LOMONOSOV AND THE DISCOVERY OF THE LAW OF THE CONSERVATION OF MATTER IN CHEMICAL TRANSFORMATIONS

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Mikhail Vasilevich Lomonosov (1711–65) was the first Russian-born scientist to achieve prominence in physics and chemistry, and as such, he is an extremely important figure for Soviet historians of science. Since 1904, when B. N. Menshutkin first published a number of Lomonosov's forgotten scientific papers in a collection entitled *Lomonosov as a Physical-Chemist*, the eighteenth-century Russian scientist has acquired a not inconsiderable reputation in nations outside of the Soviet Union. Western Europe and the United States first learned of Lomonosov when Menshutkin's work was translated in great part by Dr. Max Speter and published as No. 178 of Ostwald's *Klassiker der Exacten Wissenshaften* in 1910. Alexander Smith, former president of the American Chemical Society, praised Lomonosov unstintingly in an article entitled, "An Early Physical-Chemist—M. W. Lomonosoff", appearing in the *Journal of the American Chemical Society* in 1912. Lomonosov's total achievement as a scientist, literatus, and educator is extraordinary, and it would be impossible to discuss here the numerous discoveries and innovations attributed to him by both Russian and non-Russian historians. One enthusiastic Soviet writer ranked Lomonosov above Leonardo da Vinci and Wolfgang von Goethe in the hierarchy of world historical geniuses[1]. S. I. Vavilov, former president of the Academy of Sciences of the Soviet Union, provided even weightier praise in an article printed in Pravda on 5 January, 1949, when he wrote that Lomonosov had in the eighteenth century anticipated the concept of matter that was fully articulated in the twentieth century by V. I. Lenin[2]. Even discounting excessive enthusiasm on the part of Soviet writers, Lomonosov's work was unusually intelligent and daring. He often opposed current conceptions in physics and chemistry, and although the conceptions that he proposed in their stead were, in many instances, equally erroneous, Lomonosov must nonetheless be lauded for the kind of courage and imagination that is necessary for a forward movement in science. Lomonosov's predilection for strictly mechanical interpretations of the phenomena of physics and chemistry prompted him to reject both Newton's conception of bodies acting upon one another at a distance by gravitational attraction, and the idea of a calorific material.

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[1] B. B. Kudriavtsev, The Life and Work of Mikhail Vasilyevich Lomonosov (Moscow: Foreign Languages Publishing House, 1954), p. 5.

[2] S. I. Vavilov, "Zakon Lomonosova", *Pravda*, No. 5, 5 Jan., 1949, p. 2.

Lomonosov's unwillingness to accept these prevailing doctrines of eighteenth century physics and chemistry should not necessarily be viewed either as a symptom of conservatism or of any extreme precociousness. Like many, first-rate thinkers in science, and indeed in all areas of intellectual endeavour Lomonosov had one foot in the past and one in the future. His work was rich in intuition but uneven. In that respect he is an excellent representative of eighteenth century science.

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Soviet scholars have attributed to Lomonosov the discovery of the law of the conservation of matter in chemical transformations and have claimed that Lomonosov not only enunciated this fundamental law of chemistry, but that he substantiated it with experimental proofs[3]. A claim of this nature demands careful scrutiny, particularly since it endangers the reputation of the man generally credited with the discovery of the law, Antoine Laurent Lavoisier. In an article printed in 1952 a Russian scholar wrote that French scientists were familiar with Lomonosov's work[4]. The author of the article implies that Lomonosov's ideas were indirectly communicated to Lavoisier[5]. That Lavoisier was indebted to a number of contemporary thinkers in a number of ways has been ably demonstrated[6]. His debt to Lomonosov is quite another question. Lomonosov's alleged law of the conservation of matter in chemical transformations is contained in a paper entitled, "A Dissertation on the Solidity and Fluidity of Bodies", which was read on 6 September, 1760, before a public session of the Imperial Academy of Sciences, and appeared in print shortly thereafter[7]. Publication of Lomonosov's dissertation was noted in the *Annales Typographiques* in November, 1762. The *Annales Typographiques* was a French journal whose purpose it was to publicize the progress of human learning, and it contained numerous references to a wide variety of scholarly publications.

[3] This contention is widely voiced by Soviet writers. I am not certain when it was first expressed, but it seems likely that B. N. Menshutkin, Soviet chemist and biographer of Lomonosov, began the myth. S. I. Vavilov, former president of the Soviet Academy of Sciences, seems to be largely responsible for the magnification of Lomonosov's achievements. He is an authority cited quite frequently by Soviet writers.

[4] L. B. Kaminer, "Iz Isterii Otkrytiia Zakona Sokhraneniia Veshchestva M.V. Lomonosovym", *Trudy Instituta Istorii Estestvoznaniia*, IV (1952), 306. Hereinafter referred to as *Kaminer*.

