Photosynthesis: Impact of various parameters

With this experiment, the photosynthetic performance of plants can be analysed quantitatively and without sensors as a function of the decisive photosynthetic parameters. The parameters to be measured are light intensity, wavelength of light, CO2 content, ambient temperature and plant mass. Further parameters are possible. The volume of oxygen produced is measured. In addition, the oxygen produced can be captured and detected with the glow chip sample.

Biology | Plant Physiology / Botany | Photosynthesis

Difficulty level	Group size	Preparation time	Execution time
easy	2	20 minutes	45+ minutes

This content can also be found online at:

https://www.curriculab.de/c/68e8c9b2d297160002934f29

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Teacher information

Application (1/2)

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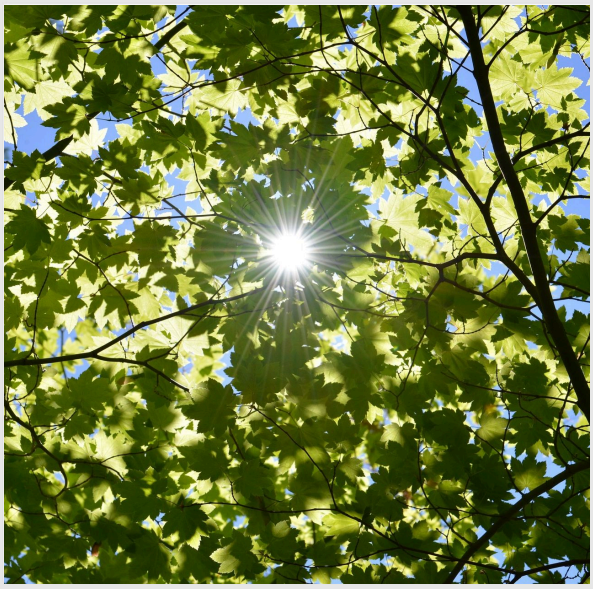

The green plant absorbs water and nutrients from the soil and carbon dioxide from the air. Photosynthesis takes place using sunlight, whereby the plant assimilates new, endogenous substances such as carbohydrates, proteins and fats from the absorbed substances. This produces oxygen as a by-product, which is released into the atmosphere. This light-dependent process is known as photosynthesis. The assimilation capacity of green plants can be measured in various ways:

- through the determination of assimilate formation
- through the measurement of carbon dioxide consumption
- by determining the amount of oxygen developed

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Application (2/2)

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The observation of oxygen formation is a particularly suitable method for directly monitoring assimilation. Oxygen is excreted by the plant as a waste product during assimilation.

If the oxygen is collected and detected, this is proof that assimilation is taking place. This is not so easy to do with terrestrial plants, but with aquatic plants in the aquarium you can observe the release of small gas bubbles that can be captured.

The experimental setup in this experiment is designed in a way that the assimilation activity of aquatic plants can be demonstrated in class by measuring the volume of oxygen produced. This requires a graduated test tube to collect the oxygen.

This experimental setup makes it possible to quantitatively determine the parameters that influence the assimilation activity of the plant.

Other teacher information (1/9)

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Prior knowledge

The students should be familiar with the basics of photosynthesis and know that the photosynthetic and thus assimilation performance depends on various factors. They should also know that oxygen is produced during photosynthesis (chemical reaction equation of photosynthesis) and that photosynthesis is a light-dependent process.

Principle

The students investigate the influence of light intensity, wavelength of light, CO2 concentration of the environment, ambient temperature and density of vegetation on the formation of oxygen by an aquatic plant.

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Other teacher information (2/9)

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Learning objectives

The students should find out how great the influence of various growth parameters is on photosynthesis performance. They should also prove that the measured variable is oxygen.

Tasks

Using a single experimental set-up, the students should carry out various sub-experiments that only differ from each other in terms of changes to the growth parameters of a plant. If time is limited, it is possible to omit sub-experiments or divide them between the different groups of students.

Other teacher information (3/9)

Notes on material procurement

Aquatic plants are used, preferably fresh waterweed (*Elodea canadensis*). This can be obtained wherever aquarium supplies are available (pet shops).

If the results need to be comparable and reproducible, it is particularly important that the shoot sections used are as similar in size as possible.

