

TEACHER GUIDE

1. Chemicals
All of the required chemicals are listed in the worksheet. Tap water and hot water are also required.

2. Equipment
Most of the apparatus required can be found in a RADMASTE Basic or Advanced Microchemistry Kit. A large container is needed to hold the hot water.

3. Hints
One can use empty 2 litre ice-cream containers in which to place the hot water. These are ideal for individual use and the comboplate® can fit comfortably into them.

Float the comboplate® in the hot water and do not push it to the bottom of the container.

It is preferable to use near boiling water. At this temperature, the reaction between the calcium hydroxide ($Ca(OH)_2(s)$) and the ammonium chloride ($NH_4C\ell(s)$) proceeds rapidly and a good result is obtained in approximately 1 minute. The lower the temperature of the water, the slower the reaction occurs and the less convincing the result (eg. the universal indicator is light blue instead of purple).

If at any time during the experiment there is evidence of suck-back of water from well F2 into well F1, remove the silicone tube from the set-up.

4. Cautions
Please remember the following cautions and inform your students of all safety hazards:

Ammonia is a toxic gas. Avoid inhaling the fumes generated in well F1. Make sure the experiment is performed in a well ventilated room.

5. Model Answers to Questions in the Worksheet
It is recommended that learners write down all of the questions and answers in their workbooks. If this is done, then the answers to questions do not have to be in full sentences. If the learners do not copy the questions into their workbooks, then answers should be written in full sentences. Note that some of the questions can only be answered by learners in higher grades. Word equations can be written instead of chemical equations where required.

Q1. What is the colour of the universal indicator in tap water ? What does this imply about tap water ?
A1. The colour of universal indicator is green in the water. The tap water is neutral.

Q2. What has happened to the mixture of ammonium chloride and calcium hydroxide in well F1 ?
A2. Nothing seems to have happened to the mixture in well F1.

Q3. Describe the smell from well F1.
A3. There is a pungent smell characteristic of ammonia coming from well F1.

Q4. What has happened to the colour of the universal indicator in well F2 ?
What does this imply about the solution in well F2 ?
A4. The colour of the universal indicator has changed from green to blue or purple. The solution in well F2 is basic.

Q5. What evidence is there that a gas was produced from the reaction between ammonium chloride and calcium hydroxide, even if it appeared as if nothing was happening to the mixture in well F1 ?
A5. A pungent smell was detected from well F1. The universal indicator solution in well F2 changed colour, showing that some type of gaseous product must have been formed in well F1 and entered the water in well F2 via the silicone tubing.

Q6. What do your results with the universal indicator solution tell you about the gas produced in well F1 ? Give a reason for your answer.
A6. The gas is soluble in water and forms a basic solution. Before the experiment, the water in well F2 was shown to be neutral. After the mixture in well F1 was heated, the solution in well F2 was basic. This implies that the gas produced in well F1 is basic and dissolved in the water in well F2 to form a basic solution.

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Q7. What is the name of the gas produced in well F1 ?
A7. The gas produced in F1 is ammonia.

Q8. Why was calcium hydroxide ($Ca(OH)_2(s)$) used in the mixture with ammonium chloride ($NH_4C\ell(s)$) ?
A8. When ammonium chloride is heated two gaseous products form: ammonia and hydrogen chloride. The calcium hydroxide reacts with the hydrogen chloride in a neutralisation reaction to form a salt ($CaC\ell_2(s)$). This allows for the gaseous ammonia to be detected in the absence of hydrogen chloride gas.

Q9. Write a balanced chemical equation to represent the reaction that occurred in well F1.
A9. $2NH_4C\ell(s) + Ca(OH)_2(s) \rightarrow 2NH_3(g) + CaC\ell_2(s) + 2H_2O(\ell)$

Q10. Write a balanced chemical equation to represent the reaction that occurred in well F2.
A10. $NH_3(g) + H_2O(\ell) \rightarrow NH_4^+(aq) + OH^-(aq)$

PREPARATION AND PROPERTIES OF NITROGEN DIOXIDE

TEACHER GUIDE

1. Chemicals
All of the required chemicals for Parts 1 and 2 are listed in the worksheets. Tap water is also required. Hot water and cold water are needed in Part 2.

2. Equipment
Most of the apparatus required can be found in a RADMASTE Basic or Advanced Microchemistry Kit. Two plastic cups are required in Part 2. If plastic cups are not available, any containers that can hold the hot and cold water will suffice.

3. Hints

PART 1: Preparation of Nitrogen Dioxide

If the copper turnings are dull, they will not be as effective in producing the nitrogen dioxide gas (NO_2(g)). Try to use brightly coloured copper turnings that will rapidly produce a substantial volume of NO_2(g).

The nitric acid must be added slowly to the copper turnings in well F2, otherwise the vigorous bubbling in the well may force the solution in well F2 through the silicone tube into well F1.

To detect the smell of the gas, wave your hand over well F1 towards your nose. **Do not inhale the gas directly**, as it is choking and poisonous.

PART 2: The Effect of Temperature on the Nitrogen Dioxide/Dinitrogen Tetroxide Equilibrium

In Part 2, the air inside the bulb of the propette must be forced out by pressing the bulb between the thumb and index finger. The bulb must then be held in this depressed position until the tip of the propette is inserted into the outlet of lid 1. When the bulb is released, it will fill up with the brown NO_2(g).

To prevent the nitrogen dioxide gas from escaping from the propette, the tip of the propette should be pinched closed at all times.

The room should be well ventilated, as the nitrogen dioxide gas escaping from the outlet in lid 1 may become overwhelming. After collecting the NO_2(g), the reaction in well F1 may be slowed down by removing the lid and diluting the contents of the well with water.

4. Cautions
Please remember the following cautions and inform your students of all safety hazards:

Nitric acid is very corrosive. If any acid is spilt on the skin, the affected area must immediately be rinsed with copious amounts of water. Severe burns must receive medical attention.

Never point a propette or a syringe containing acid upwards. A momentary lapse of concentration can result in a nasty accident. If any acid is squirted into the eye, immediately rinse the eye out under running water. Always have a dilute solution of sodium hydrogencarbonate (household baking soda), or milk close by to apply to the injury. These substances will help neutralise the acid in the eye. The patient should be referred to a doctor.

Nitrogen dioxide is a pungent, toxic gas. Do not inhale the fumes. Make sure the experiment is performed in a well ventilated room.

The copper nitrate solution formed in the reaction of nitric acid with copper may be irritating to the skin. Wash your hands thoroughly with soap and water after the experiment.

5. Model Answers to Questions in the Worksheets
It is recommended that learners write down all of the questions and answers in their workbooks. If this is done, then the answers to questions do not have to be in full sentences. If the learners do not copy the questions into their workbooks, then answers should be written in full sentences. Note that some of the questions can only be answered by learners in higher grades. Word equations can be written instead of chemical equations where required.

PART 1: Preparation of Nitrogen Dioxide

Q1. Note the pH of the water in well F1. (☺ Hint: Use the pH indicator colour strip)
A1. The colour of the universal indicator solution is green. Hence the water is neutral (pH 7).

Q2. What do you observe happening in well F2 ?
A2. The copper turnings are rapidly dissolved by the nitric acid in well F2.

Q3. Can you smell anything from the vent in well F1 ? (Describe what you smell.)
A3. Yes. There is a pungent (choking) smell coming from the vent in well F1.

Q4. What is the colour of the gas produced in well F2 ?
A4. The gas produced in F2 is brown in colour.

Q5. What is the pH of the solution in well F1 ?
A5. The universal indicator solution is red. The solution is therefore acidic (pH~3).

Q6. What is the name of the gas formed in well F2 ?
A6. The gas formed in F2 is nitrogen dioxide.

Q7. What is the chemical formula of the gas formed in well F2 ?
A7. The chemical formula is $NO_2(g)$.

Q8. What is the name of the aqueous product in well F2 ?
A8. The aqueous product is copper nitrate.

Q9. Give a balanced chemical equation for the reaction of 6 M nitric acid and copper.
A9. $8HNO_3(aq) + 3Cu(s) \rightarrow 3Cu(NO_3)_2(aq) + 2NO(g) + 4H_2O(\ell)$

Note, however, that nitrogen monoxide is colourless and the gas formed in well F2 was brown. This occurs when the nitrogen monoxide is oxidised by the oxygen in the well: $2NO(g) + O_2(g) \rightarrow 2NO_2(g)$.

Thus the overall equation is:

$8HNO_3(aq) + 3Cu(s) + O_2(g) \rightarrow 3Cu(NO_3)_2(aq) + 2NO_2(g) + 4H_2O(\ell)$

PART 2: The Effect of Temperature on the Nitrogen Dioxide/Dinitrogen Tetroxide Equilibrium

Q1. Note the colour of the gas in the bulb of the propette.
A1. The gas in the propette bulb is dark brown in colour.

Q2. Note the colour of the gas in the bulb of the propette.
A2. The gas in the propette is light brown in colour.

Q3. Using the given chemical equation, explain the colour difference between the gaseous mixture in the propette at a high temperature and at a low temperature.
A3. The mixture is darker brown (and so has a larger concentration of nitrogen dioxide) at the higher temperature. When the temperature is lowered the mixture becomes a lighter brown, indicating a smaller concentration of nitrogen dioxide (and a larger concentration of dinitrogen tetroxide).

Q4. Write a statement describing the effect of temperature on the equilibrium between NO_2 and N_2O_4.
A4. Temperature affects the equilibrium between $NO_2(g)$ and $N_2O_4(g)$. At higher temperatures the concentration of nitrogen dioxide is greater; at lower temperatures the concentration of dinitrogen tetroxide is greater.

Q5. Which molecules are the higher energy molecules – NO_2 or N_2O_4 ? Justify your answer.
A5. NO_2 molecules are higher energy molecules. They form from N_2O_4 molecules at higher temperatures.

Q6. According to le Chatelier's Principle, and on the basis of your observations, which direction of reaction is exothermic?
A6. The forward direction ($2NO_2(g) \rightarrow N_2O_4(g)$) is exothermic since this is the direction favoured by lower temperatures.

PREPARATION AND TESTING FOR CHLORINE

TEACHER GUIDE

1. Chemicals

All of the required chemicals are listed in the worksheet. Tap water is also needed. The procedure requires that 5.5 M hydrochloric acid (HCℓ(aq)) be diluted to 2.75 M. Remember to always add the acid to the water and not the other way around. **If you add 5.5 M hydrochloric acid to the potassium permanganate, you will damage the well of the comboplate®.**

2. Equipment

All of the apparatus required can be found in a RADMASTE Basic or Advanced Microchemistry Kit. White paper and a koki (felt-tip) pen are also required.

3. Hints

Add the 2.75 M hydrochloric acid (HCℓ(aq)) slowly to the potassium permanganate ($KMnO_4$(s)), otherwise the vigorous bubbling in well F1 may force the solution through the silicone tube into well F2.

The bleaching effect of the chlorine can be demonstrated using other materials: try dipping coloured fabrics or flower petals into the solution in well F2.

As soon as the bleach test has been completed, thoroughly rinse the comboplate® with water. Add a little 10% hydrogen peroxide solution to well F1, otherwise the well will be stained brown.

4. Cautions

Please remember the following cautions and inform your students of all safety hazards:

Hydrochloric acid is corrosive. If any acid is spilt on the skin, the affected area must immediately be rinsed with copious amounts of water. Severe burns must receive medical attention.

Never point a propette or a syringe containing acid upwards. A momentary lapse of concentration can result in a nasty accident. If any acid is squirted into the eye, immediately rinse the eye out under running water. Always have a dilute solution of sodium hydrogencarbonate (household baking soda), or milk close by to apply to the injury. These substances will help neutralise the acid in the eye. The patient should be referred to a doctor.

Chlorine is a pungent, toxic gas. Do not inhale the fumes. Make sure the experiment is performed in a well ventilated room.

Potassium permanganate is poisonous. Rinse your hands thoroughly if any crystals make contact with the skin.

The chlorine water formed in well F2 during the experiment is corrosive. Rinse your hands well after the experiment and do not allow the solution in well F2 to make contact with any fabrics, as it is a bleach.

