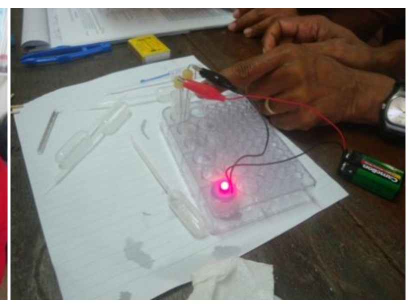
Microscience Manual

Chemistry Teachers' Manual

(DRAFT)

First Guyana Version Adaptation of Teaching and Learning Materials on Microscience Experiments



United Nations
Educational, Scientific and
Cultural Organization

Funded by UNESCO in collaboration with the Ministry of Education and the University of Guyana

Contents

The Ministry of Education wishes to acknowledge the team of participants in the consultations for the selection of the Microscience Experiments relevant to the national curriculum for Biology, Chemistry and Physics.

Participants

Name	Institution
Mr. Gregory Blyden	Faculty of Natural Sciences - University of Guyana
Mr. Mohandatt Goolsarran	Ministry of Education - NCERD
Mr. Navindra Hardyal	Queens College
Mr. Sirpaul Jaikishun	Faculty of Natural Sciences - University of Guyana
Ms. Petal Jetoo	Ministry of Education - NCERD
Ms. Noella Joseph	Cyril Potter College of Education
Ms. Samantha Joseph	Faculty of Natural Sciences - University of Guyana
Mr. Azad Khan	School of Education and Humanities - University of Guyana
Mr. Patrick Ketwaru	Faculty of Natural Sciences - University of Guyana
Professor Lloyd Kunar	Physics Department - University of Guyana
Mr. Marvin Lee	Queens College
Mr. Andrew Mancey	School of the Nations
Mr. Gary Mendonca	Faculty of Natural Sciences – University of Guyana
M. Kamini Ramrattan	Richard Ishmael Secondary School
Ms. Wendel Roberts	Ministry of Education – NCERD
Ms. Medeba Uzzi	Faculty of Natural Sciences – University of Guyana

Introduction to the first Guyana version adaptation of UNESCO teaching and learning materials on micro science experiments

The contents of this document are recommended by the participants of UNESCO/Kingston/Ministry of Education, NCERD consultations on Micro-Science Experiments held in Georgetown (Guyana) on 27-30 June, 2011. The present materials correspond fully to the existing National Curriculum for teaching basic sciences at the different levels. The materials were selected by the participants of the working consultations. The participants worked with teaching and learning packages on microscience experiments which are available on UNESCO's website and are free for all types of adaptations and modifications. The different types of microscience kits donated by UNESCO/Kingston Office to Guyana can be used in practical classes. The experiments are classified according to grades and some were given first priority (refer to appendix 1). The 'priority one' experiments are recommended for the pilot of the microscience experiments. It is very clear that, new experiments can be developed and tested using the same kit, as proposed by the participants of the working consultations which included curriculum development specialists. Developing new materials can be recommended, as a second stage of the project development. It is noted that the microscience experiments, as a new methodology for hands on laboratory work by students, can work in conjunction with macroscience experiments. Furthermore the microscience kits can be used by teachers for demonstration purposes. We hope, that the Science Teachers in Guyana will find the microscience experiments methodology and teaching and learning materials, interesting and of great value for the enhancement of science education.

Participants of the working consultations

May 2012

EXPERIMENT 1 – ELECTROYSIS OF WATER

CSEC OBJECTIVE: 6.24 – 6.25

6.24 – Predict the electrode to which an ion will drift

6.25 – Discuss electrolysis of certain substances

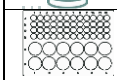
Grade Level - 10

	**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.
	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. It is suggested that connecting wires with crocodile clips be used to ensure that the connections 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 hydrogen carbonate (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

