Cambridge Assessment International Education

Teaching Pack

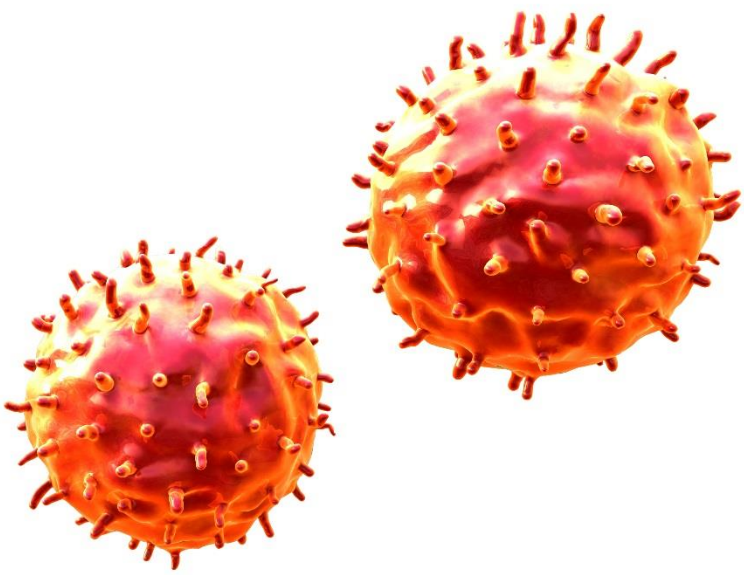
Investigating photosynthesis

Cambridge IGCSE™

Combined Science 0653

This *Teaching Pack* can also be used with the following syllabuses:

- Cambridge IGCSE™ (9–1) Biology **0970**
- Cambridge IGCSE™ Biology (US) **0438**
- Cambridge IGCSE™ (9–1) Co-ordinated Sciences (Double Award) **0973**
- Cambridge O Level Biology **5090**
- Cambridge O Level Combined Science **5129**



Version 2.0

Cambridge Pathway

In order to help us develop the highest quality resources, we are undertaking a continuous programme of review; not only to measure the success of our resources but also to highlight areas for improvement and to identify new development needs.

We invite you to complete our survey by visiting the website below. Your comments on the quality and relevance of our resources are very important to us.

www.surveymonkey.co.uk/r/GL6ZNJB

Do you want to become a Cambridge International consultant and help us develop support materials?

Please follow the link below to register your interest.

www.cambridgeinternational.org/cambridge-for/teachers/teacherconsultants/

Contents

Icons used in this pack:

Briefing lesson

Lab lesson: Option 1 – run the experiment

Lab lesson: Option 2 – virtual experiment

Debriefing lesson

Introduction

This pack will help you to develop your learners' experimental skills as defined by assessment objective 3 (AO3 Experimental skills and investigations) in the course syllabus.

Important note
Our *Teaching Packs* have been written by **classroom teachers** to help you deliver topics and skills that can be challenging. Use these materials to supplement your teaching and engage your learners. You can also use them to help you create lesson plans for other experiments.

This content is designed to give you and your learners the chance to explore practical skills. It is not intended as specific practice for Paper 5 (Practical Test) or Paper 6 (Alternative to the Practical Test).

There are two options for practising experimental skills. If you have laboratory facilities this pack will support you with the logistics of running the experiment. If you have limited access to experimental equipment and/or chemicals, this pack will help you to deliver a virtual experiment.

This is one of a range of *Teaching Packs*. Each pack is based on one experiment with a focus on specific experimental techniques. The packs can be used in any order to suit your teaching sequence.

The structure of each pack is as follows:

Briefing lesson (1 hour*)
This lesson introduces the focus experimental skill(s) to be developed. It also introduces any content needed for your learners to understand the experiment being carried out in the *Lab lesson*.

↓

Lab lesson (1 hour*)	
Option 1 – run the experiment	**Option 2 – virtual experiment**
This lesson allows the experiment to be run with your learners, providing an opportunity to practise the experimental skill(s) introduced in the *Briefing lesson*.	This lesson allows your learners to complete a virtual experiment, providing an opportunity to practise the experimental skill(s) introduced in the *Briefing lesson*.

↓

Debriefing lesson (1 hour*)
This lesson consolidates and builds on the progress learners have made. In some cases, it will also provide the opportunity to practise extended writing skills.

** the timings are a guide only; you may need to adapt the lessons to suit your circumstances.*

In this *Teaching Pack* you will find the lesson plans, worksheets for learners and teacher resource sheets needed to successfully complete this experiment.

Experiment: Investigating photosynthesis

This *Teaching Pack* focuses on the effect of light intensity on the rate of photosynthesis.

Oxygen produced during photosynthesis in submerged aquatic plants forms bubbles that are released into the water. The rate of bubble formation can be used as a measure of the rate of photosynthesis. The light intensity is varied by moving a lamp closer to the plant and the difference in the number of bubbles released is recorded.

The experiment has links to the following syllabus content:

- B5 Plant nutrition

The experiment covers the following experimental skills, adapted from **AO3: Experimental skills and investigations**:

- follow a sequence of instructions and use equipment safely
- suggest possible improvements to methods
- plan experiments.

Prior knowledge

Knowledge from the following syllabus topics is useful for this experiment.

- B5 Plant nutrition

Going forward

The knowledge and skills gained from this experiment will be useful for when you teach photosynthesis.

Briefing lesson: Ordering instructions and safety

Resources	• Worksheets A, B, and C

Learning objectives	By the end of the lesson: • ***all*** learners should understand the importance of following instructions in the correct sequence • ***most*** learners should know how to identify the potential safety hazards in a method • ***some*** learners will be able to use their initiative to adapt instructions to reduce a risk or improve a method.

Timings	Activity
10 min	**Starter/introduction** Ask your learners to carry out the activity on Worksheet A. For each experiment, they should arrange the instructions in the most appropriate order and suggest what might go wrong if a step is carried out in the wrong order. Discuss some of the examples; for ideas see the suggested answers for Worksheet A.
25 min 20 min	**Main lesson** Give learners Worksheet B, which contains the steps in a reaction catalysed by an enzyme. Arrange learners into small groups (2–4) and ask them to put the steps in the most appropriate order, giving reasons for their decisions. Ask groups to share their sequences. Highlight any differences in the sequence between groups and decide if any would be an improvement and why. Points to discuss could include the need for equilibration time before mixing, for both substrate and enzyme solutions; the need to start the stop clock immediately upon mixing; and the idea that if the water-bath is progressively warmed to each temperature in order, a series of measurements can be made efficiently. Learners should have linked 'Stop the stop clock and record the time taken' back to 'Use a Bunsen burner to warm the water to the required temperature' with an arrow to repeat the process for the different temperatures. You could ask your learners to identify the safety hazards associated with this method (risk of knocking over tripod and hot water and breaking the beaker; exposed Bunsen flame between periods of use; hot tripod and gauze when clearing away) and how to minimise the risk by choice of equipment or technique (small beaker of water for water-bath; turn off or move Bunsen burner away between periods of use). Introduce the idea of a risk assessment and explain it involves considering all the possible risks involved in an experiment and how to prevent them. Give learners Worksheet C and ask them to list all the potential hazards they can see and to think of ways to prevent those hazards. Towards the end of the activity, discuss the ideas as a class; you could also discuss other, general, rules for safe practice in a laboratory.
5 min	**Plenary** Explain that the image on Worksheet C is actually the experiment they will do/watch in the next lesson. As a class, devise a list of safety precautions they should take when carrying out the experiment (or as if they were). Include in this list general safe practice in a laboratory, e.g. wearing eye protection; wearing a lab coat; no eating or drinking; no throwing; tucking bags and stools away to avoid trip hazards; careful handling of glassware, etc.

