

Bubbles and Sensors: Two Datasets on Light and Photosynthesis

Learning target: I can graph and calculate from data on oxygen bubbles and carbon dioxide levels to show how light affects what a plant takes in and gives off, and explain why a plant in the dark still changes the air.

Data and graphing About 40 min Individual MS-LS1-6 · practice data analysis independent practice

Standards connections

MS-LS1-6 (practice): Students analyze evidence that light drives a plant's uptake of carbon dioxide and release of oxygen, the data they will cite in an explanation of photosynthesis's role in moving matter and energy. No biochemical mechanism is involved.

Purpose: practice · **Time:** about 40 minutes · **Format:** individual

Answers with reasoning

Part A: Bubbles from a water plant

A student placed a sprig of elodea, a common aquarium plant, in a beaker of water with a pinch of baking soda (a source of dissolved carbon dioxide). He set a lamp at a measured distance, waited two minutes, and counted the bubbles rising from the cut stem in one minute. He repeated the count three times at each distance, then covered the beaker with a box and turned the lamp off for the last set. The water temperature stayed at 22 °C throughout.

Bubbles per minute from an elodea sprig at different lamp distances (teaching dataset)

Simulated teaching dataset: the numbers are invented to be realistic, not measured.

Lamp distance (cm)	Trial 1 (bubbles/min)	Trial 2 (bubbles/min)	Trial 3 (bubbles/min)
10	31	29	33
20	21	23	22
30	14	15	13
40	8	9	7
50	4	3	5
Dark (lamp off, box on)	0	0	0

Simulated data for teaching. Bubbles from a cut elodea stem in light are mostly oxygen.

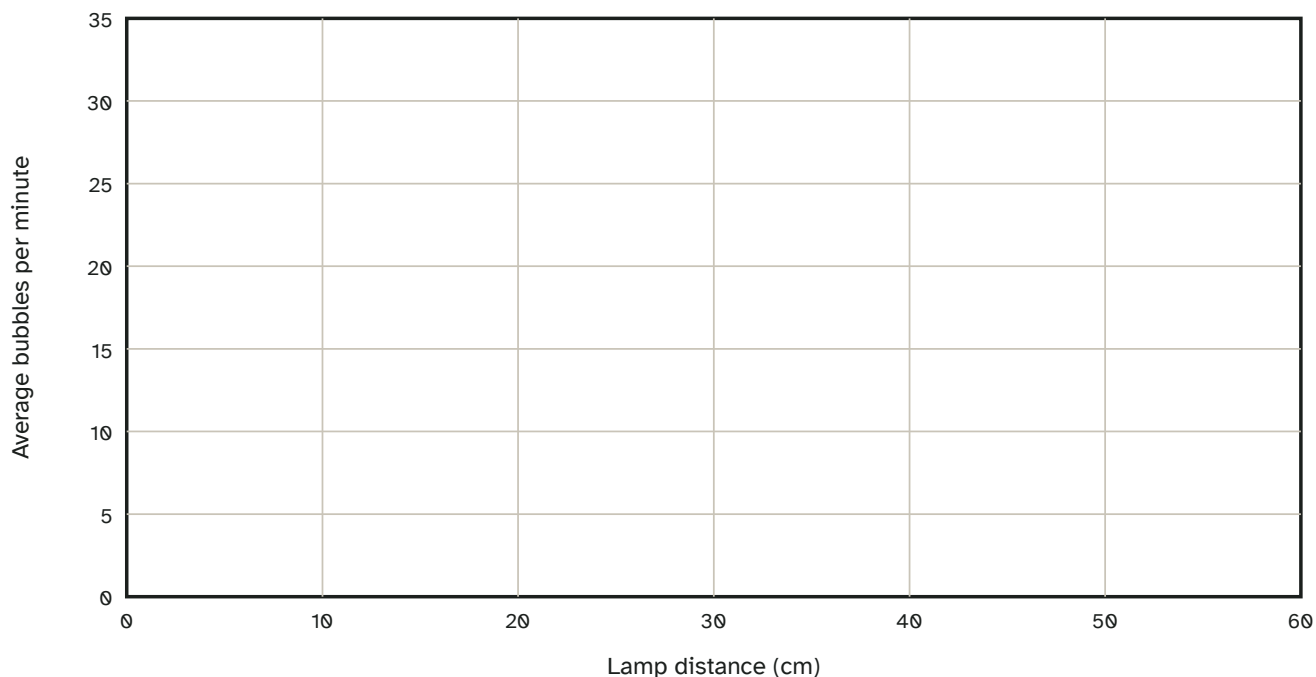
1. Complete the table: add the three trials and divide by 3. Show one full calculation below the table.

