Le Symposium Lavoisier

Introductory notes

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All international symposia take many years to plan and prepare, but even by these standards this meeting can claim an especially long gestation. The initial stimulus occurred over 250 years ago, in 1743, with the birth of a remarkable man, Antoine Laurent Lavoisier, shown with his wife, Marie Anne, in the famous portrait by Jacques Louis David which now hangs in the Metropolitan Museum of Art in New York (Fig. 1).

This is not a detailed biography of Antoine Lavoisier; far more may be learnt of him by visiting the display of some of Lavoisier's original apparatus housed at the Conservatoire National des Arts et Métiers (CNAM) in Paris. However, this introduction to the symposium explains the link between a man primarily known as a chemist and the topic chosen for this symposium, '*Metabolic fuel selection*'.

Lavoisier's greatest achievements were in the fields of what we would now call pure and physical chemistry, and in these fields his progress was astonishing. Although first trained as a barrister, and with numerous non-scientific commitments in his life, some of which were the cause of his later downfall, Lavoisier soon became a leading member of a vibrant academic community in Paris. Elected to l'Académie des Sciences at the age of only 24 years he established a reputation for applying the most detailed and exhaustive quantitative methods to the investigation of a wide variety of challenges. Always reluctant to accept current dogma, and with an intuitive flair for interpreting the results of both his own and others' experiments, he is now regarded as the founder of modern chemistry.

It is impossible to do justice to Lavoisier's incredible achievements in the limited space available here, so readers are urged to buy one of the new biographies now available in both French and English (Poirier, 1993; Donovan, 1993).

Some of Lavoisier's first work was on the chemistry of salts and on the process then known as 'calcination'. Using extremely accurate balances he noticed that as metals are oxidized their weight is 'sensibly increased'. This eventually led to his demolition of the phlogiston theory of combustion which had first been proposed by Stahl about 60 years earlier. Phlogiston was thought to be a substance contained within combustible material which was released into the air on burning and calcination. The demonstration that metals increased in weight when oxidized was clearly incompatible with a loss of phlogiston unless, as was suggested by some of the diehards, phlogiston had negative weight! Lavoisier's memoir to the Académie is now one of the most widely quoted classics by historians of science (Fig. 2).

Lavoisier had reached a true understanding of the nature of Priestley's 'dephlogisticated air' (so-called because it had the ability to take up phlogiston and, thus, support combustion) and of 'fixed air' (CO_2). In this paper he removed respiration from the confines of the phlogiston theory and established that during respiration the O_2 in air is

Fig. 1. Antoine Laurent Lavoisier et sa femme by Jacques Louis David. Reproduced with permission from Metropolitan Museum of Art, New York.

https://doi.org/10.1079/PNS19950033 Published online by Cambridge University Press

DES SCIENCES. 505

RÉFLEXIONS
SUR LE PHLOGISTIQUE,
Pour ſervir de développement à la théorie de la Combuſtion & de la Calcination, publiée en 1777.

Par M. LAVOISIER.

DANS la ſuite de Mémoires que je viens de communiquer à l'Académie *, j'ai paſſé en revue les principaux phénomènes de la Chimie; j'ai inſiſté ſur ceux qui accompagnent la combuſtion, la calcination des métaux, & en général toutes les opérations où il y a abſorbtion & fixation d'air. J'ai déduit toutes les explications d'un principe ſimple, c'eſt que l'air pur, l'air vital, eſt compoſé d'un principe particulier qui lui eſt propre, qui en forme la baſe, & que j'ai nommé *principe oxygine*, combiné avec la matière du feu & de la chaleur. Ce principe une fois admis, les principales difficultés de la Chimie ont paru s'évanouir & ſe diſſiper, & tous les phénomènes ſe ſont expliqués avec une étonnante ſimplicité.

Mais ſi tout s'explique en Chimie d'une manière ſatisfaiſante, ſans le ſecours du phlogiſtique, il eſt par cela ſeul infiniment probable que ce principe n'exiſte pas; que c'eſt un être hypothétique, une ſuppoſition gratuite: & en effet, il eſt dans les principes d'une bonne logique, de ne point multiplier les êtres ſans néceſſité. Peut-être aurois-je pu m'en tenir à ces preuves négatives, & me contenter d'avoir prouvé qu'on rend mieux compte des phénomènes ſans phlogiſtique qu'avec le phlogiſtique: mais il eſt temps que je m'explique d'une manière plus préciſe & plus formelle ſur une opinion

* Quelques-uns de ces Mémoires ne ſont point encore imprimés.