Lab lesson: Option 1 – run the experiment

Resources	• Worksheets D, E, and F • *Teacher walkthrough* video, *Teacher notes, Teacher method* • Equipment as outlined in the Teacher notes • Graph paper

Learning objectives	By the end of the lesson • ***all*** learners should understand how to measure the rate of photosynthesis in a submerged aquatic plant • ***most*** learners should be able to describe and follow the sequence of steps required to investigate the effect of changing the light intensity on the rate of photosynthesis in a submerged aquatic plant • ***some*** learners will understand that other limiting factors should be controlled whilst varying light intensity.

Timings	Activity
5 min	**Starter/introduction** Show your learners the experimental set-up (Worksheet E) and review the method (Worksheet D). Ensure that your learners understand that the experiment involves varying the light intensity to discover the effect this has on photosynthesis in a submerged aquatic plant. They need to understand that the bubbles that come from the cut end of the stem are oxygen, a product of photosynthesis. The rate of bubbling will be used as a measure of the rate of photosynthesis. Ask them how they can vary the light intensity using the equipment. When discussing moving the lamp closer / further away to adjust light intensity, make sure they realise that this is just an approximation of the effect of changing light intensity, rather than an accurate measure but that it is sufficient for the purpose of this experiment. Ask them to suggest what variables should be kept the same whilst varying the light intensity. With prompting, they should be able to suggest using the same temperature, the same piece of aquatic plant and perhaps the same carbon dioxide concentration.
10 min 30 min	**Main lesson** Learners collect the equipment and set it up using Worksheet E to help. Make sure you draw their attention to the safety precautions they should take, such as, the care needed when handling the lamp and pond water, or the safe positioning of glassware. When you have checked all of the equipment is set up correctly and safely, learners should begin the experiment. They follow the method on Worksheet D and record their results in the blank table on Worksheet F. Alternatively, you could ask your learners to draw their own table. Table 1 on Worksheet F should be used if repeats are not done; use table on page 2 if you plan to do repeats. If you decide that there is time for the learners to do repeats in order to calculate a mean, then learners will need to use the second table on Worksheet F. For those learners creating their own table, you will need to tell them that each bubble count is repeated three times, so they will need to include columns for repeats and a mean value for each distance between the aquatic plant and the lamp. *Continues on next page …*

Timings	Activity
10 min	**Main lesson continued …** **Safety** Circulate the classroom at all times during the experiment so that you can make sure that your learners are safe and that the data they are collecting is accurate. Make sure learners are careful whilst moving the lamp and do not spill water on electrical parts. Once the experiment is complete, ask learners to interpret their results by drawing a graph. Some learners might benefit from the following instructions: 1. Draw the axes using a ruler and a sharp pencil. 2. The independent variable is on the *x*-axis. 3. The dependent variable is on the *y*-axis. 4. The scale on each axis is even and appropriate. 5. Draw a smooth curve of best fit. 6. Give the graph a title.
5 min	**Plenary** Discuss what the graph suggests about the effect of light intensity on the rate of photosynthesis. Ask learners to explain the shape of the graph. Draw their attention to the flat section of the graph at the highest light intensities (there should be one). Ask if they can suggest reasons for this. The idea of another limiting factor (temperature, carbon dioxide concentration or the amount of chlorophyll) can be introduced at this point. Note that *limiting factors* is Supplementary content in the syllabus, so adjust the level of the discussion according to the needs of your learners.

Teacher notes

Watch the *Teacher walkthrough* video and read these notes before starting the lab lesson.

Each group will require:

- pond water
- piece of aquatic plant (for example, *Cabomba* or *Elodea*)
- a boiling tube
- a bench lamp
- a stop clock
- a pair of scissors
- a 250 cm^3 beaker of water (at 21°C)
- a beaker or syringe for excess pond water
- a syringe
- forceps
- a paperclip
- a metre ruler

Safety

The information in the table below is a summary of the key points you should consider before undertaking this experiment with your learners.

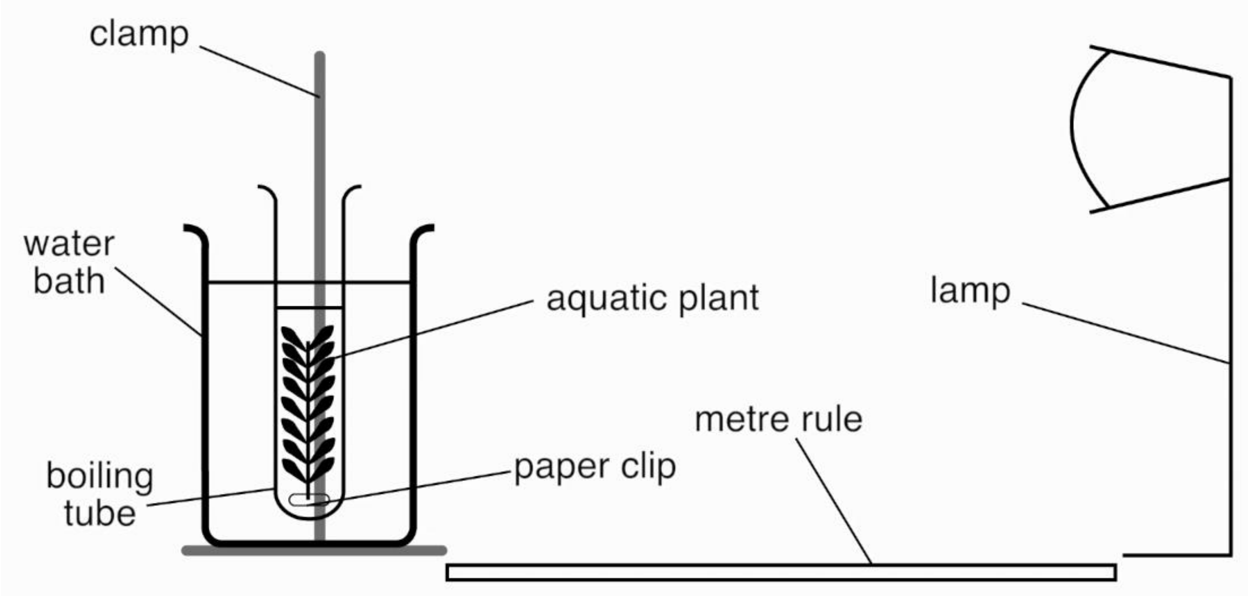
Some associated safety precautions include:

1 Learners must dry their hands thoroughly before handling the lamp.
2 Learners must move the lamp carefully by its base and not touch it by the hot bulb.
3 Wires should be tucked out of the way as much as possible to prevent pulling equipment over.
4 Existing cuts should be covered and gloves could be worn. Eye protection can also be worn to prevent pond water being splashed into eyes.
5 Care should be taken not to tighten the clamp too much on the boiling tube, otherwise the boiling tube could break. Be prepared for breakages and have a sharps bin nearby. Learners should not handle broken glassware.

It is your responsibility to carry out an appropriate risk assessment for this practical.

Substance	Hazard	First aid
Plants, fungi and seeds	IRRITANT  **GHS06 (*acutely toxic* T)**	**Skin rash from irritant plants:** Cool the affected area with cold water (if available) and cover with a sterile dressing. You might self-medicate by rubbing a nettle sting (acidic) with a dock leaf (alkaline).
Aquatic plants	Contamination by pond water	**In the eyes:** Flood the eye with gently-running tap water for 10 minutes. If discomfort persists, see a doctor. **Swallowed:** do no more than wash out the mouth with water. Do not induce vomiting. See a doctor if necessary. **Spilt on the skin or clothing:** Remove contaminated clothing; wash skin thoroughly with (antibacterial) hand soap and running water. **Spilt on the floor, bench, etc.:** clean the area thoroughly using an appropriate disinfectant (**you must do a risk assessment for any disinfectant used**).
Sharps (e.g. scalpels, knives, cork borers, mounted needles, broken glassware)	Risk of cuts or puncture wounds due to sharps. Wounds can lead to infection, especially if the blade or point is contaminated.	**Minor cuts:** Rinse the wound with water. Get the casualty to apply a small, sterile dressing. **Severe cuts**: Lower the casualty to the floor. Raise the wound as high as possible. If feasible, ask the casualty to apply pressure on or as close to the cut as possible, using fingers, a pad of cloth or, better, a sterile dressing (adding further layers as necessary). If the casualty is unable to do so, apply pressure yourself, protecting your skin and clothes from contamination by blood if possible. Leave any embedded large bodies and press around them. Send for a first aider.
Latex gloves	Allergic reaction	Remove the gloves and wash hands under water. Look out for severe allergic reactions such as difficulty breathing and/or swelling of the face, body or tongue. Seek emergency medical attention immediately.
Water around electrical equipment	Electrocution	**If in casualty is in contact with live electricity supply:** break contact by switching off or removing the plug. If this is not possible, use a wooden broom handle or wear rubber gloves to pull the casualty clear. See a doctor. If the casualty is unconscious, check that airways are clear and that the casualty is breathing and has a pulse. If so, place the casualty in the 'recovery position'. If a pulse is found but the casualty is not breathing, artificial ventilation is necessary. If no pulse is found and the casualty is not breathing, cardio-pulmonary resuscitation is necessary.
Hot bulb	Burns	Flood burnt area with water for at least 10 minutes. For serious injuries see a doctor.

Experiment set-up



Teacher method

This is your version of the method for this experiment that accompanies the teacher video.

Do not share this method with learners. Give them Worksheet D.

Before you begin

Plan how you will arrange your learners during the experiment session.

Think about:

- the number of groups you will need (group size 2–4 learners)
- the amount of aquatic plant required
- if there is time to repeat three times for each distance so that a mean number of bubbles can be calculated for each distance

Experiment

Circulate during the experiment in case learners encounter any difficulties, especially with getting their aquatic plant to begin producing bubbles.

Steps	Notes
1. Learners should collect all the equipment they need from the front of the class.	
2. Learners should prepare a water-bath by filling a 250 cm^3 beaker about two-thirds of the way with tap water.	*They should do this right at the start so the water has time to reach room temperature. This water-bath is to help prevent the aquatic plant from being heated too much by the lamp.*
3. Learners should select a single piece of pondweed and cut it to 5 cm in length.	*If you are keeping the aquatic plants for some time prior to the experiment, it is best to keep them in pond water and change the water once a day or use an aquarium aerator.*
4. Learners should fit a paperclip to the uncut end; this weighs it down in the water.	
5. They should then place the length of plant paperclip-first into a boiling tube.	
6. Learners should then add sufficient pond water to the boiling tube to submerge the pondweed.	*It is best to use pond water rather than tap water because this will better reflect the plant's normal conditions. The cut end of the stem should be beneath the water surface and pointing upwards.*

Step	Notes
7. They will then clamp the boiling tube into the water-bath so that it is held vertically.	*Care should be taken not to tighten the clamp too much otherwise the boiling tube could break. Be prepared for breakages and have a sharps bin nearby. Learners should not handle broken glassware.*
8. Learners should then top up the tap water in the beaker until the water surface level is slightly above that in the boiling tube.	
9. Next learners will place a metre ruler on the bench in front of the beaker.	*The zero mark on the metre ruler should be positioned in line with the aquatic plant or the front edge of the beaker. The exact position doesn't matter so long as it's consistent for each distance within a group.*
10. They will then place a bench lamp against the ruler so that the bulb is positioned at the 50 cm mark.	*The lamp should be switched off until learners are ready to start the experiment.*
11. Learners should ensure they have Worksheet F ready to record their results, or alternatively, they should draw their own results table.	
12. Learners should switch on the lamp and wait for 3–4 minutes.	*As far as possible, the lab should be dark so that each bench lamp is the only source of light. Remind learners not to touch the lamp with wet hands.*
13. They should then count the number of bubbles leaving the cut end of the stem in one minute.	*Circulate the room to help learners: if a steady stream of bubbles does not appear after 3–4 minutes, learners can cut 2–3 mm from the cut end of the stem or gently squeeze the cut end of the stem. Watch groups carefully to check that all have streams of bubbles and be ready to substitute another piece of aquatic plant if necessary.*
14. Learners should keep a tally and record the total number of bubbles released in a minute in their table.	*If the bubbling rate is very slow, the time interval for recording can be increased, but the same time interval must then be used for each light intensity.*