5. Model Answers to Questions in the Worksheet

It is recommended that learners write down all of the questions and answers in their workbooks. If this is done, then the answers to questions do not have to be in full sentences. If the learners do not copy the questions into their workbooks, then answers should be written in full sentences. Note that some of the questions can only be answered by learners in higher grades. Word equations can be written instead of chemical equations where required.

Q1. Record the colour of the indicator paper with tap water.
A1. If blue litmus paper is used, it remains blue in colour when dipped in the tap water. If universal indicator paper is used, the colour of the paper changes to green when placed in the tap water.

Q2. What happened in well F1 when you added hydrochloric acid to the potassium permanganate ?
A2. The solution in well F1 bubbled vigorously as a gas was produced.

Q3. What do you observe in the water in well F2 after HCℓ(aq) is added to the $KMnO_4$(s))?
A3. Bubbles can be seen in F2 after the hydrochloric acid has been added to the potassium permanganate. This is further evidence that a gas is produced in well F1.

Q4. Can you smell anything coming from the vent in the lid of well F2 ? (If you are unsure, wave your hand across the vent towards your nose.) Identify the smell.
A4. Yes, there is a strong smell of bleach coming from well F2.

Q5. What is the colour of this second piece of indicator paper ?

A5. The indicator paper is white in colour. In other words, the indicator paper is bleached.

Q6. What happens to the ink on the white paper ?

A6. The ink is also bleached.

Q7. Explain the observations you made with the indicator paper and the ink writing on the white paper.

A7. The gas formed in well F1 has dissolved in the water in well F2. This solution is a bleaching agent.

Q8. Name the gas formed in well F1 and write its chemical formula.

A8. The gas formed in F1 is chlorine. Its chemical formula is $C\ell_2(g)$.

Q9. Write a chemical equation for the reaction occurring between the gas formed in well F1 and the water in well F2.

A9. The chemical reaction occurring in well F2 is:

$$H_2O(\ell) + C\ell_2(g) \rightarrow HOC\ell(aq) + HC\ell(aq)$$

Q10. What type of reaction occurred in well F1 ? (Hint: Think about the oxidation states of the different species in the reactants and the products.)

A10. A reduction-oxidation (redox) reaction occurred in F1.

Q11. Justify your answer to question 10.

A11. The chlorine atom in $HC\ell(aq)$ has an oxidation state of -1. This has changed to zero in the chlorine ($C\ell_2(g)$). Chlorine atoms have thus lost electrons:

$$2C\ell^- \rightarrow C\ell_2 + 2e^-$$

The oxidant is $KMnO_4(s)$. (Mn oxidation state = +7)

Q12. From your answers to questions 10 and 11, what kind of substances are required to obtain chlorine from hydrochloric acid ?

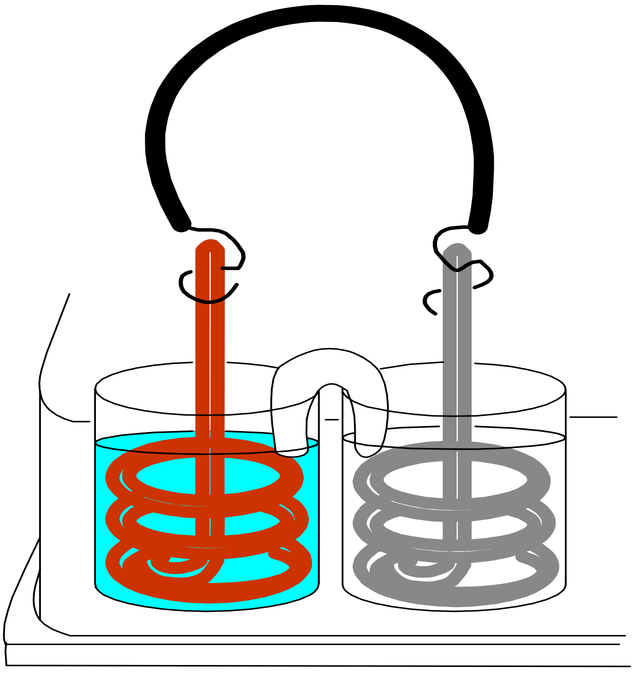
A12. Oxidising agents (oxidants) are required to obtain chlorine from hydrochloric acid.

Q13. Which of the following substances would you use to produce chlorine ($C\ell_2(g)$) from hydrochloric acid ($HC\ell(aq)$) ? Explain your choice.

1. Sodium chloride ($NaC\ell(s)$)
2. Manganese dioxide ($MnO_2(s)$)
3. Potassium chloride ($KC\ell(s)$)

A13. Of the three substances only $MnO_2(s)$ is an oxidant, and therefore could possibly be used.

MICROCHEMISTRY
CHAPTER V



RATE OF REACTION –
FACTORS AFFECTING THE RATE OF A HETEROGENEOUS REACTION

TEACHER GUIDE

1. Chemicals
All of the required chemicals are listed in the worksheet. Tap water is required.

2. Equipment
Most of the apparatus required can be found in a RADMASTE Basic or Advanced Microchemistry Kit.

3. Hints

PART 1: The Effect of State of Division of Reactants

In Part 1, the student will need to rely on personal judgement in deciding what size calcium carbonate lump to use. The lumps are not all uniform in size. If a small lump is used, the quantity of calcium carbonate powder must be reduced. Similarly, more of the powder will be needed for comparison if the lump used is large. Large lumps may also be broken into smaller pieces with a hard object. Do not try and break the lumps in the comboplate® as they are very hard and will crack the comboplate®.

When adding water and hydrochloric acid to the lump, these must not be dropped directly onto the lump as it may begin to break up. The observed rate of reaction will be affected because the surface area of the lump will change.

If the lump of calcium carbonate has not completely reacted after Part 1, it can be removed from the well, rinsed with water and dried in air. The lump can be used again in other experiments.

PART 2: The Effect of Concentration of Reactants

In Part 2, the calcium carbonate powder must be spread in the large wells to prevent portions of the powder from forming small clumps.

The different concentrations of hydrochloric acid used in Part 2 must be already in the propettes before each is added to the $CaCO_3$(s). The propettes should be lined up in order of increasing concentration, and then each concentration of acid added quickly so that a good comparison of the rate can be made from one concentration of acid to the next.

PART 3: The Effect of Temperature

In Part 3, the hot glass rod must be twirled around in the well to ensure uniform heating of the solution.

4. Cautions
Please remember the following cautions and inform your students of all safety hazards:

11 M hydrochloric acid is extremely corrosive. If any acid is spilt on the skin, the affected area must immediately be rinsed with copious amounts of water. Severe burns must receive medical attention.

Never point a propette or a syringe containing acid upwards. A momentary lapse of concentration can result in a nasty accident. If any acid is squirted into the eye, immediately rinse the eye out under running water. Always have a dilute solution of sodium hydrogencarbonate (household baking soda), or milk close by to apply to the injury. These substances will help neutralise the acid in the eye. The patient should be referred to a doctor.

Calcium carbonate may be harmful if ingested or absorbed by the skin. Wash your hands thoroughly with soap and water after handling this chemical.

Methylated spirits is poisonous. Do not inhale the vapour or drink the liquid.

Never allow the learners to play with matches. Treat any burn with cold running water or ice, and seek medical assistance where necessary.

Be careful not to burn yourself when working with the microburner and hot rod. Do not allow the hot rod or flame of the burner to touch the comboplate®, as this will melt the plastic. Ensure that all burners are extinguished when not in use.

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5. Model Answers to Questions in the Worksheet

It is recommended that learners write down all of the questions and answers in their workbooks. If this is done, then the answers to questions do not have to be in full sentences. If the learners do not copy the questions into their workbooks, then answers should be written in full sentences. Note that some of the questions can only be answered by learners in higher grades. Word equations can be written instead of chemical equations where required.

PART 1: The Effect of State of Division of Reactants

Q1. What can be observed in wells F1 and F2 ?

A1. Well F1: Small bubbles form around the lump of calcium carbonate. The bubbles rise steadily to the surface of the water for a long period of time.

Well F2: A vigorous stream of bubbles occurs in well F2 for a short period of time where the calcium carbonate is in powder form. A fizzing sound is heard.

Q2. In which well would you say the reaction is going faster ? Give a reason for your answer.

A2. The reaction is faster in well F2. Bubbles of gaseous carbon dioxide ($CO_2(g)$) are given off vigorously for a short period of time, whereas the gentle bubbling in well F1 continues steadily. In well F1, the lump of calcium carbonate has a small surface area and thus provides less molecules of calcium carbonate for reaction with molecules of hydrochloric acid. In well F2, the powder form of the calcium carbonate provides a much larger surface area and hence there are more molecules of calcium carbonate able to react with molecules of hydrochloric acid, resulting in the rapid production of gaseous carbon dioxide ($CO_2(g)$).

[NB: In this answer we refer to $CaCO_3$ molecules. In fact, solid $CaCO_3$ is made up of Ca^{2+} and CO_3^{2-} ions. If your students are familiar with this, then it would be better to refer to the carbonate ions rather than calcium carbonate molecules. Similarly, it is correct to refer to hydrogen ions, $H^+(aq)$ or $H_3O^+(aq)$, instead of molecules of hydrochloric acid.]

Q3. Write a statement describing the effect of the state of division of solid calcium carbonate on the rate of its reaction with hydrochloric acid.

A3. The state of division of calcium carbonate affects the rate of the heterogeneous chemical reaction between solid calcium carbonate and hydrochloric acid. The more finely divided the calcium carbonate is, the greater is the surface area (exposed reactant molecules) available for reaction with hydrochloric acid and the faster the reaction proceeds.

PART 2: The Effect of Concentration of Reactants

Q1. What can be observed in wells F3, F4 and F5 ?

A1. Well F3: A very slow reaction takes place in well F3 when 0.1 M $HC\ell$ is added.

Well F4: Carbon dioxide is given off gently in small quantities in well F4 when 1.0 M $HC\ell$ is added. The bubbles rise to the surface of the water at a steady pace.

Well F5: Carbon dioxide is vigorously given off in well F5 when 11 M $HC\ell$ is added. The bubbles rise very quickly to the surface with a fizzing sound.

Q2. Place the wells in a sequence, from the well in which the reaction is the fastest to the one in which it is the slowest.

A2. The sequence of wells from the fastest to the slowest reaction is F5, F4, F3.

Q3. What is the reason for the difference in reaction rates ?

A3. Wells F3, F4 and F5 have the same amount of calcium carbonate powder, but differing concentrations of hydrochloric acid. The greater the concentration of the acid, the more $HC\ell$ molecules there are available for reaction with the $CaCO_3$. Well F5 contains the highest concentration of hydrochloric acid (i.e. 11 M) and the greatest number of $HC\ell$ molecules per volume. The reaction in well F5 is therefore the fastest and the most rapid evolution of gaseous carbon dioxide is observed. Well F4 contains about one tenth of the previous concentration of hydrochloric acid (i.e. 1,0 M) and less $HC\ell$ molecules per volume are available for reaction with $CaCO_3$. The reaction in well F4 is therefore the next fastest and as a result, gaseous carbon dioxide is formed less rapidly in well F4 than in well F5. Well F3 contains about one tenth of the previous concentration of hydrochloric acid (i.e. 0,1 M) and the least number of $HC\ell$ molecules per volume available for reaction . The reaction in well F3 is therefore the slowest and the least volume of $CO_2(g)$ is given off per time. [NB: In this answer we refer to $HC\ell$ molecules. In fact there will be very few of these in aqueous solution because $HC\ell$ is a strong acid. In aqueous solution there would be only hydrogen ions ($H^+(aq)$ or $H_3O^+(aq)$) and chloride ions. If your students are familiar with this, it would be better to refer to the hydrogen ions rather than $HC\ell$ molecules.]

Q4. Write a statement describing the effect of concentration of hydrochloric acid on the rate of its reaction with solid calcium carbonate.

A4. The greater the concentration of the hydrochloric acid, the faster the reaction with solid calcium carbonate proceeds. We say the reaction rate increases when the concentration of one of the reactants (in this case, hydrochloric acid) increases.

