MICROSCIENCE MANUAL

Integrated Science Teachers' Manual (Draft)

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

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

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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.

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Introduction

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

CSEC Objective (s) - Section A Unit 1 Objective 3

Explain the processes of diffusion and osmosis using an experimental approach

Experiment 1. DIFFUSION IN A GAS

Grade Level – 10

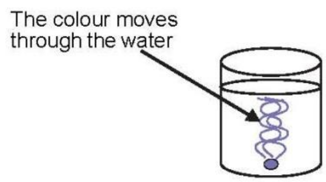
	Questions 1. What colour was the universal indicator paper when it was placed in the straw? **A1. Yellow.** 2. What happens to the indicator paper when ammonia solution is dropped onto the cotton wool? **A2. It becomes dark green after a short while.** 3. What caused the colour of the universal indicator paper to change? **A3. Some of the ammonia solution on the cotton wool evaporated inside the tube. Ammonia molecules then moved through the air inside the tube. The molecules came into contact with the indicator paper where a reaction took place and caused the colour to change to dark green.** 4. Do you think that an air current through the tube could be responsible for the change which occurred to the universal indicator paper? **A 4. No, the tube is closed off with cotton wool and air is not likely to blow through the tube. The only movement taking place in the tube is the movement of molecules from areas of high concentration to areas of low concentration.**

Experiment 2. MORE DIFFUSION IN A GAS

Grade Level – 10

	Questions 1. What happened in the glass tube? **A 1. A small whitish cloud formed in the glass tube.** 2. What are the tiny white spots which have formed on the glass tube? **A2. They are solid ammonium chloride particles.** 3. How did these white spots appear? **A3. Some of the ammonia solution and some of the hydrochloric acid evaporated from the cotton wool at each end. Ammonia molecules diffused from the one side of the glass tube and hydrochloric acid molecules diffused from the other side of the glass tube. The molecules collided with each other and reacted to form solid ammonium chloride.**

Experiment 3.   DIFFUSION IN A LIQUID

<table>
<tr><td></td><td>

F5</td></tr>
<tr><td></td><td>Questions
1. What happened when the crystal of potassium permanganate was dropped into the water?
A 1. The crystal dropped into the bottom of the well. Then the purple colour slowly moved upwards in the water.
2. Explain your observation:
A2. The crystal slowly dissolved forming a concentrated solution of potassium permanganate at the bottom. By diffusion the potassium permanganate molecules spread throughout the water. In this way, the purple colour was evenly distributed (i.e. the same everywhere).</td></tr>
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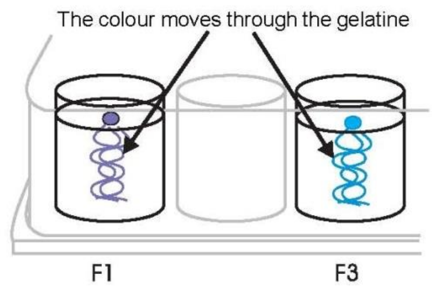
Experiment 4. DIFFUSION IN A SOLID

Grade Level – 9&10

	
	Questions 1. What did you observe in F1? **A1. A bright purple colour moved downwards in the gelatine.** 2. What did you observe in F3? **A 2. A pale blue colour moved downwards in the gelatine.** 3. Why did the colours move downwards in wells F1 and F3? **A3. The potassium permanganate molecules and the copper sulphate molecules moved from the top of the well where there were many per volume (highly concentrated) to where there were a few or none (less concentrated).** 4. If you leave these wells to stand for another day what would happen? **A4. The gelatine in well F1 would become entirely red and the gelatine in F3 would become entirely blue indicating that the molecules have become evenly distributed and have reached dynamic equilibrium.**
	EXTENSION QUESTION Repeat the entire procedure. This time, wait for half an hour then invert (turn upside down) the comboplate® after step 5. Discuss your findings with other members of the class.
	Note to the Teacher *This extension exercise is necessary to enable students to undestand that the particles (molecules) do not just "fall down" into the gel, but that there is movement that is not caused by gravity.*

Experiment 5. HOW DOES OSMOSIS OCCUR IN LIVING TISSUE?

Grade Level – 10

Potato or other Vegetable Piece		What it Felt Like		Length in mm
F1	(tap water)	Before:	Quite Firm	10
		After:	Firm	10
F2	(tap water)	Before:	Quite Firm	10
		After:	Very Firm	11
F3	(10% sucrose solution)	Before:	Quite Firm	10
		After:	Same	10
F4	(10% sucrose solution)	Before:	Quite Firm	10
		After:	About the Same	10
F5	(30% sucrose solution)	Before:	Firm	10
		After:	Soft	8
F6	(30% sucrose solution)	Before:	Firm	10
		After:	Soft	8.5

Note to the Teacher
The results in the table above are examples of what is likely to be found.
Compare your findings with those of other groups.

Questions

1. In general, what happened to the potato or other vegetable pieces in the tap water?

A1. The potato or other vegetable pieces in the tap water became swollen and larger.

2. In general, what happened to the potato or other vegetable pieces in the 10 % sucrose solution?

A2. The potato or other vegetable pieces in the 10 % sucrose solution did not change in size or texture.

3. In general what happened to the potato or other vegetable pieces in the 30 % sucrose solution?

A3. The potato or other vegetable pieces in the 30 % sucrose solution became shrunken and soft to the touch (flaccid).

4. Try to give reasons for your findings in each case

A4. Tap water is hypotonic to cell sap so the potato or other vegetable pieces in the tap water absorbed water by osmosis and became swollen. 10% sucrose solution is isotonic with cell sap so overall, the number of water molecules moving into the potato or other vegetable pieces equalled the number of water molecules moving out of the potato or other vegetable pieces. In other words, there was no net movement of water molecules into or out of the potato or other vegetable pieces. The potato or other vegetable pieces remained the same size. 30% sucrose solution is hypertonic to cell sap so water molecules moved out of the potato or other vegetable pieces into the solution. The potato or other vegetable pieces became shrunken due to water loss.
Water moves through selectively permeable membranes from regions of high water potential to regions of low water potential.

CSEC Objective (s) - Section A Unit 2 Objective 1

Describe the process of photosynthesis

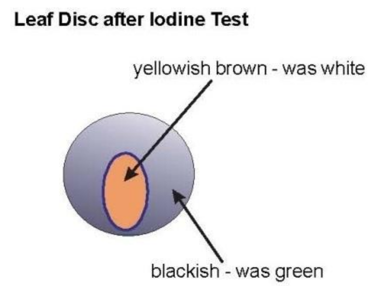
Experiment 6. TESTING A LEAF FOR STARCH

Grade Level – 9&10

	Questions 1. What is the colour of the alcohol after 10 minutes? **A 1. Greenish.** 2. What is the colour of the leaf after 10 minutes? **A 2. Whitish.** 3. What has the alcohol done to the leaf? **A 3. It has removed the chlorophyll.** 4. What colour did the leaf discs turn after the iodine was added? **A 4. Blackish.** 5. What does this colour change tell you about the storage product in these leaves? **A5. The leaves of these plants store starch.**

Experiment 7. IS CHLOROPHYLL NECESSARY FOR PHOTOSYNTHESIS?

Grade Level – 10

	Questions 1. What was the final colour of the leaf discs which were originally green and white? **A1. The green parts were blackish and the white parts were brownish.** 2. Make a drawing of a leaf disc which was originally both green and white.
	Note to the Teacher *Such a drawing could look something like the figure shown.*  3. What do your results suggest about the role of chlorophyll in photosynthesis? **A3. Chlorophyll is necessary for photosynthesis to occur.** 4. The white parts of the leaf discs had no starch. This means that there is no food for the plant in the white parts of the plant. The white parts of the leaf must get food, otherwise they would die. How do you suppose these parts get their food?
	Note to the Teacher *Allow some discussion here. It is not likely that all students will be able to work out all the details immediately. In the green parts of the leaf, glucose is formed during photosynthesis. Some of this glucose is used by the green parts and some is transported to the white parts as required. Glucose which is not used immediately is stored as starch. When required, the starch is converted back to glucose.*
	SOMETHING TO THINK ABOUT **A. Epsom Salts is another name for magnesium sulphate. A magnesium atom is part of the chlorophyll molecule. Without magnesium, plants cannot manufacture chlorophyll. A symptom of magnesium deficiency in plants is yellowing between the veins of the leaves.**

Experiment 8. IS LIGHT NEEDED FOR PHOTOSYNTHESIS ?

Grade Level – 10

Table to show Results of Iodine Test on Leaf after One Day

Part of Leaf	**Colour after Testing with Iodine Solution**	**Conclusion**
Covered	yellowish	no starch present
Uncovered	blackish	starch present

Questions

1. What did the foil or black paper do?

A1. It excluded light from a part of the leaf

2. What do you suppose is the link between light and photosynthesis?

A 2. Light is needed for photosynthesis

3. What does the word "photosynthesis" mean?

A 3. Making or synthesising something with the energy of light.

Note to the Teacher

Many students confuse a number of issues here.

- *Light is needed for photosynthesis because the chlorophyll molecule is activated by light during the light-dependent phase of the process.*
- *However, light is also needed for the formation of chlorophyll. This fact is demonstrated for example when a patch of grass is kept covered and becomes yellow or white after a while.*

It is essential that students are clear on all these points.

Experiment 9. IS CARBON DIOXIDE NEEDED FOR PHOTOSYNTHESIS ?

Grade Level – 10

Table to show Results of Iodine Test on Leaf Discs after One Day

Leaf	**Colour after Testing with Iodine Solution**	**Conclusion**
Enclosed i.e. no CO_2 available	yellowish	no starch present
Open to atmosphere i.e. CO_2 available	blackish	starch present

Questions

1. Did the leaf discs which did not receive carbon dioxide have any stored starch?

A1. No they did not.

