# Light intensity and the rate of photosynthesis

Answers, marking points and revision notes | AQA Combined Science 8464 and AQA GCSE Biology 8461

**GCSE science required practicals**

This practical online

## Answers

**1** Look at Tomasz and Priya's investigation.

a. Name the independent variable.

b. Name the dependent variable.

(2 marks)

a) The distance of the lamp from the pondweed.

b) The number of bubbles of oxygen given off per minute.

**Marking points**

- Independent: distance of the lamp (or light intensity)
- Dependent: number of bubbles per minute (rate of photosynthesis)

**2** Give one control variable in this investigation and explain why it must be kept the same. (2 marks)

The temperature of the solution. A higher temperature would speed up the enzymes that control photosynthesis, so the rate would change for a reason other than light.

**Marking points**

- A sensible control variable, such as temperature, carbon dioxide concentration or the same pondweed
- A matching reason, such as temperature affects enzyme activity or carbon dioxide is also a limiting factor

**3** Explain why the pondweed is placed in sodium hydrogencarbonate solution rather than plain tap water. (2 marks)

Sodium hydrogencarbonate releases carbon dioxide into the water. This means the plant has plenty of carbon dioxide, so carbon dioxide does not limit the rate and only light intensity is being tested.

**Marking points**

- It provides (dissolved) carbon dioxide
- So carbon dioxide is not a limiting factor

**4** Describe one hazard in this practical and how the risk can be reduced. (2 marks)

The lamp bulb can get hot and burn your hand. Use an LED lamp and only hold it by the base, letting it cool before moving it away.

**Marking points**

- A hazard, such as a hot lamp or water near mains electricity
- A matching precaution, such as using an LED lamp or keeping the solution away from the plug


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**5** Describe the pattern in the mean results. (2 marks)

As the lamp is moved further away, the mean number of bubbles per minute decreases. The fall is steep at first and then gets smaller, from 58.7 at 10 cm to 10.0 at 50 cm.

**Marking points**

- As distance increases, the rate (bubbles per minute) decreases
- The decrease is not linear: it is largest at short distances and levels off, quoting data

**6** Identify the anomalous result in the table and say what Tomasz and Priya should do with it. (2 marks)

The 25 bubbles per minute at 40 cm (count 2) is anomalous, as the other counts were 15 and 14. They should leave it out of the mean, or repeat that count.

**Marking points**

- Identifies 25 at 40 cm
- Leave it out when calculating the mean (or repeat that reading)

**7** Calculate the mean number of bubbles per minute at 40 cm. Do not include the anomalous result. (2 marks)

(15 + 14) / 2 = 14.5 bubbles per minute

Leave out 25

15 + 14 = 29

29 / 2 = 14.5

Mean = 14.5 bubbles per minute

**Marking points**

- Adds 15 and 14 and divides by 2
- 14.5 bubbles per minute

**8** Priya tried a longer count. With the lamp at 30 cm she counted 115 bubbles in 5 minutes.

Calculate the rate of photosynthesis in bubbles per minute. Say whether it agrees with the table. (2 marks)

115 / 5 = 23 bubbles per minute. This agrees with the mean of 23.0 in the table.

Rate = number of bubbles / time

Rate = 115 / 5

Rate = 23 bubbles per minute

**Marking points**

- 115 / 5 = 23 bubbles per minute
- States it agrees with the table mean at 30 cm


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**9** Calculate the percentage decrease in the mean rate when the lamp is moved from 10 cm to 50 cm. Give your answer to the nearest whole number. Show your working. (3 marks)

Decrease = 58.7 - 10.0 = 48.7

Percentage decrease = 48.7 / 58.7 x 100 = 83%

Decrease = 58.7 - 10.0 = 48.7 bubbles per minute

Percentage decrease = (48.7 / 58.7) x 100

= 82.96...

= 83%

**Marking points**

- Finds the decrease: 58.7 - 10.0 = 48.7
- Divides by the starting value and multiplies by 100
- 83%

**10** **Higher tier**

Light intensity is inversely proportional to the square of the distance from the lamp.

a. The lamp is moved from 10 cm to 30 cm. By what factor does the light intensity change?

b. Using relative light intensity = 10 000 / distance$^2$, calculate the relative light intensity at 40 cm.

Show your working. (3 marks)

a) The distance is 3 times greater, so the light intensity is 1 / $3^2$ = 1/9 of what it was (it falls by a factor of 9).

b) 10 000 / $40^2$ = 10 000 / 1600 = 6.25 (arbitrary units)

a) 30 / 10 = 3

$3^2$ = 9

New intensity = 1/9 of the old intensity

b) $40^2$ = 1600

10 000 / 1600 = 6.25

Relative light intensity = 6.25 arbitrary units

**Marking points**

- Distance trebles so intensity is 1/9 (decreases by a factor of 9)
- Squares 40 to get 1600
- 6.25 arbitrary units

**11** **Higher tier**

Halima repeated the investigation and found that moving the lamp from 10 cm to 5 cm made almost no difference to the rate. Explain why. (3 marks)

At 10 cm the light is already very bright, so light is no longer the limiting factor. Something else, such as the amount of carbon dioxide or the temperature, is now limiting the rate. Adding more light cannot make photosynthesis go any faster until that other factor is increased.

**Marking points**

- Light intensity is no longer the limiting factor
- Another factor (carbon dioxide concentration or temperature) is now limiting
- So extra light does not increase the rate


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**12** Counting bubbles is not a very accurate way of measuring the rate. Suggest an improvement and explain why it gives a more accurate measurement.

(2 marks)

Collect the gas in an upturned measuring cylinder or a gas syringe and measure the volume given off in a set time. Bubbles are not all the same size, so measuring the volume gives a truer measure of how much oxygen is made.