Step	Notes
15. The count should be repeated two more times, with learners recording the number of bubbles released in one minute each time.	*You will need to decide if there is time to do the repeats. A mean value is more accurate than a single data point and helps to reduce the effect of any anomalies but it takes more time.*
16. Learners should then calculate the mean number of bubbles released in one minute and record it in their table.	
17. Learners will then move the lamp to a distance of 40 cm and wait for a further 3–4 minutes.	*It is important to allow the aquatic plant sufficient time to adjust to the new light intensity. Remind learners to avoid touching the hot parts of the lamp when they re-position it.*
18. They should again count the number of bubbles leaving the cut end of the stem in one minute, record this number and repeat two more times at this distance before calculating a mean value.	
19. Learners will then repeat this procedure at distances of 30, 20 and 10 cm.	*Remind learners to give the plant time to adjust to the new light intensity by waiting 3–4 minutes each time the lamp is moved before starting to count.*
20. Learners should then switch off their bench lamp and allow it to cool.	
21. Once finished, the learners should check their mean values and start to interpret their results by drawing a graph.	*Learners should draw a line graph with distance (which represents the light intensity) on the x-axis and the (mean) number of bubbles per minute (which represents the rate of photosynthesis) on the y-axis.*

Clean-up

After the experiment learners should:

- empty and clear away all glassware
- tidy up their work space
- ensure any water has been mopped up
- return all remaining equipment to you.

Lab lesson: Option 2 – virtual experiment

Resources	• *Virtual experiment* video • Worksheets D, E, F, G and H • Graph paper

Learning objectives	By the end of the lesson: • ***all*** learners should understand how to measure the rate of photosynthesis in a submerged aquatic plant • ***most*** learners should be able to describe and follow the sequence of steps required to investigate the effect of changing the light intensity on the rate of photosynthesis in a submerged aquatic plant • ***some*** learners will understand that other limiting factors should be controlled whilst varying light intensity.

Timings	Activity
	**Starter/introduction** Give learners Worksheet D and Worksheet E, then watch the introduction to the video; it will automatically pause on the equipment screen. Ensure that your learners understand that the experiment involves varying the light intensity to discover the effect this has on photosynthesis in a submerged aquatic plant. They need to understand that the bubbles that come from the cut end of the stem are oxygen, a product of photosynthesis. The rate of bubbling will be used as a measure of the rate of photosynthesis. Give them a few minutes to read through the method and look at the set-up. Ask them how they could vary the light intensity using the equipment. When discussing moving the lamp closer / further away to adjust light intensity, make sure they realise that this is just an approximation of the effect of changing light intensity, rather than an accurate measure but that it is sufficient for the purpose of this experiment. Ask them to suggest what key variables should be kept the same whilst varying the light intensity. With prompting, they should be able to suggest using the same temperature, the same piece of aquatic plant and perhaps same carbon dioxide concentration.
 	**Main lesson** Resume play of the video. Click on the ‘Video question’ buttons throughout the video to reveal some questions about the method. Learners can answer the questions as a whole class, or be asked to think about their answers in pairs or groups before sharing answers. Ask learners to remind you of the safety precautions they discussed at the end of the previous lesson, such as, the care needed when handling the lamp and pond water, or the safe positioning of glassware. Explain that they will need to count the number of bubbles released from the aquatic plant in the video. This might be difficult for learners at the back of the class as the bubbles are difficult to see. The master version of the video includes a large number next to the bubbles that counts along with the bubbles, you might find this preferable. *Continues on next page …*

Timings	Activity
	Main lesson continued …
	Explain that they will be shown where to look for the bubbles before they have to start counting (e.g. the image at time 3:53). Explain that once they've seen the guide they need to get ready; a red banner will appear at the bottom of the screen with a timer on it and once the timer starts, they should start counting.
5 min	Give your learners the blank table on page 2 of Worksheet F or ask them to draw their own table. If they draw their own table, you will need to tell them that each bubble count is repeated three times, so they will need columns for repeats and a mean value as well as one for the distance between the pondweed and the lamp. (Note that they won't actually see the repeats in the video, but it is good practice for them to understand how to draw a suitable table.)
15 min	Resume play of the video. Before each set of results is shown (once for 50 cm, 40 cm, 30 cm, 20 cm and 10 cm) the previous screen will always show them where to look first, they should only start counting once the timer on screen starts. The video will automatically pause after the last set of results. Give learners Worksheet G and explain that these are the results from repeating the experiment in the video. Ask them to calculate the mean number of bubbles using the data for each repeat. Resume play of the video, it will pause on the table of results; discuss if anyone missed some of the counts or got a different count to those shown in the table. Discuss why that might be. Learners correct their tables using the one on the video.
10 min	Ask learners to interpret their results by drawing a graph as described in the last section of the video. Resume play of the video until it finishes. A copy of the graph from the video is on Worksheet H. Some learners might benefit from the following instructions: 1. Draw the axes using a ruler and a sharp pencil. 2. The independent variable is on the *x*-axis. 3. The dependent variable is on the *y*-axis. 4. The scale on each axis is even and appropriate. 5. Draw a smooth curve of best fit. 6. Give the graph a title.
	Plenary
5 min	Discuss what the graph suggests about the effect of light intensity on the rate of photosynthesis. Ask learners to explain the shape of the graph. Draw their attention to the flat section of the graph at the highest light intensities. Ask if they can suggest reasons for this. The idea of another limiting factor (temperature, carbon dioxide concentration or the amount of chlorophyll) can be introduced at this point. Note that *limiting factors* is Supplementary content in the syllabus, so adjust the level of the discussion according to the needs of your learners.

Debriefing lesson: Planning a follow-up experiment

Resources	• Learners' drawn graphs from the previous lesson • Worksheets I and J

Learning objectives	By the end of the lesson: • ***all*** learners will be able to write a conclusion by interpreting a graph • ***most*** learners should know that when one factor is varied in an experiment, other key factors should be kept the same • ***some*** learners will be able to plan an experiment to investigate the effect of a limiting factor of photosynthesis other than light intensity, including safety precautions.

