Introduction

IN this study I have tried to shed some light on a particularly obscure, yet especially noteworthy, period in the career of the great French chemist, Antoine-Laurent Lavoisier (1743–1794). We are quite familiar with his early years of scientific apprenticeship, when his interests ranged over a wide variety of scientific problems; and though much is still to be learned about the work of his mature years, there is a substantial literature dealing with Lavoisier's discovery of the role of oxygen, his share in the revision of chemical nomenclature, and other aspects of his massive scientific achievement. But we have understood very imperfectly, if at all, the time of Lavoisier's life when he took the fortunate step of turning to the central problem of combustion. If we cannot know why, and precisely when, he entered on this new path, we will be at a loss to account for one of the truly significant new departures in the history of science.

My primary concern, therefore, has been to determine when, in what manner, and under what influences Lavoisier was led before February, 1773, to the key experiments and generative ideas that touched off the Chemical Revolution. In historical episodes of this importance, a study of origins—even one as detailed as this has turned
INTRODUCTION

out to be—needs no special defense. But if my findings can help illuminate the broader problem of the scientific revolution in chemistry (to which our modern age owes so much), the reader may perhaps forgive the rather intricate argument I have been forced to present in this work.

We need hardly stress Lavoisier's pivotal position in the history of chemistry and his role as the chief architect of the Chemical Revolution. He is one of those epoch-making figures in the history of science—like Newton in physics and Darwin in biology—who loom larger than life. If he did not create a new science ex nihilo, as some earlier writers believed, he and his disciples nevertheless refashioned the materials, the concepts, and even the language of chemistry so radically that, despite a long and complex early history, the science as we know it today seems almost to have been born with him.

Like the political revolution with which it coincided in time, the Chemical Revolution was the work of many hands and the product of diverse forces that are difficult to unravel and assess. Both revolutions were prepared on French soil with materials in part at least—and in the case of the Chemical Revolution quite conspicuously—of British origin. But, as will appear, there were Continental currents related to our problem, influences upon Lavoisier and his contemporaries, which deserve more attention than they have received.¹

The Chemical Revolution had manifold aspects, and

¹ In a recent paper ("Some French Antecedents of the Chemical Revolution," Chymia, 5 [1959], 73–112) I tried to show how the general economic and technical preoccupations of eighteenth-century France promoted an interest in chemistry during Lavoisier's youth and set the stage for the Chemical Revolution.
there have been many diverse attempts to characterize it by a single salient feature. Perhaps I should make explicit how I differ from other writers and what I think chiefly characterizes it, since a recognition of this central feature has served to focus my inquiry and to guide it throughout.

It has long been a cliché of histories of chemistry that Lavoisier’s chief contribution was to usher in the age of quantitative chemistry, to enunciate for the first time the principle of the Conservation of Mass in chemical reactions, and to inaugurate the use of the balance. To say the least, this is a gross oversimplification. The so-called Conservation Law—which Dumas, among the earliest, attributed to Lavoisier—had long been a working principle of chemists and had been clearly enunciated at least as early as the first decades of the seventeenth century.² From that time onward, the testimony of the balance was increasingly invoked by chemists, especially by the British school—the school of Boyle, Newton, Mayow, and Hales—which sought to develop a “statical,” that is

² The principle was accepted implicitly by Van Helmont. See Hélène Metzger, Les doctrines chimiques en France (Paris, 1923), pp. 177–179. It is clearly stated by Jean Rey in his Essays of 1630 (see below, p. 114) and by Francis Bacon in the aphorisms of the Novum organum and in the Sylva sylvarum (Exp. 100) where he attributes the doctrine to “an obscure writer of the sect of the chemists” (The Works of Francis Bacon, ed. James Spedding and R. L. Ellis [Cambridge, 1863], I, 462, and IV, 223). For the views of Newton and his influence on this question, see Hélène Metzger, Newton, Stahl, Boerhaave et la doctrine chimique (Paris, 1930), pp. 30–33. The popularity of classical atomism and the new corpuscularianism, with their doctrines of the indestructibility of matter, played an important part in the emergence of this chemical postulate.
to say a quantitative, chemistry akin to physics. By the mid-eighteenth century it was piously hoped that every chemical operation would be performed "in an exact, or geometrical, manner," with the use of accurate balances and weights. For British science, at least, Joseph Black’s *Experiments upon Magnesia Alba, Quick-lime, and Some Other Alcaline Substances* (1756) was an admirable exemplification of this method applied with scrupulous care and finesse. But the Continental chemists repeatedly invoked the same ideal, though they lagged somewhat behind their British compeers. In 1766 P. J. Macquer, one of Lavoisier’s seniors, applauded the fact that chemistry was beginning to be cultivated "suivant la méthode de la saine Physique." Later, in reporting upon Lavoisier’s first book, another French scientist wrote that the author “a soumis tous ses résultats à la mesure, au calcul et à la balance: méthode rigoureuse, qui, heureusement pour l’avancement de la chimie, commence à devenir indispensable dans la pratique de cette science.” There is here no suggestion that Lavoisier was doing anything

---

3 Peter Shaw, *A New Method of Chemistry; Including the History, Theory, and Practice of the Art: Translated from the Original Latin of Dr. Boerhaave's Elementa Chemiae* (London, 1741), II, 385. This translation of the authorized edition of Boerhaave’s famous textbook, containing important notes and additions by Shaw, will be cited henceforth in this study as Shaw-Boerhaave (1741).