PART 3: The Effect of Temperature

Q1. What can be observed in wells E1 and E2 ?

A1. Well E1: Bubbles of gaseous carbon dioxide rise steadily to the surface in well E1 for some time.

Well E2: Carbon dioxide bubbles rise quickly and vigorously with fizzing for a short period of time.

Q2. In which of these wells would you say the reaction is going faster ? Give a reason for your answer.

A2. The reaction is proceeding faster in well E2, as shown by the more vigorous and shorter evolution of gaseous carbon dioxide (CO_2(g)).

Q3. What is the reason for your observations in question 1 ?

A3. The water in well E2 was heated with the glass rod, causing the reaction to proceed faster and thus the formation of carbon dioxide was vigorous and rapid. The water added to well E1 was at room temperature, resulting in a slower reaction with a more gentle stream of carbon dioxide bubbles liberated.

Q4. Write a statement describing the effect of temperature on the rate of the reaction.

A4. The greater the temperature at which the reaction occurs, the faster the reaction proceeds. We say the reaction rate increases when the temperature of a heterogeneous chemical reaction increases.

RATES OF REACTION –
THE EFFECT OF CATALYSTS

TEACHER GUIDE

1. Chemicals

All of the required chemicals are listed in the worksheet. The procedure requires that 10% hydrogen peroxide (H_2O_2(aq)) be used. This solution should be fresh, since peroxide solutions that are left in storage are susceptible to decomposition. A fresh solution is best prepared from a 30% H_2O_2(aq) solution, and should be kept in dark bottles in a cool, dark place to minimise decomposition.

2. Equipment

Most of the apparatus required can be found in a RADMASTE Basic or Advanced Microchemistry Kit.

3. Hints

As an introduction to the experiment, it may be useful to the students to explain how they can identify the reaction:

$$2H_2O_2(aq) \rightarrow 2H_2O(\ell) + O_2(g)$$

i.e oxygen bubbles are given off as the hydrogen peroxide decomposes. The more quickly (or vigorously) the bubbles appear, the faster the hydrogen peroxide is decomposing. Sometimes hydrogen peroxide reacts with other substances and bubbles are also seen. It should then be pointed out to the students that such substances are not catalysts for the decomposition of H_2O_2, because after the reaction new substances have been formed. When MnO_2(s) is added to H_2O_2, bubbling occurs and the MnO_2(s) does not get used up in the reaction. This is shown by the black mass left in the well after the reaction. If more H_2O_2 is added to the MnO_2 in the well, more bubbles will be seen because the MnO_2 will catalyse the decomposition of the peroxide just added.

4. Cautions

Please remember the following cautions and inform your students of all safety hazards:

Hydrogen peroxide is corrosive, and is a bleaching agent. If any solution is spilt on the skin or fabric, the affected area must immediately be rinsed with copious amounts of water.

Never point a propette or a syringe containing hydrogen peroxide upwards. A momentary lapse of concentration can result in a nasty accident. If any peroxide is squirted into the eye, immediately rinse the eye under running water.

5. Model Answers to Questions in the Worksheet

It is recommended that learners write down all of the questions and answers in their workbooks. If this is done, then the answers to questions do not have to be in full sentences. If the learners do not copy the questions into their workbooks, then answers should be written in full sentences. Note that some of the questions can only be answered by learners in higher grades. Word equations can be written instead of chemical equations where required.

PART 1: Finding a Catalyst for the Decomposition of Hydrogen Peroxide

Q1. What can be observed in wells F1, F2 and F3 ?
A1. Well F1: No reaction occurred in well F1.
Well F2: No immediate reaction occurred in well F2. (After a while, some bubbles do form.)
Well F3: Bubbles can be observed rising rapidly to the surface of the solution in well F3, and a fizzing sound is heard.

Q2. Can you still see NaCℓ(s) in well F1 ? Give a reason for your observation.
A2. No. The NaCℓ(s) has dissolved in the H_2O_2(aq).

Q3. Can you still see Cu(s) in well F2 ?
A3. Yes, there is still Cu(s) in well F2.

Q4. What happens when more H_2O_2(aq) is added to F2 ?
A4. Nothing happens when more H_2O_2(aq) is added to the copper remaining in well F2.

Q5. Can you still see MnO_2(s) in well F3 ?
A5. Yes, there is a black mass of MnO_2(s) at the bottom of well F3.

Q6. What happens when more H_2O_2(aq) is added to F3 ?
A6. As soon as the hydrogen peroxide is added to the manganese dioxide at the bottom of well F3, more bubbling occurs with a fizzing sound.

Q7. In which well/s is the decomposition reaction of hydrogen peroxide being catalysed ? Give reasons for your answer.
A7. Hydrogen peroxide decomposition is being catalysed in well F3 only. This was first shown by the appearance of bubbles, which can be assumed to be gaseous oxygen (O_2(g)) forming as soon as the MnO_2(s) was added. (Hint: see the equation). When more hydrogen peroxide was added to the MnO_2(s) at the bottom of the well, further decomposition occurred proving that the MnO_2(s) was not used up in the first decomposition and was available to decompose more H_2O_2(aq). NaCℓ(s) slowly dissolved in the aqueous hydrogen peroxide. Cu(s) did not actively catalyse the decomposition of H_2O_2(aq), and when the remaining copper was tested with more hydrogen peroxide, no decomposition was observed.

Q8. Write a statement describing which of the substances tested, catalyse the decomposition of hydrogen peroxide.
A8. Manganese dioxide powder (MnO_2(s)) is a catalyst for the decomposition of hydrogen peroxide (H_2O_2(aq)), NaCℓ(s) and Cu(s) are not.

PART 2: The Effect of Quantity of Catalyst on the Rate of Decomposition of Hydrogen Peroxide

Q1. What can be observed in wells F5 and F6 ?
A1. Well F5: A fizzing is heard and bubbles are rapidly given off from the solution.
Well F6: A violent fizzing is heard and bubbles are given off more vigorously than in well F6.

Q2. In which well does the bubbling stop first ?
A2. The bubbling ceases first in well F6.

Q3. In which well is the decomposition of hydrogen peroxide proceeding faster ? Give reasons for your answer.
A3. Hydrogen peroxide is decomposing faster in well F6. Gaseous oxygen (O_2(g)) is given off more vigorously here, and the bubbling ceases quickly because the decomposition proceeds more rapidly than in well F5.

Q4. Write a statement describing the effect of quantity of catalyst on the rate of decomposition of hydrogen peroxide.
A4. The greater the quantity of catalyst (MnO_2(s)), the faster the decomposition of hydrogen peroxide.

RATES OF REACTION – THE EFFECT OF CONCENTRATION

TEACHER GUIDE

1. Chemicals
All of the required chemicals are listed in the worksheet. Tap water is required.

2. Equipment
Most of the apparatus required can be found in a RADMASTE Basic or Advanced Microchemistry Kit. A stop watch or wrist watch, white paper and graph paper are required.

3. Hints

PART 1: The Effect of Concentration of Sodium Thiosulphate

As the concentration of sodium thiosulphate decreases so the time taken for the solution to appear milky increases. Hence the last determination (i.e. 1 drop of sodium thiosulphate:7 drops of water, followed by the addition of 5 drops of 11 M HCℓ(aq)) takes in excess of 4 minutes. It is not essential to obtain this point in order to draw the graph if your class is short of time.

A faint sulphur dioxide (SO_2(g)) smell is produced during the experiment. This originates from the sulphur dioxide generated in the chemical reaction. This could be mentioned to the learners doing the experiment. Alternatively they could be asked to note if they smelt anything during the experiment, and then asked if they could identify what was causing the smell.

PART 2: The Effect of Concentration of Hydrochloric Acid

This is investigated in Part 2, where the rates of reaction of 5.5 M hydrochloric acid and 11 M hydrochloric acid with the same concentration of sodium thiosulphate are compared.

The water used in the experiment could be heated beforehand and the experiment repeated, to see how temperature affects the rate of a homogeneous chemical reaction.

The comboplate® should be cleaned out as soon as possible after the experiment to prevent the sulphur adhering to the inside of the small wells. If this happens, the comboplate® can be flushed out with boiling water. Any stubborn residues can then be removed with a little cotton wool that has been twirled around a toothpick or wooden skewer.

4. Cautions
Please remember the following cautions and inform your students of all safety hazards:

11 M hydrochloric acid is extremely corrosive. If any acid is spilt on the skin, the affected area must immediately be rinsed with copious amounts of water. Severe burns must receive medical attention.

Never point a propette or a syringe containing acid upwards. A momentary lapse of concentration can result in a nasty accident. If any acid is squirted into the eye, immediately rinse the eye out under running water. Always have a dilute solution of sodium hydrogencarbonate (household baking soda), or milk close by to apply to the injury. These substances will help neutralise the acid in the eye. The patient should be referred to a doctor.

5. Model Answers to Questions in the Worksheet
It is recommended that learners write down all of the questions and answers in their workbooks. If this is done, then the answers to questions do not have to be in full sentences. If the learners do not copy the questions into their workbooks, then answers should be written in full sentences. Note that some of the questions can only be answered by learners in higher grades. Word equations can be written instead of chemical equations where required.

Part 1: The Effect of Concentration of Sodium Thiosulphate

Q1. Prepare a table like Table 1 below.
A1. Table 1

Well	Drops Sodium Thiosulphate Solution	Start time (min:sec)	Finish time (min:sec)	Reaction Time (seconds)	1/Reaction Time (x 10^{-3} s^{-1})
A1	**1**	**0:00**	**> 4:00**	**> 240**	
A2	**2**	**0:00**	**2:18**	**138**	**7.25**
A3	**3**	**0:00**	**1:10**	**70**	**14.3**
A4	**4**	**0:00**	**0:59**	**59**	**16.9**
A5	**5**	**0:00**	**0:40**	**40**	**25.0**
A6	**6**	**0:00**	**0:36**	**36**	**27.8**
A7	**7**	**0:00**	**0:28**	**28**	**35.7**
A8	**8**	**0:00**	**0:20**	**20**	**50.0**

Q2. Note the starting time and the finishing time (when the "X" is no longer visible) in well A8 and enter your results in the table.
A2. See Table 1.

Q3. Complete your table.
A3. See Table 1.

Q4. What happened when 11 M hydrochloric acid was added to the sodium thiosulphate solution ?
A4. Some time after adding the 11 M hydrochloric acid, the solution went milky.

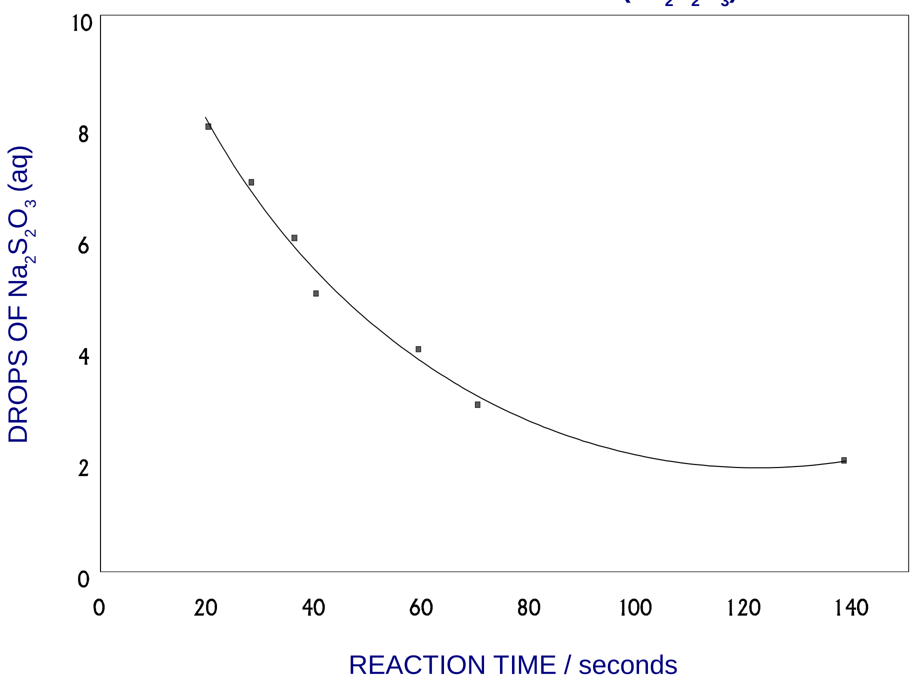
Q5. Which well has the greatest concentration of sodium thiosulphate solution ?
A5. Well A8 has the greatest concentration of sodium thiosulphate.