Timings	Activity
10 min	**Starter/introduction** Review the graph from the photosynthesis experiment. Remind your learners that it shows that the rate of photosynthesis increases with increasing light intensity, but only up to a point. Ask them to use their graph to write a conclusion for the practical in their own words. Remind them that a conclusion should be a judgement based on their results; they should quote their data as evidence to support their conclusion. Circulate the room and support learners in discussions and writing. For less able learners, you might want to give the following scaffold; gaps that the learners should fill in themselves are given in [square brackets]: At lower light intensities, increasing the light [intensity] causes the rate of photosynthesis to [increase]. This is shown by the [sloping] line on the graph. Above a certain light intensity, increasing the light intensity further will not increase the rate of [photosynthesis]. This is shown by the line on the graph reaching a [plateau]. Ask some learners to read out their conclusion to the class, and discuss the extent to which they are or are not good conclusions. Good conclusions will mention both sections of the graph. They will describe how, at lower light intensities, the rate of photosynthesis varies in proportion to light intensity, but will also include the idea that a maximum rate of photosynthesis is eventually reached, beyond which increasing the light intensity has no further effect. Good conclusions will use descriptive words such as 'slope', 'straight line' and 'plateau' when quoting evidence from the graph. Ask learners to think about the method for the experiment they carried out. Ask them to answer the questions on Worksheet I to make sure they understand the method.
5 min	Briefly discuss the strengths and weakness of the experiment as a class. Suggestions might include: aquatic plants provide an easy, visible way to measure the rate of photosynthesis by counting the bubbles of oxygen produced; and aquatic plants respond quickly to changes in light intensity (strengths). However, bubbles vary in size so are not a reliable measure of the volume of oxygen produced; the experiment is time-consuming because repeats must be carried out one after another with the same piece of aquatic plant rather than at the same time with multiple pieces, because different pieces of aquatic plant are not comparable; and the temperature of the water-bath was not checked to verify that the temperature stayed the same (weaknesses). *Continues on next page …*

Timings	Activity
15 min	**Main lesson** Arrange learners into groups of 2–4. Explain that you want them to use what they have learnt from the previous experiment to design a new experiment in which they will investigate how either temperature or carbon dioxide concentration affect the rate of photosynthesis. Explain that they can use the same or similar equipment. You might need to introduce them to potassium hydrogencarbonate solution and hydrogencarbonate indicator if they have not come across them before. They should evaluate the strengths and weaknesses of their methods and consider the equipment they might need, as well as any potential safety hazards. They should discuss the plan in their groups. Ideas might include: keeping the lamp in the same place to keep the light intensity the same but varying the temperature of the water-bath containing the boiling tube, either by adding warm water or by heating it and using a thermometer to record the temperature; keeping the light intensity and temperature the same but breathing out through a straw into the pond water to increase the carbon dioxide concentration; or substituting the pond water with progressively more concentrated solutions of potassium hydrogencarbonate, which is used as a source of carbon dioxide. The concentration of carbon dioxide could be qualitatively detected using hydrogencarbonate indicator.
25 min	Following group discussion, groups should share and list their ideas with the rest of the class to establish the points needed for planning their follow-up experiments. A key point to establish is that when one variable is changed in an experiment (independent variable), other key variables should be kept the same (control variables) in order to determine the impact of the independent variable. Ask your learners to formally write down their plan for carrying out their new investigation. They should include details of the variable they are changing, how they plan to keep other key variables the same, what they will measure, the equipment they will need and any safety hazards, as well as the sequence of steps involved in their method. You might want to provide some scaffolding to support your learners in this extended writing task (Worksheet J).
5 min	**Plenary** Summarise the four key elements required in a plan for an experiment: what is being investigated, what will be varied, what will be measured and what will be kept the same.

Worksheets and suggested answers

	Worksheets	Suggested answers
For use in the Briefing lesson:		
A: Sequencing instructions	**20–21**	**35**
B: Sequencing a method	**22–23**	**37**
C: Spotting hazards	**24**	**38**
For use in *Lab lesson: Option 1:*		
D: Method	**25–26**	**—**
E: Equipment set-up	**27**	**—**
F: Results	**28–29**	**—**
For use in *Lab lesson: Option 2:*		
D: Method	**25–26**	**—**
E: Equipment set-up	**27**	**—**
F: Results	**28–29**	**—**
G: Results from video	**30**	**—**
H: Graph from *Virtual experiment* video	**31**	**—**
For use in the *Debriefing lesson:*		
I: Thinking about the method	**32–33**	**39**
J: Writing a plan for an experiment	**34**	**40**

Worksheet A: Sequencing instructions

Arrange the instructions in the correct order (1 to 12).

Experiment 1

A student wants to find the volume of two stones to see which is the largest. The method involves placing the stones in a measuring cylinder containing water and measuring the increase in volume of the water.

Step description	Step order
Read off the volume in the measuring cylinder	
Add some water to the measuring cylinder	
Read off the volume in the measuring cylinder	
Read off the volume in the measuring cylinder	
Subtract the first volume from the second volume	
Compare the two volumes	
Add some water to the measuring cylinder	
Place the first stone into the measuring cylinder	
Empty the measuring cylinder	
Subtract the first volume from the second volume	
Read off the volume in the measuring cylinder	
Place the second stone in the measuring cylinder	

What might go wrong if the steps were carried out in the wrong order?

………

………

………

………

………

………

Arrange the instructions in the correct order (1 to 8).

Experiment 2

Yeast needs water and warmth to produce carbon dioxide. A student wants to find out if yeast also needs sugar to produce carbon dioxide. Carbon dioxide released by the yeast can be collected in balloons. The student sets up a method to observe which balloons inflate, in order to determine which sample of yeast releases carbon dioxide.

Step description	Step order
Add some sugar to one of the bottles	
Half fill two bottles with warm water	
Observe what happens to the balloons	
Add some yeast to both bottles	
Put the bottles in a warm place	
Stir the water	
Leave the bottles for an hour	
Fit a balloon onto the neck of each bottle	

What might go wrong if the steps were carried out in the wrong order?

………

………

………

………

………

………

………

………

Worksheet B: Sequencing a method

Below are the steps involved in an experiment to investigate the effect of temperature on the rate of a reaction catalysed by an enzyme. Cut out the steps and arrange them in the correct sequence on the next page. Make sure you can justify your decision.

Place a test-tube containing some substrate solution into the water-bath.
Allow the enzyme solution time to adjust to the temperature of the water-bath.
Clear away the equipment.
Place a thermometer in the water-bath.
Use a Bunsen burner to warm the water to the required temperature.
Collect all your equipment from the front of the class.
Add the enzyme solution to the substrate solution.
Place a test-tube containing some enzyme solution into the water-bath.
Allow the substrate solution time to adjust to the temperature of the water-bath.
Stop the stop clock and record the time taken.
Prepare a water-bath by half filling a beaker with tap water.
Start the stop clock.
Place the beaker on a tripod and gauze.
Wait until all the substrate has been converted into product.

Add an arrow to indicate where or how the sequence would be repeated if you wanted to time the reaction at different temperatures.

Worksheet C: Spotting hazards

Worksheet D: Method

Follow these step-by-step instructions to carry out the experiment.

1. Collect all your equipment from the front of the class.

2. Prepare a water-bath by filling a 250 cm^3 beaker with tap water, so that it is about two-thirds full.

> *The bench lamp will release heat so the water-bath is used to keep the aquatic plant at a constant temperature throughout the experiment.*

3. Cut a piece of aquatic plant to about 5 cm in length.

> *Make sure you do not get pond water in any open cuts; wear gloves if necessary.*

4. Gently fix a paperclip to the uncut end.

5. Put the pondweed into a boiling tube paperclip first.

> *Steps 4 and 5 ensure that the cut end of the plant is at the top.*

6. Add pond water to the boiling tube until the cut end of the plant is covered. Pour pond water into a small beaker and then pour into the boiling tube, or use a syringe.

