The Case of the Vanishing Gas

Student Notebook/Journal Page

I am a tenth-grade student at Central High School. Last semester, my chemistry teacher challenged us to disprove a basic law of physics, the law of conservation of mass. In simple terms, this law states that mass cannot be created or destroyed. The law usually applies to chemical changes (which do not include nuclear changes). But I was asked to demonstrate how a physical change could, at least in theory, cause a loss of matter. I was given no clue about how I might do this.

Hot air balloons have intrigued scientists since the 18th-century.

After doing a lot of research online and in various books, I came upon a description of an experiment performed by a French physicist in about 1787. The man's name was Jacques Charles.

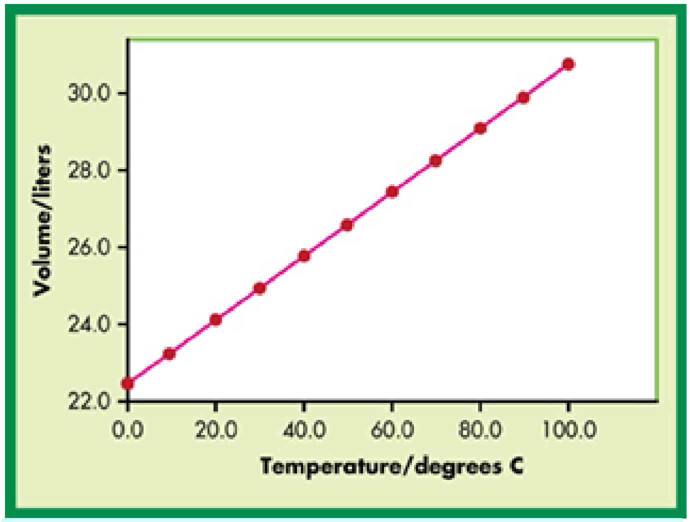
Oddly, at the time of his experiment, Charles was better known for being a balloonist than being a physicist. However, his work with balloons turned out to be related to physics. You see, Charles discovered that a balloon bag filled with hydrogen gas would rise more efficiently than a balloon bag filled with hot air. This encouraged Charles to investigate the behavior of gases in general. He conducted a famous experiment that I thought I could use to meet my challenge.

It took me a while and some advice from my teachers to design my experiment. I made sketches and outlined the steps of an experimental procedure. First, I wrote down this hypothesis: *The volume of a gas will decrease steadily as temperature decreases.*

Based on this hypothesis, I predicted that at some very cold temperature, the volume of the gas would reach zero. Because an object that has no volume cannot have mass, at some cold temperature the mass would have to disappear. My experiment was designed to find evidence to support my hypothesis. I could then logically argue that my prediction and conclusion made sense.

Here's the procedure I used and the data I collected:

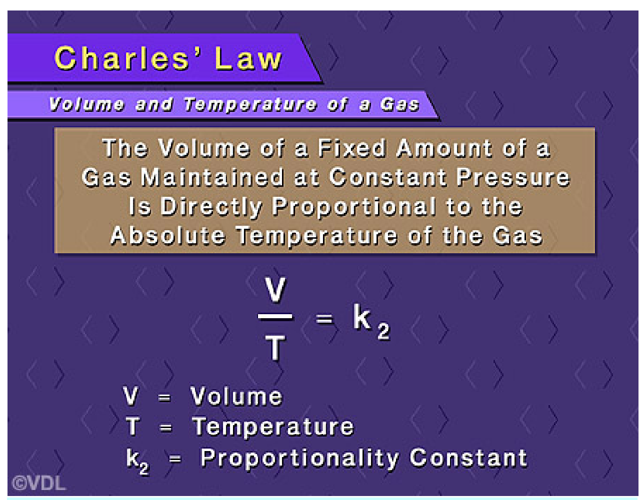
1. I filled an airtight cylinder with gas.
2. I marked the cylinder with a volumetric scale.
3. The cylinder was fitted with a weighted piston that pressed down on the gas. This applied a pressure on the gas that did not vary. In other words, pressure on the gas in my experiment was constant.
4. I also fitted the cylinder with a gauge that measured the temperature inside the cylinder.
5. I then placed the cylinder in a freezer that had a clear glass window.
6. I started recording temperature and volume changes after the gas reached 0°C. As the temperature of the gas fell, I recorded changes in its volume. The data I collected are shown below.



The graph shows that the volume of a gas varies directly with temperature, provided pressure remains constant.

Temperature (°C)	Change in Volume from Original
0	--------
1	–1/273
2	–2/273
3	–3/273
4	–4/273
5	–5/273

From my data, it was clear that volume varied directly with temperature, which turned out to express a relationship confirmed by Charles. This relationship came to be known as Charles's law. The data indicated the volume of the gas would be zero at –273°C. In other words, at that temperature both volume and mass would disappear.



Charles's law applies to a fixed amount of a gas held at constant pressure.

Had I disproved the law of conservation of mass? Not quite. My experiment and its conclusions were based only on the behavior of gases. As I later learned, all gases change to liquids before they get to –273°C. And liquids do not obey Charles's law. I was left with only one conclusion: I had not disproved the law of conservation of mass. But I had learned a lot in the process.

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