

The Sealed Greenhouse Ledger: Where Did the Basil's Mass Come From?

Learning target: I can use measurements of gases, water, minerals and dry mass from a sealed growth chamber to argue where a plant's new matter came from and what its energy source was.

Claim, evidence, reasoning About 40 min Individual MS-LS1-6 · assesses writing data analysis

Standards connections

MS-LS1-6 (assesses): The CER asks for a scientific explanation, based on evidence, of how matter moves into a plant through photosynthesis and where the energy comes from. It traces matter and energy only; no biochemical mechanism is required, which respects the assessment boundary.

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

Answers with reasoning

The scenario

A plant research lab grows basil in two identical sealed, clear chambers. The plants sit in trays of water mixed with minerals; there is no soil. Every gram that goes into or out of each chamber is recorded on a ledger, the way a bank records money. Chamber A gets bright lamps for 14 hours a day. Chamber B is kept dark. Both run for 30 days at the same temperature. Because weighing a living plant includes the water inside it, the lab measures **dry mass**: a matched set of plants was dried in an oven and weighed on day 0, and the chamber plants were dried and weighed on day 30. The numbers below are a teaching dataset, invented to be realistic and to add up cleanly.

Thirty-day ledger for two sealed basil chambers (teaching dataset)

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

Item	Chamber A: lit 14 h per day	Chamber B: dark
Dry mass of plants, day 0 (g)	40	40
Dry mass of plants, day 30 (g)	166	36
Carbon dioxide added to keep the level steady (g)	176	0
Carbon dioxide removed because the level kept rising (g)	0	6
Oxygen removed because the level kept rising (g)	128	0
Oxygen added because the level kept falling (g)	0	4
Water taken from the tray by the plants (g)	9400	310
Water collected as condensation from the air (g)	9328	312

Item	Chamber A: lit 14 h per day	Chamber B: dark
Minerals taken up from the tray solution (g)	6	0.3
Hours of light over 30 days	420	0

Simulated data for teaching. 'Added' means pumped into the chamber to keep the level steady; 'removed' means drawn out of the chamber and weighed.

How to read the water rows — Plants pull far more water from the tray than they keep; most of it evaporates from the leaves and the chamber collects it again as condensation. The water the plants actually **kept** is the difference between the two water rows.

Warm-up: organize the evidence

1. Calculate the change in dry mass for each chamber (day 30 minus day 0). Then calculate how much water each chamber's plants kept (taken minus condensed). Show your work.

Answer: Chamber A dry mass: $166\text{ g} - 40\text{ g} = +126\text{ g}$. Chamber B dry mass: $36\text{ g} - 40\text{ g} = -4\text{ g}$. Water kept, Chamber A: $9400\text{ g} - 9328\text{ g} = 72\text{ g}$. Water kept, Chamber B: $310\text{ g} - 312\text{ g} = -2\text{ g}$ (the dark plants gave off 2 g more water than they took).

Why: The dry-mass changes are the central numbers. The negative water figure for Chamber B is real: using sugar with oxygen produces a little water.

Also acceptable: Accept 'about 0' for Chamber B's water if the student notes it is slightly negative.

2. For Chamber A, add up all the matter that went **into** the plants (carbon dioxide added, water kept, minerals) and all the matter that came **out** or stayed as new plant (oxygen removed plus the dry-mass gain). Compare the two totals. What does the comparison show?

Answer: In: 176 g (carbon dioxide) + 72 g (water kept) + 6 g (minerals) = 254 g . Out or kept: 128 g (oxygen) + 126 g (dry-mass gain) = 254 g . The totals match: every gram that entered the plants is accounted for as either new plant material or oxygen released. Matter was conserved.

Why: The balanced ledger is the quantitative form of conservation of matter and is the backbone of the CER reasoning.

Also acceptable: Accept a one- or two-gram mismatch if the student rounded; the point is that the totals are essentially equal.

3. What percent of Chamber A's dry-mass gain could the minerals account for at most? Show the division. What does the rest of the gain have to be made of?

