Core practical 10: Investigate the effects of different wavelengths of light on the rate of photosynthesis

Objectives

- To understand how to measure the rate of photosynthesis by measuring oxygen production
- To investigate the effect of changing the wavelength of light on the rate of photosynthesis

Safety

- Wash your hands after handling pondweed.
- Sodium hydrogen carbonate is low hazard, but avoid inhalation and contact with eyes.

Specification links

- Practical techniques 1, 3, 8
- CPAC 1a, 2a–2c, 4a, 4b, 5b

Procedure

Prior to the lesson your teacher will tell you which coloured filters are available. Carry out some research, including the action spectra of photosynthetic pigments, and write a referenced introduction with a hypothesis to explain what patterns you expect to see.

Before starting this investigation you should also examine the equipment and read all the instructions carefully. Set up a pilot run if you have time. The independent variable is the wavelength, or colour, of light used. There are many other variables that should be controlled, but these have not been accounted for in the instructions. Under the heading 'Controlling variables' write down any of these factors that you can think of and give details of how you will control them. When you are ready, begin the investigation, controlling factors as you have determined.

1. Place a piece of pondweed approximately 10 cm long into a large beaker of water. Remove any bubbles by gently running a finger and thumb over the surface of the pondweed under the water.
2. Cover one side of the beaker with aluminium foil so that light can only enter the beaker from the other side.
3. Add half a spatula of sodium hydrogen carbonate to the water and leave for 5 minutes.
4. Position the bench lamp close to the beaker with a colourless filter between the lamp and beaker. This will be a white light control. Allow the pondweed to adjust for 5 minutes.
5. Fill the capillary tubing of the photosynthometer with water.

Notes on procedure

- This investigation lends itself to an initial demonstration followed by research and planning carried out as homework. The planning stage is important to meet CPAC 2c, while initial research addresses CPAC 5b.
- Note: *Cabomba* has been the usual pondweed of choice for this practical. CLEAPSS have advised that it will shortly be impossible for schools to buy *Cabomba* and *Elodea* (although you can still use them if they are in your school pond/aquarium tank). Alternative plants are likely to produce fewer and smaller gas bubbles and a very bright light source is needed. CLEAPSS have an alternative method of calculating rate of photosynthesis, which uses a video recorder and a concave mirror, detailed in the accompanying technician sheet. It will deliver the same data as a photosynthometer, but it will work with any aquatic plant.
- Factors that should be controlled in plans include the concentration of sodium hydrogen carbonate, specifying the mass of $NaHCO_3$ and the volume of water; time (2 minutes may be sufficient); temperature, which students should monitor with a thermometer while adding cold water if necessary; the distance of the lamp from the pondweed and the size of the piece of pondweed, given as length or mass. Time constraints are likely to make it necessary to pool data in order to provide replicate measurements. Students may therefore have to follow a class protocol, rather than their individual plans.
- Check that the students do not add too much sodium hydrogen carbonate to the water as a high concentration will have a negative effect on the plant and its ability to photosynthesise. Half a spatula in the

	beaker should be sufficient. ● It is important to monitor the water temperature since the lamp will heat the water and affect the results. ● A suitable graph would be a bar chart. The precision of results for each filter can be shown as error bars using either the range or standard deviation.
6. Place the funnel end of the tubing into the beaker of water and add the pondweed, positioning it with the cut end at the top in the funnel opening of the apparatus. A paperclip attached to the opposite end can help to weight it in the correct position. 7. As the bubbles of oxygen begin to form and pass into the capillary tube, start the stop clock. After a suitable time draw up any oxygen produced into the capillary tubing using the syringe. Record the volume of gas produced. 8. Replace the filter with another filter of a different colour and leave for 5 minutes. 9. Refill the capillary tube using the syringe and then begin recording again. 10. Repeat steps 7–9 to test a number of different coloured filters. If time permits, collect repeats for each type of filter.	

Answers to questions

1. We assume that the gas is oxygen and that the rate of bubble formation will be directly proportional to the rate of photosynthesis.
2. Oxygen will be produced by photosynthesis but there could be a small amount of carbon dioxide in the bubbles from respiration. Some of the oxygen produced will be used internally in respiration. Nitrogen may also come out of solution in the water.

   The rate of respiration is likely to be constant and is unlikely to be affected by altering the wavelength of light. Providing the temperature remains constant, the assumption that any change in rate of gas production is due to changes in the rate of photosynthesis is therefore probably valid.
3. Ideas could include longer test periods, better ways of ensuring that no ambient light influences results, repeating the procedure with different pieces of pondweed, greater control of factors such as temperature, measurement of light wavelength and quantification of light intensity or plant biomass.
4. The absorption of CO_2 per unit time; the increase in biomass or production of carbohydrate per unit time.

Sample data

Filter colour	Rate of oxygen production/mm^3 min^{-1}		
	Test 1	Test 2	Test 3
colourless (white light)	23	19	21
red	12	10	11
green	6	4	3
blue	14	16	12

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All the maths you need

- Recognise and make use of appropriate units in calculations.
- Estimate results.
- Use an appropriate number of significant figures.
- Construct and interpret frequency tables and diagrams, bar charts and histograms.
- Translate information between graphical, numerical and algebraic forms.
- Calculate the circumferences, surface areas and volumes of regular shapes.