Mém. 1783. Sſſ

Fig. 2. Lavoisier's paper on phlogiston presented to l'Académie des Sciences.

https://doi.org/10.1079/PNS19950033 Published online by Cambridge University Press

(a)

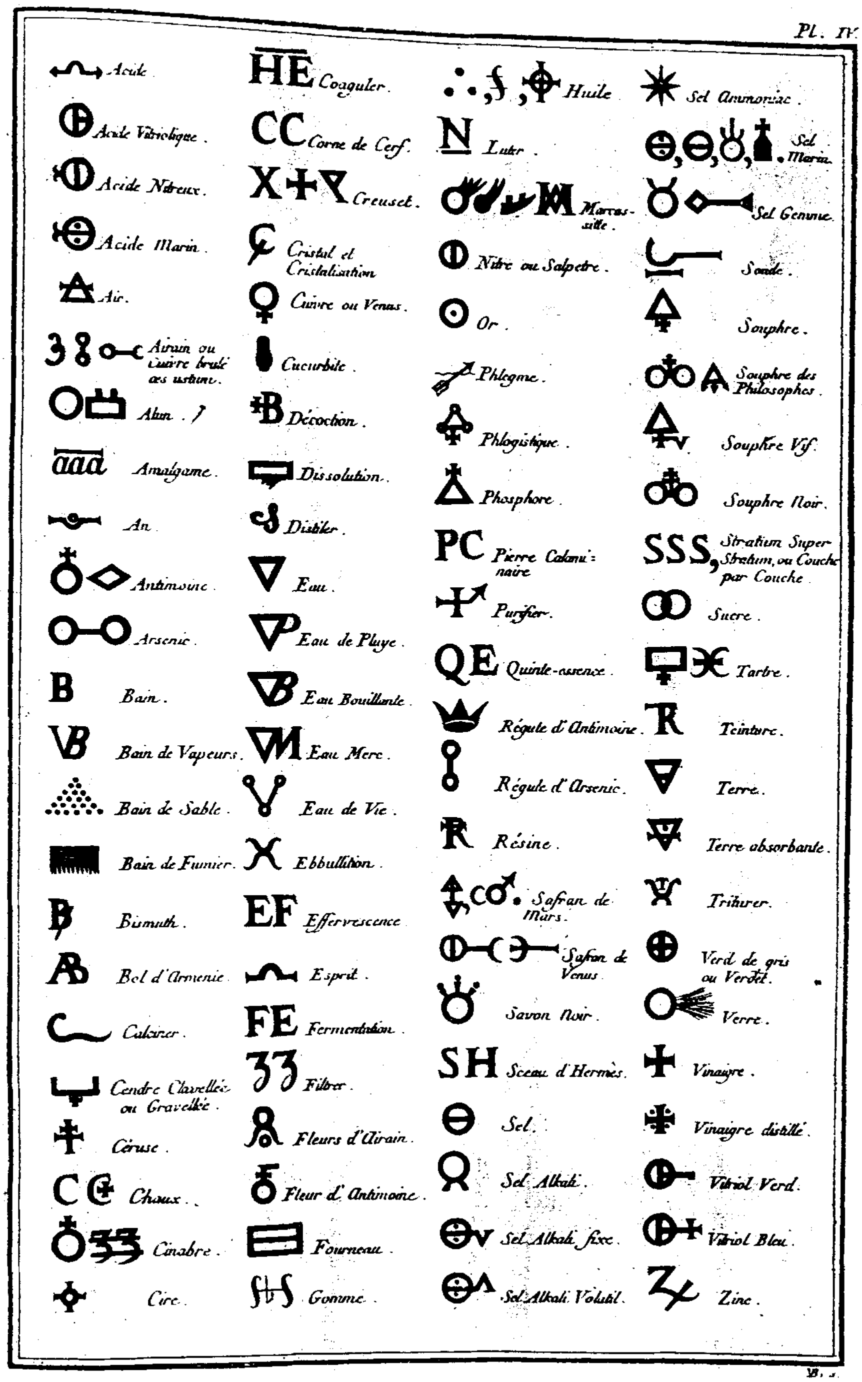

Fig. 3. The ancient system of chemical terminology (a) and the new system (b) recommended by Lavoisier with Guyton de Morveau, Berthollet and Fourcroy.

