

The Sealed Vessel: How Careful Weighing Found a Law

Learning target: I can use evidence from a passage to explain how sealed-vessel experiments showed that matter is conserved, and to tell the difference between the law and the atomic explanation of it.

Reading with evidence

About 35 min

Individual

MS-PS1-5 · practice

reading

writing

Standards connections

MS-PS1-5 (practice): The passage gives the historical evidence for conservation of mass and the atomic reasoning behind it. Students practice the logic of the PE (same atoms, therefore same mass) with text evidence rather than with their own model.

Purpose: build · **Time:** about 35 minutes · **Format:** individual

Answers with reasoning

The Sealed Vessel

[1] Put a log in a fireplace and come back in the morning. The log is gone. In its place is a small heap of gray ash that weighs far less than the wood did. For centuries, people looked at that ash and drew the obvious conclusion: fire destroys matter. Part of the log, they thought, had stopped existing. It was a reasonable idea. It was also wrong, and showing why took careful weighing.

[2] The first clues came from metals, which seemed to do the opposite of wood. In the 1600s, chemists noticed that tin or lead heated in air for a long time turned into a crumbly powder that weighed more than the metal had. The English scientist Robert Boyle reported this in the 1670s. He heated tin in a sealed glass vessel, then opened the vessel and weighed the powder. It was heavier. Boyle suggested that tiny 'particles of fire' had passed through the glass and attached themselves to the metal. That explanation fit the facts he had. It missed one measurement.

[3] The missing measurement was made a century later by the French chemist Antoine Lavoisier. In the 1770s he repeated the experiment with a change that sounds small. He sealed tin inside a glass vessel, weighed the whole sealed vessel, and only then heated it. The tin turned to powder inside. He weighed the sealed vessel again. The reading had not changed. Then he broke the seal. Air hissed in, and the vessel became heavier. The amount it gained was the same as the amount the powder had gained compared with the original tin.

[4] Lavoisier saw what that meant. Nothing had passed through the glass. The tin had taken something from the air sealed inside with it, and when the vessel was opened, fresh air rushed in to replace what the tin had used up. The mass of the powder was the mass of the tin plus the mass of the part of the air it had captured. Today we know that part is oxygen and the powder is tin oxide. The work was a team effort. Lavoisier's wife, Marie-Anne Paulze Lavoisier, kept records, translated scientific papers written in English, and drew the detailed illustrations of the equipment.

[5] Precise weighing was at the center of everything Lavoisier did. He used some of the best balances in Europe and insisted that a chemist account for every bit of matter going into an experiment and every bit coming out. In 1789 he published a textbook, the *Elementary Treatise on Chemistry*, that stated the principle plainly: in every change, the quantity of matter is the same before and after. We now call this the law of conservation of matter, or conservation of mass.

[6] A law describes a pattern; it does not explain it. The explanation came from the idea that matter is made of atoms. In a chemical reaction, atoms do not appear, vanish, or turn into other kinds of atoms. They only change partners: bonds between atoms break, and new bonds form. Since every atom keeps its own mass, rearranging atoms cannot change the total. The burning log is the same story as the tin, run in reverse. Carbon and hydrogen atoms in the wood bond with oxygen atoms from the air and leave the fireplace as invisible gases, carbon dioxide and water vapor. The ash is only what did not become a gas. Add the mass of the gases to the mass of the ash and you get the mass of the wood plus the mass of the oxygen it used.

[7] So the rule for reading a balance is simple. In a closed system, where no matter can enter or leave, the mass does not change during a reaction. In an open system, the reading can fall when a gas escapes or rise when a gas joins in, and every change on the dial means matter crossed the boundary. It did not stop existing, and it did not come from nowhere. The law holds for all ordinary chemical and physical changes; changes inside an atom's nucleus follow different rules and belong to a later course. More than two centuries after Lavoisier, the sealed vessel is still the fairest test.

Questions: cite the passage

1. According to paragraph 1, what conclusion did people draw from the ash, and what evidence led them to it? Quote the two short sentences that tell you the author thinks the conclusion was understandable but wrong.

Answer: People concluded that fire destroys matter, because the ash left after a log burns weighs far less than the wood did. The two sentences: 'It was a reasonable idea. It was also wrong.'