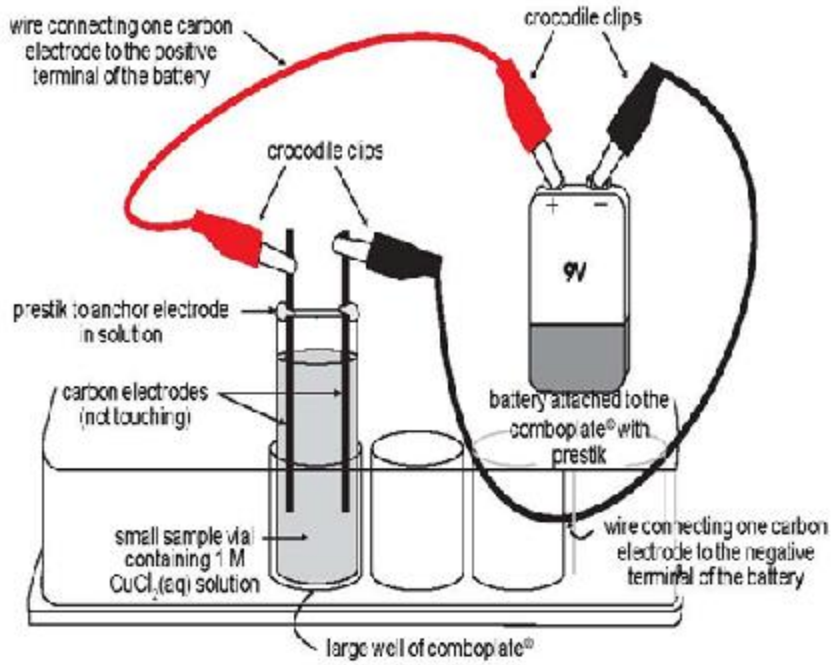
	running water or ice, and seek medical assistance where necessary.
	5. Model Answers to Questions in the Worksheet It is recommended that learners write down all of the questions and answers in their workbooks. If this is done, then the answers to questions do not have to be in full sentences. If the 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 ($H_2O(l)$) 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 there in 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.**

EXPERIMENT 2 - THE ELECTROLYSIS OF A COPPER(II) CHLORIDE SOLUTION
CSEC OBJECTIVE: 6.24 – 6.25
6.24 – Predict the electrode to which an ion will drift
6.25 – Discuss electrolysis of certain substances
Grade Level - 10

	**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. 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. "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). Questions10, 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.



3. Hints

The 9V 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 aluminum foil connectors reach the terminals of the battery.

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 Cl^{-}(aq). The charged particles or ions are aqueous copper(II) ions and aqueous chloride ions. There are two Cl^{-}(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:** **$CuCl_2$ (aq) $\rightarrow$ Cl_2(g) + Cu(s). This is a redox reaction. The charge on the chloride ion in $CuCl_2$ (aq) is -1. The charge on the chlorine atoms in Cl_2 (g) is 0. Chloride ions have therefore lost electrons and have been oxidised to chlorine atoms. The charge on the copper ion in $CuCl_2$ (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:** **$2Cl^{-}$(aq) $\longrightarrow$ Cl_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- $\longrightarrow$ Cu(s)**

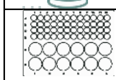
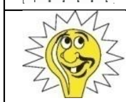
EXPERIMENT 3 - THE REACTION OF COPPER WITH OXYGEN
CSEC OBJECTIVE: Section B2. - 4.1
4.1 Discuss the reactivity of metals
Grade Level - 10

	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) $\longrightarrow$ 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:** $CuO(s) + H_2(g) \longrightarrow Cu(s) + H_2O(l)$ **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.**

EXPERIMENT 4 – THE REACTION OF SULPUR WITH OXYGEN

CSEC OBJECTIVE: Section B2. - 3.1
3.1 Describe the physical and chemical properties of non-metals
Grade Level - 10

	**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 m*l* 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.	**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) → 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.	**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.**

EXPERIMENT 5 – THE REACTION OF MAGNESIUM WITH OXYGEN

CSEC OBJECTIVE - Section B.2 , 1.1

1.1 Describe the physical and chemical properties of metals

Grade Level - 10

	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 MnO2(s) to produce more oxygen. (The addition of 0.2 m*l* 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. $$\mathbf{MgO(s) + H_2O(\textit{l}) \longrightarrow Mg(OH)_2(aq)}$$
	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.**
Q3	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.