2. Did the leaf discs which did receive carbon dioxide have any stored starch?

A 2. Yes.

3. What do these results suggest to you?

A 3. Carbon dioxide is needed for photosynthesis.

4. What elements are present in carbon dioxide?

A4. Carbon and oxygen.

5. What elements are present in glucose and in starch?

A5. Carbon, oxygen and hydrogen.

6. Where does the additional element come from?

Note to the Teacher

Answers will depend on what students already know and how they have been taught. If they are familiar with the theory of photosynthesis, they may remember that the hydrogen is derived from water. If they are not familiar with the theory, they may make some suggestions. Guide them by asking questions like:

"What compound is very plentiful on this planet?"

"What compounds do you know which contain hydrogen?"

If it is not possible to conduct this investigation, it could be used as a "thought" experiment. The same or similar questions to those above should be asked.

Experiment 10. IS OXYGEN RELEASED DURING PHOTOSYNTHESIS?

Grade Level – 10

	Questions 1. Note what you observe in each of the tubes. **A1. Tube A** **At first, bubbles were formed near the plant and they floated in the water.** **Later in the week, the blue colour of the solution in tube A became darker.** **Tube B** **No such changes took place.** 2. What can you deduce from your observations? **A 2. The bubbles show that a gas was released. Methylene blue solution turns blue in the presence of oxygen so the gas must have been oxygen.** 3. Why did we add sodium hydrogen carbonate ($NaHCO_3$) to the water? **A3. The sodium hydrogen carbonate dissolves in the water, and is a source of carbon dioxide which the plant uses during photosynthesis.** 4. What happened to the solution in tube B? **A4. There was no colour change, showing that the blue colouration (in Tube A) was due tothe plant and not to any other factor.**

CSEC Objective (s) - Section A Unit 2 Objective 3

Explain the importance of food

Experiment 11. BENEDICT'S TEST FOR A REDUCING SUGAR

Grade Level – 9&10

Observations

Enter your results in Table 1 below.

Table 1

WELL	COLOUR CHANGE OBSERVED DURING HEATING	FINAL COLOUR OF SOLUTION AFTER 5 MINUTES
F1	blue to green to orange to red	bright red
F3	blue to green to orange-brown	orange-brown
F5	blue to pale green	pale blue-green
F6	none	blue

Questions

Q1. Why did the colour of the Benedict's solution change when it was heated with each of the glucose solutions?

A1. Glucose is a reducing sugar. It reduced the copper(II) sulphate, which is blue, to copper(I) oxide.

Q2. Which well contained the highest concentration of glucose? Explain.

A2. Well F1. Four large spatulas of glucose powder were added to this well and dissolved in 1.0 ml of water.

Q3. What do you notice about the colour changes observed in well F1?

A3. The solution in well F1 showed the most colour changes. It also had the darkest colour (red) of all the glucose solutions after 5 minutes of heating.

Q4. Which well contained the lowest concentration of glucose? Explain.

A4. Well F5. Only one small spatula of glucose powder was added to well F5 and dissolved in 1.0 ml of water.

Q5. What do you notice about the colour changes observed in well F5?

A5. The solution in well F5 showed the least number of colour changes. It also had the palest colour (pale green) of all the glucose solutions after 5 minutes of heating.

Q6. From your answers to questions 3 and 5, deduce the relationship between the concentration of reducing sugar present in a sample, and the colour change/s observed in the Benedict’s test within a specified time period.

A6. The greater the concentration of the reducing sugar in the sample, the more colour changes that are observed and the more intense the red colour of the copper(I) oxide formed within the specified time period.

Q7. Why did the colour of the solution in well F6 show no change?

A7. There was no glucose present in the solution.

Q8. How can one test for the presence of reducing sugars in food?

	A8. A solution of the food to be tested is heated in a water bath with Benedict's solution. If reducing sugars are present, the blue colour of the solution changes to green and then orange and finally red. The solution will remain blue if no reducing sugars are present. (If other reducing agents are present in the food, a colour change may also be observed.)
	Extension Questions (These questions are aimed at students who also have a chemistry background.) Q9. What was the purpose of testing water with the Benedict's solution? **A9. The test serves as a control. When the solution containing water did not change colour, it showed that the water itself could not reduce the copper ions in Benedict's solution. Hence, it must have been the glucose in the glucose solution that caused the reduction.** Q10. Write down the ionic equation for the reduction of copper sulphate to copper oxide. **A10.** $Cu^{2+} + e^- \rightarrow Cu^+$ Q11. When glucose is oxidised, gluconic acid is formed. Which functional group in glucose do you think is responsible for the reduction of copper(II) to copper(I)? **A11. The aldehyde group at position 1.** Q12. Give a reason for your answer to question 5. **A12. The aldehyde group at position 1 has been oxidised to a carboxylic acid group. The carbon atom at position 1 in glucose has an oxidation state of +1, whereas the carbon atom at position 1 in the corresponding carboxylic acid has an oxidation state of +3. The aldehyde functional group is known to be easily oxidised.**

Experiment 12. DOES THE FOOD WE EAT CONTAIN REDUCING SUGARS?

Grade Level - 9&10

Observations

Table 1

WELL	FOOD SOLUTION	COLOUR OF SOLUTION AFTER HEATING
F1	**apple**	**brick-red**
F2	**carrot**	**bright orange**
F3	**potato**	**pale blue-green**
F4	**cooked white rice**	**blue**
F5	**cooked white mealie meal**	**blue**
F6	**milk**	**orange-green**

Questions

Q1. How is the colour of the solution related to the concentration of reducing sugar detected in the food during the time specified? (Hint: look at the results for Activity 1.)

A1. The more reducing sugar/s present in the food, the greater the number of colour changes observed. In other words, if the whole series of colour changes is seen (blue → green → red), the food contains a large concentration of reducing sugar. If only the blue → green colour change is observed, the food contains little reducing sugar.

Q2. Which food contains the highest concentration of reducing sugar/s? Explain.

A2. Apple. The solution turned brick-red, indicating that all the copper(II) in the Benedict's solution was reduced to copper(I). The other solutions underwent colour changes that showed partial reduction of the copper(II).

Q3. Which food contains the lowest concentration of reducing sugar/s? Give a reason for your answer.

A3. White rice and white mealie meal. After 7 minutes, the colour of the solutions was still blue.

Q4. What is the answer to the focus question?

A4. Apples and carrots contain high concentrations of reducing sugars; potatoes and milk contain lower concentrations of reducing sugars. White rice and white mealie meal do not contain detectable concentrations of reducing sugars.

Extension Questions

Q5. Besides the colour change that occurred, what other change did you notice in the appearance of the milk when it was heated with Benedict's solution?

A5. Tiny white clumps appeared in the milk solution, i.e. the milk coagulated.

Q6. Why did the appearance of the milk change?

A6. The heat caused the protein in the milk to denature.

Experiment 13. HOW CAN ONE TEST FOR THE PRESENCE OF A NON-REDUCING SUGAR IN FOOD?

Grade Level – 9&10

	Questions Q1. Does the colour of the solution in well F2 change after floating the comboplate in the water bath for a few minutes? What does this observation imply? **A1. No. Sucrose is not a reducing sugar.** Q2. What happens when the sodium bicarbonate is added to the acidified sucrose solution? **A2. Effervescence occurs.** Q3. What happens to the colour of the solution in well F5 during heating? What does this observation imply? **A3. It changes quickly from blue to green, and then becomes clear as a brickred precipitate settles. The solution contains reducing sugars.** Q4. From your observations, what do you think is the function of the hydrochloric acid in this experiment? Explain your answer. **A4. The hydrochloric acid breaks the disaccharide into its constituent monosaccharides. Since all monosaccharides are reducing sugars, the blue copper(II) sulphate in the Benedict's solution is reduced to insoluble, red copper(I) oxide which precipitates.** Q5. Which reducing sugar/s caused the Benedict's solution to change colour? Give a reason for your answer. **A5. Glucose and fructose. These are the monosaccharides that form sucrose.** Q6. What is the name given to the reaction in this experiment where hydrochloric acid breaks up the disaccharide to form its constituent monosaccharides? **A6. Hydrolysis.** Q7. What is the answer to the focus question? **A4. The food is first heated with hydrochloric acid to hydrolyze any non-reducing sugars into reducing sugars. The resulting solution of reducing sugars is then neutralised and tested with Benedict's solution, which changes from blue to red.**
	Extension Questions Q8. What other biological compound will perform the same function as the hydrochloric acid in hydrolysing sucrose? **A8. The enzyme sucrase (also called invertase).** The following questions are aimed at students with a chemistry background. Q9. Write down the chemical equation for the reaction of the sodium bicarbonate with the acidified (HCl(aq)) sucrose solution. **A9. $NaHCO_3$(s) + HCl (aq) → NaCl (aq) + CO_2 (g) + H_2O (l)** Q10. Use your answer to question 9 to explain why "fizzing" was heard when the sodium bicarbonate was added. **A10. As soon as the sodium bicarbonate was added, carbon dioxide (CO_2(g)) was given off and caused the fizzing sound.**

Experiment 14. IODINE TEST FOR STARCH

Grade Level – 9&10

	Questions Q1 What is the colour of the solution in well A1 after adding a drop of iodine solution? **A1 Yellow-brown.** Q2 What is the colour of the solution in well A2 after adding a drop of iodine solution? **A2 Blue-black.** Q3 How can one test for the presence of starch in food? **A3 A solution of the food is tested with a dilute iodine solution. If starch is present, the solution will become blue-black. If starch is absent, the solution should remain brown.**

Experiment 15. DOES THE FOOD WE EAT CONTAIN STARCH?