Why: Paragraph 1 links the light ash to the belief that part of the log stopped existing; the paired short sentences signal the author's judgment.

Also acceptable: Accept a close paraphrase of the quote if the student gives the paragraph number.

- States the conclusion (fire destroys matter)
- Gives the evidence (ash weighs less than the wood)
- Quotes the two short sentences

2. Paragraph 2: What did Boyle observe, and how did he explain it? Explain why the author says his explanation 'fit the facts he had.'

Answer: Boyle observed that tin heated in a sealed glass vessel turned into a powder that weighed more than the original metal once he opened the vessel and weighed it. He explained the gain by saying tiny particles of fire passed through the glass and attached to the metal. The explanation fit his facts because the only thing he had measured was the powder getting heavier, and fire particles passing through glass would make the powder heavier; he had not weighed the sealed vessel itself before and after heating, so nothing he measured contradicted the idea.

Why: The point is that a wrong explanation can fit incomplete data; the missing measurement is the whole-vessel weighing.

Also acceptable: Accept 'he never weighed the whole sealed vessel' as the reason the explanation survived.

- Observation: the powder was heavier
- Explanation: fire particles through the glass
- Says his data did not include the measurement that would test it

3. Paragraph 3 says Lavoisier made 'a change that sounds small.' What exactly did he do differently from Boyle, and what did his two weighings of the sealed vessel show?

Answer: Lavoisier weighed the whole sealed vessel before heating and again after heating, while it was still sealed, instead of only weighing the powder after opening. The two weighings showed the same reading: the sealed vessel's mass did not change while the tin turned to powder inside.

Why: The 'small change' is weighing the closed system as a whole; paragraph 3 states the reading 'had not changed.'

Also acceptable: Accept 'he kept it sealed during the heating and weighed it both times.'

- Names weighing the sealed vessel before and after
- States the result: no change while sealed

4. Imagine Lavoisier's tin had a mass of 50.0 g and the powder inside the vessel had a mass of 52.4 g. (These numbers are made up to practice the logic.) (a) How much mass did the tin gain? (b) How much did the sealed vessel's reading change while it was sealed? (c) How much did the vessel gain when he broke the seal? Show how the passage supports each number.

Answer: (a) $52.4\text{ g} - 50.0\text{ g} = 2.4\text{ g}$ gained by the tin. (b) 0 g; paragraph 3 says the sealed vessel's reading had not changed. (c) 2.4 g; paragraph 3 says the vessel gained the same amount when opened as the powder had gained compared with the original tin, so the air that rushed in had a mass of 2.4 g.

Why: The logic is the passage's: the tin took 2.4 g of something from the sealed air, the sealed total stayed the same, and opening the vessel let in 2.4 g of fresh air to replace it.

Also acceptable: Accept (b) written as 'no change' or 'the same.' All three numbers must be consistent with each other.

5. Using paragraph 4, explain why air rushing into the opened vessel proved that nothing had passed through the glass.

Answer: If fire particles had come in through the glass, the vessel would have become heavier while it was still sealed, and no air would need to rush in when it was opened. Instead the sealed reading stayed the same and air rushed in afterward, which means the tin had used up part of the air that was already inside. The air moving in filled the space (and mass) that the tin had taken from the sealed air. So the extra mass came from inside the vessel, not through the glass.

Why: Students must connect the inrush of air to a shortage of air inside, created by the tin capturing part of it. *Also acceptable: Accept an answer that focuses only on the unchanged sealed reading if it says that rules out anything entering.*

- Explains that the sealed reading did not change, so nothing entered through the glass
- Explains that the inrush of air replaced air the tin had used up

6. Paragraph 6 begins, 'A law describes a pattern; it does not explain it.' Using paragraphs 5 and 6, state the law in your own words and then state the explanation. Make clear which is which.

Answer: The law (paragraph 5): in every change, the amount of matter is the same before and after; mass is conserved. The explanation (paragraph 6): matter is made of atoms, atoms are not created, destroyed, or changed into other kinds of atoms in a chemical reaction, they only change partners as bonds break and form, and because each atom keeps its mass, rearranging them cannot change the total.

Why: The law is the pattern; the atomic model is the reason. The student must label each.