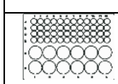
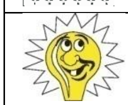
A9.	**oxygen(g) + magnesium(s) $\rightarrow$ magnesium oxide(s)**
Q10.	Write a balanced chemical equation for the combustion of magnesium in oxygen.
A10.	**O_2(g) + 2Mg(s) $\rightarrow$ 2MgO(s)**

EXPERIMENT 6 – DECOMPOSITION OF COPPER CARBONATE

CSEC OBJECTIVE Section B.2 - 1.2

1.2 Describe the reactions of metal oxides, hydroxides, nitrates and carbonates

Grade Level - 10

	**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 Basic or 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. `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 hydrogen carbonate (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.**
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.	**No bubbles were given off. (However, a pale blue-green liquid may be observed.-, indicating that a reaction had taken place)**
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 give off a gas as the copper oxide slowly reacts with sulphuric acid to form blue copper sulphate and water.)**
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) $\rightarrow$ copper(II) oxide(s) + carbon dioxide(g)** **Pale green black colourless**
Q11.	Write a chemical formula equation for the reaction in Q10 above.
A11.	**$CuCO_3(s) \rightarrow CuO(s) + CO_2(g)$**

EXPERIMENT 7 – DECOMPOSITION OF AMMONIUM CARBONATE

CSEC OBJECTIVE Section B.2 - 1.2

1.2 Describe the reactions of metal oxides, hydroxides, nitrates and carbonates

Grade Level - 10

**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 Basic or 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.	$(NH4)_2CO_3(s) \rightarrow 2NH_3(g) + CO_2(g) + H_2O(l)$

EXPERIMENT 8 – REDUCTION OF COPPER (II) OXIDE

Section A. Objective 6.15

6.15 Identify oxidation and reduction reactions including reactions at electrodes

Grade Level - 10

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 HCl(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 hydrogen carbonate (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.
	What happens when 5.5 M HCl(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.**
Q7	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.	**$Zn(s) + 2HCl(aq) \longrightarrow ZnCl_2 (aq) + H_2(g)$**
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.	**$CuO(s) + H_2(g) \longrightarrow Cu(s) + H_2O(l)$**
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 ($CuSO_4.5H_2O(s)$).**

EXPERIMENT 9 – ACID/BASE TITRATION – AN INTRODUCTION

Section A. Objective 3.7

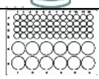
3.7 Use results from volumetric analysis to calculate:

(I) The number of reacting moles

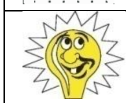
(ii) the mole ratio in which reactants combine

Grade Level - 10

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 (HCl) 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 HCl(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 hydrogen carbonate (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.

<table>
<tr><td></td><td>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.</td></tr>
<tr><td>Q1.</td><td>Note the colour of the solution in well A1.</td></tr>
<tr><td>A1.</td><td>Yellow/Orange</td></tr>
<tr><td>Q2.</td><td>Note the colour of the solution in well A2.</td></tr>
<tr><td>A2.</td><td>Red.</td></tr>
<tr><td>Q3.</td><td>Prepare a table like Table 1 below, and enter the number of drops.</td></tr>
<tr><td>A3.</td><td>Table 1
<table>
<tr><th>Acid Used</th><th>Number of drops of Acid A</th><th>Number of Drops of NaOH</th><th>Average number of drops of NaOH</th></tr>
<tr><td>A</td><td>5
5
5</td><td>5
5
5</td><td>5</td></tr>
</table></td></tr>
<tr><td>Q4</td><td>Prepare a table like Table 2 below, and enter the number of drops. Prepare a table like Table 2 below, and enter the number of drops.</td></tr>
<tr><td>A4</td><td>Table 2
<table>
<tr><th>Acid Used</th><th>Number of Drops of Acid A</th><th>Number of Drops of NaOH</th><th>Average number of drops of NaOH</th></tr>
<tr><td>B</td><td>5
5
5</td><td>10
10
10</td><td>10</td></tr>
</table></td></tr>
<tr><td>Q5.</td><td>What is the volume ratio of NaOH/acid A in the titration of 0.10 M acid A?</td></tr>
<tr><td>A5.</td><td>1:1.</td></tr>
<tr><td>Q6.</td><td>What is the volume ratio of NaOH/acid B in the titration of 0.10 M acid B ?</td></tr>
<tr><td>A6.</td><td>2:1</td></tr>
<tr><td>Q7.</td><td>Compare your answers to questions 5 and 6 above and then explain these results.</td></tr>
<tr><td>A7.</td><td>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</td></tr>
</table>

