then something else in the vessel must have lost an equivalent amount of weight. That something else, it seemed, would have to be air. If that were so, then a partial vacuum must exist in the vessel. Sure enough, when Lavoisier opened the vessel, air rushed in. Once that had happened, the vessel and its contents proved to have gained in weight.

Lavoisier had thus shown that the conversion of a metal into a calx was not the result of a loss of mysterious phlogiston, but was the gain of something very material, a portion of the air.

Now it was possible for him to advance a new explanation for the formation of metals from ores. Ores were a combination of metal and gas. When an ore was heated with charcoal, the charcoal took the gas from the metal, forming carbon dioxide and leaving the metal behind.

Thus, whereas Stahl said the process of smelting involved the passage of phlogiston from charcoal to ore, Lavoisier said it involved the passage of gas from ore to charcoal. But were not these two explanations the same thing, with one equal to the other backwards? Was there any reason to prefer Lavoisier's explanation to Stahl's? Yes, there was, for by Lavoisier's theory of gas-transfer, one could explain the weight changes that resulted in combustion.

A calx was heavier than the metal from which it formed, by the weight of the added portion of the air. Wood also burned through addition of air to its substance, but it did not appear to gain weight, because the new substance formed (carbon dioxide) was itself a gas and vanished into the atmosphere. The ash left behind was lighter than the original wood. If wood were burned in a closed vessel, the gases formed in the process would remain in the system, and then it could be shown that the ash,

plus the vapors formed, plus what was left of the air, would retain the original weight of wood plus air.

In fact, it seemed to Lavoisier in the course of his experiments that if all the substances taking part in a chemical reaction and all the products formed were taken into consideration, there would never be a change in weight (or, to use the more precise term of the physicists, a change in mass).

Lavoisier maintained, therefore, that mass was never created or destroyed, but was merely shifted from one substance to another. This concept is the *law of conservation of mass,* which served as the very cornerstone of nineteenth-century chemistry.[1]

Lavoisier's achievements through the use of measurement were so great, as you can see, that chemists accepted the principle of measurement wholeheartedly from his time forward.

Combustion

Lavoisier was not yet entirely satisfied. Air combined with metal to form a calx and with wood to form gases, but not all the air combined in this fashion. Only about a fifth of it did. Why was this?

Priestley, discoverer of "dephlogisticated air" (see page 54), visited Paris in 1774 and described his discoveries to Lavoisier. Lavoisier saw the significance at once and in 1775 published his views.

Air is not a simple substance, he said, but is a mixture of two gases in a 1 to 4 proportion. One-fifth of the air was Priestley's "dephlogisticated air"

[1] With the opening of the twentieth century, this law was shown to be incomplete, but the correction made necessary by the increased sophistication of twentieth-century science is an extremely small one and can be neglected in the ordinary reactions occurring in the chemical laboratory.

(though Lavoisier unfortunately neglected to give Priestley due credit). It was this portion of the air, and this portion only, that combined with burning or rusting materials, that was transferred from ore to charcoal, and that was essential to life.

It was Lavoisier who gave this gas its name, oxygen. This was from Greek words meaning "acid producer," Lavoisier having the idea that oxygen was a necessary component of all acids. In this, as it turned out, he was mistaken (see page 90).

The remaining four-fifths of the air, which could not support combustion or life (Rutherford's "phlogisticated air"), was a separate gas altogether. Lavoisier called it "azote" (from Greek words meaning "no life") but later the term nitrogen replaced it. This word means "forming niter," since niter, a common mineral, was found to contain nitrogen as part of its substance.

Lavoisier was convinced that life was supported by some process that was akin to combustion,[2] for we breathe in air rich in oxygen and low in carbon dioxide, but breathe out air that is lower in oxygen and considerably richer in carbon dioxide. He and a co-worker, Pierre Simon de Laplace (1749–1827)

—who was later to become a famous astronomer—attempted to measure the oxygen taken in and the carbon dioxide given off by animals. The results were puzzling, for some of the oxygen that was inhaled did not appear in the carbon dioxide exhaled.

In 1783 Cavendish was still working with his inflammable gas (see page 52). He burned some of it and studied the consequences. He found that the vapors produced by the burning condensed to form a liquid that, on investigation, proved to be nothing more nor less than water.

[2] In this, he proved to be right.

Glass retort

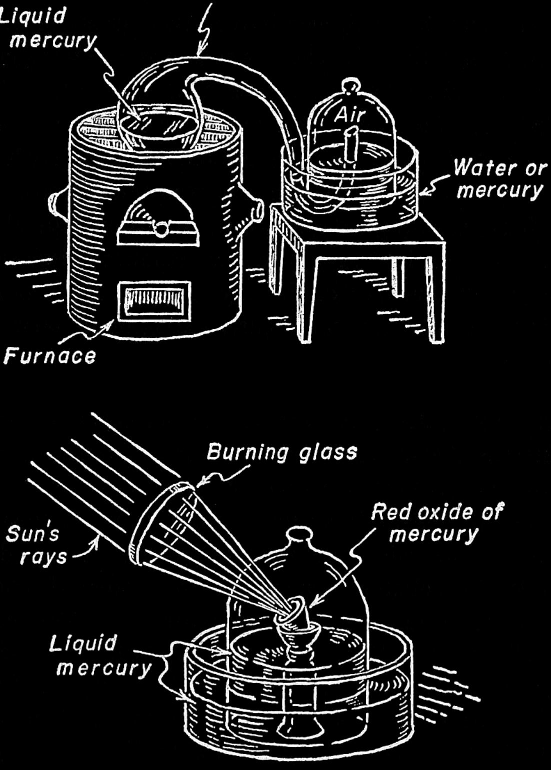

FIG. 7. Lavoisier's experiments were illustrated in *Ele-*

ments of Chemistry with drawings by Madame Lavoisier. (From Great Books edition)

This was a crucially important experiment. In the first place, it was another hard blow at the Greek theory of the elements, for it showed that water was not a simple substance but was the sole product of the combination of two gases.

Lavoisier, hearing of the experiment, named Cav-