Answer: $6\text{ g} \div 126\text{ g} = 0.048$, about 5 percent. The other 95 percent of the gain (about 120 g) has to be made from the carbon dioxide and water that entered, because those are the only other inputs on the ledger.

Why: This mirrors van Helmont's willow (W3): the mineral share is small and the rest must come from the gas and water.

Also acceptable: Accept 4.8 percent or 'about 5 percent.'

Your argument

Answer: Claim: The basil's 126 g of new dry matter was built mostly from carbon dioxide taken from the air, with a smaller share from water and only about 5 percent from minerals; the energy came from the lamps' light. Evidence: (1) Chamber A took in 176 g of carbon dioxide and 72 g of water (9400 – 9328) and only 6 g of minerals while gaining 126 g of dry mass; minerals can explain at most 5 percent ($6 \div 126$). (2) The ledger balances: $176 + 72 + 6 = 254$ g in, and 128 g of oxygen out plus 126 g of new plant = 254 g, so the new mass is accounted for by the gas and water that entered. (3) Chamber B, identical except for 0 hours of light, took in no carbon dioxide, lost 4 g of dry mass, used 4 g of oxygen and gave off 6 g of carbon dioxide. (4) Chamber A released 128 g of oxygen, a product that appears only in the lit chamber. Reasoning: Matter is never created or destroyed, so the 126 g of new basil must have come from substances that entered the plants, and the ledger shows those were carbon dioxide, water and a little mineral; that is why the in and out totals have to match. Light was necessary (no light, no gain) but light has no mass and cannot be a source of matter; its energy was captured and is now stored as chemical energy in the sugar, starch and cellulose that make up the new 126 g. Chamber B shows what plants do with that stored sugar: in the dark they keep using it for energy, reacting it with oxygen and giving off carbon dioxide, which is why the dark plants lost matter instead of gaining it.

Why: This is the solved model response. Full credit requires a claim naming carbon dioxide (largest share), water and minerals (small share) plus light as the energy source; at least three numbered evidence items including an A-versus-B comparison; and reasoning that uses conservation of matter, separates energy from matter, and interprets Chamber B's losses as sugar use.

Also acceptable: A student who claims 'air and water' without separating their shares is acceptable at the claim level if the evidence gives the 176 g and 72 g figures. A student who claims water as the main source has misread the dry-mass rows and can earn evidence credit only.

- Claim names carbon dioxide as the main matter source, water as a secondary source, minerals as minor, and light as the energy source
- At least three evidence items with ledger numbers
- At least one evidence item compares Chamber A with Chamber B
- Reasoning uses conservation of matter to explain the balanced ledger
- Reasoning states that light is energy, not matter, and that its energy is stored in the new plant material
- Reasoning explains Chamber B's dry-mass loss as the plants using stored sugar

4. A classmate says: 'Plants are mostly water, so the water is obviously where the basil's mass came from.' Use the dry-mass rows and the water rows to respond.

Answer: A living basil plant is mostly water, which is exactly why the lab measured dry mass: all the water was driven off before weighing. The 126 g gain is dry matter, not water. The water rows show the plants kept only 72 g of the 9400 g they took, and the ledger needs 176 g of carbon dioxide to balance, so water is a real but smaller part of the new dry matter.

Why: The classmate confuses the water content of living tissue with the source of the plant's solid material. The dry-mass method removes that confusion.

Also acceptable: Accept 'water is part of it (72 g) but carbon dioxide is more (176 g).'

- Explains that dry mass excludes water
- Uses the water-kept figure or the carbon dioxide figure to show water is not the main source of dry matter

5. The lab plans a Chamber C: lit 14 hours a day like Chamber A, but with a device that strips carbon dioxide out of the air. Predict the day-30 dry mass and explain what result would **confirm** your claim and what result would **force you to change** it.