Q6. In which well has the reaction taken place in the shortest time ?
A6. In well A8, the "X" disappeared in the shortest time.

Q7. In which well has the reaction been the fastest ? Explain your answer.
A7. The rate of the reaction has been the fastest in well A8, since that is the well in which the time taken to produce a specific quantity of sulphur is least.

Q8. Draw the graph: Drops sodium thiosulphate solution (y-axis) vs Reaction Time (x-axis).

GRAPH 1: DROPS OF SODIUM THIOSULPHATE ($Na_2S_2O_3$) vs REACTION TIME



The rate of a chemical reaction is dependent on temperature. These times were determined at 22°C.

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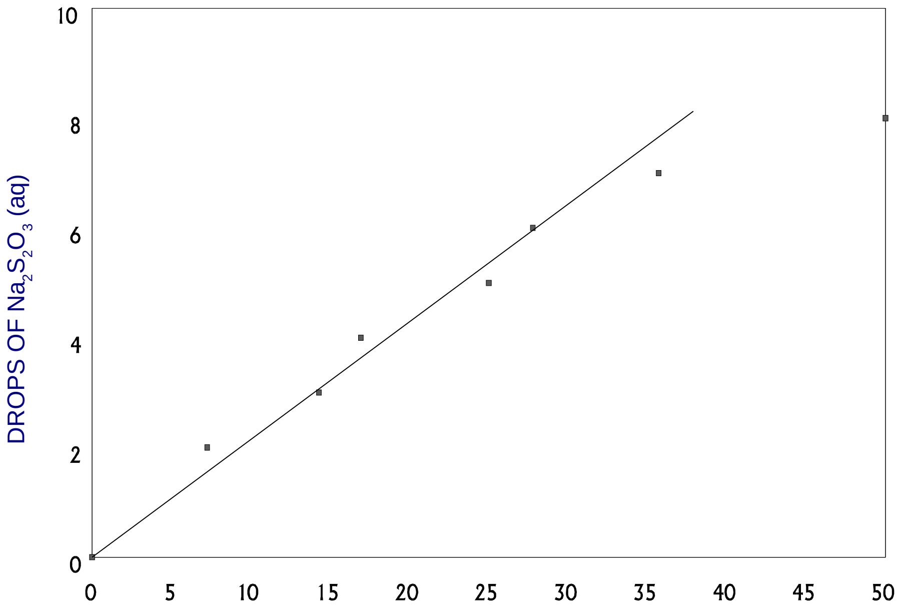
Q9. Draw the graph: Drops sodium thiosulphate solution (y-axis) vs 1/Reaction Time (x-axis).

GRAPH 2: DROPS OF SODIUM THIOSULPHATE ($Na_2S_2O_3$) vs 1/REACTION TIME



The rate of a chemical reaction is dependent on temperature. These times were determined at 22^{0}C.

Q10. What is the relationship between the number of drops of sodium thiosulphate solution and reaction time ?

A10. As the number of drops increases the reaction time decreases (see graph 1). In fact, the reaction time is inversely proportional to the number of drops (see graph 2).

Q11. Write a statement describing the effect of the concentration of sodium thiosulphate on the rate of its reaction with hydrochloric acid.

A11. The rate of reaction is given by 1/reaction time; the concentration of sodium thiosulphate is proportional to the number of drops used. Therefore, the rate of reaction of sodium thiosulphate with hydrochloric acid is directly proportional to the concentration of sodium thiosulphate in the mixture. As the concentration of sodium thiosulphate increases, the rate of reaction increases and vice versa.

PART 2: The Effect of Concentration of Hydrochloric Acid

Q1. Note the time when the “X” is no longer visible beneath well A1.

A1. The “X” is no longer visible at 1 min 15 sec (i.e. 75 seconds).

Q2. Note the time when the “X” is no longer visible beneath well A2.

A2. The “X” is no longer visible beneath well A2 at 55 seconds.

Q3. Write a statement describing the effect of the concentration of hydrochloric acid on the rate of its reaction with sodium thiosulphate.

A3. When the concentration of hydrochloric acid is increased, the rate of its reaction with sodium thiosulphate increases.

ENTHALPY CHANGES FOR REACTIONS OF ACIDS WITH A STRONG BASE

TEACHER GUIDE

1. Chemicals
All of the required chemicals are listed in the worksheet. Tap water is required for rinsing of the syringe and thermometer.

2. Equipment
Most of the apparatus required can be found in a RADMASTE Basic or Advanced Microchemistry Kit. A thermometer is required to measure temperature changes.

3. Hints
To make recording of temperature changes easier and more accurate, it is better to supply thermometers that are graduated in 0.1°C intervals. If this is not possible, the learners will have to rely upon personal judgement of the level of mercury in the thermometer.

When measuring temperatures of solutions, wait a few seconds before recording values. Make sure that the bulb of the thermometer is adequately covered with solution. You may need to tilt the comboplate® slightly to achieve this, if the thermometer has a long bulb.

The solutions in the wells of the comboplate® must be stirred thoroughly with the thermometer before the maximum temperature is recorded. Always rinse and dry the thermometer before measuring the temperature of a different solution.

Make sure that the syringe is thoroughly dry inside before it is used to dispense a different solution, otherwise water in the syringe will dilute and/or contaminate the acid/base and introduce errors into the results.

The solutions used to prepare the model answers were standardised prior to the experiment in order to obtain the expected mole ratios of acid:base. This allowed for the most accurate enthalpy changes to be calculated. The acid and base solutions provided by chemical suppliers are often not standardised, and the solutions you have for this experiment may therefore not all be exactly 1.0 M in concentration.

It is not absolutely essential to use standardised solutions for this experiment, but if you wish to obtain results which agree closely you will have to establish the exact concentrations of the acid or base by titration before allowing the learners to perform the experiment. An analyte volume of 10,0 mℓ sodium hydroxide should be titrated with the acid of choice. The expected volume ratio of acid:base is 1.0 i.e you should require 10,0 mℓ of hydrochloric acid to neutralise the sodium hydroxide. If you find that the volume ratio is greater than 1.0 you will have to adjust the concentration of the base by dilution. If the volume ratio is less than 1.0, the acid will need dilution. Another titration should then be carried out to confirm that the acid and base react in a volume ratio of 1:1.

4. Cautions
Please remember the following cautions and inform your students of all safety hazards:

Hydrochloric acid is corrosive. If any acid is spilt on the skin, the affected area must immediately be rinsed with copious amounts of water. Severe burns must receive medical attention.

Acetic acid fumes are irritating to the eyes and mucous membranes of the upper respiratory tract. Keep the bottle closed when not in use.

Sodium hydroxide is a corrosive base. If any base is spilt on the skin, treat as for acid burns described above.

Never point a propette or a syringe containing acid or base upwards. A momentary lapse of concentration can result in a nasty accident. If any acid or base is squirted into the eye, immediately rinse the eye out under running water. In the case of an acid, always have a dilute solution of sodium hydrogencarbonate (household baking soda), or milk close by to apply to the injury. Use a dilute boric acid solution for injuries involving a base. These substances will help neutralise the acid or base in the eye. The patient should be referred to a doctor.

Mercury is an expensive, poisonous metal. Be careful not to drop the thermometers!

5. Model Answers to Questions in the Worksheet
It is recommended that learners write down all of the questions and answers in their workbooks. If this is done, then the answers to questions do not have to be in full sentences. If the learners do not copy the questions into their workbooks, then answers should be written in full sentences. Note that some of the questions can only be answered by learners in higher grades. Word equations can be written instead of chemical equations where required.

PART 1: The enthalpy change (ΔH) for the reaction between hydrochloric acid ($HC\ell(aq)$) (a strong acid) and sodium hydroxide ($NaOH(aq)$) (a strong base)

Q1. What is the initial temperature of the sodium hydroxide solution ?
A1. The initial temperature of NaOH(aq) is 22.0 °C.

Q2. What is the initial temperature of the hydrochloric acid ?
A2. The initial temperature of $HC\ell(aq)$ is 22.7 °C.

Q3. Calculate the average of the two initial temperatures. This is the average initial temperature, T_i.
A3. The average initial temperature, T_i = 22.35 °C.

Q4. What is the maximum temperature of the mixture ? This is the final temperature, T_f .
A4. The final temperature, T_f, of the mixture is 26.7 °C.

Q5. Calculate the change in temperature ΔT.
A5. $\Delta T = T_f - T_i$ = 26.7 °C – 22.35 °C = 4.35 °C.

Q6. Was the final temperature of the reaction mixture higher or lower than the initial average temperature of the reagents ?
A6. T_f was higher than the initial average temperature (T_i).

Q7. Was energy absorbed or released by the surroundings as this reaction took place ?
A7. Energy was absorbed by the surroundings as the reaction took place.

Q8. Was energy absorbed or released by the reactants as this reaction took place ?
A8. Energy was released by the reactants as the reaction took place.

Q9. Is such a reaction exothermic or endothermic ?
A9. This is an exothermic reaction.

Q10. The heat capacity, C, of the comboplate® and contents is approximately 13.03 J °C $^{-1}$. Calculate q, the energy absorbed or released by the surroundings.

A10. $q = C \times \Delta T$

$C = 13.03\ J\ °C^{-1}$

$\Delta T = +4.35\ °C$

then, $q = 13.03\ J\ °C^{-1} \times 4.35\ °C$
$= 56.7\ J$

As the result is a positive quantity, this energy is absorbed by the surroundings.

Q11. Write down a balanced chemical equation for the reaction between hydrochloric acid and sodium hydroxide.
A11. $HC\ell(aq) + NaOH(aq) \rightarrow NaC\ell(aq) + H_2O(\ell)$

Q12. Calculate the enthalpy change of the reaction in J, and the enthalpy change per mole of reaction, in kJ mol^{-1}.
A12. $q = -\Delta H$ or $\Delta H = -q$
then, ΔH = – 56.7 J. This is the enthalpy change for the reaction performed.

The balanced chemical equation shows that the mole ratio of $HC\ell$:NaOH is 1:1. We used 1.0 mℓ each of 1.0 M $HC\ell$ and 1.0 M NaOH.

∴ the no. of moles of each used = 1.0 mol ℓ^{-1} x 1.0 x 10^{-3} ℓ = 1.0 x 10^{-3} mol.

$$\therefore \Delta H = \frac{-56.7\ J}{1 \times 10^{-3}\ mol} = -56\ 700 J\ mol^{-1} = -56.7\ kJ\ mol^{-1}$$ **(the enthalpy change per mole of reaction)**

PART 2: The enthalpy change (ΔH) for the reaction between acetic acid ($CH_3COOH(aq)$) (a weak acid) and sodium hydroxide ($NaOH(aq)$) (a strong base)

Q1. What is the initial temperature of the sodium hydroxide solution ?
A1. The initial temperature of the sodium hydroxide solution is 20.0 °C.

Q2. What is the initial temperature of the acetic acid ?
A2. The initial temperature of acetic acid is 20.1 °C.

Q3. Calculate the average of the two initial temperatures. This is the average initial temperature, T_i.
A3. T_i = 20.05 °C.

Q4. What is the maximum temperature of the mixture ? This is the final temperature, T_f .
A4. T_f = 24.0 °C.

Q5. Calculate the change in temperature, DT.
A5. ΔT = + 3.95 °C.

Q6. Was the final temperature of the reaction mixture higher or lower than the initial average temperature of the reagents?
A6. T_f was higher than T_i.

Q7. Was energy absorbed or released by the surroundings as this reaction took place ?
A7. Energy was absorbed by the surroundings as the reaction occurred.

Q8. Was energy absorbed or released by the reactants as this reaction took place ?
A8. Energy was released by the reactants as the reaction occurred.

Q9. Is the reaction of acetic acid with sodium hydroxide endothermic or exothermic ?
A9. The reaction of acetic acid with sodium hydroxide is exothermic.