Grade Level – 9&10

Q1. Prepare a table like Table 1 below in your books. Record your results in Table 1.

Table 1

WELL	FOOD SOLUTION	COLOUR OF SOLUTION AFTER IODINE ADDED
A1	apple	brown
A3	carrot	brown
A5	potato	blue-black
A7	milk	brown
A9	white rice	blue-black
A11	white mealie meal	blue-black

Q2. What is the answer to the focus question?

A2. Apples, carrots and milk do not contain starch. Potatoes, white rice and white mealie meal do contain starch. (NB: some varieties of apples may contain some starch.)

Extension Questions

Q3. Starch is a polymer of glucose. What does this statement mean?

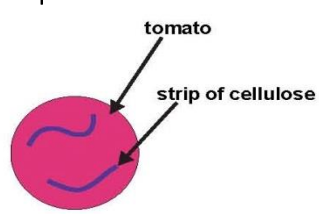
A3. A starch molecule is formed from successive condensation reactions between a very large number of glucose molecules (monomers).

Q4. Starch molecules (polymers) can be broken down into glucose molecules (monomers) by hydrolysis, in the same way that sucrose is broken down into fructose and glucose. Using this information, choose the food/s from Table 1 above which you would eat the most of if you were going to run a long race the next day. Explain your choice.

A4. Potatoes, rice and mealie meal. Running is an action which requires energy. Glucose is a major source of energy for humans. Since starch is made up of many repeating units of glucose that can be released into the body by hydrolysis, eating foods that contain starch can provide the body with energy over a long period. Potato, rice and mealie meal are the foods in Table 1 that contain starch.

Q5. Consider the statement made above in question 4. What result would you expect in the Benedict's test if the potato, rice or maize solutions were heated with 5.5 M HCl(aq), neutralised with sodium bicarbonate, treated with Benedict's solution and then placed in a boiling water bath? Explain your answer.

A5. The colour of the Benedict's solution would gradually change from blue to green to orange to red. Starch is non - reducing because the reducing functional groups of its monomers are linked together in glycosidic bonds in the starch polymer. However,

	hydrochloric acid would hydrolyze the glycosidic bonds, resulting in the release of glucose molecules into solution. These reducing sugars would then reduce the copper(II) in Benedict's solution to copper(I).
	Notes to the Teacher The following list provides some information about a number of foods which can be tested for the presence of starch. Chick Peas .... yes but it does not react unless the seed coat is removed Milk Powder .... no Split Peas .... yes Soya Mince .... full of starch Sugar .... no - a different carbohydrate but many people are confused Red Apple .... sometimes if the apple is very "floury" Green Apple .... no Tomato.. no Carrot .... no Orange .... possibly on the white bits - cellulose. See underneath Celery .... as above Pasta...yes Popcorn Mealies .... yes after cutting See note underneath Rice.. yes Oats .... yes Barley .... yes Rye (bread) .... yes Wheat (bread) .... yes Yellow Maize Meal .... yes
	1 If you find a positive test in certain plants eg tomato it is possible that you have found a strip of cellulose which also tests positive with iodine solution. You won't find the whole tomato going black - but an isolated area. If they don't believe you, they can drop some iodine solution on the tissue paper. Paper is made from cellulose.  2 The interesting point about starch in soya mince, peas and chick peas is that these items are used by vegetarians as a source of protein. Many people don't realise that there is a lot of starch, too. 3 The starch will not be obvious in the chick pea until the outer covering of the seed (pea) is removed. This covering is not starchy but you MAY find a small quantity of cellulose. 4 The popcorn mealie like other mealies is of course a source of starch. The outer covering - yellow bit - is composed of other materials including a bit of protein. It is better to eat yellow mealie meal because it has other nutrients in addition to starch. In fact, yellow mealie meal (as opposed to white) goes some way towards preventing kwashiorkor in communities who eat mainly mealie meal.

Experiment 16. EMULSION TEST FOR LIPIDS

Grade Level – 9&10

	Questions Q1. What do you observe in well F1 after adding the vegetable oil? **A1. The oil forms a globule that floats on the water.** Q2. What do you see in well F1 after stirring? **A2. Tiny droplets of oil form in the water, but the oil and water quickly separate again into two layers.** Q3. What happens to the oil in well F3 when the ethanol is added? **A3. The oil dissolves in the ethanol.** Q4. What happens in well A1 after adding the water to the ethanol/oil mixture? **A4. The solution becomes cloudy and tiny droplets of oil can be seen in the solution. No separation into layers occurs.** Q5. What is the general name given to the kind of cloudy liquid observed in well A1? **A5. An emulsion.** Q6. How can one identify lipids in food using the emulsion test? **A6. A sample of the food is mixed with ethanol. If lipids are present in the food, they will dissolve in the ethanol. As soon as the ethanol/oil solution makes contact with water, a cloudy emulsion is formed because the oil is not soluble in water. The solubility of the lipid decreases as the proportion of water added to the ethanol increases.**
	Extension question (The following question is aimed at students with a chemistry background.) Q7. The structure of a complete lipid molecule is given below. Use this structure to explain your observation when oil was added to water. **A7. The long hydrocarbon tails are hydrophobic i.e. they are excluded by water. Lipid molecules have three hydrophobic tails, explaining why the oil did not dissolve in the water and why the oil and water layers soon separated after the oil was stirred with the water.**

Experiment 17. GREASE SPOT TEST FOR LIPIDS

Grade Level – 9&10

	Questions Q1. What do you see on the surface of the filter paper once it has dried? **A1. The oil spot has stained the paper. The water spot has dried up and left no stain. The water in the spot of the emulsion has dried up, but there are small oil stains where the drop of the emulsion was placed. There is also an oil stain where the ethanol/oil solution was placed. The ethanol has left no stain.** Q2. What do you notice about the oil stains on the paper when the paper is held up to the light? **A2. The light shines through the oil stains. The oil stains are translucent.** Q3. It was found in the emulsion test that oil dissolves in ethanol. Why, then, was an oil stain left where the ethanol/oil spot was placed on the filter paper? **A3. The ethanol evaporated from the filter paper, leaving the oil.** Q4. Explain your observations concerning the spot of the oil/water mixture. **A4. When the oil and water were shaken together in the bulb of the propette, a temporary emulsion of tiny oil droplets in the water was formed. When a spot of this emulsion was placed on the filter paper, the water evaporated, leaving small oil stains where the tiny droplets made contact with the paper.** Q5. What would you have seen on the dried filter paper if the oil and water were not shaken together in the propette before placing a spot on the paper? Explain. **A5. Nothing. Only water would have constituted the spot, since the oil would have formed a layer on top of the water in the propette so that only water would have filled the stem of the propette.** Q6. How can the grease spot test distinguish between lipids and non-lipids in food? **A6. Lipids form translucent stains on absorbent paper. Non-lipids do not.**

Experiment 18. DOES THE FOOD WE EAT CONTAIN LIPIDS?

Grade Level – 9&10

	Questions Q1. Does an emulsion form in well A1 when the water is added to the apple solution? **A1. No.** Q2. Does an emulsion form in well A3 when the water is added to the carrot solution? **A2. No.** Q3. Do emulsions form with rice and mealie meal? **A3. No.**
	Q4. Prepare a table like table 1 below in your books. Complete the table. **A4. Table 1** (see table below) Q5. What is the answer to the focus question? **A5. Apples, carrots, rice and mealie meal do not contain lipids, but milk does.** Q6. Give reasons for your answer to question 5. **A6. When the grease spot test was applied to carrot-ethanol, apple-ethanol, rice-ethanol and maize-ethanol solutions, the ethanol solvent evaporated and no stain was left on the filter paper. Similarly, when the emulsion test was carried out on these same solutions, an emulsion did not form. In contrast, the milk spot left transluscent patches where the lipid in the milk stained the filter paper.**
	Extension question Q7. Why was the emulsion test not carried out on the milk? (*Hint: what does milk look like?*) **A7. Milk is an emulsion of lipid in an aqueous solution containing other constituents, like protein. The cloudy appearance of this emulsion is similar to that of the emulsion formed in Lipid Activity 1.**

FOOD TESTED	**APPEARANCE OF PAPER AFTER DRYING**
apple	**No stain**
carrot	**No stain**
white rice	**No stain**
white mealie meal	**No stain**
full cream milk	**Pale translucent patches**

Experiment 19. BIURET TEST FOR PROTEINS

Grade Level – 9&10

	Questions Q1. What do you observe in well A1 after adding the copper sulphate solution? **A1. The solution becomes blue in colour.** Q2. What do you observe in well A3 after adding the copper sulphate solution? **A2. A blue ring appears at the surface of the solution.** Q3. What happens to the solution in well A3 when it is mixed with the copper sulphate? **A3. It becomes purple in colour.** Q4. How can one test for the presence of proteins in food? **A4. An alkaline solution of the food is mixed with a dilute solution of copper sulphate. If protein is present, the solution changes to a purple or mauve colour. If not, the solution remains blue.**

Experiment 20. DOES THE FOOD WE EAT CONTAIN PROTEIN?

Grade Level – 9&10

Questions

Q1. Prepare a table like Table 1 below in your workbooks. Record your results with the different foods tested.

Table 1

WELL	**FOOD SOLUTION**	**COLOUR WITH COPPER SULPHATE**
A1	**potato**	**purple**
A3	**apple**	**blue**
A5	**carrot**	**blue/orange**
A7	**White rice**	**blue**
A9	**white mealie meal**	**blue**

Q2. What is the answer to the focus question?

A2. Potatoes contain protein. Carrots, apples, white rice and white mealie meal do not.

