Story Lavoisier and the conservation of mass

The month of September had been nice in 1782, and Paris was a very enjoyable town at this time of the year. One morning saw a couple walking from their breakfast table to a room which they used as a chemical laboratory. They were evidently wealthy, their clothing as well as their house identified them as being members of the French upper class of the late 18th century. Actually, the man was Antoine Laurent Lavoisier, a well-known chemist in his forties. He had been a member of the Paris Academy of Sciences since the late 1760s, and also one of the tax collectors for the French King – a position that was the basis of his wealth. His wife Marie was about 15 years younger than Antoine, a beautiful and very bright person who was not only interested in the Sciences, but also good in languages (she actually translated English publications for her husband). Moreover, she hosted a salon where a lot of intelligent and influential people regularly met to discuss recent literature, arts, and sciences.

Currently, Antoine and Marie were working on experiments on gases, more particular on a part of the air. Initially, air had been considered to be a simple substance, an element, however, recently some chemists such as Joseph Priestley and Henry Cavendish had demonstrated that common air was a mixture of different gases. Moreover, water had turned out to be decomposable into two gases, and could be composed again from these two gases. This was also remarkable as water – like air – had been considered as being a chemical element. And one of the gases that formed water was also part of the air, a gas that Lavoisier had called oxygen (acid producer) as he considered it to be crucial for the formation of acids. At the same time, naming this new gas was of course an attempt to demonstrate the importance of the own work on these substances. It was in particular this gas which Lavoisier had been experimenting with for quite some time recently.

When walking towards the laboratory, Marie asked "What are we going to do today, shall we go back to examining the reactions between oxygen and the metals?" Antoine responded "I think I shall redo the experiment on combining oxygen with the flammable gas as Mr. Priestley had called it. It would be good to see whether the decomposition can be reversed." "What do you mean by reversed?" asked Marie. "Well, we have learned that water can be decomposed into oxygen and flammable air. Moreover, when we ignite flammable air in common air, we get water. Thus it seems that water is a compound formed by oxygen and flammable air. When I can demonstrate that water can be composed from and decomposed into oxygen and flammable air, we can be sure that water is the combination of these two substances." "Hmm," said Marie, "I see your point but …" She hesitated and thought for some moments whilst Antoine was already setting up the glass apparatus he was about to use for the combustion experiment. "Antoine, listen, how can you be sure that the water you are going to produce is the exact combination of the two gases?" Without interrupting his work, Antoine said "What do you mean by the exact combination?" "How can you be sure that it is just these two gases that form the water" "Well, I had this glass full of water at the beginning of the decomposition, and it will be full again at the end of the combustion."

Marie thought: "This sounds reasonable, however … The gases are so much more than the water – how could that be that these huge amounts of gases form this small volume of liquid water?" "Because so much gas is produced from the same small amount of liquid" responded Antoine. But Marie kept insisting: "How can you be sure that there is nothing else entering or leaving the process of combustion? You seem to be a bit too incautious with this reaction." "What do you mean?" At least Marie had gotten Antoine's attention, he was no longer working on the apparatus. "Antoine, what I am concerned is the following: You assume that when you produce from a certain amount of water the two gases, and when you produce from the same gases water again, you conclude that nothing else is involved. Let me use an analogy: For collecting taxes, you are very delicate in bookkeeping every item that enters the town of Paris. Even more, you have just suggested to have a wall to be erected around the city to control the incoming and outgoing goods for taxation purposes. I am just wondering whether we should be as cautious with our chemical reactions."

Antoine was thinking aloud: "Bookkeeping in chemistry, this would be a completely new approach. And yet, there might be some gain in it. Well, we would have to weigh all substances, in order to make possible such an approach. This would be difficult with gases, however, we could try to do this more systematically with the metals." He started to set up a different apparatus, a glass flask in which he placed some lead. When heated, the lead was transformed into the calx of lead, a substance initially considered to be an element, but as Lavoisier had recently shown, it was a combination of lead and oxygen, thus lead was to be considered as the element. However, this time, at the beginning of the experiment he had weighed the lead, and at the end, he determined the weight of the calx – there was a significant gain. Marie pointed out: "If I understand your new interpretation of the reaction correctly, the metal is combining with oxygen from the air – thus, if this is correct, the air should have lost weight." "Brilliant" responded Antoine, and it was not clear whether he was serious or sarcastic, "and how shall we measure this loss of weight of air?" "Well, if you close in everything hermetically, then we can see whether there is some change in the weight, if there is none, then …" Antoine jumped in:" … then the gain of weight of the metal oxide must be due to the loss of weight of air. As I said, my dear, you are brilliant" Marie smiled, "My dear Antoine, bookkeeping in chemistry, isn't it after all what you've been doing since you burned sulphur in a closed vessel?" whilst Antoine set up the new experiment, this time making sure that the flask was sealed hermetically. He weighed the sealed flask on a beam balance, then heated the lead, which was transformed into its oxide, and then put the sealed flask again on the balance. "Equilibrium" he whispered, "it is still in the equilibrium".

"Let's try some others" Marie suggested, and immediately, they set up similar experiments with different metals. The following days were laborious, a lot of experiments were carried out, and their result was always alike, mass was conserved. Antoine was enthusiastic, yet, he was well aware that some scholars might come up with criticisms that the changes in mass might be very small and thus not detected by the balance. Therefore, he invited Nicolas Fortin, one of the leading instrument makers to his laboratory.

When Fortin arrived, the three went to the laboratory room, and Antoine showed him the experiments he had done. Fortin was impressed and pointed out: "But M. Lavoisier, you have already a very sensitive balance made by my colleague M. Mégnié." "I know, but I want an even better instrument, do the best you can – money does not matter, and time is also not that much an issue. But I want the most sensitive balance ever made, a balance that can measure larger masses with an unprecedented accuracy." Fortin agreed, but it was evident that this balance would probably not be ready this year or the following one.

"Now, let's go back to the water" Antoine suggested to Marie. He designed a set-up that would enable to weight the produced gases as well as the liquid water, and vice versa. He produced oxygen and flammable air from water, placed the apparatus on the balance – equilibrium. He made the two gases combine once again forming water and put the apparatus once again on the balance – equilibrium. He smiled: "This is it, and this also means that water is created by flammable air just in combination with oxygen, so it should be represented in the name of the substance – for the publication, we will no longer use the name of flammable air, but we will call the gas Hydrogen, or Hydrogenium in Latin – water producer.

Antoine Lavoisier developed with the strong personal support of his wife Marie a new chemical system that became dominant and forms the basis of our chemical system of the elements. During the French Revolution, he was beheaded due to his position as a tax collector – his wife Marie survived and, after the French Revolution, she continued to publish his chemical findings.

Story Lavoisier and the conservation of mass was edited by Brigitte van Tiggelen and it is based, in part, on **Historical Background: Atoms** and on Historical Background: The development of the periodic table written by Peter Heering and on **Biography: John Dalton** written by Emilia Dobrowolska.

Story Lavoisier and the conservation of mass was written by Peter Heering with the support of the European Commission (project 518094-LLP-1-2011-1-GR-COMENIUS-CMP) and the University of Flensburg, Germany. This publication reflects the views only of the author, and the Commission cannot be held responsible for any use which may be made of the information contained therein