Q10. Write down a balanced chemical equation for the reaction between acetic acid and sodium hydroxide.
A10. $CH_3COOH(aq) + NaOH(aq) \rightarrow CH_3COONa(aq) + H_2O(\ell)$

Q11. The heat capacity, C, of the comboplate® and contents is approximately 13.03 J °C $^{-1}$. Calculate the enthalpy change of the reaction in J, and the enthalpy change per mole of reaction in kJ mol^{-1}.
A11. $q = -\Delta H = C \times \Delta T$
$C = 13.03$ J °C^{-1}
$\Delta T = +3.95$ ° C
then, $\Delta H = -13.03$ J °$C^{-1} \times 3.95$ ° C
$= -51.5$ J.

This is the enthalpy change for the reaction performed.

We used 1.0 mℓ each of 1.0 M CH_3COOH and 1.0 M NaOH.

∴ the no. of moles of each used = 1.0 mol ℓ^{-1} x 1.0 x 10^{-3} ℓ = 1.0 x 10^{-3} mol.

$$\therefore \Delta H = \frac{-51.5 \text{ J}}{1 \times 10^{-3} \text{ mol}} = -51\,500 \text{ J mol}^{-1} = -51.5 \text{ kJ mol}^{-1}$$ **(the enthalpy change per mole of reaction)**

Q12. Is the enthalpy change the same as found in Part 1 ?
A12. No. The enthalpy change for Part 1 was greater than that for Part 2.

Q13. What is the explanation for your finding ?
A13. Strong acids and bases are completely dissociated in aqueous solutions. Hence the reaction between solutions of such acids and bases is always essentially,

$$H^+(aq) + OH^-(aq) \rightarrow H_2O(\ell)$$

However with a solution of a weak acid, there is only partial dissociation. When reaction with a strong base occurs, only part of the reaction is of the above type. The rest involves acid molecules (undissociated) reacting with hydroxide ions, e.g.

$$CH_3COOH(aq) + OH^-(aq) \rightleftharpoons CH_3COO^-(aq) + H_2O(\ell)$$

This reaction has a different ΔH. Therefore the enthalpy change for Part 1 differed from that for Part 2.

THE EFFECT OF pH ON THE CHROMATE/DICHROMATE EQUILIBRIUM

TEACHER GUIDE

1. Chemicals
All of the required chemicals are listed in the worksheet. Tap water is also required.

2. Equipment
Most of the apparatus required can be found in a RADMASTE Basic or Advanced Microchemistry Kit.

3. Hints
When preparing the potassium dichromate solution in steps 1 and 2 of the procedure, make sure that only a small amount of the solid is added to each well. If too much is added, it will not completely dissolve in the 5 drops of water.

In step 3, the sodium hydroxide solution must be added dropwise and the solution in well A2 must be stirred after each drop is added. Sometimes it may appear that only the surface of the solution has changed colour, but when the solution is stirred and the sodium hydroxide is thoroughly mixed with the potassium dichromate solution, the entire solution will become yellow. This instruction also applies when adding the hydrochloric acid in step 5.

For every drop of sodium hydroxide or hydrochloric acid that is added to well A2, an equal number of drops of water must be added to well A1 (see steps 4 and 6). This is done to prove that the colour change observed is not due to dilution.

4. Cautions
Please remember the following cautions and inform your students of all safety hazards:

Hydrochloric acid is very corrosive. If any acid is spilt on the skin, the affected area must immediately be rinsed with copious amounts of water. Severe burns must receive medical attention.

Sodium hydroxide solutions are also very corrosive. If any base is spilt on the skin, treat as for acid burns above.

Never point a propette or a syringe containing acid or base upwards. A momentary lapse of concentration can result in a nasty accident. If any acid or base is squirted into the eye, immediately rinse the eye out under running water. In the case of an acid, always have a dilute solution of sodium hydrogencarbonate (household baking soda), or milk close by to apply to the injury. These substances will help neutralise the acid in the eye. The patient should be referred to a doctor.

5. Model Answers to Questions in the Worksheet
It is recommended that learners write down all of the questions and answers in their workbooks. If this is done, then the answers to questions do not have to be in full sentences. If the learners do not copy the questions into their workbooks, then answers should be written in full sentences. Note that some of the questions can only be answered by learners in higher grades. Word equations can be written instead of chemical equations where required.

Q1. What is the colour of solid potassium dichromate ?
A1. Solid potassium dichromate is orange in colour.

Q2. What is the colour of the solutions in wells A1 and A2 ?
A2. The solutions in wells A1 and A2 are both orange in colour.

Q3. Which ion in solution is responsible for this colour ?
(Refer to the given equation and your former observation.)
A3. The dichromate ion ($Cr_2O_7^{2-}$(aq)) is responsible for the orange colour.

Q4. What number of drops of sodium hydroxide were required to make the solution change colour ?
A4. One or two drops of NaOH(aq) caused the solution to change colour.

Q5. Describe the colour change in well A2.
A5. The colour of the solution in A2 changed from orange to yellow.

Q6. Which ion in solution is responsible for the new colour ? (Refer to the given equation.)
A6. The chromate ion (CrO_4^{2-}(aq)) is responsible for the new yellow colour.

Q7. What number of drops of nitric acid (6 M) were required to make the solution change colour ?
A7. One drop of HNO_3(aq) made the solution change colour again.

Q8. Describe the colour change in well A2.
A8. The colour of the solution in A2 changed from yellow to orange.

Q9. Which ion in solution is responsible for the new colour ? (Refer to the given equation.)
A9. The dichromate ion ($Cr_2O_7^{2-}(aq)$) is responsible for the new colour.

Q10. Propose a reason why adding sodium hydroxide to the solution of potassium dichromate caused a colour change.
A10. As a result of the equilibrium that exists when potassium dichromate dissolves in water, there are hydrogen ($H^+(aq)$) ions in solution. These $H^+(aq)$ ions react with the added hydroxide ions ($OH^-(aq)$) ions to form water. This causes the hydrogen ion concentration in the following equilibrium to decrease:

$$\underset{\text{(orange)}}{Cr_2O_7^{2-}(aq)} + H_2O(\ell) \rightleftharpoons \underset{\text{(yellow)}}{2CrO_4^{2-}(aq)} + 2H^+(aq)$$

According to Le Chatelier's principle, orange dichromate ions reacted with the water to form yellow chromate ions ($CrO_4^{2-}(aq)$) and more hydrogen ions.

Q11. Propose a reason why adding nitric acid to the solution containing chromate ions caused a colour change.
A11. Adding nitric acid caused the $H^+(aq)$ ion concentration to increase. The $CrO_4^{2-}(aq)$ ions formed in the previous reaction (see answer to question 10) reacted with the $H^+(aq)$ ions as follows:

$$\underset{\text{(yellow)}}{2CrO_4^{2-}(aq)} + 2H^+(aq) \rightarrow \underset{\text{(orange)}}{Cr_2O_7^{2-}(aq)} + H_2O(\ell)$$

The dichromate ions ($Cr_2O_7^{2-}(aq)$) formed in this reaction are thus responsible for the new colour of the solution.

Q12. Write down colour indications for the species in the chemical equation:
A12. $$\underset{\text{orange}}{Cr_2O_7^{2-}(aq)} + \underset{\text{colourless}}{H_2O(\ell)} \rightleftharpoons \underset{\text{yellow}}{2CrO_4^{2-}(aq)} + \underset{\text{colourless}}{2H^+(aq)}$$

Q13. You are given the following list of reagents:
Nitric acid ($HNO_3(aq)$),
sodium chloride ($NaC\ell(s)$),
potassium hydroxide ($KOH(s)$).
Which would you choose to add to an orange coloured solution of potassium dichromate to cause it to change to a yellow colour ?
A13. Potassium hydroxide would cause an orange coloured potassium dichromate solution to change to yellow.

Q14. Give the reason for your answer in question 13.
A14. From the equation supplied in question 12, it can be seen that adding nitric acid to the dichromate/chromate equilibrium mixture will generate more of the orange dichromate ions. Sodium chloride should have no effect on the equilibrium as neither sodium nor chloride ions are involved in the reaction. However if potassium hydroxide were to be added, the hydroxide ions would combine with the hydrogen ions to form water. The equilibrium would be disturbed by the decrease in the $H^+(aq)$ concentration, and dichromate ions would react with the water to form more hydrogen and chromate ions. The solution would then appear yellow.

Q15. Write a statement describing the effect of pH on the chromate/dichromate equilibrium.
A15. $$Cr_2O_7^{2-}(aq) + H_2O(\ell) \rightleftharpoons 2CrO_4^{2-}(aq) + 2H^+(aq)$$
The presence of hydrogen ions in the equation for the reaction implies that pH will affect the equilibrium. If the pH is increased, e.g by adding a base like $NaOH(aq)$, the $OH^-(aq)$ ions react with the $H^+(aq)$ ions shown in the above reaction equation. The decreased $H^+(aq)$ concentration disturbs the equilibrium and orange dichromate ions react with the water to form more chromate ions and hydrogen ions. The solution becomes yellow. Similarly, if the pH is decreased by the addition of an acid like $HNO_3(aq)$, then the concentration of $H^+(aq)$ is high. The equilibrium is disturbed once again, and the chromate ions react with the hydrogen ions to form dichromate ions. The solution becomes orange.

CHEMICAL EQUILIBRIUM – LE CHATELIER'S PRINCIPLE

TEACHER GUIDE

1. Chemicals
All of the required chemicals are listed in the worksheet. Tap water is needed in Part 1. Ice or cold water is required in Part 2.

2. Equipment
Most of the apparatus required can be found in a RADMASTE Basic or Advanced Microchemistry Kit.

3. Hints

PART 1: The effect of the concentration of the reactants on the chemical equilibrium:

$$Cu(H_2O)_4^{2+}(aq) + 4C\ell^-(aq) \rightleftharpoons CuC\ell_4^{2-}(aq) + 4H_2O(\ell)$$

It may become confusing to learners when they are informed that the blue colour of the copper nitrate solution is due to $Cu(H_2O)_4^{2+}(aq)$ ions, and the green colour resulting from the addition of $HC\ell$ is due to $CuC\ell_4^{2-}(aq)$ ions. They should be told that when a salt, like copper nitrate, dissolves in water, the ions making up the salt are surrounded by polar water molecules. Thus each Cu^{2+} ion in solution becomes bonded to four water molecules and is said to be **hydrated**. When the hydrochloric acid is added to the copper nitrate solution, H^+ and $C\ell^-$ ions are introduced. The four water molecules bonded to the Cu^{2+} ions can be replaced with four chloride ions to form the green $CuC\ell_4^{2-}$ complex ion.

In Part 1, 8 drops of water must be added to well A2 after the solution has become green upon the addition of 11 M $HC\ell$. The colour should change back to blue, but sometimes one more drop of water is needed before the colour change is complete.

Remember that well A1 in Part 1 is the standard of comparison for the dilution effect. Whenever a drop of $HC\ell$ is added to well A2, a drop of water must be added to well A1. Similarly, whenever a drop of water is added to well A2, a drop of water must also be added to well A1.

PART 2: The effect of temperature on the chemical equilibrium:

$$Cu(H_2O)_4^{2+}(aq) + 4C\ell^-(aq) \rightleftharpoons CuC\ell_4^{2-}(aq) + 4H_2O(\ell)$$

In Part 2, the glass rod must not be made too hot, otherwise the solution in well A2 boils. If the colour change is not convincing, the rod can be wiped, passed through the flame again and placed back into well A2. If the rod is twirled in the well, the heat will be distributed more evenly. Similarly, when the cold rod is placed into the well, the colour change may take a long time. The rod should then be cooled again and placed back into the well to make the colour change complete. Note that ice is much better to use than cold water as it makes the rod colder.

4. Cautions
Please remember the following cautions and inform your students of all safety hazards:

11 M hydrochloric acid is extremely corrosive. If any acid is spilt on the skin, the affected area must immediately be rinsed with copious amounts of water. Severe burns must receive medical attention.