(b)

	Noms nouveaux.	*Noms anciens correſpondans.*
Subſtances ſimples qui appartiennent aux trois règnes & qu'on peut regarder comme les élémens des corps.	Lumière........	Lumière.
	Calorique........	Chaleur. Principe de la chaleur. Fluide igné. Feu. Matière du feu & de la chaleur.
	Oxygène........	Air déphlogiſtiqué. Air empiréal. Air vital. Baſe de l'air vital.
	Azote...........	Gaz phlogiſtiqué. Mofete. Baſe de la mofete.
	Hydrogène.......	Gaz inflammable. Baſe du gaz inflammable.
Subſtances ſimples non métalliques oxidables & acidifiables.	Soufre...........	Soufre.
	Phoſphore........	Phoſphore.
	Carbone..........	Charbon pur.
	Radical muriatique.	Inconnu.
	Radical fluorique..	Inconnu.
	Radical boracique,.	Inconnu.
Subſtances ſimples métalliques oxidables & acidifiables.	Antimoine........	Antimoine.
	Argent...........	Argent.
	Arſenic..........	Arſenic.
	Biſmuth..........	Biſmuth.
	Cobolt...........	Cobolt.
	Cuivre...........	Cuivre.
	Etain............	Etain.
	Fer..............	Fer.
	Manganèſe.......	Manganèſe.
	Mercure.........	Mercure.
	Molybdène.......	Molybdène.
	Nickel...........	Nickel.
	Or..............	Or.
	Platine..........	Platine.
	Plomb...........	Plomb.
	Tungſtène........	Tungſtène.
	Zinc............	Zinc.
Subſtances ſimples ſalifiables terreuſes.	Chaux...........	Terre calcaire, chaux.
	Magnéſie.........	Magnéſie, baſe du ſel d'Epſom.
	Baryte..........	Barote, terre peſante.
	Alumine........	Argile, terre de l'alun, baſe de l'alun.
	Silice..........	Terre ſiliceuſe, terre vitrifiable.

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diminished, the CO_2 is increased and the N_2 content remains unchanged. It was Lavoisier who coined the term 'oxygen' (the begetter of acids) in 1777.

Many of the terms that we now use to describe chemical compounds can be traced back to Lavoisier who with Guyton de Morveau, Berthollet and Fourcroy transformed the ancient chemical terminology (Fig. 3(a)), by introducing a radically new system of chemical nomenclature, into something readily recognizable today (Fig. 3(b)) in which terms such as 'oxide' and 'sulphate' appeared for the first time.

Another of Lavoisier's great achievements, and again one made possible through the use of precise quantitative methods, was his demonstration that water was not an element but rather a compound made from H_2 and O_2. He did this by burning a constant flow of the two gases and by showing that the weight of water formed was exactly equal to the weight of gases combusted.

But it is his studies on respiration and animal heat which are of greatest interest to physiologists and nutritionists. Working in close collaboration with Pierre Laplace he performed what has been called 'the most important group of experiments in the history of metabolic heat studies'. It is remarkable, 200 years later, how much detail we know about these experiments both from written records and from Madame Lavoisier's engravings (Fig. 4).

At 08.12 hours on the morning of 3 February 1783, Lavoisier placed a guinea-pig in an ice machine designed by Laplace (Fig. 5) and measured heat production from the amount of ice melted. We know that the experiment lasted for over 5 h and that in the evening the same guinea-pig was returned to the calorimeter for a further 10 h. We even know that this historic creature was called Gina.

Lavoisier and Laplace were soon to combine direct (heat loss) and indirect (gas exchange) calorimetry to demonstrate that the quantity of heat produced was directly proportional to the amount of O_2 consumed. Lavoisier referred to the conservation of animal heat more than 50 years before the general law of conservation of energy was enunciated.