	(diprotic). Examples of formulae of two such possible acids are: **HCl and H_2SO_4**

EXPERIMENT 10 – THE EFFECT OF DILUTE ACIDS AND BASES ON INDICATORS

CSEC OBJECTIVE Section A – 6.6

6.6 Relate acidity and alkalinity to the pH scale

Grade Level - 10

	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 **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 hydrogen carbonate (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 HCl(aq)	**In H_2 SO_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**
Q6.	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.**

EXPERIMENT 11 – REACTIONS WITH ACIDS AND SODIUM HYDROXIDE

CSEC OBJECTIVE Section A – 6.8

6.8 Investigate the reactions with non-oxidizing acids with:
(i) metals, (ii) carbonates, (iii) hydrogen carbonates (iv) bases

Grade Level - 10

	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 hydrogen carbonate (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.**

EXPERIMENT 12 – PREPARATION OFA SALT: THE REACTION BETWEEN AN ACID AND A METAL CARBONATE

CSEC OBJECTIVES – Section A – 6.10 Section B 2 - 1.2

6.10 Identify an appropriate method of salt preparation based on the solubility of the salt

1.2 Describe the reactions of metallic oxides, hydroxides, nitrates and carbonates

Grade Level - 10

	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 hydrogen carbonate (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 medicalassistance 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) $\longrightarrow$ calcium carbonate(s) + water(l)**
Q5.	Write down a balanced chemical equation for the reaction between carbon dioxide and limewater.
A5.	$CO_2(g) + Ca(OH)_2(aq) \longrightarrow CaCO_3(s) + H_2O(l)$
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 ($CaCl_2(s)$).**
	The other product in this reaction evaporated when you heated the solution and left the comboplate® overnight. What could this possibly be?

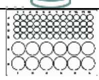
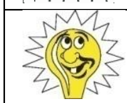
A9.	**Water.**
Q10.	Write a word equation for the chemical reaction that took place in well F1.
A10.	**Hydrochloric acid(aq) + calcium carbonate(s) $\rightarrow$ calcium chloride(s) + water(l) + carbon dioxide(g)**
Q11.	Write a balanced chemical equation for this reaction in well F1.
A11.	**$2HCl\,(aq) + CaCO_3(s) \rightarrow CaCl_2(s) + H_2O(l) + CO_2(g)$**
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.	**$Na_2CO_3(s) + 2HCl\,(aq) \rightarrow 2NaCl(s) + H_2O(l) + CO_2(g)$**
Q17.	In this experiment you looked at the reaction between hydrochloric acid and calcium carbonate. Complete the general chemical equation: acid + metal carbonate $\rightarrow$
A17.	**acid + metal carbonate $\rightarrow$ salt + water + carbon dioxide**

EXPERIMENT 13 - PREPARATION OF A SALT: THE REACTION OF A METAL WITH AN ACID

CSEC OBJECTIVE – Section A – 6.10

6.10 Identify an appropriate method of salt preparation based on the solubility of the salt

Grade Level - 10

	**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 hydrogen carbonate (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.**
	What, if anything, is in the gas collecting tube at the start of the experiment ?
A3.	**Air.**
	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.**
	Why does the gas not escape from the upside-down gas collecting tube ?
A5.	**The gas that formed is less dense than air.**
	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.**
	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.