Q3. What does the colour of the potato solution tell you about the type of proteins present in potato?

A3. The purple colour indicates that potatoes contain the higher proteins i.e. those with many peptide bonds.

Extension question

Q4. It is often stated that rice and mealie meal contain protein. Mealie meal is a staple food in many African countries. How can the results obtained in this experiment help to explain the high incidence of Kwashiorkor (an illness related to a lack of protein in the diet) in Africa?

A4. The results of the Biuret test with white rice and white mealie meal shows that these foods do not contain protein. People who eat a diet consisting mainly of mealie meal are not being provided with sufficient protein, explaining the incidence of Kwashiorkor. (Brown or unpolished rice and yellow, unrefined mealie meal contain protein. The refining process therefore removes the protein.)

CSEC Objective (s) Section A Unit 2 Objective 5

Explain the process of digestion in human beings

Experiment 21. THE ACTION OF AMYLASE ON STARCH

Grade Level - 10

	Questions 1. What is the colour of the I_2 /KI solution (iodine solution)? **A. Yellowish-brown.** 2. What happens when we add iodine solution to starch suspension or to a food which contains starch? **A. The mixture turns dark blue or blackish.** 3. What is the colour of the mixture in well F2 after iodine solution has been added? **A. Blackish.** 4. What does this observation suggest? **A. There is starch present in well F2.** 5. What is the colour of the solution in well F1 after iodine solution has been added? **Any of:** • **yellowish** • **brown pale** • **black or grey.** 6. What does this observation suggest? **A. There is no (or very little) starch present in the well.** 7. What substance did well F1 have which well F2 did not have? **A. Amylase**. 8. What did the amylase do? **A. Amylase converts starch to something else.** 9. Where do we find amylase in ourselves? **A. In our mouths and our intestines.** 10. Amylase is an enzyme. What sort of enzyme is it? **A. Amylase is a digestive enzyme.**

Experiment 22. THE ACTION OF AMYLASE ON STARCH OVER A PERIOD OF TIME

Grade Level - 10

Table to Show the Effect of Amylase on Starch over a Period of Time

Well	**F1**	**F2**	**F3**	**F4**	**F5**	**F6**
Colour	blue-black	blackish	greyish	pale grey	streaky grey	yellowish

Note to the Teacher
The colours listed in the table do not represent the only correct answers. They serve as an indication of the gradual colour change over time.

Questions

1. What was the substrate in this investigation?
   A. Starch.
2. What was the enzyme in this investigation?
   A. Amylase.
3. What do you think the end-products of the reaction are?
   A. A disaccharide / maltose.

Note to the Teacher
The answer will depend on how much the students already know. They should at least be able to deduce that the end products are molecules smaller than starch molecules.

4. What do your observations suggest?
   A. The longer an enzyme has to act, the more substrate it can convert.
5. Amylase acts in the mouth which has a pH around 7. What do you suppose happens when the food with enzyme enters the stomach which has a pH around 2 to 3?

Note to the Teacher
The answer depends on what the students already know. They should be able to deduce that the enzyme could be denatured to some extent. The low pH of the stomach stops the action of amylase. The gastric enzymes function in a low pH medium.

Experiment 23. THE EFFECT OF pH ON THE ACTION OF AMYLASE ON STARCH

Grade Level - 10

Table to Show the Effect of Amylase on Starch in Solutions of Different pH

Well	F1	F2	F3	F4
Solution	Neutral and no reaction	allowed acidic	slightly acidic to neutral	alkaline
Colour	black	black	brownish	black

Questions

1. What was the substrate in this investigation?
   A. Starch.
2. What was the enzyme in this investigation?
   A. Amylase.
3. What do you think the end-products of the reaction are?
   A. Maltose.
4. What do your observations suggest?
   A. Amylase functions best in a pH medium around 7.
5. Amylase acts in the mouth which has a pH around 7. What do you suppose happens when the food with enzyme enters the stomach which has a pH around 2 to 3?
   A. The enzyme is denatured.
6. Explain your answer in terms of the lock-and-key theory of enzyme activity.
   A. The shape of the molecule is distorted. It can no longer function.

Experiment 24. THE EFFECT OF TEMPERATURE ON THE ACTION OF AMYLASE ON STARCH

Grade Level - 10

Questions

1. What are the possible variables in this investigation?
   A. Time, temperature, pH, substrate concentration, enzyme concentration . . .
2. What was the altered variable in this investigation?
   A. Temperature.
3. What do your observations suggest?
   A. Amylase works best in temperatures around 35 ^{0}C to 40 ^{0}C.
4. What is the significance of a temperature around 30 ^{0}C to 40 ^{0}C?
   A. Mammals have a constant body temperature of about 37 ^{0}C.
5. What do you suppose happens to the enzyme at low temperatures?
   A. At low temperatures, enzymes cannot function. Their reaction with substrate has an activation energy. There is little or no denaturation hence, when the temperature rises, the enzyme is able to function normally.
6. What do you suppose happens to the enzyme at high temperatures?
   A. At temperatures higher than 40 ^{0}C, the enzyme becomes denatured in a similar way to how it is affected by pHs which are too low or too high.
7. An experiment, similar to the one which you have just done, was conducted in order to determine the effect of temperature on an enzyme. The enzyme was allowed to react for half an hour. The results of the experiment are shown in the graph below.

7.1 What is the optimum temperature for this enzyme?
A. Around 34 ^{0}C to 39 ^{0}C.

7.2 At which temperature(s) does the enzyme function at 20% activity?
A. 10 ^{0}C and 80 ^{0}C.

7.3 How do you suppose enzyme activity is measured?
A. By measuring the quantity of substrate remaining or by measuring the quantity of end product produced in a given period of time

7.4 Why does the enzyme activity not reach 100%?
A. The reaction was not left long enough to go to completion. As the quantity of substrate remaining gets smaller, the rate of reaction gets less. It takes an infinite time to reach 100%.

Experiment 25. EXPERIMENT 8 – THE ACTION OF THE ENZYME CATALASE ON HYDROGEN PEROXIDE

Grade Level - 10

<table>
<tr><td></td><td>Table showing the Effect of Types of Tissue on Hydrogen Peroxide

Tissue	Effect
example: **liver**	**greatest**
</td></tr>
<tr><td></td><td>Note to the Teacher
Plant tissues usually show less effect than animal tissues.</td></tr>
<tr><td></td><td>Questions
1. What is the effect of the enzyme catalase on hydrogen peroxide?
A. Catalase causes hydrogen peroxide to decompose into oxygen and water.
2. Suggest another name for the enzyme catalase.
HINT: Enzymes are often named after the substrate on which they act.
A. Peroxidase</td></tr>
</table>

CSEC Objective (s) - Section A Unit 3 Objective 3

Discuss the importance of respiration to organisms

Experiment 26. IS OXYGEN USED DURING RESPIRATION?

Grade Level – 10

	Questions 1. What do you observe? **A 1. In well F1, the methylene blue becomes colourless.** **In well F3, the methylene blue remains blue.** 2. What do your results suggest to you? **A2 In well F1 methylene blue solution became colourless because oxygen was used.** **In well F2 methylene blue solution remained blue because no oxygen was used.** 3. In this investigation, which set-up was the control? **A 3. The control was the set-up with the dry seeds.**

Experiment 27. IS ENERGY RELEASED DURING RESPIRATION?

Grade Level – 10

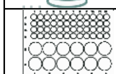
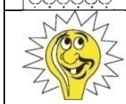
	Note to the Teacher Students should find that the thermometer in the well with germinating (i.e. living, respiring) seeds indicates a slightly higher temperature (between 1 ^{0}C and 3 ^{0}C) than the other thermometer. In order to ensure good results, try a variety of seeds (radish, lentils, popcorn mealies all work well). If students would like to try organisms other than seeds, try using a handful of soil from a compost heap for the "respiring" setup and sterilised soil as the control. What do your findings suggest to you? **Energy is released during respiration.**
	Questions 1. Which setup was the control in this investigation? **A 1. The setup with the dry seeds.** 2. What else could be used as a control? **A2. Nothing, stones, boiled seeds, poisoned seeds . . .** 3. Why do you suppose that it is necessary to keep the setups away from the sun and artificial heaters? **A3. We are trying to avoid these other factors increasing the temperature of the seeds and their surroundings.** 4. Give another example of a temperature rise due to respiration. **A4. Students may make a number of suggestions. One example is that of a person feeling very hot, possibly sweating, after exercise or hard physical work. During such times, the respiration rate increases and so does the temperature.**

CSEC Objective (s) - Section A Unit 3 Objective 6

Identify the causes of air pollution

Experiment 28. AIR POLLUTION BY SULPHUR DIOXIDE

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.**

CSEC Objective (s) - Section A Unit 4 Objective 1

Compare growth patterns in selective organisms

Experiment 29. PATH OF WATER THROUGH THE PLANT

Grade Level – 9&10

	1 CHEMICALS: Note that the chemicals required per activity can be found in the RADMASTE Biology Chemicals Kit. Food colouring is not part of the kit and should be purchased from a grocery store.
	2 EQUIPMENT: All the equipment you need is listed under the Requirements for each investigation. Most of these items are available as part of the RADMASTE Microscale Biology Kit and RADMASTE Biology Teacher Resource Kit.
	Questions 1. In what tissue did you observe the red food colouring? **A1. The red dye (food colouring) stained the xylem.** 2. What can you conclude from this observation? **A2. Water travels in the xylem of plants, from the roots through the stems and to the other aerial parts of the plant.**
	Extension Activities 1. Repeat the procedure with other plants which have variegated (for example, green and white) leaves and observe the leaf veins after a few hours. **A .The leaf veins will become stained with the food colouring.** 2. Repeat the procedure with pale-coloured flowers and observe changes which occur in the petals. **A. The veins of the petals will be stained with the food colouring.**

Experiment 30. DOES THE ROOT SYSTEM OF A PLANT PUSH WATER UP THE STEM?