4 *Dictionnaire de chymie, contenant la théorie & la pratique de cette science, son application à la physique, à l’histoire naturelle, à la médecine & à l’économie animale, etc.* (Paris, 1766), II, 326.

5 *Oeuvres de Lavoisier publiées par les soins de son Excellence le Ministre de l’Instruction Publique et des Cultes* (Paris, 1862–1893), I, 663. This indispensable, though not exhaustive, collection of Lavoisier’s memoirs, Academy reports, and occasional papers on various subjects will henceforth be cited as *Oeuvres de Lavoisier*. xvi
novel—only that he was a successful exponent of a method that was proper and up-to-date, but still not widely enough employed. What, in point of fact, Lavoisier did do was to use the balance (and other quantitative techniques as well) with such fidelity and persistence—though not always with rigorous accuracy—that it became in his hands, as Dumas put it so well, "a veritable reagent." 6

An equally common appraisal of the Chemical Revolution makes it tantamount to the overthrow of the Becher-Stahl phlogistic theory of combustion. But this says at once too much and too little; it exaggerates the break with the past; it neglects the accumulated body of old and recent factual knowledge that was absorbed unaltered by the newer chemistry; and it overlooks the point that something more fundamental occurred than the mere substitution of one theory of combustion for another, centrally important though this proved to be.

There is some truth in all these explanations, but what I believe to be the most significant ingredient in the Chemical Revolution is often overlooked. In the person of Lavoisier two largely separate and distinct chemical traditions seem for the first time to have been merged. At his hands, the pharmaceutical, mineral, and analytical chemistry of the Continent was fruitfully combined with the results of the British "pneumatic" chemists who discovered and characterized the more familiar permanent gases. It was centrally important that for the first time

INTRODUCTION

these permanent gases came to be recognized as chemically active participants in very common reactions and processes. Methodologically, the key to the Revolution was Lavoisier's systematic application of his special "reagent," the balance, not merely to solids and liquids, but also to the gases. While the British chemists of the eighteenth century, following the trail broken by Robert Boyle, John Mayow, and Stephen Hales, came gradually to perceive that gases made up a third class of substances as important to the chemist as solids and liquids, their work was often more physical than strictly chemical. It was Lavoisier who most convincingly and systematically demonstrated—as Black, to be sure, had done for some special cases and for a particular gas—that this newly discovered group of substances must be regularly accounted for in strict chemical bookkeeping if the constitution of familiar substances and the nature of familiar reactions were to be correctly understood. Perhaps it is not too much to say that the Chemical Revolution—to hazard a metaphor—supplanted a two-dimensional by a three-dimensional quantitative chemistry.

The first, and I believe the decisive, step in the Chemical Revolution was Lavoisier's recognition of this new aerial dimension. But it is clear that this step was taken well before the discovery of oxygen, and indeed before Lavoisier suspected that there exist different gases with different chemical and physical properties. The crucial event in Lavoisier's career was his realization that air (which nearly everyone believed to be a simple substance defined by its physical, rather than by any chemical,

7 This point is made by Sir Philip Hartog in "The Newer Views of Priestley and Lavoisier," Annals of Science, 5 (1941), 27.
properties) must play a part in chemical transformations—most dramatically those observed in ordinary combustion, the roasting (calcining) of metals, and the reduction of ores or calxes. With all due credit to the British pneumatic chemists, the full appreciation of this crucial fact belongs to Lavoisier alone. Because he kept it constantly in view and used it as the guiding principle of his later research, he could be the first to grasp the significance of the new gas, oxygen, and the first to discover its chemical role, though we now recognize that Scheele and Priestley had independently isolated it before him and noted its most striking properties.

It was, therefore, to discover from what clues, and by what avenues of thought, Lavoisier hit upon this crucial idea of the role of air in combustion that this investigation into the origins of his classic researches was first undertaken. How successful I have been in finding an answer among the scattered and sparse materials (sparse especially from Lavoisier's hand) the reader must, of course, decide for himself.
LAVOISIER—THE CRUCIAL YEAR:

*The Background and Origin of His First Experiments on Combustion in 1772*
Plus les faits sont extraordinaires, plus ils s'éloignent des opinions reçues et accréditées, plus il est important de les constater par des expériences répétées et de manière à ne laisser aucun doute. – Lavoisier