Never point a propette or a syringe containing acid upwards. A momentary lapse of concentration can result in a nasty accident. If any acid is squirted into the eye, immediately rinse the eye out under running water. Always have a dilute solution of sodium hydrogencarbonate (household baking soda), or milk close by to apply to the injury. These substances will help neutralise the acid in the eye. The patient should be referred to a doctor.

Methylated spirits is poisonous. Do not inhale the vapour or drink the liquid.

Never allow the learners to play with matches. Treat any burn with cold running water or ice, and seek medical assistance where necessary.

Be careful not to burn yourself when working with the microburner and hot rod. Do not allow the hot rod or flame of the burner to touch the comboplate®, as this will melt the plastic. Ensure that all burners are extinguished when not in use.

5. Model Answers to Questions in the Worksheet
It is recommended that learners write down all of the questions and answers in their workbooks. If this is done, then the answers to questions do not have to be in full sentences. If the learners do not copy the questions into their workbooks, then answers should be written in full sentences. Note that some of the questions can only be answered by learners in higher grades. Word equations can be written instead of chemical equations where required.

PART 1: The effect of the concentration of the reactants on the chemical equilibrium:

$$Cu(H_2O)_4^{2+}(aq) + 4C\ell^-(aq) \rightleftharpoons CuC\ell_4^{2-}(aq) + 4H_2O(\ell)$$

Q1. What is the colour of the solution in each well ?
A1. The solution in each well is blue.

Q2. Which ion in solution is responsible for this colour ? (☺Refer to the given equation.)
A2. The $Cu(H_2O)_4^{2+}(aq)$ is responsible for the blue colour.

Q3. Describe the colour change.
A3. The colour changes from blue to yellow/pale green when hydrochloric acid is added.

Q4. Which ion in solution is responsible for the new colour ? (☺ Refer to the given equation.)
A4. The $CuC\ell_4^{2-}(aq)$ is responsible for the yellow/pale green colour.

Q5. Note the colour change in well A2.
A5. The colour of the solution changes back from yellow/pale green to blue when water is added to A2.

Q6. Propose a reason why adding $HC\ell$ to the solution containing $Cu(NO_3)_2$, turns it yellow/pale green.
A6. Adding $HC\ell$ to the solution results in an increase in the concentration of chloride ($C\ell^-$) ions. The concentration of the $CuC\ell_4^{2-}(aq)$ ions then increases, and the concentration of the $Cu(H_2O)_4^{2+}(aq)$ ions decreases. (The $CuC\ell_4^{2-}(aq)$ ions are responsible for the yellow/pale green colour of the solution. The $Cu(H_2O)_4^{2+}(aq)$ ions are responsible for the blue colour of the solution.)

Q7. Write down colour indications for the species in the chemical equation:

$$Cu(H_2O)_4^{2+}(aq) + 4C\ell^-(aq) \rightleftharpoons CuC\ell_4^{2-}(aq) + 4H_2O(\ell)$$

☺ **Water (H_2O) is colourless.**

A7.

$Cu(H_2O)_4^{2+}(aq)$	+	$4C\ell^-(aq)$	$\rightleftharpoons$	$CuC\ell_4^{2-}(aq)$	+	$4H_2O(\ell)$
Blue		**Colourless**		**Yellow/pale green**		**Colourless**

Q8. You are given the following list of reagents:
nitric acid (HNO_3)
sodium chloride ($NaC\ell$)
sodium hydroxide (NaOH)
Which would you choose to add to a blue copper nitrate solution to cause it to turn yellow/pale green ?
A8. Sodium chloride ($NaC\ell$) will cause a blue copper nitrate solution to change to yellow/pale green.

Q9. Give the reason for your answer to Question 8.
A9. Adding sodium chloride ($NaC\ell$) to the solution results in an increase in the concentration of chloride ($C\ell^-$) ions in solution. Thus, once again the concentration of $CuC\ell_4^{2-}(aq)$ is increased and the solution turns yellow/ pale green.

Q10. Write a statement describing the effect of concentration of reactants on the equilibrium you have studied.
A10. By adding chloride ions ($C\ell^-$) or water (H_2O) to the solution, the concentration of either $CuC\ell_4^{2-}(aq)$ or $Cu(H_2O)_4^{2+}(aq)$ respectively, is increased. The colour of the solution reflects the colour of the species which are present in the greater concentration. This behaviour is typical of a chemical equilibrium.

PART 2: The effect of temperature on the chemical equilibrium:

$$Cu(H_2O)_4^{2+}(aq) + 4C\ell^-(aq) \rightleftharpoons CuC\ell_4^{2-}(aq) + 4H_2O(\ell)$$

Q1. Describe the colour change in well A2. (If the colour change is not convincing, wipe the rod and repeat step 1.)
A1. The colour in well A2 changes from blue to pale green.

Q2. Which ion in solution is responsible for the new colour ? (☺Refer to the chemical equation.)
A2. $CuC\ell_4^{2-}(aq)$ is responsible for the pale green colour.

Q3. Describe the colour change in well A2. (If the colour change is not convincing, repeat step 2.)
A3. The colour changed from pale green to blue.

Q4. Which ion in solution is responsible for the new colour ? (☺ Refer to the chemical equation.)
A4. $Cu(H_2O)_4^{2+}(aq)$ is responsible for the blue colour.

Q5. Do you observe the same colour changes as for well A2 ?
A5. No colour changes are seen in well A1.

Q6. Having noted the colour changes in well A2 which species, $Cu(H_2O)_4^{2+}$(aq) or $CuC\ell_4^{2-}$(aq), would you say is preferred under the following conditions:

6.1. Hot solution ?

6.2. Cold solution ?

A6. 6.1. $CuC\ell_4^{2-}$(aq) is preferred in hot solution.

6.2. $Cu(H_2O)_4^{2+}$(aq) is preferred in cold solution.

Q7. Using the given chemical equation, explain why the colour changes when the temperature of the solution in well A2 is:

7.1. increased

7.2. decreased

A7. 7.1. The concentration of the yellow/pale green $CuC\ell_4^{2-}$(aq) increases and the concentration of the blue $Cu(H_2O)_4^{2+}$(aq) decreases, when the temperature of the solution is increased.

7.2. When the solution temperature is decreased, the concentration of the blue $Cu(H_2O)_4^{2+}$(aq) increases and the concentration of the yellow/pale green $CuC\ell_4^{2-}$(aq) decreases.

Q8. Write a statement describing the effect of temperature on the chemical equilibrium you have studied.

A8. Higher temperatures give a greater concentration of $CuC\ell_4^{2-}$(aq) at equilibrium. Lower temperatures give greater concentrations of $Cu(H_2O)_4^{2+}$(aq) and chloride ($C\ell^-$(aq)) ions at equilibrium.

Q9. A student says that the temperature affects the colour of all coloured solutions.

9.1. Do you think the student is correct in his view ?

9.2. If not, how could you prove that the temperature only changes the colour of a solution when it changes the concentration of one or more of the coloured species in the solution ? Suggest an experimental set-up.

A9. 9.1. No! The student is incorrect.

9.2. An experimental set-up could involve a solution of $Cu(NO_3)_2.3H_2O$ in water to test the student's hypothesis. The solution in well A1, for example, was treated with both the hot rod and the cold rod. It should be noted that in neither case did the colour change.

CHEMICAL EQUILIBRIUM – THE COMMON ION EFFECT

TEACHER GUIDE

1. Chemicals
All of the required chemicals are listed in the worksheet. Tap water is also required.

2. Equipment
Most of the apparatus required can be found in a RADMASTE Basic or Advanced Microchemistry Kit.

3. Hints
The solution of saturated sodium chloride should be tested beforehand with 11 M hydrochloric acid. If it was prepared at a different temperature from your classroom, it may not be saturated. It may therefore not produce a precipitate when 11 M hydrochloric acid is added. If this happens, add more solid sodium chloride to the solution and stir. Each student can also prepare their own saturated sodium chloride solution as follows:

Fill about one third of one of the large wells in the comboplate® with solid sodium chloride ($NaC\ell(s)$). Fill the well with water. Use a plastic microspatula or glass rod to stir the solution thoroughly. Allow any undissolved $NaC\ell(s)$ to settle at the bottom of the well. Use a clean propette to suck up the solution above the undissolved salt, being careful not to disturb the solid. The volume of saturated sodium chloride solution in the propette should be sufficient to complete the experiment.

If the solution appears cloudy, it will need filtering. Remove the plunger of a syringe and push a small piece of cotton wool into the nozzle of the syringe. Dispense all of the solution from the propette into the syringe. Replace the plunger and position the syringe over an empty, large well. Gently push in the plunger to force the solution through the cotton wool filter and into the large well. Use a clean propette to remove the filtered solution from the well and continue with the experiment.

Remember that a precipitate will form only if the **concentration** of the common ion is **increased**. If the substance added to the saturated solution is a solid, then the amount of common ion increases but the volume of the solution remains the same. The concentration of the common ion will therefore increase and a precipitate will be observed.

However, if the substance added is a solution (eg. $HC\ell(aq)$), a precipitate will only be observed if this solution is concentrated. This is because a dilute solution contains a smaller amount of ions per volume than a concentrated solution. When a dilute solution of the common ion is added to a saturated solution, the total volume of the resultant solution increases much more than the total amount of common ion in the solution. The concentration of the common ion decreases and a precipitate is not observed. This can shown by allowing learners to repeat the experiment with 1 M hydrochloric acid. A precipitate will not form.

4. Cautions
Please remember the following cautions and inform your students of all safety hazards:

Nitric acid and hydrochloric acid are very corrosive. If any acid is spilt on the skin, the affected area must immediately be rinsed with copious amounts of water. Severe burns must receive medical attention.

Never point a propette or a syringe containing acid upwards. A momentary lapse of concentration can result in a nasty accident. If any acid is squirted into the eye, immediately rinse the eye out under running water. Always have a dilute solution of sodium hydrogencarbonate (household baking soda), or milk close by to apply to the injury. These substances will help neutralise the acid in the eye. The patient should be referred to a doctor.

5. Model Answers to Questions in the Worksheet
It is recommended that learners write down all of the questions and answers in their workbooks. If this is done, then the answers to questions do not have to be in full sentences. If the learners do not copy the questions into their workbooks, then answers should be written in full sentences. Note that some of the questions can only be answered by learners in higher grades. Word equations can be written instead of chemical equations where required.

Q1. What happens when you add the nitric acid to the saturated sodium chloride solution ?
A1. The solution appears unchanged when nitric acid is added to the saturated sodium chloride solution.

Q2. What happens when you add hydrochloric acid to the saturated sodium chloride solution ?
A2. When hydrochloric acid is added to the saturated sodium chloride solution, the solution turns milky at first then a white precipitate forms.

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Q3. Do the solutions added in well A1 have ions in common with one another ? If so, state which they are.
A3. No, the nitric acid and sodium chloride solutions do not have ions in common.

Q4. Do the solutions added in well A2 have ions in common with one another ? If so, state which they are.
A4. Yes, the chloride ion ($C\ell^-$(aq)) is common to the hydrochloric acid and sodium chloride solutions.

Q5. What is the name and chemical formula of the solid formed in well A2 ?
A5. The solid formed in A2 is sodium chloride ($NaC\ell$(s)).

Q6. In a saturated sodium chloride solution, solid sodium chloride is in equilibrium with the aqueous solution of sodium chloride, as represented in the balanced reaction equation,

$$NaC\ell(s) \rightleftharpoons Na^+(aq) + C\ell^-(aq)$$

Use this information to explain what happened in well A2.

A6. When hydrochloric acid was added to the saturated sodium chloride solution, the concentration of chloride ions was increased. The extra chloride ions reacted with sodium ions to form solid sodium chloride, which precipitated. A new equilibrium was established.

Q7. What happened to the contents of well A2 on adding water ?
A7. When water was added to A2, the precipitate dissolved and a colourless solution formed again.

Q8. Explain what happened in well A2.
A8. The sodium chloride precipitate dissolved because the ion concentrations were decreased by adding the water. The equilibrium:

$$NaC\ell(s) \rightleftharpoons Na^+(aq) + C\ell^-(aq)$$

was disturbed, and $NaC\ell$(s) dissolved to form Na^+(aq) and $C\ell^-$(aq) ions. It dissolves completely if sufficient water is added.