Equipment

- piece of pondweed
- large beaker of water
- sodium hydrogen carbonate
- aluminium foil
- spatula
- light filters
- photosynthometer
- paperclip
- bench lamp
- ruler
- thermometer
- stop clock

Diagram

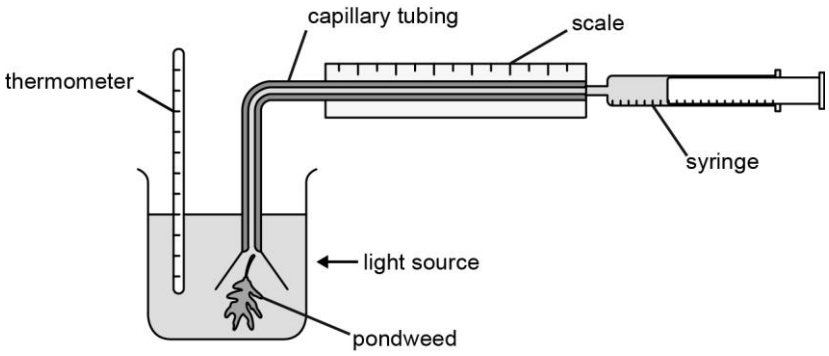

fig A Equipment suitable for measuring oxygen production in photosynthesis (photosynthometer).

Procedure

Prior to the lesson your teacher will tell you which coloured filters are available. Carry out some research, including the absorption spectra of photosynthetic pigments, and write a referenced introduction with a hypothesis to explain what patterns you expect to see.

Before starting this investigation you should also examine the equipment and read all the instructions carefully. Set up a pilot run if you have time. The independent variable is the wavelength, or colour, of light used. There are many other variables that should be controlled, but these have not been accounted for in the instructions. Under the heading 'Controlling variables' write down any of these factors that you can think of and give details of how you will control them. When you are ready, begin the investigation, controlling factors as you have determined.

1. Place a piece of pondweed approximately 10 cm long into a large beaker of water. Remove any bubbles by gently running a finger and thumb over the surface of the pondweed under the water.
2. Cover one side of the beaker with aluminium foil so that light can only enter the beaker from the other side.
3. Add half a spatula of sodium hydrogen carbonate to the water and leave for 5 minutes.
4. Position the bench lamp close to the beaker with a colourless filter between the lamp and beaker. This will be a white light control. Allow the pondweed to adjust for 5 minutes.
5. Fill the capillary tubing of the photosynthometer with water.
6. Place the funnel end of the tubing into the beaker of water and add the pondweed, positioning it with the cut end at the top in the funnel opening of the apparatus. A paperclip attached to the opposite end can help to weight it in the correct position.
7. As the bubbles of oxygen begin to form and pass into the capillary tube, start the stop clock. After a suitable time draw up any oxygen produced into the capillary tubing using the syringe. Record the volume of gas produced.
8. Replace the filter with another filter of a different colour and leave for five minutes.
9. Refill the capillary tube using the syringe and then begin recording again.
10. Repeat steps 7–9 to test a number of different coloured filters. If time permits, collect repeats for each type of filter.

Analysis of results

1. Convert your results to a rate in $mm^3\ min^{-1}$ and record your results in a suitable table.
2. Calculate the mean results for each colour of filter.
3. Plot a graph to show the mean rate of photosynthesis for each type of filter. Indicate the spread of data using the range or standard deviation.
4. Write a conclusion to discuss your results. Refer to the research that you carried out prior to the investigation and your hypothesis.

Learning tip

- Terrestrial plants require carbon dioxide as the carbon source for photosynthesis. For aquatic plants this can be supplied by the hydrogen carbonate ions in water. Adding sodium hydrogen carbonate ensures that the carbon source is not a limiting factor in the investigation.

Questions

1. What assumptions were made about the gas bubbles?
2. Evaluate the validity of these assumptions.
3. Discuss ways in which you could improve your investigation to make the results more reliable.
4. This investigation measured the production of oxygen in a given time to indicate the rate of photosynthesis. Give two other measurements that could have been used.

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Safety

- Take care to avoid breakages when connecting glassware.
- Wash your hands after handling pondweed.
- Sodium hydrogen carbonate is low hazard, but avoid inhalation and contact with eyes.

Equipment per student/group	Notes on equipment
piece of pondweed	*Cabomba* has been the usual pondweed of choice for this practical. Note, however, that it will shortly be impossible for schools to buy *Cabomba* or *Elodea* (although you can still use them if they are in your school pond/aquarium tank). Use any aquatic 'bubbling' plant that can be bought from a retail premises or by post from a UK company that has a retail premises. Native hornwort (*Ceratophyllum demersum*) is an example of a native aquatic plant that should be available indefinitely.
large beaker of water	One 400 ml beaker per group
sodium hydrogen carbonate	About half a spatula per group
aluminium foil	
spatula	One per group
light filters	Acetate sheets: colourless, red, blue, yellow and green
photosynthometer OR equipment as detailed in CLEAPSS sheet GL184: *Using video recording to measure the rate of photosynthesis*	Provide apparatus as shown in fig A on the Student sheet or a similar apparatus with a scale (Audus apparatus). Alternatively, use a large syringe attached to capillary tubing. Place the pondweed inside the barrel of the syringe, fill with water, clamp upright and position the meniscus at the top of the capillary tube. As oxygen is produced it will force the meniscus down the capillary. Note that CLEAPSS have an alternative method of magnifying and recording bubbles. It will deliver the same data as a photosynthometer but it will work with any aquatic plant, regardless of the speed or size of the bubbles. An outline of the procedure is given here: • Bubbling stems are magnified using a concave mirror and video recorded using a mobile phone.

	• A scale placed behind bubbling stems allows the diameter of the bubbles to be determined on playback of the video, and the volume of gas produced can be calculated. The rate of bubbling is the reciprocal of the interval between bubbles.
paperclip	One per group
bench lamp	One per group. The alternative plants now available for this practical are likely to produce fewer and smaller gas bubbles and a very bright light source is needed. A strong (at least 1000 lumens), cool and full spectrum light source should be used.
ruler	One per group
thermometer	One per group
stop clock	One per group
Notes	