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Other teacher information (4/9)

Collecting vessel for oxygen with graduation

Background information on the methodology

The oxygen produced during photosynthesis diffuses through the parenchyma tissue and the protective cuticle of the aquatic plant into the surrounding aquatic medium. This process can be observed visually by the rise of tiny gas bubbles in the water. Interestingly, aquatic plants with injuries, especially in the area of the stem, show a significantly intensified release of oxygen.

This phenomenon is specifically used in the following experiments: by using small shoot segments, the gas release can be precisely measured and analysed. This method makes it possible to quantify the oxygen production of plants under controlled conditions and thus provides valuable insights into the process of aquatic photosynthesis.

Other teacher information (5/9)

Helpful hints for implementation

- When conducting experiments based on the division of labour by dividing the experiments between several groups of students, it is important to ensure the same experimental conditions, i.e. (1) the same distance and orientation of the light source (photosynthesis lamp) from the experimental plants, (2) the same size of the shoot sections
- The addition of sodium hydrogen carbonate to the water (2 g per litre) in the sub-tests, with the exception of the sub-test with the different types of water, is strongly recommended to accelerate the formation of oxygen and thus reduce the duration of the test. Heated water (no more than 30°C) also helps.
- Wood shavings (e.g. PHYWE article number 39126-10) are required to carry out the qualitative test for the detection of oxygen (so-called glowing splint test).
- By using a tribrach, irradiation can also take place from below. This means that less light has to be shone through a glass wall, which is particularly helpful for experiments with filters.

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Other teacher information (7/9)

Information on the colour filters used in the experiment

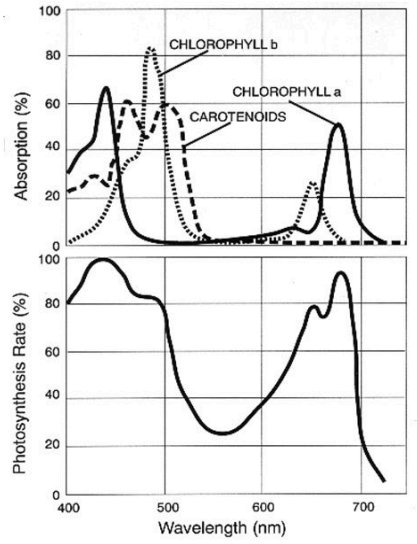
Filter colour	Maximum [nm]	Transmission [%]
Blue	452	51
Green	515	51
Yellow	604	91
Red	636	94
Grey	-	76
Colourless	-	93

Other teacher information (8/9)

Information on the influence of light colour (wavelength of light) on photosynthesis

Photosynthesis in plants is primarily fuelled by visible light (wavelengths from 400 to 700 nm) absorbed by pigment molecules (mainly chlorophyll a and b and carotenoids). Plants appear green because of chlorophyll, which is so abundant that regions of the earth appear green from space. The absorption spectrum of chloroplasts chlorophyll a and b and carotenoids as well as the photosynthesis activity spectrum of a chloroplast is shown in the figure on the right. Source:

Absorption spectrum of the most important pigments and photosynthesis activity spectrum



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Other teacher information (9/9)

Expected results of the quantitative tests: Amount of oxygen produced

1. **CO2 concentration in the water:** Tap water: low quantity; boiled water: no production, as CO2 has been expelled from the water; added sparkling water: very low production, as the CO2 gas bubbles cannot be absorbed, only CO2 dissolved in water; NaHCO3 addition: easily observable and measurable production up to a certain concentration, beyond which production decreases again.
2. **Light intensity**: the quantity decreases exponentially with increasing number of grey filters.
3. **Colour (wavelength) of the light:** Maximum for red; green: practically no production, blue and yellow: not quite as high as for red.
4. **Water temperature:** Maximum at 30°C, then reduced production again.
5. **Amount of plant mass per unit volume:** Maximum at medium plant mass, then no further increase, because of shading and interception of oxygen bubbles by the dense vegetation.

Safety instructions

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- The general instructions for safe experimentation in science lessons apply to this experiment.