> *Make sure the cut end of the plant is covered by water.*

7. Clamp the boiling tube in the water-bath.

> *Be careful not to clamp the boiling tube too tightly.*
> *If you clamp too hard the boiling tube might break.*

8. Add more tap water to the water-bath until the water level is just above the pond water in the boiling tube.

> *It important for the whole of the aquatic plant to be below the level of the water-bath.*

9. Place a metre ruler with the zero mark in front of the beaker in line with the aquatic plant.

> Keep the metre ruler in this position for the whole of the experiment.

10. Place a bench lamp at the 50 cm mark. Do not switch on the lamp yet.

11. Make sure you have a table ready to record your results and that the room is made as dark as possible before you start.

12. Switch on the lamp.

> *Make sure your hands are dry before you touch the lamp.*

13. Leave the aquatic plant for 3–4 minutes to adjust to the new light intensity.

14. Count the bubbles coming from the cut end of the stem in one minute. As you count, keep a tally and then record the total number in your table on Worksheet F (or your own table).

15. Repeat for two more periods of one minute (your teacher will tell you at the start if you will do repeats or not). If you do repeats, use table 2 on Worksheet F instead of table 1.

16. Move the lamp to the 40 cm mark on the metre ruler.

> *Take care not to touch any hot surfaces on the lamp. Move it by holding the base and the back, away from any electrical parts.*

17. Allow the pondweed 3–4 minutes to adjust to the new light intensity.

18. Count the number of bubbles coming out of the cut end of the stem in a minute; repeat three times and record the results (if you are doing repeats).

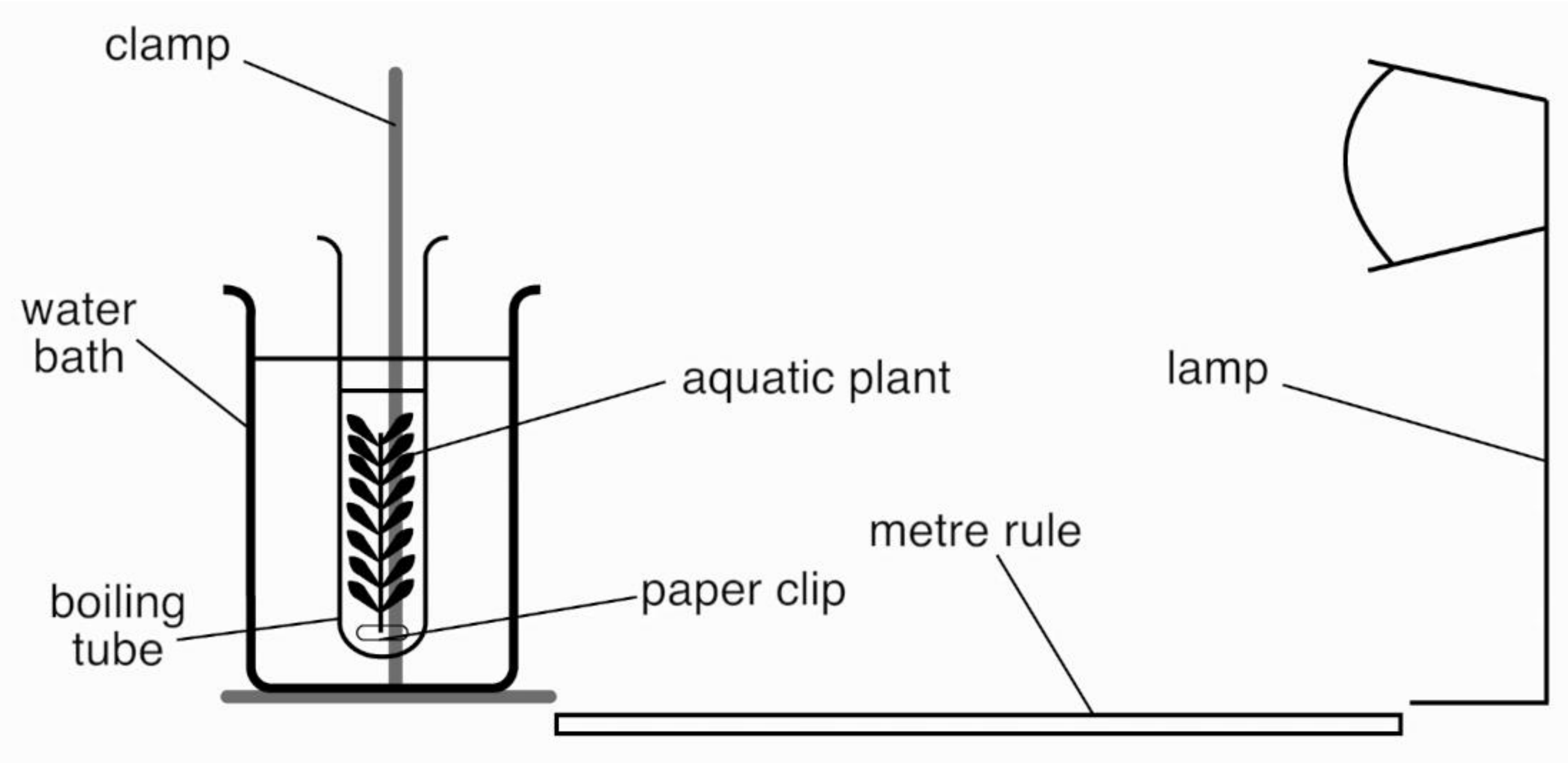
19. Repeat steps 16, 17 and 18 for three other distances (30, 20 and 10 cm). Remember to let the pondweed adjust each time before you start counting.

20. Switch off the lamp and allow it to cool.

21. If you did repeats, calculate the mean number of bubbles per minute for each distance and record the mean values in your table.

22. Draw a line graph with the lamp distance on the *x*-axis (representing light intensity) and the number of bubbles per minute on the *y*-axis (representing the rate of photosynthesis). If you calculated the mean number of bubbles per minute, use this on the *y*-axis instead (to represent the mean rate of photosynthesis).

Worksheet E: Equipment set-up



Worksheet F: Results

Table 1. Use if you are not doing repeats.

Distance (cm)	Number of bubbles in 1 min	
	Tally	Total
50		
40		
30		
20		
10		

The rate of photosynthesis in this experiment is taken to be the number of bubbles released per minute; this is the same as the total count you made above.

Table 2. Use if you are doing repeats.

Distance (cm)	Number of bubbles in 1 min						Mean number of bubbles in 1 minute
	Repeat 1		Repeat 2		Repeat 3		
	Tally	Total	Tally	Total	Tally	Total	
50							
40							
30							
20							
10							

The rate of photosynthesis in this experiment is taken to be the mean number of bubbles released per minute; this is the same as the mean value you calculated above.