Answer: 10 cm: $31 + 29 + 33 = 93$; $93 \div 3 = 31$. 20 cm: $21 + 23 + 22 = 66$; $66 \div 3 = 22$. 30 cm: $14 + 15 + 13 = 42$; $42 \div 3 = 14$. 40 cm: $8 + 9 + 7 = 24$; $24 \div 3 = 8$. 50 cm: $4 + 3 + 5 = 12$; $12 \div 3 = 4$. Dark: 0; 0.

Why: All sums divide evenly by 3 by design, so averages are whole numbers of bubbles per minute.

Also acceptable: None.

Average bubbles per minute versus lamp distance



2. Describe the shape of your graph. Is the drop in bubbles the same size for each 10 cm step, or does it change? Use two numbers from your table.

Answer: The curve falls steeply at first and then flattens: from 10 cm to 20 cm the average drops by 9 (31 to 22), but from 40 cm to 50 cm it drops by only 4 (8 to 4). The drop is not the same size for each step; it gets smaller as the lamp moves away.

Why: The data are curved, not linear, because light reaching the plant falls off quickly with distance. Students need two numbers and the idea that the steps shrink.

Also acceptable: Accept 'the first steps lose more bubbles than the later steps.'

- Describes a falling curve that flattens
- Cites two numbers from the table
- States the drop per step is not constant

3. By what percent did the average bubble rate fall between 10 cm and 50 cm? Show the subtraction and the division.

Answer: $31 - 4 = 27$ bubbles per minute lost. $27 \div 31 = 0.87$, so about 87 percent.

Why: Percent decrease is the change divided by the starting value.

Also acceptable: Accept 87.1 percent or 'about 87 percent.' A student who divides by 4 (675 percent) has used the wrong base; give partial credit for the subtraction.

4. Use your graph to predict the average bubble rate at 15 cm and at 70 cm. Explain how you made each prediction.

Answer: At 15 cm: between 31 and 22, about 26 or 27 bubbles per minute, read from the curve between the two points. At 70 cm: close to 0, perhaps 1 or 2 bubbles per minute, because the curve is flattening toward zero and the dark value is 0.

Why: The first is interpolation, the second extrapolation. Students should note that the 70 cm prediction is less certain because it lies outside the data.

Also acceptable: Accept 24 to 28 for 15 cm and 0 to 3 for 70 cm.

- 15 cm prediction between 22 and 31
- 70 cm prediction near zero
- Explains reading the curve or the trend

5. In the dark the plant made zero bubbles. Does that mean the plant stopped doing everything? Explain what the zero does and does not tell you.

Answer: No. Zero bubbles means the plant released no measurable oxygen gas in the dark. It does not mean the plant stopped everything: its cells still use sugar for energy and still release carbon dioxide, which does not bubble out in this setup. The count measures only oxygen release, not all plant activity.

Why: This item targets the belief that plants 'turn off' in the dark. Part B gives the evidence for continued activity.

Also acceptable: Accept 'it is still alive and using its stored food.'

- States zero means no oxygen release
- States the plant is still active, using sugar or releasing carbon dioxide

6. Counting bubbles is a quick way to measure oxygen, but not a perfect one. Give two reasons the count might not match the true amount of oxygen produced, and one way to improve the measurement.

Answer: Reasons, any two: bubbles are not all the same size, so ten small bubbles may hold less gas than five large ones; some oxygen dissolves into the water instead of forming bubbles; the bubbles may contain some other gas besides oxygen; counting by eye misses very small or very fast bubbles. Improvement: collect the gas in an upside-down water-filled tube and measure its volume, or use a dissolved-oxygen sensor.

Why: Measurement limits are part of data analysis; the volume method is the standard improvement.

Also acceptable: Accept 'use a longer counting time and more trials' as an improvement.

- Two valid limitations
- One valid improvement

Part B: Carbon dioxide inside sealed jars

A second student put a leafy pothos cutting in each of two large sealed jars with a carbon dioxide sensor inside. Jar 1 sat under a bright lamp. Jar 2 sat inside a dark box. A third sealed jar, with a sensor but no

plant, sat under the same lamp as Jar 1. All three started at 800 parts per million (ppm) of carbon dioxide; normal outdoor air is a little above 400 ppm. The sensors were read every 10 minutes.