**Marking points**

- Collect the gas and measure its volume (measuring cylinder, gas syringe or capillary tube)
- Because bubbles vary in size (or can be missed when they come off fast)

**13** The lamp in a second group's experiment was a filament bulb, and the temperature of their solution rose from 21 °C to 27 °C at the closest distance. Explain how this affects whether their results are valid.

(2 marks)

Temperature was not controlled, so the extra bubbles at short distances could be partly caused by the warmer water speeding up the enzymes, not just by the brighter light. The test is no longer fair, so the results are less valid. A heat shield or an LED lamp would fix this.

**Marking points**

- Temperature changed, so it was not a fair test (results less valid)
- Higher temperature also increases the rate, so the effect of light cannot be separated


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**14** Plan an investigation to find out how the concentration of sodium hydrogencarbonate (carbon dioxide) affects the rate of photosynthesis in pondweed. (6 marks)

Make up sodium hydrogencarbonate solutions of 0.0%, 0.5%, 1.0%, 1.5% and 2.0% by diluting a stock solution with distilled water, using a measuring cylinder. Put the same volume, 250 $cm^3$, of the first solution into a beaker. Cut a 6 cm piece of pondweed, weigh it down with a paper clip and place it under an upturned glass funnel in the beaker, cut end upwards. Fill a 10 $cm^3$ measuring cylinder with the same solution and turn it upside down over the stem of the funnel so the gas collects in it. Place an LED lamp 15 cm away, measured with a ruler, and keep this distance the same for every test. Stand the beaker in a water bath at 25 °C to keep the temperature steady. Leave the pondweed for 2 minutes to adjust, then collect the gas for 5 minutes and read the volume. Repeat three times for each concentration and work out a mean, leaving out any anomalous results. Use the same species and length of pondweed each time. Plot the mean volume per minute against concentration to see the pattern.

**Marking points (any 6, with the method in a logical order)**

- Uses a range of at least five different concentrations of sodium hydrogencarbonate
- Same volume of solution each time
- Same length or mass of the same type of pondweed
- Light intensity kept constant: lamp at a fixed measured distance
- Temperature controlled, for example with a water bath
- Leaves the pondweed to adjust before measuring
- Measures bubbles or gas volume over a fixed time
- Repeats each concentration and calculates a mean
- Plots rate against concentration

**How it is marked**

- 5-6 marks: a clear, logical plan that someone else could follow; changes concentration over a sensible range, measures rate properly over a fixed time, controls light, temperature and pondweed, and repeats to get means.
- 3-4 marks: a workable plan with most of the main steps, but some controls or details such as timing or repeats are missing or vague.
- 1-2 marks: a few relevant ideas, such as putting pondweed in different solutions and counting bubbles, with no clear order and few controls.

## Revision notes: the method

**Aim:** To find out how the distance of a lamp, and so the light intensity, affects the rate of photosynthesis in pondweed.

**Equipment**

- Fresh pondweed (for example Elodea or Cabomba)
- Boiling tube in a rack
- LED lamp (gives out very little heat)
- Metre ruler
- Sodium hydrogencarbonate solution (supplies carbon dioxide)
- Paper clip to weigh the pondweed down
- Stopwatch
- Thermometer


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- Beaker of water (optional heat shield if a filament lamp is used)

### Method

1. Fill a boiling tube with sodium hydrogencarbonate solution and stand it in a rack.
2. Cut a 6 cm length of pondweed, attach a paper clip near the cut end and place it in the tube with the cut end at the top.
3. Darken the room and place the lamp so its bulb is 10 cm from the pondweed, measured with a metre ruler.
4. Leave the pondweed for 2 minutes so it adjusts to the new light level.
5. Count the number of bubbles that rise from the cut end in 1 minute.
6. Repeat the count twice more at this distance and work out a mean.
7. Check the temperature of the solution with a thermometer and keep it the same throughout.
8. Move the lamp to 20 cm, 30 cm, 40 cm and 50 cm, repeating steps 4 to 6 each time.
9. Calculate the mean number of bubbles per minute for each distance and plot a graph of rate against distance.

### Variables

- **Independent:** Distance of the lamp from the pondweed (which changes the light intensity).
- **Dependent:** Rate of photosynthesis, measured as the number of oxygen bubbles released per minute.
- **Control:** Temperature of the solution, because enzymes in photosynthesis work faster when warmer; Concentration of sodium hydrogencarbonate, because carbon dioxide is also a limiting factor; The same piece and length of pondweed; The same lamp and the same background light (room darkened); Time allowed to adjust before counting

### Hazards

| Hazard | What could happen | How to reduce the risk |
|---|---|---|
| Lamp gets hot | Burns to the fingers when moving it | Use an LED lamp and do not touch the bulb; let it cool before packing away |
| Water near mains electricity | Electric shock if the solution is spilt on the lamp or socket | Keep the boiling tube in a rack away from the plug and mop up spills at once |
| Darkened room | Tripping over bags or stools | Clear bags away and keep a little light on near the exit |

### Key points

- The gas in the bubbles is oxygen, a product of photosynthesis, so more bubbles per minute means a faster rate.
- Moving the lamp further away lowers the light intensity, so the rate falls.
- Light intensity is proportional to 1 / distance$^2$ (Higher): doubling the distance gives one quarter of the light.
- A filament lamp also heats the water, so use an LED or a heat shield to keep temperature controlled.
- Bubbles can be different sizes, so collecting the gas in a measuring cylinder or gas syringe gives a more accurate measure of volume.
- Leave the pondweed to adjust for a couple of minutes after each move before counting.


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