Worksheet G: Results from video

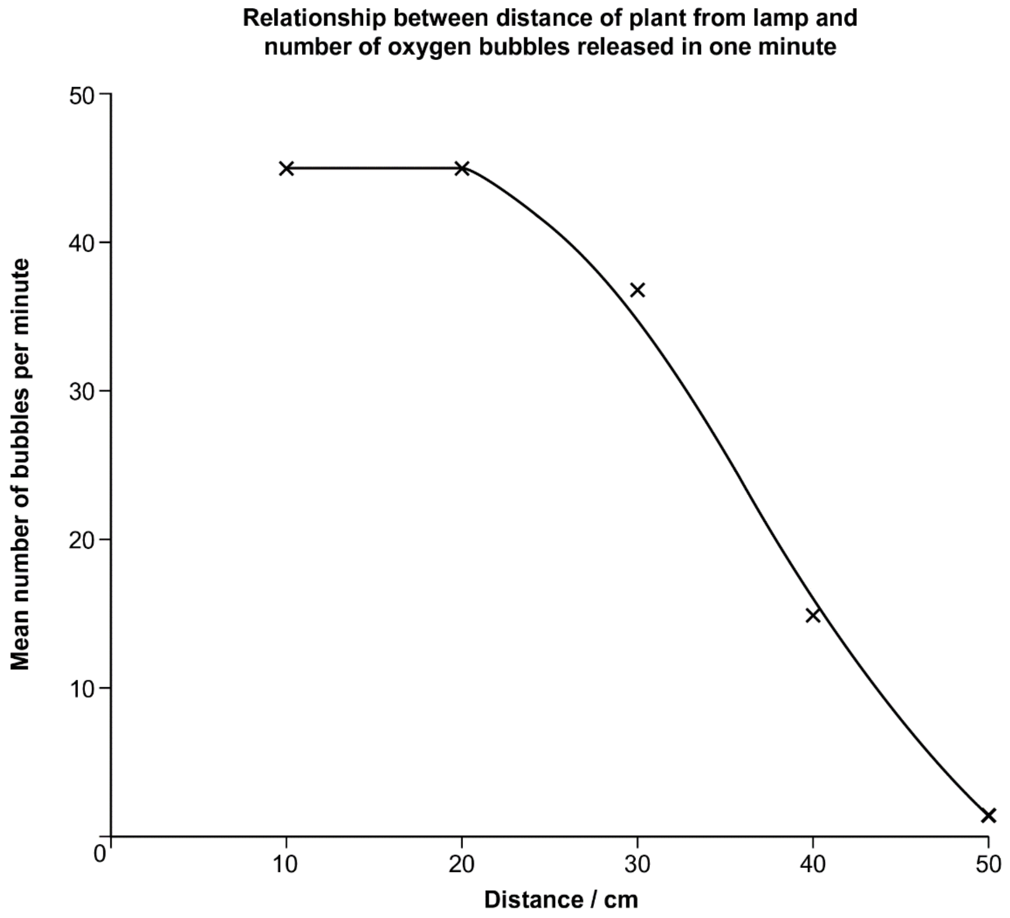
The experiment in the video was repeated three times for each distance. The results of the second and third repeats are given in the table below.

Add your results to the column for 'Repeat 1', then calculate the mean number of bubbles released per minute for each distance.

Distance (cm)	Number of bubbles in 1 min			Mean number of bubbles in 1 minute
	Repeat 1	Repeat 2	Repeat 3	
50		1	2	
40		16	14	
30		30	32	
20		45	44	
10		44	46	

The rate of photosynthesis in this experiment is taken to be the mean number of bubbles released per minute; this is the same as the mean value you calculated above.

Worksheet H: Graph from *Virtual experiment* video



Worksheet I: Thinking about the method

Answer the following questions to make sure you understand the method used.

1. The water-bath was used to keep the aquatic plant at a constant temperature throughout the experiment. Why is that important?

   ……………………………………………………………………………………………………

   ……………………………………………………………………………………………………

   ……………………………………………………………………………………………………

   ……………………………………………………………………………………………………

2. Why was it important to make sure that the cut end of the plant was at the top?

   ……………………………………………………………………………………………………

   ……………………………………………………………………………………………………

   ……………………………………………………………………………………………………

   ……………………………………………………………………………………………………

3. Why was it important for the cut end of the plant to be covered by water?

   ……………………………………………………………………………………………………

   ……………………………………………………………………………………………………

   ……………………………………………………………………………………………………

   ……………………………………………………………………………………………………

4. Why is it important for the whole of the aquatic plant to be below the level of the water-bath?

   ……………………………………………………………………………………………………

   ……………………………………………………………………………………………………

   ……………………………………………………………………………………………………

   ……………………………………………………………………………………………………

5. Why is it important for the ruler's position to be fixed?

……

……

……

……

6. Why should the room be as dark as possible?

……

……

……

……

7. What would happen if you did not give the plant time to adjust to the new light intensity?

……

……

……

……

8. Do you think there are any problems with measuring photosynthesis rate by counting bubbles?

……

……

……

……

9. What is the advantage of taking repeat readings and calculating a mean value?

……

……

……

……

……

Worksheet J: Writing a plan for an experiment

Use this worksheet to help you write a plan for your experiment.

You should include:

- what you will investigate
- what you will vary
- what you will measure
- what you will keep the same
- the equipment you will use
- any safety precautions you will take

Writing checklist

1. I have included:

• what I intend to investigate (e.g., the effect of ……………..… on ………………...).	☐
• the variable I am going to change (independent variable) and how I will change it.	☐
• the variable I am going to measure (dependent variable) and how I will measure it.	☐
• any variables I need to keep the same (control variables) for the experiment to be valid, and how I will do this.	☐
• details of the equipment I will need to carry out my experiment	☐
• any safety precautions I will take.	☐
2. I have read my plan through to check that someone else could carry out the experiment by following what I have written.	☐

Worksheet A: Suggested answers

Experiment 1

Step description	Step order
Read off the volume in the measuring cylinder	**4**
Add some water to the measuring cylinder	**7**
Read off the volume in the measuring cylinder	**2**
Read off the volume in the measuring cylinder	**8**
Subtract the first volume from the second volume	**5**
Compare the two volumes	**12**
Add some water to the measuring cylinder	**1**
Place the first stone into the measuring cylinder	**3**
Empty the measuring cylinder	**6**
Subtract the first volume from the second volume	**11**
Read off the volume in the measuring cylinder	**10**
Place the second stone in the measuring cylinder	**9**

Things that might go wrong in Experiment 1 include:

- Forgetting to read the initial volume before adding stones
- Not emptying the measuring cylinder between stones could cause it to overflow
- If the measuring cylinder is large enough, the two stones could be added sequentially without emptying (more efficient method than one at a time)

Experiment 2

Step description	Step order
Add some sugar to one of the bottles	**2**
Half fill two bottles with warm water	**1**
Observe what happens to the balloons	**8**
Add some yeast to both bottles	**3**
Put the bottles in a warm place	**6**
Stir the contents of each bottle	**4**
Leave the bottles for an hour	**7**
Fit a balloon onto the neck of each bottle	**5**

Things that might go wrong in Experiment 2 include:

- Fitting the balloons too early before adding the yeast.
- Not adding yeast before leaving bottles in a warm place for an hour (would result in no carbon dioxide being produced).
- Not mixing the water after adding the yeast (would result in the yeast not being evenly dispersed to access the sugar).