Grade Level – 9&10

	Questions 1. Why do you suppose we placed oil over the water in the tube? **A1. The oil prevents evaporation of water in the tube.** 2. What did you observe about the level of water in the tube above the stem? **A2. The level of water rose.** 3. Where did this water come from? **A3. It came from the conducting tissue (xylem) of the plant.** 4. Do you think the water level rose because of transpiration? **A4. Transpiration is not taking place (little or no aerial parts of the plant). Therefore some other factor is responsible for the movement of water through the plant.** 5. What system of the plant caused the water level to rise? **A5. The roots are intact. Therefore the roots (or the water in the root system) exert a force upwards.**

CSEC Objective (s) - Section A Unit 5 Objective 3

Identify the waste product of flowering plants and methods of excretion

Experiment 31. IS WATER LOST THROUGH THE AERIAL PARTS OF A PLANT?

Grade Level – 9&10

	Questions 1. What was the purpose of the oil on the surface of the water? **A1. The oil prevents evaporation from the surface.** 2. Which plant part lost the most, second most and least liquid? **A2. The leafy twig lost the most, then the flower and the leafless twig lost the least liquid.** 3. What happened to the blue cobalt chloride paper when you used it to test the liquids in each of the plastic bags? **A3. The paper turned pink.** 4. What liquid did the plant parts lose? **A4. The plant parts lost water.** 5. Summarise all your findings in one or two sentences. **A 5.The aerial parts of plants lose water (vapour) into the atmosphere. The leaves of plants generally lose more water than the other parts.**

Experiment 32. INVESTIGATING HOW THE LEAVES OF PLANTS LOSE WATER

Grade Level – 9&10

	Note to the Teacher *Sometimes it is possible to see minute pink dots, indicating the positions of the stomata. Usually, however, the blue cobalt chloride paper is streaked with pink.*
	Questions 1. Was there any change in the colour of the cobalt chloride paper on any side of the leaves? **A1. Yes. The blue cobalt chloride paper became pink in parts.** 2. What does this observation suggest? **A2. Plants lose water (vapour) through the surfaces of their leaves.** 3. Do leaves lose water from both surfaces, from the upper surface, from the lower surface? **A3. Different leaves show different results. Some leaves lose more water from the upper surface than the lower surface, some leaves lose water equally from both surfaces.**
	Note to the Teacher *Most leaves are dorsiventral; i.e. there are unequal numbers of stomata on the upper and lower surfaces. Some leaves, however, notably those of monocotyledons, are isobilateral; i.e. having equal numbers of stomata on the upper and lower surfaces.*

Experiment 33. LOSS OF LIQUID WATER FROM PLANTS

Grade Level – 9&10

	Questions 1. What can be seen along the margins of the leaves? **A1. Droplets of water are observed.** 2. What process has taken place? **A2. Guttation has taken place.** 3. Under which environmental conditions would this process take place in plants? **A3. Under humid conditions.** 4. Why would guttation occur under these conditions? **A 5.The humid atmosphere cannot hold any more water vapour. The water lost from the plant is therefore released in liquid form.**
	Note to the Teacher *It is possible that not all of the seedlings will lose water to the same extent. Use the findings to discuss variation between organisms.*

Experiment 34. LOSS OF WATER FROM PLANTS UNDER VARIOUS ENVIRONMENTAL CONDITIONS

Grade Level – 10&12

	Questions 1. Which plant or plants lost the most water? **A 1.Those in hot, dry, windy areas.** 2. Which plant or plants lost the least water? **A2. Those in cool, shady, still and humid areas.** 3. Was any water lost from the control setups? **A3 (Sometimes) Very little**
	Note to the Teacher *In this investigation, we are comparing directly the loss of water from plants with the loss of water from a similar set-up with no plant. Indirectly, we make comparisons between plants (and between set-ups) under different conditions. We are not comparing directly the loss of water in a single plant under various conditions. We can only assume how a single plant would behave under a range of conditions, and we cannot make generalisations.*

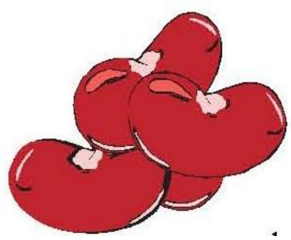
CSEC Objective (s) - Section A Unit 7 Objective 8

Compare growth patterns in selective organisms

Experiment 35. OBSERVING GERMINATION

Grade Level –

Stage 2 - Germination of the Seed
INFORMATION

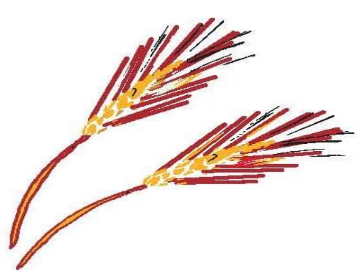


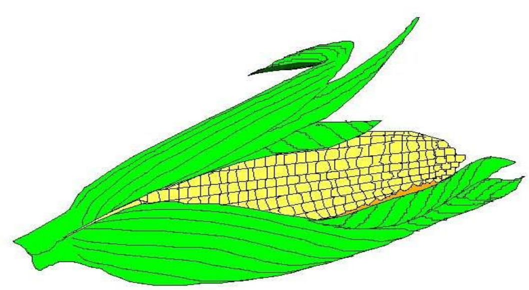
The word "germination" refers to the first stages of growth in a seed, spore, or pollen grain. Seeds germinate when they are exposed to factors such as moisture, oxygen and a favourable temperature. The process begins with the uptake of water by the seed. After this, the metabolic rate of the seed increases markedly and various physiological changes take place. Enzymes convert food reserves in the seed to monomers which are absorbed by the seedling.

The embryonic root, or radicle, normally appears first, with the plumule second. In dicotyledons the first structure to appear above the soil is the hypocotyl. In monocotyledons it is the coleoptile. The appearance of the first leaves signals the end of germination and the start of growth.

The endosperm is the nutritive tissue in the seeds of most flowering plants. It contains food reserves such as starch, fat, and protein . Your learners may have tested certain seeds for these foods in a previous activity. Seeds are a good source of food for the developing embryo and are also a good source of food for us. Photosynthesis begins when the first green leaves open out.

Note that most of the equipment for this activity can be found in the RADMASTE Microscale Biology Kit and accompanying RADMASTE Biology Teacher Resource Kit.





CSEC Objective (s) - Section B Unit 3 Objective 9

Describe the various navigation devices used at sea

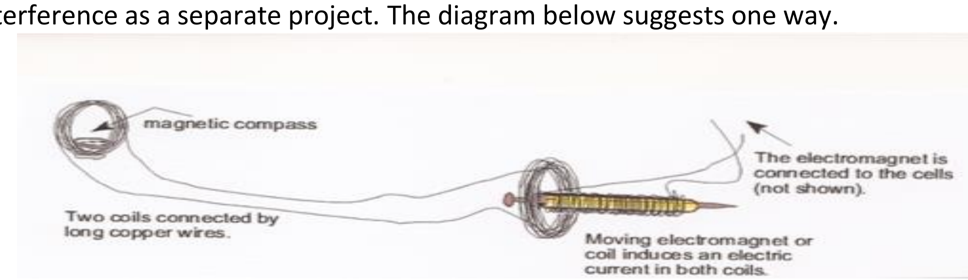
Experiment 36. CAN MAGNETISM PRODUCE ELECTRICITY?

Grade Level – 10

OVERVIEW OF THE ACTIVITY In this Activity, learners will investigate ways to produce an electric current in a coil of copper wire, with an electromagnet (or a magnadur magnet).

THE INVESTIGATION

1. Learners must think of connecting the electromagnet to a source of power, like the two cells from the kit. There must be current in the electromagnet to produce a magnetic field. The coil should be connected to the ammeter. When the ammeter shows a reading, it indicates current in the coil. Learners most probably will mention that small currents should be expected, which is true. Not enough to light up a bulb from the kit. In this case, they should use a scale marked 200 mA or 2000 mA. If learners are not sure about the magnitude of the current, they should think of starting on a larger scale and reduce it if there is no reading.
   Let learners explore, it is possible that they will induce a current. The given hint in the learners' worksheet will guide them to move the electromagnet or the coil. The magnadur magnet will induce a larger current. If stronger magnets are available in class, try them by all means.
2. Learners could use a compass needle. If there is a current induced in the coil, it will produce its own magnetic field, which will cause the magnetic needle to deflect. If learners try this out, they must think of the interference of the magnetic field of the electromagnet. The electromagnet must be kept as far from the compass as possible. Learners could investigate a way to avoid this interference as a separate project. The diagram below suggests one way.



3. Learners must mention that a current is induced in the coil, when the magnet or the coil moves. If they mention the word **change** in the magnetic field, or in the motion of the components, it is even better. It is the change in the number of magnetic field lines through the coil that induces the current in the coil. This change can be usually brought about by:
   - moving the coil relative to the magnet,
   - moving the magnet relative to the coil,
   - rotating the coil, while inside a magnetic field,
   - changing the shape of the coil, while inside a magnetic field.

   The induced current will be of the order of a few milli- or micro-amps. Learners should notice the positive or negative readings on the ammeter, and they should comment on the direction of the current when the magnet approaches or leaves the coil and vice-versa. They should comment on the effect of the speed of the magnet or coil (whichever moves). Challenge learners if they run out of ideas - this is a difficult investigation, but don't give them the answers.

Learners must mention ways to increase the induced current, i.e. by increasing the windings in the coil, or by increasing the strength of the electromagnet, or by moving the electromagnet or the coil faster.