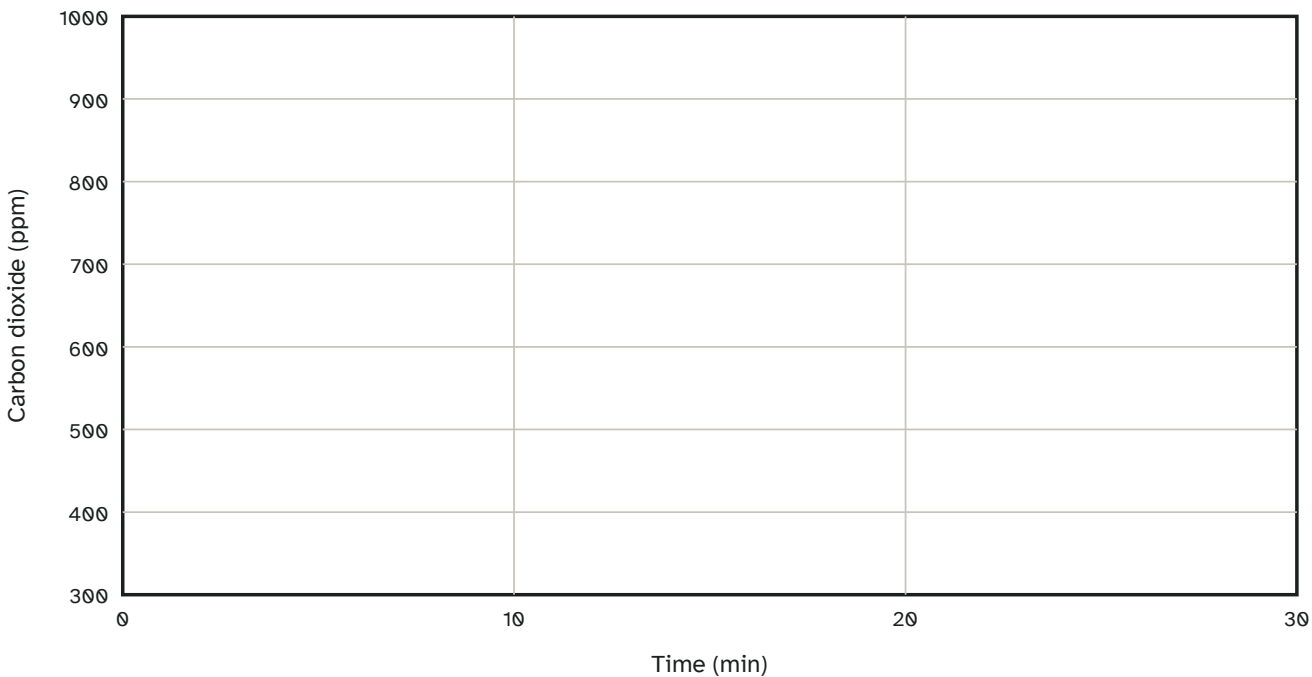
Carbon dioxide level in three sealed jars (teaching dataset)

Simulated teaching dataset: the numbers are invented to be realistic, not measured.

Time (min)	Jar 1: plant in light (ppm)	Jar 2: plant in dark (ppm)	Jar 3: no plant, in light (ppm)
0	800	800	800
10	650	860	800
20	500	920	801
30	350	980	800

Simulated data for teaching. ppm = parts per million. Realistic for a leafy cutting in a 4 liter jar.

Carbon dioxide level versus time in three sealed jars



7. Calculate the rate of change of carbon dioxide for each jar in ppm per minute over the 30 minutes. Use a minus sign for a falling level. Show your work for all three.

Answer: Jar 1: $(350 - 800) \div 30 = -450 \div 30 = -15$ ppm per minute. Jar 2: $(980 - 800) \div 30 = 180 \div 30 = +6$ ppm per minute. Jar 3: $(800 - 800) \div 30 = 0$ ppm per minute.

Why: Ending minus starting, divided by 30 minutes. Signs matter: Jar 1 falls, Jar 2 rises, Jar 3 is flat.

Also acceptable: Accept Jar 3 as 'about 0' given the 801 reading at 20 minutes.

8. What is Jar 3 for? What would it have meant if Jar 3's level had also fallen?

Answer: Jar 3 is the control: it shows that the lamp, the jar and the sensor by themselves do not change the carbon dioxide level, so any change in Jar 1 is due to the plant. If Jar 3 had also fallen, the drop in Jar 1 could have been caused by the lamp or a leaky jar, and the plant's effect could not be separated from it.

Why: Students should name the control's role and what a falling control would have meant.

Also acceptable: Accept 'it proves the lamp alone does nothing to the gas.'