Also acceptable: Accept 'the atoms are the same, just rearranged, so the mass is the same' as the explanation.

- Law stated as a pattern about mass before and after
- Explanation stated in terms of atoms changing partners
- Each labeled correctly

7. Paragraph 6 calls the burning log 'the same story as the tin, run in reverse.' Explain what is the same and what is reversed, and write the 'mass sentence' for the log that the paragraph gives (what added to what equals what).

Answer: Same: in both, atoms from the air (oxygen) bond with atoms of a solid, and the total mass of everything involved is unchanged. Reversed: with tin the oxygen joins the solid, so the solid gets heavier and the air gets lighter; with the log the solid's carbon and hydrogen atoms join oxygen and leave as gases, so the solid (now ash) gets lighter and the air gets heavier. Mass sentence: mass of the gases + mass of the ash = mass of the wood + mass of the oxygen used.

Why: Both are joining-with-oxygen reactions; the difference is where the products end up (solid versus gas), which is what the balance sees.

Also acceptable: Accept the mass sentence rearranged, for example 'wood + oxygen = ash + gases.'

- Identifies oxygen joining in both cases
- Explains the reversal: product stays as solid versus leaves as gas
- Writes the mass sentence with all four parts

8. A student runs a fizzing reaction in an open dish on a balance and watches the reading drop by 0.5 g. She writes, 'Half a gram of matter was destroyed.' Using evidence from at least two different paragraphs, explain what actually happened to the 0.5 g and describe how she should redesign the experiment so the balance tells the full story.

Answer: The 0.5 g was not destroyed. The fizzing produced a gas, and in an open dish the gas escaped into the room (paragraph 7: in an open system the reading falls when a gas escapes, and every change means matter crossed the boundary). The atoms in that gas still exist and still have their mass (paragraph 6: atoms do not vanish; they only change partners). To let the balance tell the full story she should run the reaction in a sealed, rigid container, weigh the whole sealed container before and after (paragraph 3, Lavoisier's method), and expect the reading to stay the same; if she then opens it, the reading should drop by about 0.5 g as the gas leaves.

Why: Full credit needs the gas-escape explanation, the conservation reasoning, and a sealed-system redesign that weighs the whole container, with evidence from two or more paragraphs.

Also acceptable: A student who adds 'the sealed container must be strong enough not to leak or burst' is thinking like Lavoisier; credit it. A student who notes that a sealed bag would puff up and read a little low because the air lifts it is also correct.

- Says the gas escaped and carried the mass with it
- Says the atoms still exist with their mass
- Redesign: sealed container weighed as a whole before and after
- Evidence cited from at least two paragraphs

Teacher notes

The passage is about 700 words. Historical facts are checked: Robert Boyle reported in the 1670s that metals heated in sealed glass gained weight after the vessel was opened and attributed the gain to particles of fire passing through the glass; Antoine Lavoisier's sealed-vessel experiments with tin in the 1770s showed no change while sealed and a gain on opening equal to the metal's gain; his 1789 *Traité élémentaire de chimie* states that an equal quantity of matter exists before and after every operation; Marie-Anne Paulze Lavoisier translated, recorded and illustrated his work. The numbers in q4 are invented for practice and are labeled that way on the sheet. The passage deliberately limits the law to ordinary chemical and physical changes, where the textbook says 'any other changes in matter'; nuclear changes are outside this course. Common error on q4: students give (b) as 2.4 g; remind them that the vessel was sealed, so the tin's gain came from the air already inside.

Scaffold offered to students: Two-column notes before the questions

On scrap paper, make two columns: 'Who and when' and 'What the weighing showed.' Fill a row for Boyle (1670s), Lavoisier sealed (1770s), Lavoisier opened, and the 1789 textbook. Most questions can be answered by finding the right row and rereading that paragraph. For q6 and q7, add a third row labeled 'atoms' and write one sentence from paragraph 6 that mentions bonds.

Extension: What Boyle could not have known

Boyle's explanation was wrong, but he was not careless. Write a paragraph defending Boyle: list what he measured correctly, explain what single measurement would have overturned his fire-particle idea, and then explain why a scientist today would still call his work valuable. Finish with one sentence about what this episode shows about how a scientific law gets established: is it one experiment, or something else?