4. If learners succeeded to induce a current in the coil, they should have noticed that the current is induced only when something moves, either the coil or the magnet/electromagnet. It is the **change** in the magnetic field, or the change in the number of field lines that pass through the coil, that induces the current, not the magnetic field itself. This is something difficult to comprehend. One should imagine that scientists first tried magnetic fields of different strengths and orientations, without any success.

   Challenge learners to think of Alex's comment at the beginning of this activity. "We can't get something out of nothing!" A change in the external magnetic field will induce a current in the coil. A change happens only when there is energy transfer.

5. b) Learners have perhaps an idea, or even heard of the words substations, transformers, step-up and step-down transformers. What do transformers do? Let them discuss their ideas. Later on, they will investigate transformers and learn more about induction.

THE CHALLENGE!

1. a) (a) To the right, (b) to the left, (c) to the left, (d) to the right.
   b) A current is induced in the coil in each case.
   c) Learners may use the right hand rule to find the direction of the current in the coil. The induced current is in such a direction, so as to produce a magnetic field that opposes the change brought about by the external field of the magnet (Lenz's law).
   d) Only when it moves relative to the coil.

CSEC Objective (s) - Section B Unit 4 Objective 1

Describe the conditions which promote the growth of microorganisms

Experiment 37. WHAT MOULDS WILL GROW ON BREAD?

Grade Level - 10

INFORMATION

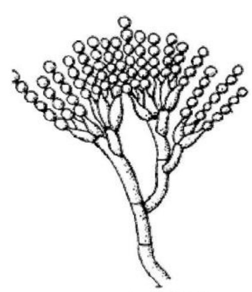
The Kingdom Fungi is one of the five kingdoms of living organisms. It contains about 100,000 species. Included in the kingdom are mushrooms, puffballs, truffles, stinkhorns, yeasts, and moulds as well as the pathogenic forms which cause athlete's foot, potato blight, ringworm and dry rot.

Most fungi are multicellular as is the bread mould. These are usually filamentous, composed of

strands called hyphae. The hyphae are clustered together to form a mycelium. Fungi reproduce by means of spores, which, under favourable conditions, germinate and grow into new fungi.

Most fungi feed on dead and decaying matter and grow very easily on a suitable source of food like bread, potato, cake, fruit and other things. These fungi play an important role in any

ecosystem because they usually start the process of decomposition. Some fungi, like bread mould, cause us inconvenience when they grow on our food, spoiling it. People use extracts of other fungi to fight disease. The antibiotic, penicillin, is produced from a fungus called *Penicillium*.



Penicillium sp

The instructions for the maintenance of a fungus colony can be followed quite easily by the learners. Note that most of the equipment for this activity can be found in the RADMASTE Microscale Biology Kit and accompanying RADMASTE Biology Teacher Resource Kit.

Stage 1: Colonies of Moulds

Questions

1. Which type of mould did you identify most frequently?
2. Did you notice that any type of mould was more common on any of the substrates?
3. What is happening to the bread or cake as the mould gets bigger?

The answers to the above questions will vary from one situation to another.

There are no right or wrong answers.

Stage 2 Detailed Study of Bread Mould

Initially the hyphae are all identical but later three types are produced. Each type of hypha is specialised for the job it has to perform. The stolons cover the surface of the substrate. The

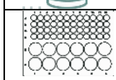
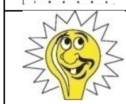
	rhizoids grow down into the substrate. The sporangiophores grow up from the stolons.
	Stage 3 Examining a section of fungal mycelium - *Optional Activity* By using a light microscope, learners will see more detail of the structure of the sample of mould, including the spores.

CSEC Objective (s) - Section B Unit 6 Objective 3

Describe the reaction of metals with oxygen, acid, alkali, water and steam

Experiment 38. THE REACTION OF COPPER WITH OXYGEN

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 39. THE REACTION OF SULPUR WITH OXYGEN

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) $\rightarrow$ sulphur dioxide(g)**
Q7.	Some carbon fuels, such as coal, contain sulphur as an impurity. When these fuels burn they form sulphur dioxide. Using the observations in the above experiment with the universal indicator, explain how the burning of sulphur in the environment can contribute to the problem of acid rain.
A7.	**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 40. THE REACTION OF MAGNESIUM WITH OXYGEN

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. $$\mathbf{MgO(s) + H_2O(\mathit{l}) \longrightarrow Mg(OH)_2(aq)}$$
	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.**

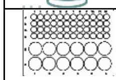
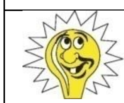
	5. Model Answers to Questions in the Worksheet It is recommended that learners write down all of the questions and answers in their workbooks. If this is done, then the answers to questions do not have to be in full sentences. If the learners do not copy the questions into their workbooks, then answers 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) $\longrightarrow$ magnesium oxide(s)**
Q10.	Write a balanced chemical equation for the combustion of magnesium in oxygen.
A10.	**$O_2(g) + 2Mg(s) \longrightarrow 2MgO(s)$**

CSEC Objective (s) - Section B Unit 7 Objective 2

Distinguish among acids, bases and salts.

Experiment 41. THE EFFECT OF DILUTE ACIDS AND BASES ON INDICATORS

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:** (see table below)
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.**

Table 1:

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

Experiment 42. REACTIONS WITH ACIDS AND SODIUM HYDROXIDE

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 43. PREPARATION OF A SALT: THE REACTION BETWEEN AN ACID AND A METAL CARBONATE

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 44. PREPARATION OF A SALT: THE REACTION OF A METAL WITH AN ACID

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.	$H_2SO_4(aq) + Mg(s) \longrightarrow MgSO_4(s) + H_2(g)$

CSEC Objective (s) - Section C Unit 1 Objective 1

Discuss the use of good and poor conductors of electricity

Experiment 45. GET TO KNOW YOUR MICRO-ELECTRICITY KIT

Grade Level - 9

In the old educational system, this would not be a learning Activity. But in the light of the Outcomes Based Education System, this is a most valuable Activity, where learners can practice, investigate and explore with the kit. This is a great opportunity to assess skills.

OVERVIEW OF THE ACTIVITY

In this Activity, learners will meet the different components of the micro-electricity kit. They will explore the role of each component. They will investigate ways to make the components work in simple electric circuits.

WHY DO WE USE ELECTRIC CIRCUITS?

1.

a) For example, an electric heater, the stove, the fan, the light torch, the portable radio, etc. Challenge learners to think of devices which work with the mains or with batteries.

b) The heater and stove for heating, the fan for air motion, the torch for light, the radio for sound.

c) It does not matter if learners use the wrong terms, as long as they realise that transformations/changes take place in the electrical device as soon as it is switched on. In the heater and stove, electrical energy transforms into thermal energy, in the fan into mechanical energy, in the torch into "light" energy, in the radio into "sound" energy ?(light and sound are not forms of energy, they transfer energy like all waves, but we can use the terms for the time being).

WHAT IS AN ELECTRIC CIRCUIT?

2.

a) No, this is not a circuit and there is no electric current in the wire-loop.

b) Phoka must connect a power supply, like a battery/cell. Learners will have ideas based on past experience and knowledge.

c) Yes, now there is a current in Phoka's wire-loop.

d) Yes, this is a useless circuit. No device is connected to the circuit, to produce an effect, to transform the electrical energy, to show something is happening - a change!

e) Learners after completing the questions 2a to d, should come to the conclusion that:

An electric circuit is a closed conducting path, which is made out of three parts:

- a source of power,
- an electrical device which transforms the electrical energy into "usable" forms,
- the connecting wires (or other suitable connectors), which complete the path between source and device and make the transfer of energy possible.

Usually, learners do not feel comfortable with the concept of energy. They will possibly use the concept of the electric current when describing an electric circuit. From time to time, challenge learners to think in terms of energy, in order to build on the concept. Research has also shown that using current as the starting point to learn electricity, leads to several misconceptions. After all current itself is a difficult concept. Learners usually think of current as something that flows in the circuit.

4-5 Learners are expected to justify and reason why they have put a component into a certain category. Let the learners explore and find their own ways of how to use the components. They might have some good ideas! In the meantime, you may assess their improvisation, handling of apparatus and group-work skills. Learners will discover the use of more specialised components in the activities to come.

Experiment 46. LIGHTEN UP, PREDICT AND EXPLORE

Grade Level - 9

OVERVIEW OF THE ACTIVITY

In Part A of this Activity, learners will be shown several diagrams of bulbs and cells. Their task will be to predict which diagrams represent a complete circuit. In other words, they must predict in which diagrams the bulb/s will glow. They will discuss the reasons why with the other members of their group.

In Part B of this Activity, they will use components of the micro-electricity kit to construct simple circuits to test their predictions in Part A.

PART A

Bulb	Your Prediction	Group's Prediction	Observation	Comments
A	No			
B	No			
C	No			
D	No			
E	No			
F	Yes			
G	Yes			
H	Yes			
I	No			
J	No			
K	Yes			
L	Yes			
M	No			
N(1)	Yes			
N(2)	Yes			

PART B

1. a) Let the learners use the components of the micro-kit as they please. Let them find ways to construct each circuit. This is a good opportunity to assess their improvisation and reasoning skills.
2. Learners must mention the need for a closed circuit or loop, connecting the positive terminal of the cell to one terminal of the bulb (no matter which) and the negative terminal of the cell to the other terminal of the bulb.

Experiment 47. CAR HEADLIGHTS

Grade Level - 9

OVERVIEW OF THE ACTIVITY

In this Activity learners will discuss how the two main headlights of a car work. They will then draw a picture showing a simple circuit of the two headlights and the car battery. They will then use the micro-electricity kit to test their circuit.