- Identifies Jar 3 as a control or comparison
- Explains that a falling Jar 3 would have made the plant's effect unclear

9. Explain the results of Jar 1 and Jar 2 together. Your explanation must say what the plant is doing with carbon dioxide in the light and what it is doing in the dark, and must use the idea that a plant's cells use sugar for energy at all times.

Answer: In the light (Jar 1), the plant takes in carbon dioxide for photosynthesis faster than it gives any off, so the level falls. In the dark (Jar 2), photosynthesis stops, but the plant's cells keep using sugar for energy, and that releases carbon dioxide, so the level rises. The cells use sugar in the light too; the level falls anyway because photosynthesis takes in carbon dioxide faster than the cells release it. The sensor shows the balance between the two, not either one alone.

Why: Full credit needs both directions explained, the dark release attributed to the plant using sugar, and the point that sugar use continues in the light.

Also acceptable: A student who names the process of using sugar as 'cellular respiration' is correct; the term is not required.

- Light: uptake by photosynthesis exceeds release, level falls
- Dark: no photosynthesis; sugar use releases carbon dioxide, level rises
- States that sugar use happens at all times

10. Suppose the plant releases carbon dioxide from using its own sugar at the same rate in the light as in the dark. Use the Jar 2 rate to estimate how fast photosynthesis in Jar 1 was actually **removing** carbon dioxide. Show your reasoning and explain why the sensor in Jar 1 does not show this number directly.

Answer: In the dark the plant adds carbon dioxide at +6 ppm per minute, so in the light it is still adding about 6 ppm per minute from using sugar. The sensor shows a net fall of 15 ppm per minute. For the level to fall by 15 while 6 is being added, photosynthesis must remove $15 + 6 = 21$ ppm per minute. The sensor measures only the net change (removal minus addition), so it cannot show the 21 directly.

Why: This is a net-versus-gross argument built from the two rates. The assumption that the release rate is the same in light and dark is stated in the question; it is an approximation.

Also acceptable: Accept 21 ppm per minute with the reasoning; accept 'about 20' if the student rounds and explains.

11. Look back at the air plant kept in a dark cabinet in Worksheet 1, which lost mass. Use the Part B results to explain where that lost mass went.

Answer: In the dark the cabinet plant could not make sugar, but its cells kept using the sugar and starch it had stored, releasing carbon dioxide into the air, just as Jar 2's level rose. The carbon atoms that left as carbon dioxide gas are the lost mass. The plant did not shrink because water dried out; it lost matter as a gas.

Why: This closes the loop with W1: mass loss in the dark is matter leaving as carbon dioxide. Students should connect Jar 2's rising level to the cabinet plant.

Also acceptable: Accept 'it used up its stored food and breathed out the carbon as a gas.'

- Links the dark plant to Jar 2
- States the lost mass left as carbon dioxide gas from using stored sugar

Teacher notes

Both datasets are simulated. Part A's averages (31, 22, 14, 8, 4, 0) are built to fall off in a curve (the drops shrink: 9, 8, 6, 4), which is realistic because light intensity drops rapidly with distance from a small lamp; the baking soda supplies carbon dioxide so that it is not the limiting factor. Part B's rates (–15, +6 and 0 ppm per minute) are the heart of the sheet: they let students separate net change from what the plant is actually doing, and they give evidence for the accurate statement that plants use sugar for energy day and night rather than 'only breathing out carbon dioxide at night.' Keep the word 'net' in the discussion of q10. If students ask whether bubbles in Part A are pure oxygen, say they are mostly oxygen with some other dissolved gases, which is one of the q6 limitations. The extension's 53 minutes comes from $800 \div 15 \approx 53$; the real curve flattens because photosynthesis slows as carbon dioxide becomes scarce and because the plant's own release continues.

Scaffold offered to students: Rates in two steps

A rate of change is 'how much it changed' divided by 'how long it took.' Step 1: subtract the starting value from the ending value (ending – starting). If the result is negative, the level fell. Step 2: divide by the time, 30 minutes. Write the unit as ppm per minute. Example with made-up numbers: $(500 - 740) \div 30 = -240 \div 30 = -8$ ppm per minute, so the level fell 8 ppm every minute.

Extension: When does the jar stop changing?

If Jar 1 kept falling at the same rate, it would reach 0 ppm after about 53 minutes. In reality the fall slows and then stops at a low level that is not zero. Propose two reasons the rate would slow as carbon dioxide gets scarce, and sketch what the Jar 1 line would look like over 90 minutes. Then explain why Jar 2's rise would also slow eventually, even in the dark.