Answer: Prediction: Chamber C's plants would gain little or no dry mass, probably losing some (near 36 to 40 g), because without carbon dioxide they have no source of carbon even with light. A result near 36 to 40 g would confirm the claim that carbon dioxide is the main matter source. A gain close to Chamber A's 166 g would force a change: it would mean the plants built matter from water and minerals alone, and carbon dioxide was not needed.

Why: This asks students to state in advance what would confirm or overturn their claim. The predicted result follows from carbon dioxide being the only carbon source on the ledger.

Also acceptable: Accept a prediction of a small gain if the student explains the plants may use carbon dioxide already in the chamber air before the stripper removes it.

- Predicts little or no gain
- States a confirming result and a disconfirming result

Scoring rubric

Criterion	4 • Exemplary	3 • Proficient	2 • Developing	1 • Beginning
Claim	Names carbon dioxide as the main source of new matter, water as a secondary source, minerals as minor, and light as the energy source, in one clear statement.	Names carbon dioxide and water as matter sources and light as the energy source, without shares or without minerals.	Names only one matter source, or names light as a matter source.	No claim, or a claim that contradicts the ledger (for example, soil or water alone).
Evidence	Three or more ledger figures with units, including an A-versus-B comparison, each tied to what it rules in or out.	Three ledger figures, but one is not tied to the claim or the A-versus-B comparison is missing.	One or two figures, or figures copied without saying what they show.	Evidence missing, invented, or contradicts the ledger.
Reasoning	Uses conservation of matter to explain the balanced ledger, distinguishes light energy from matter, and interprets Chamber B's loss as sugar use with oxygen.	Uses conservation of matter and separates energy from matter, but does not explain Chamber B's loss.	Restates the evidence or gives a general statement that plants need light, without the conservation idea.	No reasoning, or reasoning that treats light as matter or treats the chamber as not sealed.
Scientific language and accuracy	Uses dry mass, reactant, product, carbon dioxide, oxygen and chemical energy correctly; energy is 'stored in' or 'captured by' the plant material, never 'turned into' it; no errors.	Terms mostly correct; one slip (for example, 'weight' for mass, or 'breathes' for takes in).	Several terms used loosely (sugar and starch confused with water; oxygen and carbon dioxide swapped once).	Scientific language absent or consistently wrong.

Teacher notes

The ledger is simulated and built from the photosynthesis ratios so it balances exactly: 176 g of carbon dioxide and 72 g of water make 120 g of sugar-type material and 128 g of oxygen (the 264 : 108 : 180 : 192 ratio of the equation), and 6 g of minerals brings the dry-mass gain to 126 g. Chamber B's figures follow the reverse reaction: 4 g of dry mass plus 4 g of oxygen gives 6 g of carbon dioxide and about 2 g of water,

which is why the condensation slightly exceeds the water taken. The 9400 g of water taken is realistic for 20 basil plants over a month; most of it is lost from leaves. Keep the conversation on tracing matter and energy; do not open the biochemical steps. If students ask why Chamber B's plants did not die, say 30 days on stored starch is survivable for a leafy plant, though they would be weak and pale. The extension's word equation is $\text{sugar} + \text{oxygen} \rightarrow \text{carbon dioxide} + \text{water}$, with energy released for the plant's cells.

Scaffold offered to students: A two-column ledger before writing

On scrap paper draw two columns for Chamber A: 'In' and 'Out or kept.' Copy the carbon dioxide added, water kept and minerals into 'In' and the oxygen removed and the dry-mass gain into 'Out or kept.' Total each column. Then write one sentence beside each number saying what it proves (for example, '176 g of gas went in, so the air supplied matter'). Those sentences are your Evidence; the matching totals are the start of your Reasoning.

Extension: Balance Chamber B

Chamber B's plants lost 4 g of dry mass while 4 g of oxygen was added and 6 g of carbon dioxide was removed, and the water rows show about 2 g of water appeared that the plants did not take from the tray. Set up the 'In' and 'Out' ledger for Chamber B, show that it balances, and then write the word equation for what the plants in the dark were doing with their stored sugar. Explain why this reaction is, in terms of matter, the reverse of photosynthesis.