He moved on to respiration experiments with humans (Fig. 4), and by 1790 had determined that O_2 consumption is increased by the ingestion of food, by muscular work and by exposure to cold. In the Musée de Technologie at CNAM it is possible to see many pieces of Lavoisier's original apparatus including the animal calorimeters and some of the Cu face masks used to collect expired air from humans.

With these experiments Lavoisier was the founder of calorimetry and, hence, the connection with the topic of the present symposium. Lavoisier himself coined an apt phrase to link together his work in chemistry and metabolism: 'La vie est une fonction chimique'.

For those of you who do not know the end of Lavoisier's story, here is a brief summary. In 1789 the citizens of France rose up against their oppressors and began a period when no one was safe. On 8 May 1794, Antoine Laurent Lavoisier was convicted of conspiring against the people of France and immediately led to the Place de la République and the guillotine. Such was the violence of the latter years of the French Revolution that a man now counted alongside Galileo, Newton, Darwin, Mendel and Einstein as one of the leaders of a major scientific revolution could be unceremoniously executed and buried in a nameless grave. Lavoisier's crime was to be a member of *la ferme générale* (through whose activities the taxes were collected), a director of the Gunpowder Administration, and to be known as the planner of a new tax wall around

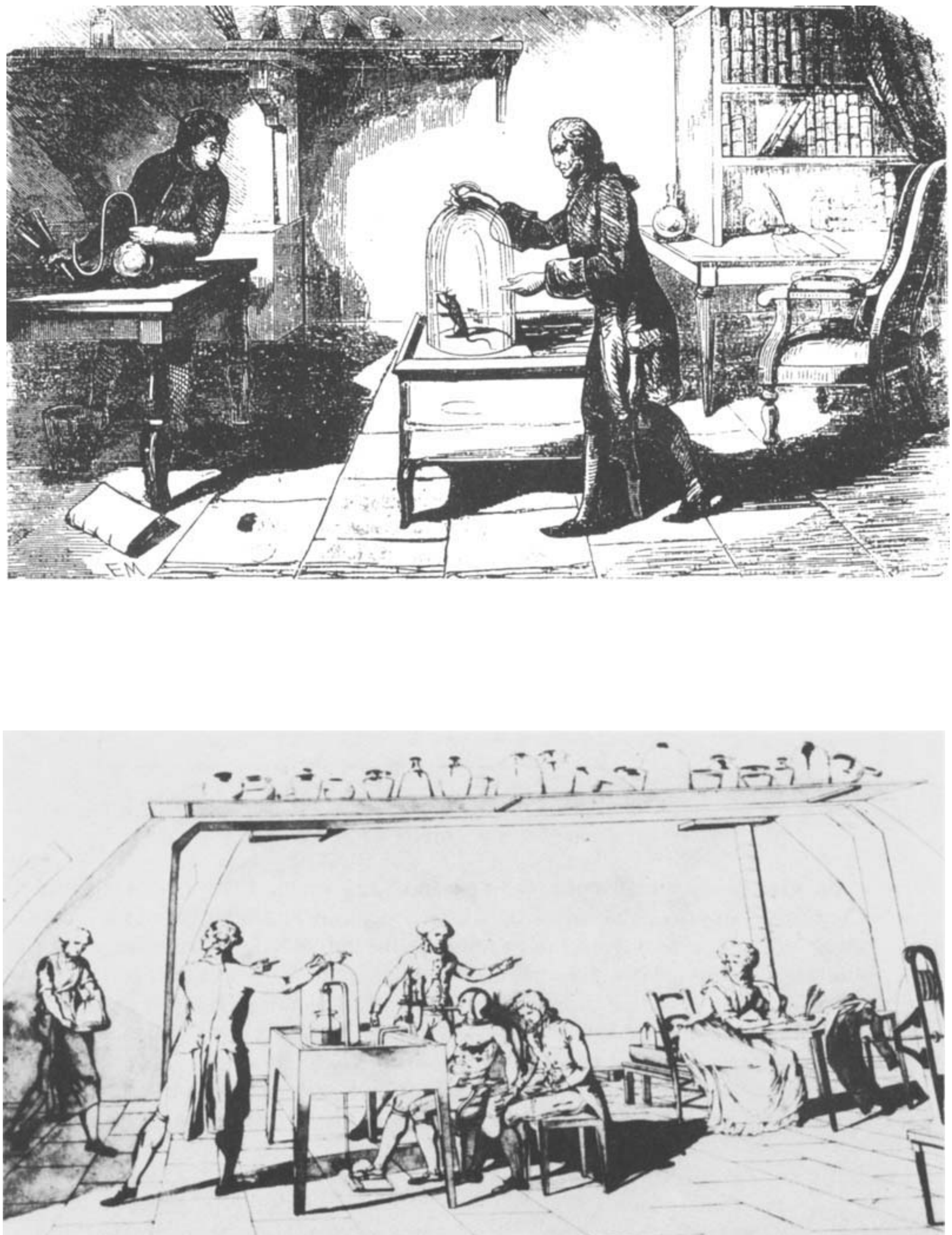

Fig. 4. Lavoisier at work in his laboratory. From etchings by Madame Lavoisier. Reproduced with permission from Musée de Technologie, Conservatoire National des Arts et Métiers.

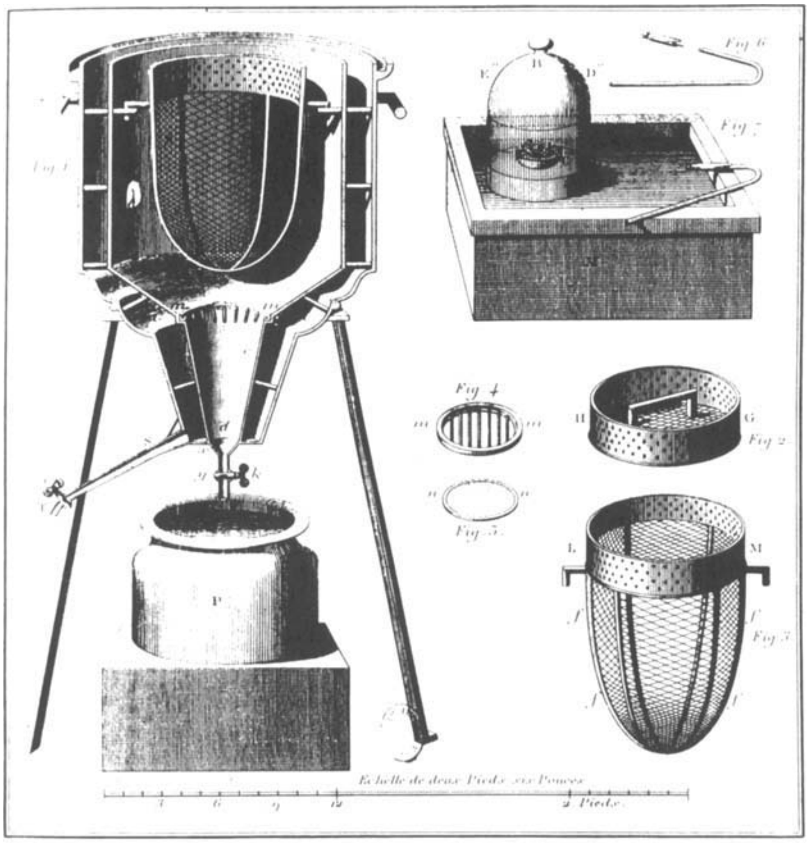

Fig. 5. Lavoisier's ice calorimeter for small animals. Reproduced with permission from Musée de Technologie, Conservatoire des Arts et Métiers.

Paris. In the atmosphere of conspiracy and paranoia that created The Terror, Lavoisier's many attempts to improve the lot of the French peasant and his undoubted scientific brilliance failed to save him from the Committee on Public Safety who disregarded his letter summarizing his own achievements. On the night of his execution his friend Lagrange whispered, 'It took but an instant to cut off his head: a hundred years will not suffice to produce one like it!'.

In a letter written on the eve of his death Lavoisier confided to his cousin, '. . . I trust my passing will be remembered with some regret and perhaps as having something of glory'. It seems that the convening of this symposium proves that yet again he was right!

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Printed in Great Britain