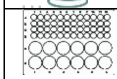
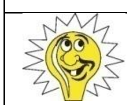
A9.	**The reaction mixtures in the wells continue to produce hydrogen gas for some time. If any flames had been brought near the comboplate®, the hydrogen gas escaping may have reacted with the oxygen in the air around it.**
Q10.	What do you see in the microwell after leaving the comboplate® overnight ?
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.	**$2HCl(aq) + Zn(s) \longrightarrow H_2(g) + ZnCl_2(aq)$**
	What chemicals would you use to prepare magnesium sulphate using a similar procedure?
A16.	**Sulphuric acid and magnesium.**
	Write down a balanced chemical equation for the reaction that you propose in question 16.
A17.	**$H_2SO_4(aq) + Mg(s) \longrightarrow MgSO_4(s) + H_2(g)$**

EXPERIMENT 14 - RATES OF REACTION –THE EFFECT OF CONCENTRATION

CSEC OBJECTIVE – Section A – 7.2

7.2 Identify the factors which affect the rate of a reaction

Grade Level – 10/11

	**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.

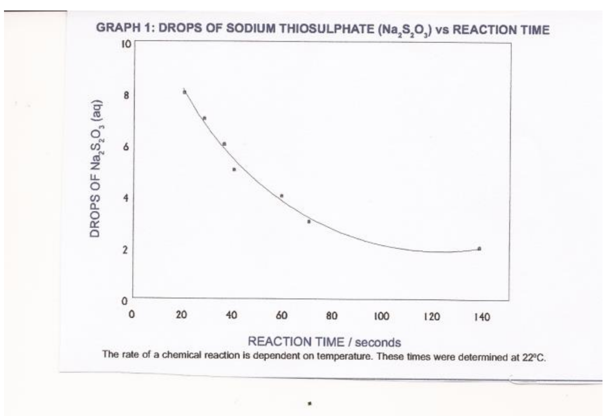
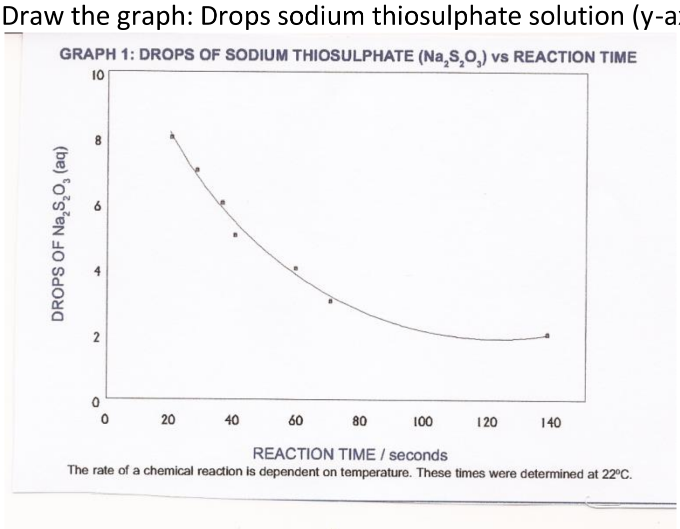
A1. **Table 1**

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.**

Complete your table.

A3.	**See Table 1.**
	What happened when 11 M hydrochloric acid was added to the sodium thiosulphate solution?
A4.	**Sometime after adding the 11 M hydrochloric acid, the solution went milky.**
	Which well has the greatest concentration of sodium thiosulphate solution?
A5.	**Well A8 has the greatest concentration of sodium thiosulphate.**
	In which well has the reaction taken place in the shortest time?
A6.	**In well A8, the "X" disappeared in the shortest time.**
	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.**
	Draw the graph: Drops sodium thiosulphate solution (y-axis) vs Reaction Time (x-axis). 
Q9.	Draw the graph: Drops sodium thiosulphate solution (y-axis) vs 1/Reaction Time (x-axis). 

