

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

Name _____

Date _____

Period _____

Directions

Read the passage once straight through. Read it a second time with a pencil, numbering the paragraphs 1 to 7 and circling every number and every name. Answer the questions in complete sentences. When a question asks for evidence, quote or closely paraphrase the passage and give the paragraph number. The experiments described here are historical; do not try to repeat them.

You will need: This worksheet, Pencil, Scrap paper for two-column notes

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.

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.'

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?

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.

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

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.

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).

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.

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.

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?