Q9. Explain what is meant by the "common ion effect".
A9. When two or more different kinds of ions in solution are in equilibrium with a solid, the equilibrium can be disturbed by several factors in accordance with Le Chatelier's Principle. One of these factors involves the concentrations of the ions in solution. If another substance is added to the solution, it may also form ions. One of these ions may be the same as that already present in the solution. This ion is common to the two substances. The equilibrium reaction is disturbed by the change in concentration of the common ion. If the concentration of the common ion increases, then solid will precipitate. This outcome is described as the "common ion effect".

Q10. A student makes a mistake when doing the above experiment and uses 1 M hydrochloric acid instead of 11 M hydrochloric acid in step 3.
Predict what the student will observe.
A10. There will be no precipitate formed if the student adds 1 M hydrochloric acid to the saturated sodium chloride solution.

CONCENTRATION AND AMOUNT OF SUBSTANCE IN SOLUTION

TEACHER GUIDE

1. Chemicals
All of the required chemicals are listed in the worksheet. Tap water is needed.

2. Equipment
Most of the apparatus required can be found in a RADMASTE Basic or Advanced Microchemistry Kit.

3. Hints
Solid copper nitrate absorbs water from the atmosphere. As a result, it can become a hard solid mass inside the bottle or container in which it is stored. The learners will be unable to use it in this form. It is therefore recommended that you break up the solid in the bottle with a sharp object before the experiment is attempted. A pointed, wooden skewer works well to crush the solid copper nitrate into small, even-sized grains.

When using the spooned end of the plastic microspatula to measure out the copper nitrate, make sure that level spatulas of solid are placed in the required wells. This will ensure that proper colour comparisons are made, and that the colour of the blue solution is equally intense in the wells which contain the same concentration of copper nitrate solution.

4. Cautions
Please remember the following cautions and inform your students of all safety hazards:

Never point a propette or a syringe upwards. A momentary lapse of concentration can result in a nasty accident.

5. Model Answers to Questions in the Worksheet
It is recommended that learners write down all of the questions and answers in their workbooks. If this is done, then the answers to questions do not have to be in full sentences. If the learners do not copy the questions into their workbooks, then answers should be written in full sentences. Note that some of the questions can only be answered by learners in higher grades. Word equations can be written instead of chemical equations where required.

Q1. Which well, comparing wells F1 and F2, has the greater concentration of Cu^{2+}(aq) ions ?

HINT **What is the definition of concentration** ?

Give the reason for your answer.

A1. Well F2 has the greater concentration of Cu^{2+}(aq) ions. The blue colour is more intense in well F2. This is because well F2 has twice as much solid $Cu(NO_3)_2.3H_2O$ per volume of water, as well F1.

Q2. Which well, comparing wells F1 and F3, has the greater concentration of Cu^{2+}(aq) ions ?
Give a reason for your answer.

A2. Both wells F1 and F3 have the same concentration of Cu^{2+}(aq) ions. The blue colour is equally intense in the two wells. This is because the ratio of the quantity of $Cu(NO_3)_2.3H_2O$ added, to the volume of water added, is the same in both cases.

Q3. Which well, comparing wells F1 and F2, has the greater amount of Cu^{2+}(aq) ions ?

HINT **What is the definition of amount** ?

Give the reason for your answer.

A3. Well F2 contains the greater amount of Cu^{2+}(aq) ions. Twice the quantity of solid $Cu(NO_3)_2.3H_2O$ has been placed in well F2, as in well F1. Twice the number of Cu^{2+}(aq) ions are thus present in solution in well F2 than in well F1.

Q4. Write a statement describing what is meant by the concentration and the amount of a substance in solution.

A4. Concentration of a substance in solution refers to the amount of substance per volume of water. In this case, concentration is the ratio of the quantity (number of spatulas) of $Cu(NO_3)_2.3H_2O$ added, to the volume (millilitres) of water added. Amount refers to the quantity of a substance in solution. This quantity is not affected by the volume of water. In this experiment, the amount of copper nitrate solid refers to the number of spatulas of $Cu(NO_3)_2.3H_2O$ in the solution.

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ACID/BASE TITRATION –
DETERMINING THE CONCENTRATION OF AN ACID

TEACHER GUIDE

1. Chemicals
All of the required chemicals are listed in the worksheet. Tap water is not required, but the syringe must be rinsed with tap water during the calibration procedure.

2. Equipment
Most of the apparatus required can be found in a RADMASTE Basic or Advanced Microchemistry Kit.

3. Hints
The hydrochloric acid (HCℓ(aq)) chosen for the purpose of providing model answers is approximately 0.1 M, but any concentration of this acid may be used. Bear in mind, however, that the best results will be obtained if the concentration of HCℓ(aq) does not exceed 0.1 M. If larger concentrations are used, the number of drops of 0.1 M sodium hydroxide (NaOH(aq)) required to neutralise the acid will be too many to fit in the small wells of the comboplate®.

The graduation markings printed on the side of the syringe are not standard. This means that learners may get different numbers of drops per unit volume with different syringes, even when the same acid or base is used for calibration. As a result the precision and accuracy of the results obtained may be less than desired. However, learners must be encouraged to complete the experiment because the final calculations will yield suitable answers.

Step 4 in the calibration procedure suggests that the number of drops of HCℓ(aq) be counted from the zero mark, until the volume of acid reaches another measuring mark a few units above the zero mark. You will notice that the model answers show the number of drops obtained for 0.5 mℓ of HCℓ(aq) and NaOH(aq). You may use 0.2 or 0.3 mℓ, especially if you want to save chemicals.

4. Cautions
Please remember the following cautions and inform your students of all safety hazards:

Hydrochloric acid is corrosive. If any acid is spilt on the skin, the affected area must immediately be rinsed with copious amounts of water.

Never point a propette or a syringe containing acid upwards. A momentary lapse of concentration can result in a nasty accident. If any acid is squirted into the eye, immediately rinse the eye out under running water. Always have a dilute solution of sodium hydrogencarbonate (household baking soda), or milk close by to apply to the injury. These substances will help neutralise the acid in the eye. The patient should be referred to a doctor.

Sodium hydroxide is a corrosive base. If any base is spilt on the skin, the affected area must immediately be rinsed with copious amounts of water. As with acids, propettes containing a base should never be pointed upwards.

5. Model Answers to Questions in the Worksheet
It is recommended that learners write down all of the questions and answers in their workbooks. If this is done, then the answers to questions do not have to be in full sentences. If the learners do not copy the questions into their workbooks, then answers should be written in full sentences. Note that some of the questions can only be answered by learners in higher grades. Word equations can be written instead of chemical equations where required.

Q1. Prepare a table like Table 1 below.

TABLE 1

Solution Used	Volume of syringe from "zero mark" /mℓ	No. of drops of solution needed for set volume	Average No. of drops of solution needed for set volume
HCℓ	0.5 0.5 0.5	**32** **33** **35**	**33 drops**
NaOH	0.5 0.5 0.5	**30** **30** **28**	**29 drops**

Q2. Enter your results into your table.
A2. See Table 1.

Q3. Enter your results into your table.
A3. See Table 1.

Q4. Enter your results into Table 1.
A4. See Table 1.

Complete the procedure for the conversion, that follows.

CONVERSION:

I) Hydrochloric acid:
33 (average) drops of HCℓ occupy **0.5** mℓ.
Therefore 1 drop of HCℓ occupies **0.015** mℓ.

II) Sodium hydroxide:
29 (average) drops of NaOH occupy **0.5** mℓ.
Therefore 1 drop of NaOH occupies **0.017** mℓ.

Q5. What is the colour of the solution ?
A5. The colour of the solution in well A1 is orange.

Q6. What is the colour of the solution ?
A6. The colour of the solution in well A2 is red.

Q7. Prepare a table like Table 2 below.

TABLE 2

Acid used	No. of drops of HCℓ	No. of drops of NaOH	Average No. of drops of NaOH
HCℓ	5 5 5	**5** **5** **5**	**5**

Q8. What number of drops of NaOH was required ? Enter the result in your table.
A8. See Table 2.

Q9. Enter your result in your table.
A9. See Table 2.

Q10. What *average volume* of the 0.10 M sodium hydroxide solution was required to titrate the hydrochloric acid ?
A10. We calculated that 1 drop (average) of sodium hydroxide solution occupies 0.017 mℓ (see calibration). But we used an average number of 5 drops in the titration.

$$\therefore \textbf{ Average Volume NaOH} = \frac{0.017 \text{ m}\ell}{1 \text{ drop}} \times 5 \text{ drops NaOH}$$

$$= 0.085 \text{ m}\ell = 0.085 \times 10^{-3} \ell$$

$$= 8.5 \times 10^{-5} \ell$$

Q11. What amount of sodium hydroxide was this ?
A11. We know that the concentration of sodium hydroxide is 0.10 M or 0.10 moles of NaOH per 1 litre of solution. Since there are only 8.5 x 10^{-5} ℓ of sodium hydroxide used then:

$$\text{Conc. of NaOH} = \frac{\text{amount of NaOH}}{\text{volume of solution}}$$

or in other words:

Amount of NaOH = conc. of NaOH x volume of solution

$$= 0.10 \text{ moles } \ell^{-1} \times 8.5 \times 10^{-5} \ell$$

$$= 8.5 \times 10^{-6} \text{ moles}$$

Q12. What amount of HCℓ reacted with this sodium hydroxide ?
A12. The chemical equation which represents this reaction is:

$$1\ HC\ell\ (aq) + 1\ NaOH\ (aq) \rightarrow 1\ NaC\ell\ (aq) + 1\ H_2O\ (\ell)$$

We can see that the stoichiometric ratio is 1 HCℓ : 1 NaOH in this case. Thus at the end point of this titration (when the colour of the solutions in wells A2, A3 and A4 had just changed from red to orange) then for every mole of sodium hydroxide that reacted, one mole of hydrochloric acid reacted with it.

For this reason 8.5×10^{-6} moles of HCℓ reacted with 8.5×10^{-6} moles of sodium hydroxide.

Q13. What *volume* of HCℓ solution contained this amount of HCℓ ?
A13. We calculated that 1 drop (average) of hydrochloric acid occupies 0.015 mℓ (see calibration). But we used an average number of 5 drops in the titration.

$$\therefore \text{Average Volume HC}\ell = \frac{0.015\ \text{m}\ell}{1\ \text{drop}} \times 5\ \text{drops HC}\ell$$

$$= 0.075\ \text{m}\ell = 0.075 \times 10^{-3}\ \ell$$

Q14. What is the concentration of the hydrochloric acid ?
A14. We know that 8.5×10^{-6} moles of HCℓ are contained in a volume of $7.5 \times 10^{-5}\ \ell$. Thus the unknown concentration of the hydrochloric acid is:

$$\text{Conc. of HC}\ell = \frac{8.5 \times 10^{-6}\ \text{moles of HC}\ell}{7.5 \times 10^{-5}\ \text{litres of solution}}$$

$$= 0.11\ \text{moles}\ \ell^{-1}$$

Q15. If the 5 drops of hydrochloric acid (HCℓ(aq)) supplied were replaced with 5 drops of sulphuric acid (H_2SO_4(aq)) of the same concentration, how many drops of 0.10 M sodium hydroxide (NaOH(aq)) solution would be required to reach the end point in this titration ? Explain your answer.
A15. 10 drops of 0.10 M NaOH(aq) will be required. This is because sulphuric acid (H_2SO_4(aq)) is a diprotic acid whereas hydrochloric acid (HCℓ(aq)) is a monoprotic acid. Thus for every molecule of sulphuric acid two hydrogen ions will be generated, while for every molecule of hydrochloric acid one hydrogen ion will be generated. Even though the concentration of the two acids is the same, twice as much sodium hydroxide solution will be needed to reach the end point. The equation which represents this reaction is:

$$1\ H_2SO_4(aq) + 2\ NaOH(aq) \rightarrow 1\ Na_2SO_4(aq) + 2\ H_2O(\ell)$$

THE ZINC/ COPPER CELL

TEACHER GUIDE

1. Chemicals
All of the required chemicals are listed in the worksheet.

2. Equipment
Most of the apparatus required can be found in a RADMASTE Advanced Microchemistry Kit. A 9V battery, a voltmeter and connecting wires for the voltmeter are required.