This is an exploratory activity. Hopefully, in their discussions the learners will arrive at the conclusion that the car headlights need to be connected in such a way that if the one headlight goes out the other stays on (in other words, a parallel circuit).

The learners have not been taught about the difference in bulbs connected in series or in parallel. If their diagram shows the bulbs in series when they use the micro-electricity kit they will soon learn that car headlights are connected differently.

ASSESSMENT - Collect the groups' notes and sketches of their circuits. Decide on the criteria you will use to assess whether the learners meet the mentioned outcomes.

In the table below is an example of levels for the circuit diagrams.

Level 1	Level 2	Level 3	Level 4
Open circuit with actual components drawn in series	Closed circuit with actual components drawn in series	Closed circuit with actual components drawn in parallel	Closed circuit with symbols of components drawn in parallel

You may wish to add more levels. This is an example of a group assessment. You can choose any aspect of the Activity to assess. If you wish to assess a learner rather than the group you can ask the learner to explain how the circuit drawn by the group represents the workings of the car headlights.

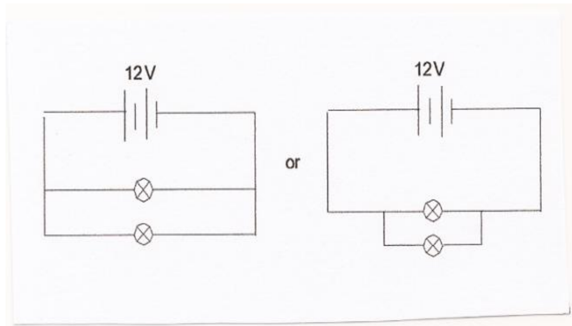
ASSESSMENT - A number of learners may find this part of the Activity frustrating. When they try and make an extra path they may short circuit the bulbs. This means neither of the bulbs glow because there is no current in those branches with the bulbs. The current is in the part of the circuit without the bulbs (the extra metal strip). Through trial and error (and a little bit of guidance from you) they will overcome the problem. In the table below is an example of levels for the micro-electricity circuits.

Level 1	Level 2	Level 3	Level 4
Closed circuit with bulbs in series	Closed circuit with bulbs in parallel but there is a short circuit and the bulbs do not glow independently of each other	Closed circuit with two bulbs in parallel. Each bulb can glow independently of the other.	Closed circuit with two bulbs in parallel. Each bulb can glow independently of the other. A switch is introduced.

Another aspect you could assess is the manipulation of the micro-electricity kit. In the table below is an example of levels of micro-electricity kit manipulation.

Level 1	Level 2	Level 3	Level 4
Do not use combo plate or springs. Hold circuit components.	Partly use the combo plate but still hold parts of circuit.	Use combo plate to support all circuit components; clumsy manipulation of components especially springs	Use combo plate to support all circuit components; controlled manipulation of components

1. Hopefully, the majority of learners have constructed a parallel circuit for their car lights. The importance of the independent glowing of the bulbs (car lights) should be part of the learner's explanation for their type of circuit. An example of the circuit is given below.



2. The learners may want to include the voltage (12 V) of the car battery on their circuit diagrams. You can collect their circuit diagrams to assess how they have drawn their circuit diagrams using the symbols information supplied. Draw up your own criteria for this assessment.

   This Activity is a nice way to introduce learners to circuit diagrams. If the learners already know about circuit diagrams etc, ask them to leave out this question.

Experiment 48. MAKING AN ELECTRIC CURRENT DETECTOR

Grade Level - 9

OVERVIEW OF THE ACTIVITY

In this Activity learners will make an electric current detector which they will test on various objects around them. If a substance lets a current flow in it, it is called a conductor. If a substance does not let a current flow in it, it is called an insulator.

What to discuss

1. Learners should discuss each component of their detector. The cell supplies electrical energy, the copper strips are components of the circuit along which the current transfers energy, the bulb lights up when the circuit is closed by a substance that conducts electricity. The importance of a closed circuit must be mentioned.
2. This question is given to the learners to prevent them thinking that conductors are only solids. They may mention the gases in fluorescent tubes which light up because they conduct electricity. The acid in car batteries, electrolysis, water conducts electricity. It is very dangerous if electrical wires or electrical appliances touch water.
3. The learners should identify a number of conductors and insulators and discuss their positive effects. Here are a few examples.

Conductors:

- electrical wires are metal, copper. They are a cheap and efficient way of transferring energy.
- technology: all the different kinds of electrical appliances we can buy, eg, electric kettle, washing machine, toaster, television, computers, etc
- electric trains instead of steam/coal trains
- power lines
- the battery in a car
- lightning conductors

Insulators

- the plastic cover around electrical wires of all electrical appliances.
- the materials used to construct electrical appliances. There are many, many examples here.

We would not be able to use any electrical appliance if it conducted the current in it.

Experiment 49. THE CURRENT IN A SERIES CIRCUIT

Grade Level - 9

OVERVIEW OF THE ACTIVITY

In this Activity learners will set up a series circuit. They will observe the brightness of a light bulb placed at different points in the circuit.

Bulb position	Brightness Prediction	Bulb brightness
Before switch		bright
After switch		bright
Before battery		bright

1. Many learners believe that current gets used up as it flows in a circuit. The strength of the current remains the same. What gets used up is the electrical energy that is transferred to the light bulb by the current.
2. Most learners will predict that their bulbs will glow dimly. In actual fact, the bulb doesn't glow at all. This could lead the learners to believe there is no current in the circuit. The LED will show that there is a very small current in the circuit.
3. This task was included as resistors will be used in further Activities.

ASSESSMENT

One of the performance indicators of the outcome SO1 is 'carry out experimental procedures presented as diagrams'. You can assess the learners in their constructions of the circuits.

In the table below are some examples of possible levels of constructing and following instructions from diagrams.

Level 1	Level 2	Level 3	Level 4
The set up does not resemble the diagram	The set up resembles the diagram but the learners have omitted a component e.g., the switch	The set up resembles the diagram; the instructions on the diagram are not followed	The set up resembles the diagram; the instructions on the diagram are followed

Experiment 50. LIGHT BULBS IN SERIES

Grade Level - 9

ACTIVITY 6 - LIGHT BULBS IN SERIES

OVERVIEW OF THE ACTIVITY

In this Activity learners will set up a series circuit with one light bulb. They will then add more light bulbs in series to the circuit. They will observe the change in brightness, if any, of the light bulbs.

Bulb position	Brightness Prediction	Bulb brightness
1		bright
1 and 2		both equally dim
1, 2 and 3		all equally very dim

Note: All the bulbs used are identical 6 V bulbs. Unfortunately, they sometimes do not give the same results. Should learners find that the bulbs glow differently get them to chose three bulbs that glow the same.

1. Each time a bulb is added in series the current in the circuit is reduced. This means that the bulbs will glow more and more dimly each time another bulb is connected in series. All the bulbs glow with the same dimness after each circuit change.
   Note: Some learners may raise the point that an indicator light is different to the car headlight. It will glow differently to the two headlights, but it will still glow more dimly when there is less current in it.

2. a) The light bulbs act like the resistor. The resistor reduces the current in the circuit, and so do the light bulbs. We can think of a light bulb as a type of resistor.
   b) The resistances of each of the light bulbs add up. This increased resistance reduces the current in the circuit.
3. Neither of the remaining bulbs will glow. The circuit is broken so there is no current in it.
4. **Disadvantages:**
   - The lights would glow very dimly and it would not be safe to drive the car at night time.
   - Also if one of the lights broke, the circuit would be broken and neither of the other two lights would work.
   - The energy drawn from the car battery would be used up very quickly.

   Advantages:
   - None with respect to a car. In other situations for example, the trip switch in a house, it is very important to have the trip switch in series.

Experiment 51. LIGHT BULBS IN PARALLEL

Grade Level - 9

ACTIVITY 7 - LIGHT BULBS IN PARALLEL

OVERVIEW OF THE ACTIVITY

In this Activity learners will set up a simple circuit with one light bulb. They will then add more light bulbs to the circuit. These bulbs will be connected in parallel. They will observe the change in brightness, if any, of the light bulbs.

Bulbs	'Glow' Prediction for each bulb	'Glow' of each bulb
Remove 1 bulb		remainder 2 bulbs glow
Remove 2 bulbs		remainder bulb glows

What to discuss

1. Light bulbs can continue glowing if one or more bulbs are removed in a parallel circuit. In a series circuit none of the remaining bulbs would glow.
2. a) Series: Christmas tree lights; torch
   Parallel: ceiling lights in the home; traffic lights; street lights

   b) If one Christmas tree light goes out, all the lights go out.

   The circuit of a torch is a series circuit. There is only one path for the current.

   The traffic lights and street lights are parallel circuits as any one of the lights in the circuits can be removed/broken and the rest glow.

   The ceiling lights in our homes are connected in parallel. There is a wall switch which controls the on/off state of the lights. This means the light in the kitchen can be switched off while the rest of the lights in the house stay on.

   3.a Answer: B
   3.b Answer: D
   3.c Answer: B
   3.d Answer: C

ASSESSMENT

This Activity brings together the concepts of series and parallel series. You could assess learners on SO2 performance indicators. You could collect the above section to assess the learners' understanding of the concepts.

Experiment 52. ONE AFTER THE OTHER, CAUSING A GREAT BOTHER

Grade Level - 9

OVERVIEW OF THE ACTIVITY

In this Activity, learners will connect a different number of resistors in series to two cells. They will first connect one resistor, then two, then three and finally four resistors in series. In each case, they will measure the current in the circuit and the voltage across the resistors.