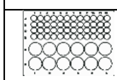
Q10.	What is the relationship between the number of drops of sodium thiosulphate solution and reaction time?
A10.	**As the number of drops increases the reaction time decreases (see graph 1). In fact, the reaction time is inversely proportional to the number of drops (see graph 2).**
Q11.	Write a statement 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.**
	Note the time when the "X" is no longer visible beneath well A2.
	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.**

EXPERIMENT 15 - ENTHALPY CHANGE FOR THE REACTIONS OF ACIDS WITH A STRONG BASE

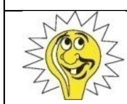
CSEC OBJECTIVE – Section A 8.3

Grade Level – 10/11

**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.

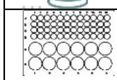
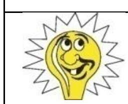
	4. Cautions Please remember the following cautions and inform your students of all safety hazards: **Hydrochloric acid is corrosive. If any acid is spilt on the skin, the affected area must immediately be rinsed with copious amounts of water. Severe burns must receive medical attention.** **Acetic acid 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 (HCl(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 HCl(aq) is 22.7 °C.**
Q3.	Calculate the average of the two initial temperatures. This is the average initial temperature, Ti.
A3.	**The average initial temperature, Ti = 22.35 °C.**

Q4.	What is the maximum temperature of the mixture? This is the final temperature, Tf .
A4.	**The final temperature, Tf, of the mixture is 26.7 °C.**
Q5.	Calculate the change in temperature ΔT.
A5.	**ΔT = Tf - Ti = 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.	**Tf was higher than the initial average temperature (Ti).**
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 x ΔT** **C = 13.03 J ° C^{-1}** **ΔT = + 4.35 ° C** **then, q = 13.03 J ° C^{-1} x 4.35 ° C** **= 56.7 J**
Q11	Write down a balanced chemical equation for the reaction between hydrochloric acid and sodium hydroxide.
A11.	**$HCl(aq) + NaOH(aq) \longrightarrow NaCl(aq) + H_2O(l)$**
	Calculate the enthalpy change of the reaction in J, and the enthalpy change per mole of reaction, in kJ mol-1.
A12.	**q = - ΔH or ΔH = - 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 HCl:NaOH is 1:1. We used 1.0**

	ml each of 1.0 M HCl and 1.0 M NaOH. **Therefore, 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 Δ H =- 56.7 J/1 x 10^{-3} mol = - 56 700J 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.**
	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, Ti.
A3.	**Ti = 20.05 °C.**
Q5.	What is the maximum temperature of the mixture? This is the final temperature, Tf.
A4.	**Tf = 24.0 °C.**
A5.	Calculate the change in temperature, Δ**T** **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.	**Tf was higher than Ti.**
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.	**$CH_3COOH(aq) + NaOH(aq) \longrightarrow CH_3COONa(aq) + H_2O(l)$**
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.** **therefore 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 $\Delta H = -\ 51.5\ J/1 \times 10^{-3}$ mol = - 51 500 J mol^{-1} = - 51.5 kJ mol^{-1} (the enthalpy change per mole of reaction)**
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, $\Delta H = .\ 56.7$ J. This is the enthalpy change for the reaction performed.** **The balanced chemical equation shows that the mole ratio of HCl:NaOH is 1:1. We used 1.0 ml each of** **1.0 M HCl and 1.0 M NaOH.** **therefore 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.**

EXPERIMENT 16 - THE ZINC/COPPER CELL
CSEC OBJECTIVE – Section A 6.20
Grade Level – 10/11 and 12

	**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.**

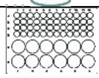
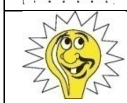
5. Model Answers to Questions in the Worksheet

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.	**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- $\longrightarrow$ Cu(s).**

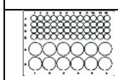
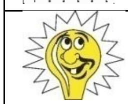
	This is a reduction process because copper ions (Cu^{2+}(aq)) receive electrons at the copper electrode surface.
Q9.	What is taking place at the zinc electrode? Write down an equation to illustrate this. Is this a reduction or oxidation process? Give a reason for your answer.
A9.	**The zinc electrode 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) $\longrightarrow$ 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)**

EXPERIMENT 17 - CONCENTRATION AND AMOUNT OF SUBSTANCE IN SOLUTION
CSEC OBJECTIVE – Section A 3.7 (iii)
Grade Level – 10/11 and 12

	**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?
Q1.	**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?
Q3.	What is the definition of amount?
Q3	Give the reason for your answer.
A3.	**Well F2 contains the greater amount of $Cu^{2+}(aq)$ ions. Twice the quantity of solid $Cu(NO_3)_2$.3H2O 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.**