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Student information

Motivation

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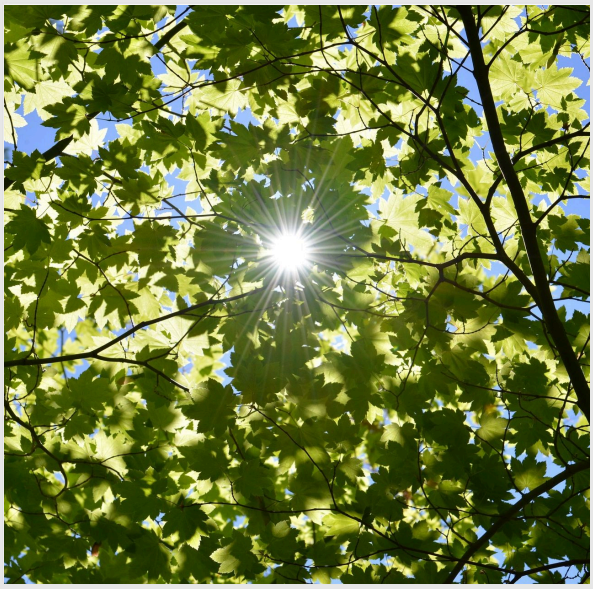

The green plant absorbs water and nutrients from the soil and carbon dioxide from the air. When irradiated with light, photosynthesis takes place, whereby the plant assimilates new, endogenous substances such as carbohydrates, proteins and fats from the absorbed substances. This produces oxygen as a by-product, which is released into the atmosphere. The assimilation capacity of green plants can be measured in various ways:

- by determining the amount of oxygen developed, as practised in this series of experiments
- also possible: through (1) determination of assimilate formation and (2) measurement of carbon dioxide consumption

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Tasks

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A. Quantitative measurement of the oxygen production of an aquatic plant as a function of

1. the CO2 concentration in the water
2. the light intensity
3. the colour (wavelength) of the light: red light, yellow light, green light, blue light
4. the water temperature
5. amount of plant mass per unit volume

B. Qualitative detection of the oxygen formed with the glowing splint test

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Equipment

Position	Material	Item No.	Quantity
1	Set Photosynthesis	64844-22	1
2	Photosynthesis lamp, LED, full spectrum, 18 W	65751-99	1
3	Wood splints, package of 100	39126-10	1
4	Sodium hydrogen carbonate, 100 g	CHE-881214431	1
5	Spatula, powder, steel, l=150mm	47560-00	1
6	CB 501 portable compact balance 500g, 0,1g	ADA-CB-501	1

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Procedure (0/7)

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Experimental setup with photosynthesis lamp and red colour filter

Test material with colour filter set

Procedure (1/7)

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General procedure for each subtest

1. Fill the beaker up to 2 cm below the rim with lukewarm tap water.
2. Add sections of an aquatic plant to the water, e.g. waterweed (*Elodea canadensis*) as follows: carefully cut the plant into sections of 1.5 cm length with a scalpel without applying pressure and place 12 of these sections of equal length into the filled beaker.
3. Place the funnel over the plant sections.
4. Fix the collection vessel with the universal holder on the rim of the beaker in such a way that no air is contained in the collection vessel or can penetrate.
5. Aim the photosynthesis lamp at the plant sections (always at the same distance - as close as possible to the beaker! -, at the same angle and with the same intensity). Now switch on the lamp and read the oxygen volume on the graduation of the collecting vessel every 5 minutes for 30 minutes and note it down.

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Procedure (2/7)

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1. Photosynthetic activity (oxygen production) of an aquatic plant as a function of the CO2 concentration in the water

1. Tap water
2. Boiled tap water
3. Carbonated mineral water (90 ml to 900 ml tap water)
4. Tap water with 2 g sodium hydrogen carbonate

Note: The 4 types of water must be at the same temperature, preferably room temperature. In the case of mineral water, no carbon dioxide must enter the collection vessel.

	Gas volume [ml]			
Measuring time [min]	**1.**	**2.**	**3.**	**4.**
0	0,0	0,0	0,0	0,0
5				
10				
15				
20				
25				
30				

Procedure (3/7)

PHYWE excellence in science

2. Photosynthetic activity (oxygen production) of an aquatic plant as a function of light intensity

1. Without filter
2. with a grey filter
3. with two grey filters

Note: the colour filters are leaned against the beaker. The lamp must be positioned so that only filtered radiation can fall into the beaker. To accelerate the formation of oxygen, the water should contain sodium hydrogen carbonate.