3. Hints
The syringe must be thoroughly rinsed before a new solution is dispensed, otherwise the copper nitrate and zinc nitrate solutions will be contaminated.

The 9V battery is a source of potential difference in the electrical circuit. It must be explained to the learner that the battery does not make the LED glow on its own. If the conducting wires are not placed in some electrolyte solution, the LED will not glow. It may be important to state this so as to avoid the misconception that the battery makes the LED glow, whether a conducting solution is present or not.

It is a good idea to try and attach the red and black wires from the current indicator to the terminals of the battery, for example by using crocodile clips or prestik. If the LED does not glow at first, check that the connections to the battery and electrodes are secure.

If the zinc electrode used in well F2 is a galvanised iron coil, it will have to be discarded after the experiment as the zinc is oxidised to $Zn^{2+}(aq)$ ions. The galvanised iron coil normally turns black after the zinc layer has been oxidised. This is because the now-exposed iron is oxidised to black iron oxide. If the zinc electrode is a pure zinc coil, it may be reused.

The copper electrode will appear dull after the cell has been connected for approximately 10 minutes, as a result of copper depositing at the surface of the electrode. The coil can be rubbed clean with sandpaper and used again.

The copper and zinc coils must be removed from the comboplate® as soon as possible after the experiment to prevent the wells staining.

4. Cautions
Please remember the following cautions and inform your students of all safety hazards:

Make sure that all learners wash their hands thoroughly after the experiment, as copper nitrate, zinc nitrate and potassium nitrate solutions can be irritating to the skin.

5. Model Answers to Questions in the Worksheet
It is recommended that learners write down all of the questions and answers in their workbooks. If this is done, then the answers to questions do not have to be in full sentences. If the learners do not copy the questions into their workbooks, then answers should be written in full sentences. Note that some of the questions can only be answered by learners in higher grades. Word equations can be written instead of chemical equations where required.

Q1. Does the current indicator glow ?
A1. No, the current indicator does not glow.

Q2. Is there a current flowing ?
A2. No, there is no current flowing.

Q3. Does the current indicator glow now ?
A3. Yes, the current indicator glows when F1 and F2 are connected via the cotton wool strip.

Q4. Is there a current flowing ?
A4. Yes, current is flowing.

Q5. What is the function of the salt bridge ?
A5. The salt bridge provides electrical connection between the two solutions i.e $Cu(NO_3)_2(aq)$ and $Zn(NO_3)_2(aq)$.

Q6. Is there a potential difference ?
A6. Yes, the needle of the voltmeter deflects showing that there is a potential difference across the cell.

Q7. Does it look as shiny as when you put it in the copper nitrate solution ?
A7. No, the copper wire coil is dull in appearance where it has been immersed in the solution.

Q8. From your observations of the copper electrode, what would you say is happening ?
Suggest a chemical equation for this process.
Is this a reduction or oxidation process ? Give a reason for your answer.

A8. Copper ions (Cu^{2+}(aq)) from the solution are being reduced to copper atoms (Cu(s)) at the surface of the copper electrode, causing the copper electrode to be dull in appearance.

The chemical equation for this process is $Cu^{2+}(aq) + 2e^- \rightarrow Cu(s)$.

This is a reduction process because copper ions (Cu^{2+}(aq)) receive electrons at the copper electrode surface.

Q9. What is taking place at the zinc electrode ?
Write down an equation to illustrate this.
Is this a reduction or oxidation process ? Give a reason for your answer.

A9. The zinc electrode is oxidised. (A galvanised iron electrode gradually becomes black as the zinc metal coating is oxidised and the iron is exposed.)

An equation to illustrate this is $Zn(s) \rightarrow Zn^{2+}(aq) + 2e^-$

This is an oxidation process because zinc atoms (Zn(s)) at the zinc electrode surface release electrons to the connecting wire.

Q10. What is the direction of the electron flow through the connecting wire ?

A10. The electron flow through the connecting wire is from the zinc electrode (anode) to the copper electrode (cathode).

Q11. Write down the chemical equation for the overall reaction.

A11. $Cu^{2+}(aq) + Zn(s) \rightarrow Cu(s) + Zn^{2+}(aq)$

or $Cu(NO_3)_2(aq) + Zn(s) \rightarrow Cu(s) + Zn(NO_3)_2(aq)$

ORGANIC CHEMISTRY – ESTERS

TEACHER GUIDE

1. Chemicals
All of the required chemicals are listed in the worksheet.

2. Equipment
Most of the apparatus required can be found in a RADMASTE Advanced Microchemistry Kit. Older versions of the kit will contain a glass sample vial suitable for esterification, while the newer editions of the kit possess a special sample vial made of a plastic that is resistant to organic solvents. **Do not use the vial of the microburner or any other plastic vial, as these will be destroyed by the organic liquids!**

3. Hints
When heating the glass rod, wave one end of the glass rod through the flame of a microburner a few times. Dip the hot end of the rod into the sample vial. If the fruity ester smell is weak or not evident, you may need to repeat the heating procedure.

Make sure that the sample vial is cleaned thoroughly before commencing step 6 of the experiment.

4. Cautions
Please remember the following cautions and inform your students of all safety hazards:

18 M sulphuric acid is extremely corrosive. If any acid is spilt on the skin, the affected area must immediately be rinsed with copious amounts of water. Severe burns must receive medical attention.

Ethanoic acid has a strong vinegary odour that is harmful if inhaled. The acid also causes skin and eye irritation. It is flammable and must be kept sealed away from all flames.

Never point a propette or a syringe containing acid upwards. A momentary lapse of concentration can result in a nasty accident. If any acid is squirted into the eye, immediately rinse the eye out under running water. Always have a dilute solution of sodium hydrogencarbonate (household baking soda), or milk close by to apply to the injury. These substances will help neutralise the acid in the eye. The patient should be referred to a doctor.

Ethanol is very flammable. It must be kept separate from sulphuric acid and must never be brought near a flame, heat or sparks. The bottle containing ethanol must be kept closed, as inhalation of high concentrations of this chemical causes headaches and dizziness. Store in a cool place away from sources of ignition.

Never allow the learners to play with matches. Treat any burn with cold running water or ice, and seek medical assistance where necessary.

The methylated spirits used in the microburner is poisonous. Do not inhale the vapour or drink the liquid.

5. Model Answers to Questions in the Worksheet
It is recommended that learners write down all of the questions and answers in their workbooks. If this is done, then the answers to questions do not have to be in full sentences. If the learners do not copy the questions into their workbooks, then answers should be written in full sentences. Note that some of the questions can only be answered by learners in higher grades. Word equations can be written instead of chemical equations where required.

Q1. Describe the smell of the contents in the sample vial.
A1. The contents have a pleasant, fruity smell.

Q2. Describe the smell of the contents in the sample vial.
A2. The contents have a sour, acidic odour (like vinegar).

Q3. What is the name of the ester that can be formed when ethanoic acid reacts with ethanol ?
A3. Ethyl ethanoate (or ethyl acetate) forms when ethanoic acid reacts with ethanol.

Q4. What is the name given to the type of reaction by which esters form from a carboxylic acid and an alcohol ?
A4. Esters form in an esterification reaction.

Q5. Was there such a reaction in the sample vial each time ?
A5. A carboxylic acid and an alcohol were both added to the sample vial each time. However, an ester was only formed in the sample vial where the sulphuric acid had been added.

Q6. What can you conclude about the role of concentrated sulphuric acid in the esterification reaction ?
A6. Concentrated sulphuric acid catalysed the reaction.

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ORGANIC CHEMISTRY –
SATURATED AND UNSATURATED HYDROCARBONS

TEACHER GUIDE

1. Chemicals
All of the required chemicals are listed in the worksheet.

2. Equipment
Most of the apparatus required can be found in a RADMASTE Basic or Advanced Microchemistry Kit.

3. Hints
The decolourisation of the bromine solution ($Br_2(aq)$) with hex-1-ene occurs as soon as the bromine/hex-1-ene mixture is stirred. You may also notice that if the bromine/cyclohexane mixture is left to stand in well A1, the brown colour of the bromine layer begins to disappear. This reaction is very slow and fumes of hydrogen bromide (HBr(g)) begin to appear. eg:

$$C_6H_{12}(\ell) + Br_2(aq) \rightarrow C_6H_{11}Br(\ell) + HBr(g)$$

This is not the reaction for unsaturated hydrocarbons and must not be confused with the rapid decolourisation of the bromine when mixed with an unsaturated hydrocarbon.

4. Cautions
Please remember the following cautions and inform your students of all safety hazards:

Bromine has a high vapour pressure i.e. the vapour above the solution will expand with an increase in temperature. It must therefore be kept in a cool, dark place in a well stoppered bottle.

The halogens are corrosive. Avoid dropping the bromine solution onto fabrics and skin. Wash hands thoroughly if any bromine solution makes contact with the skin.

The organic reagents, cyclohexane and hex-1-ene, as well as the bromine solution form toxic fumes. Avoid inhaling these fumes and make sure the experiment is performed in a well ventilated room.

5. Model Answers to Questions in the Worksheet
It is recommended that learners write down all of the questions and answers in their workbooks. If this is done, then the answers to questions do not have to be in full sentences. If the learners do not copy the questions into their workbooks, then answers should be written in full sentences. Note that some of the questions can only be answered by learners in higher grades. Word equations can be written instead of chemical equations where required.

Q1. What happens in each well immediately after adding the bromine ?
A1. Well A1: Cyclohexane/bromine: The brown colour remains in the aqueous layer.
Well A3: Hex-1-ene/bromine: The brown colour remains in the aqueous layer.

Q2. What happens in each well after stirring the contents ?
A2. Well A1: Cyclohexane/bromine: The brown colour remains in the aqueous layer.
Well A3: Hex-1-ene/bromine: The aqueous layer becomes colourless.

Q3. Explain what happened when cyclohexane was in contact with aqueous bromine.
A3. Cyclohexane does not react with aqueous bromine and therefore the brown, bromine colour of the aqueous layer did not change.

Q4. Is cyclohexane a saturated or unsaturated hydrocarbon ? Justify your answer.
A4. Cyclohexane is a saturated hydrocarbon. Cyclohexane molecules have no multiple bonds.

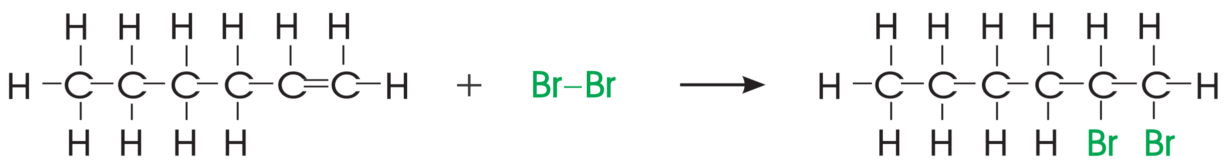
Q5. Why was it necessary to stir the contents of each well ?
A5. The bromine remained in the aqueous layer. When the contents of the wells were stirred, the bromine molecules were able to make contact with the organic molecules in order for a reaction to take place.

Q6. Explain what happened when hex-1-ene was in contact with aqueous bromine.
A6. Hex-1-ene reacts with aqueous bromine. As the bromine is consumed in the reaction the brown colour of the aqueous layer disappears.

Q7. Is hex-1-ene a saturated or unsaturated hydrocarbon ? Justify your answer.
A7. Hex-1-ene is an unsaturated hydrocarbon. Hex-1-ene molecules have double bonds.

Q8. What type of reaction occurs between hex-1-ene and aqueous bromine ? Write an equation to represent it.

A8. An addition reaction occurs between hex-1-ene and bromine i.e:



Q9. How can you test whether a hydrocarbon is saturated or unsaturated ?

A9. It is possible to test if a hydrocarbon is saturated or not with aqueous bromine. If the aqueous bromine is decolourised then the hydrocarbon is unsaturated. If, however, the aqueous bromine is not decolourised then the hydrocarbon is saturated.