EXPERIMENT 18 - ACID BASE TITRATION – DETERMINING THE CONCENTRATION OF AN ACID
CSEC OBJECTIVE – Section A 3.6
Grade Level – 10/11 and 12

	**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 ?

<table>
<tr><td>A5.</td><td>The colour of the solution in well A1 is orange.</td></tr>
<tr><td>Q6.</td><td>What is the colour of the solution ?</td></tr>
<tr><td>A6.</td><td>The colour of the solution in well A2 is red.</td></tr>
<tr><td></td><td></td></tr>
<tr><td>Q7.</td><td>Prepare a table like Table 2 below.
TABLE 2
<table>
<tr><th>Acid used</th><th>No. of drops of HCl</th><th>No. of drops of NaOH</th><th>Average No. of drops of NaOH</th></tr>
<tr><td>HCl</td><td>5
5
5</td><td>5
5
5</td><td>5</td></tr>
</table></td></tr>
<tr><td>Q8.</td><td>What number of drops of NaOH was required ? Enter the result in your table.</td></tr>
<tr><td>A8.</td><td>See Table 2.</td></tr>
<tr><td>Q9.</td><td>Enter your result in your table.</td></tr>
<tr><td>A9.</td><td>See Table 2</td></tr>
<tr><td>Q10.</td><td>What average volume of the 0.10 M sodium hydroxide solution was required to titrate the hydrochloric acid ?</td></tr>
<tr><td>A10.</td><td>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 the Average Volume NaOH = 0.017 ml/
1 drop x 5 drops NaOH

=0.085 ml = 0.085×10^{-3} l
= 8.5×10^{-5} l</td></tr>
<tr><td>Q11.</td><td>What amount of sodium hydroxide was this ?</td></tr>
<tr><td>A11.</td><td>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 8.5×10^{-5} l of sodium hydroxide used then:

Conc. of NaOH = <u>amount of NaOH</u>

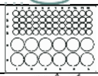
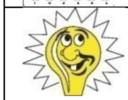
volume of solution</td></tr>
</table>

	or in other words: **Amount of NaOH = conc. of NaOH x volume of solution** **= 0.10 moles l^{-1} x 8.5 x 10^{-5} l** **= 8.5 x 10^{-6} moles**
Q12.	What amount of HCl reacted with this sodium hydroxide?
A12.	**The chemical equation which represents this reaction is:** **1 HCl (aq) + 1 NaOH (aq) $\rightarrow$ 1 NaCl (aq) + 1 H_2O (l)** **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 x 10^{-6} moles of HCl reacted with 8.5 x 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 the Average Volume HCl = 0.015 ml/** **1 drop x 5 drops HCl** **= 0.075 ml = 0.075 x 10^{-3} l**
Q14.	What is the concentration of the hydrochloric acid?
A14.	**We know that 8.5 x 10^{-6} moles of HCl are contained in a volume of 7.5 x 10^{-5} l. Thus the unknown concentration of the hydrochloric acid is:** **Conc. of HCl =<u>8.5 x 10^{-6} moles of HCl</u>** **7.5 x 10^{-5} litres of solution** **= 0.11 moles l^{-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(l)**

EXPERIMENT 19 - PREPARATION AND PROPERTIES OF SULPHUR DIOXIDE

CSEC OBJECTIVE – Section C 2 Objective 3.4

Grade Level – 10/11 and 12

	**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.	**$Na_2SO_3(s) + 2HCl(aq) \rightarrow 2NaCl(aq) + SO_2(g) + H_2O(l)$**
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:** $H_2SO_4(aq) + K_2Cr_2O_7(aq) + 3SO_2(aq) \rightarrow Cr_2(SO_4)_3(aq) + H_2O(l) + K_2SO_4(aq)$

EXPERIMENT 20 - AIR POLLUTION BY SULPHUR DIOXIDE

CSEC OBJECTIVE – Section C 2 Objective 3.4

Grade Level – 10/11 and 12

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 (HCl(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 HCl(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 HCl(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.	$SO_2(g) + H_2O(l) \rightarrow H_2SO_3(aq)$
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.	**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) $\longrightarrow$ $CaSO_3$(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.**