Worksheet B: Suggested answers

The correct order of the steps is:

Collect all your equipment from the front of the class.
Prepare a water-bath by half filling a beaker with tap water.
Place the beaker on a tripod and gauze.
Place a thermometer in the water-bath.
Use a Bunsen burner to warm the water to the required temperature.
Place a test-tube containing some substrate solution into the water-bath.
Allow the substrate solution time to adjust to the temperature of the water-bath.
Place a test-tube containing some enzyme solution into the water-bath.
Allow the enzyme solution time to adjust to the temperature of the water-bath.
Add the enzyme solution to the substrate solution.
Start the stop clock.
Wait until all the substrate has been converted into product.
Stop the stop clock and record the time taken.
Clear away the equipment.

Worksheet C: Suggested answers

Hazards that learners might spot and possible precautions include:

- Container of pond water near electric socket could cause electric shock (keep water away from socket).
- Touching bench lamp with wet hands could cause electric shock (dry hands first).
- Touching hot bulb of lamp could cause burns (move the lamp by holding the base).
- Trailing electrical wire on bench lamp could cause other equipment to get knocked over, leading to spillages of liquid near electric sockets or the breakage of glass (keep electrical wires tucked out of the way).
- Metre ruler hanging off edge of bench could be caught by someone carrying something and cause an accident (position safely).
- Beaker too close to edge of bench could get knocked off and cause slippery surface if it contains liquid and leave broken glass on the floor that could cut another learner (position safely).
- Bag and stools scattered about in dark lab are a trip hazard (position safely).
- Learner has tightened clamp too tight on boiling tube and it has snapped; broken glass is a cut hazard (take care when tightening the clamp, inform a teacher immediately if glassware gets broken).
- Learner has an open cut on their hand and is dripping pond water into it, could cause infection (cover cuts with a plaster or wear gloves).
- Someone is eating in the lab, could contaminate their food with chemicals on the surface of the bench (no eating or drinking in the lab).
- Pond water has spilt on a learners' clothes (wear a lab coat and eye protection).

Worksheet I: Suggested answers

1. The water-bath was used to keep the aquatic plant at a constant temperature throughout the experiment. Why is that important?

   Warming the plant will make it photosynthesise faster, obscuring the effect of changing the light intensity. The temperature needs to be the same for each repeat so that light intensity is the only variable that changes.

2. Why was it important to make sure that the cut end of the plant was at the top?

   Oxygen tends to rise inside the plant and collect at the top, so if the cut end is uppermost, visible bubbles will be released from this point, making it easier to see and count the bubbles as they are released.

3. Why was it important for the cut end of the plant to be covered by water?

   Escaping oxygen is only visible as bubbles if it is released underwater.

4. Why is it important for the whole of the aquatic plant to be below the level of the water-bath?

   To protect all of the plant from the heat of the lamp; so that the temperature of the plant is consistent across its whole length so that temperature does not affect rate of photosynthesis.

5. Why is it important for the ruler's position to be fixed?

   To avoid errors in measuring the distance of the lamp from the plant; if the ruler positioned is fixed, then the placement of '0' will always be the same and all measurements relative to that are accurate compared to each other.

6. Why should the room be as dark as possible?

   To ensure that the only light (as far as possible) reaching the aquatic plant is from the bench lamp so that the light intensity is being controlled.

7. What would happen if you did not give the plant time to adjust to the new light intensity?

   The rate of photosynthesis would change during the one minute counting period, causing an error in the recorded data.

8. Do you think there are any problems with measuring photosynthesis rate by counting bubbles?

   Bubbles vary in size, so counting bubbles may not be an accurate measure of the volume of oxygen released. It can be easy to miscount the number of bubbles.

9. What is the advantage of taking repeat readings and calculating a mean value?

   It allows any anomalous counts to be identified and reduces their effect on the results.

Worksheet J: Suggested answers

The following is an exemplar plan. Learners' plans will all differ.

I will investigate how changing the carbon dioxide concentration available to a piece of aquatic plant affects the rate of photosynthesis. I will set up a water-bath using a beaker of water. I will place a piece of aquatic plant, cut end upwards, in a boiling tube containing a known concentration of potassium hydrogencarbonate solution to provide carbon dioxide. I will make sure the plant stays submerged by using a paperclip. The boiling tube will be stood in the water-bath so that the temperature of the potassium hydrogencarbonate solution and the aquatic plant remains the same during the experiment. I will use a thermometer to check that the water-bath remains at the same temperature. I will place a bench lamp at a distance of 20cm from the aquatic plant and keep the surroundings as dark as possible so that the light intensity stays the same during the experiment. I will allow the aquatic plant time to adjust to the conditions and then count the number of bubbles coming from the cut end of the stem for one minute. I will repeat the count two more times. I will then replace the potassium hydrogencarbonate solution with one of a higher concentration. After allowing time for the aquatic plant to adjust to the new conditions, I will count how many bubbles come from the cut end of the stem in one minute, three times. I will repeat this for three more concentrations of potassium hydrogencarbonate solution using a higher concentration each time. I will then work out the mean bubble count for each concentration and draw a graph of mean bubble count against potassium hydrogencarbonate concentration.

To carry out this experiment, I will need a piece of aquatic plant, pond water, a paperclip, a boiling tube, a clamp, a bench lamp, a metre ruler, a stop clock, a beaker, a thermometer, five different concentrations of potassium hydrogencarbonate solution and a syringe.

Whilst carrying out this experiment, I will take care not to touch the lamp with wet hands or to touch the hot bulb. I will make sure the wire from the lamp is tucked out of the way and cannot pull the other equipment over. I will wash my hands after handling the aquatic plant and pond water, or wear gloves if I have cuts on my hands. Although potassium hydrogencarbonate is a low hazard, I will wear eye protection and a lab coat.

Cambridge Assessment International Education
1 Hills Road, Cambridge, CB1 2EU, United Kingdom
t: +44 1223 553554 f: +44 1223 553558
e: info@cambridgeinternational.org www.cambridgeinternational.org