Their aim will be to:

- investigate the effect of an increasing number of resistors on the current strength
- to compare the voltage across each connected resistor, to the voltage across all connected resistors
- to find a relationship between the voltage across a single resistor and the current in the circuit
- to compare the quantity Vx/I (where Vx is the voltage across a single resistor) for different currents in the circuit
- to reflect on the meaning of the quantity Vx/I

1. a) The use of two multimeters gives more accurate results. If only one multimeter is available, learners should take these measurements one at a time. In this case, learners should complete the circuit with a copper strip or a connecting wire while measuring the voltage across the resistor.

NOTE: If possible, learners should take readings using two multimeters. An example of measurements, taken with **two** multimeters (one as an ammeter, the other as a voltmeter) and four 20 ohm resistors are shown in Table 1 below:

TABLE 1

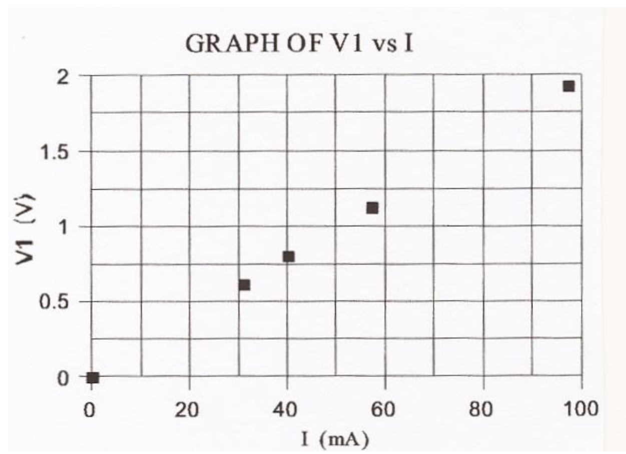
Resistors connected in circuit	Current, I (mA)	Voltage across each resistor, Vx (volts)				Voltage across all resistors, V (Volts)
		V1	V2	V3	V4	
1	97.3	1.93	-	-	-	1.93
1+2	57.2	1.12	1.12	-	-	2.24
1+2+3	40.2	0.8	0.8	0.8	-	2.4
1+2+3+4	31.2	0.61	0.61	0.61	0.61	2.48

In Table 1a, are examples of measurements taken with **one** multimeter only. (Connect multimeter to measure current, disconnect ammeter, complete circuit, connect the same multimeter to measure voltage across resistors). Notice the error, especially in the last column, due to the considerable resistance of the ammeter! Such an error would complicate things for learners in grade 9, who would fail to see that the ratio V1/I (the resistance of the resistor) remains constant.

TABLE 1a

Number of resistors	Current I (mA)	Vx across each resistor (volts)				V across all resistors (Volts)	Calculate the sum V1 + V2 + V3 + V4 (V)	Calculate the ratio V1/I (V/mA)
		V1	V2	V3	V4			
1	94.2	2.7	-	-	-	2.72	2.72	0.028
2	61.2	1.4	1.4	-	-	2.84	2.82	0.023
3	41.9	1	1	1	-	2.9	2.88	0.023
4	33.7	0.7	0.7	0.7	0.7	2.93	2.92	0.022

3. The graph represents how the current through a resistor (the first resistor) changes when the potential difference across the resistor changes. How did we change/decrease the potential difference across the resistor?
   By adding extra resistors.
   Challenge learners to think of the role of the extra resistors in the circuit.
   The best fit line, is a straight line passing through the origin. The origin is a point of the graph, since when no potential difference is applied to the circuit, the current in the circuit is zero. The graph indicates that potential difference and current are directly proportional to each other. Challenge learners to think of the meaning of proportional and of directly proportional quantities.
   Learners may mention the use of the graph by extrapolating the values of the current for a given potential difference across a resistor, and vice-versa, without actually measuring the values. Later on, learners will also use similar graphs to calculate resistance.



4. Learners should compare the data in each column. Table 1, suggests that:
   a. The current decreases with the more resistors we add in series.
   b. The current decreases as the potential difference across each resistor decreases.
   c. The potential difference (V), across all resistors increases slightly as the current decreases. In theory, the voltage across all resistors should remain constant. This discrepancy is due to the internal resistance of the cells and ammeter. The internal resistance decreases for decreasing current. This change causes the voltage to change/increase. Challenge learners to think of reasons causing this change, another resistance perhaps? Where does it come from?
5. a) Learners should calculate and tabulate the sum of the voltages across each resistor and the ratio V1/I for the first resistor. The following Table shows an example of calculations based on the measurements in Table 1.

Number of resistors	Current I (mA)	V across all resistors (Volts)	Calculate the sum V1 + V2 + V3 + V4 (V)	Calculate the ratio V1/I (V/mA)
1	97.3	1.93	1.93	0.02
2	57.2	2.24	2.24	0.02
3	40.2	2.4	2.4	0.02
4	31.2	2.48	2.44	0.02

a) The potential difference across all resistors is divided equally across each resistor, or that the sum $\Sigma Vx = V$.

b) In the last column, the quantity V1/I remains constant. This quantity indicates that for a given voltage, only a certain amount of current is allowed in the resistor. This is represented on the graph by the constant slope of the line.

6. b) Table 1 indicates that the current decreases with increasing number of resistors, or with decreasing voltage across each resistor. However, the table does not indicate how these quantities change in relation to one another. The type of relationship between current and voltage is illustrated by the graph. The table cannot "picture" the variation of the two quantities, nor is it suitable to formulate a conclusion on how the voltage affects the current.
7. An electrical conductor at a given potential difference V, allows only a certain amount of current I, so that the ratio V/I (=R), remains constant. Learners are not expected to give the right answer, but to think and become more aware of the meaning of resistance step by step.
In the next Activity, learners will build up their understanding of the concept of resistance.

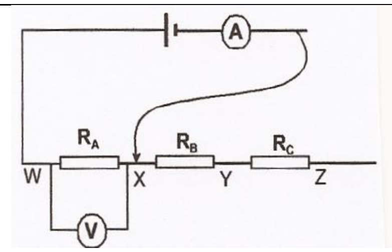
CSEC Objective (s) - Section C Unit 1 Objective 2

Explain the relationship between voltage, current and resistance in circuit

Experiment 53. OHM'S LAW

Grade level - 9

OVERVIEW OF THE ACTIVITY



In this Activity learners are going to investigate the relationship between potential difference and current in a resistor and find its resistance. They will set up a circuit with one resistor (RA) and a 3 V battery. They will use a multimeter as an ammeter to measure the current through RA, and another multimeter as a voltmeter to measure the potential difference across RA. Then they will add a second resistor (RB) in series with RA and move the lead of the ammeter to include RB in the circuit. They will then repeat the measurements of current through RA and potential difference cross RA. Finally they will add a third resistor (RC) in series and repeat the measurements of current and potential difference across RA with RC included in the circuit.

To discuss before you start

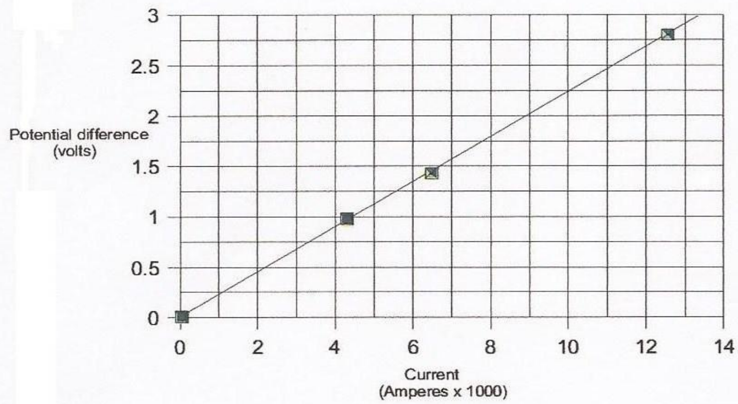
1. By adding resistors we decrease the current in the circuit.
2. The potential difference is being measured across the resistor (RA). It would be different if it was measured across other parts of the circuit. We want to look at the relationship between potential difference and current in the resistor and not of the complete circuit.
3. An increase in temperature affects the resistance of conductors and can lead to inaccurate results. To keep the temperature constant we need to stop for a few minutes between the readings to allow the resistor to reach room temperature again.
4. The current is the independent variable. The potential difference is the dependent variable.

What to do

1. Here are two examples of measurements using 220 ohm and 20 ohm resistors.

	using 220 ohm resistors		using 20 ohm resistors	
No of resistors	PDWX (V)	I (x 10-3 A)	PDWX (V)	I (x 10-3 A)
1	2.8	12.5	2.5	124
2	1.43	6.4	1.35	67
3	0.96	4.3	0.92	46

2. Following is a graph of the measurements given in the table above.



An example of the slope/gradient of the graph is:

$$\frac{(2.25 - 0)V}{(10 \times 1000 - 0)\ A} = 225$$

This value is very close to the value of 220 Σ found for one of the brown resistors in the kit, using the colour code.

6 The results of this activity are usually good. Your learners will find their resistance results are very close to the value determined using the table.

7 Again the results will be comparable. If you use 220 ohm resistors, set the multimeter/ohmmeter on the 20k or 2000 setting. If you use 20 ohm resistors, set the multimeter/ohmmeter on the 200 setting.

Assessment

One of the performance indicators of the outcome SO1 is ‘following written instructions supported by diagrams’. You can assess the learners in their constructions of the circuits and where they place the multimeters.

In the table below are some examples of possible levels for the performance indicator.

Level 1	Level 2	Level 3	Level 4
The set up does not resemble the diagram and the learners do not get any readings on the multimeters	The set up resembles the diagram, but the multimeters are connected incorrectly	The set up resembles the diagram but learners have difficulty following written instructions	The set up resembles the diagram; the written instructions are carefully followed and meaningful results are obtained