	Gas volume [ml]		
Measuring time [min]	**1.**	**2.**	**3.**
0	0,0	0,0	0,0
5			
10			
15			
20			
25			
30			

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Procedure (4/7)

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3. Photosynthetic activity (oxygen production) of an aquatic plant as a function of the wavelength of light

1. with red colour filter
2. with yellow colour filter
3. with blue colour filter
4. with green colour filter

Note: the colour filters are leaned against the beaker as vertically as possible. The lamp must be positioned so that only filtered radiation can fall into the beaker. Use sodium hydrogen carbonate!

	Gas volume [ml]			
Measuring time [min]	**1.**	**2.**	**3.**	**4.**
0	0,0	0,0	0,0	0,0
5				
10				
15				
20				
25				
30				

Procedure (5/7)

PHYWE excellence in science

4. Photosynthetic activity (oxygen production) of an aquatic plant as a function of water temperature

1. 18°C or room temperature
2. 25°C
3. 30°C
4. 35°C

Please note: Use sodium hydrogen carbonate!

	Gas volume [ml]			
Measuring time [min]	**1.**	**2.**	**3.**	**4.**
0	0,0	0,0	0,0	0,0
5				
10				
15				
20				
25				
30				

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Procedure (6/7)

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5. Photosynthetic activity (oxygen production) of an aquatic plant as a function of the amount of plant mass under the funnel

1. 12 shoot sections
2. 14 shoot sections
3. 16 shoot sections
4. 18 shoot sections

Please note: Use sodium hydrogen carbonate!

	Gas volume [ml]			
Measuring time [min]	**1.**	**2.**	**3.**	**4.**
0	0,0	0,0	0,0	0,0
5				
10				
15				
20				
25				
30				

Procedure (7/7)

PHYWE excellence in science

B. Qualitative detection of the oxygen formed with the glowing splint test

1. This experiment requires a sufficient amount of oxygen, so collect at least 2 ml of oxygen in the collecting vessel.
2. Separate the universal holder from the drip tray and remove it upwards.
3. Close the collecting vessel with the stopper while it is still under water and remove it from the water. Make sure that no air gets into the collection vessel.
4. Light a splint, let it burn for a short while and then gently blow out the flame so that the splint is still glowing.
5. Remove the plug from the collecting vessel, the opening of which is at the top, and immediately hold the glowing splint in the gas in the collecting vessel without hesitation.

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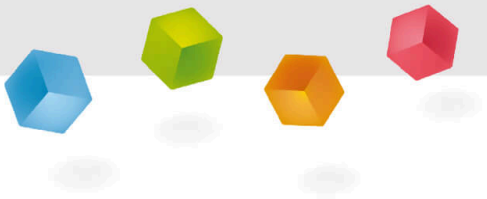

Report

Task 1

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Which statements are correct?

- [ ] The photosynthesis rate is higher with blue, yellow or red light than with green light.
- [ ] The photosynthesis rate is very low in red light.
- [ ] The photosynthesis rate is very high in green light.
- [ ] If a lot of oxygen is produced under light, the photosynthesis rate is also high.

Check

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Task 2

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Which statement is correct?

- In the glowing splint test, the splint starts to burn brightly again when it is held in the container with carbon dioxide.
- Carbon dioxide can be detected with the glowing splint test.
- In the glowing splint test, the splint starts to burn brightly again when it is held in the container with oxygen.
- Oxygen can be detected with the glowing splint test.

Task 3

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Drag the words to the correct places

The green plant absorbs water and nutrients from the _____ and _____ from the _____. When irradiated with light, _____ takes place, whereby the plant assimilates new, endogenous substances such as carbohydrates, proteins and fats from the absorbed substances. This produces _____ as a by-product, which is released into the atmosphere. The easiest way to measure the _____ of green plants is to determine the amount of oxygen produced.

- oxygen
- air
- photosynthesis
- assimilation capacity
- soil
- carbon dioxide

Check

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Task 4

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Which statements are correct? The plant produces the most oxygen at ...

- [ ] ... minimal shielding of the light
- [ ] ... maximum ambient temperature
- [ ] ... the densest plant mass
- [ ] ... maximum presence of carbon dioxide gas bubbles in the water
- [ ] ... the highest photosynthesis rate.

Check

Slide	Score / Total
Slide 26: Photosynthesis rate	0/2
Slide 27: Glowing splint test	0/1
Slide 28: Photosynthesis	0/6
Slide 29: Oxygen production	0/2

Total amount 0 / 11

Solutions Repeat

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