[5] *Ibid.*, p. 311.

[6] A thorough study has been made of the problem of Lavoisier's debt to earlier research. Lomonosov is not mentioned as a possible influence. See: H. Guerlac, *Lavoisier. The Crucial Year* (Ithaca: Cornell University Press, 1961).

[7] M. V. Lomonosov, *Polnoe Sobranie Sechinenii* (Moskva: Izdatel'stvo Akademii Nauk, 1952), III, pp. 559–61. Hereinafter referred to as Lomonosov, *Polnoe Sobranie Sochinenii*, with volume number.

Under the heading, No. CLXXII, a brief reference to Lomonosov's work appeared[8]. It is a courteous and restrained statement of about thirty words in which the "reviewer" (or so Mr. Kaminer calls him, despite the fact that it would be stretching the truth a bit to call the note that appeared in the journal a review) wrote that Lomonosov's capable work was an indication of the progress of Russian physics since the glorious reign of Peter the Great[9]. This is not such extraordinary praise if it is taken into account that before Peter the Great there was no such thing as Russian physics. The fact that Lomonosov's paper was noted in a French journal, whose express purpose it was to note scientific publications, is not in any way proof that the ideas in the paper were widely discussed and read, much less that they were prized by French scientists. There is no direct evidence that Lavoisier read any of Lomonosov's treatises, although Soviet scholars are certain that, since Lavoisier had read an article by another member of the Imperial Academy of Sciences, he must have read the four papers of Lomonosov that were contained in the same volume of the *New Commentaries of the Petersburg Academy of Sciences*[10]. This is hardly conclusive evidence. It is merely speculation. Perhaps Soviet scholars have more substantial evidence that Lavoisier had read or heard of Lomonosov's work. That in itself would prove very little, for whether or not Lavoisier knew of Lomonosov's work, either directly or indirectly, is a secondary question. The primary question is whether or not there was anything in Lomonosov's work that could have enlightened Lavoisier—whether Lomonosov did indeed enunciate the law of the conservation of matter in chemical transformations and demonstrate it with experimental proofs. It is quite clear that he did neither.

Soviet historians usually cite two of Lomonosov's works, one written in 1748 and the other, the one referred to above, written in 1760, to support their claim that he actually expressed the law. The experiments that proved the law were conducted in 1756, or thereabouts, according to Soviet scholars, although they cannot produce any genuine experimental data left behind by Lomonosov[11]. They have only a terse statement, a portion of Lomonosov's report to the president of the Imperial Academy of Sciences describing his

[8] *Kaminer*, p. 310. A photoduplicate of the page of the *Annales Typographiques* containing the note appears here.

[9] *Ibid.*

[10] M. V. Lomonosov, *Sbornik Statei i Materialov* (Moskva: Izdatel'stvo Akademii Nauk SSSR, 1951), III, pp. 44–5. Hereinafter referred to as Lomonosov, *Sbornik*, with volume number.

[11] B. N. Menshutkin claims that the experiments were conducted in 1753–56. See: B. N. Menshutkin, *Zhizneopisanie Mikhaila Vasil'evicha Lomonosova* (Moskva: Izdatel'stvo Akademii Nauk SSSR, 1937), p. 146. Other Soviet writers merely say that the experiments were conducted in 1756.

laboratory work during 1756[12]. Of the three documents mentioned above, the laboratory report is the most critical, and in a sense the most puzzling. Soviet scholars have read so much into that slender document, that their descriptions of Lomonosov's experiments are considerably more detailed than his own. It is best, however, to analyze the laboratory report later, since it is supposed to be the experimental confirmation of the law. Let us first scrutinize Lomonosov's theoretical works dealing with the problem—passages cited by Soviet authors to support their claims and other passages which have somehow been overlooked, but which nonetheless bear critically upon the problem.

Lomonosov enunciated his alleged law in a letter to Leonard Euler on 5 July, 1748[13]. The letter was really a treatise in epistolary form, and it was largely devoted to an attack upon several of Newton's major physical conceptions[14]. Lomonosov's argument against the Newtonian concept of gravity, which he believed violated the law of the conservation of motion, culminated in a statement about the universal natural law of conservation:

> . . . But all changes met with in nature occur so, that if to anything something is added, then it is taken from some other thing. Thus, as much matter is added to some kind of body, so much is taken from another, as many hours I spend on sleep, so many I withdraw from wakefulness, etc. Since this is a universal law of nature, then it applies also to the laws of motion. A body which, by impulse [by a push, P.P.] excites another body to motion, loses as much of its motion as it communicates to the other moved by it . . .[15].

This fragment from Lomonosov's letter to Euler reveals that Lomonosov's major concern was the principle of the conservation of motion or momentum, and that as an ancillary argument he stated a general law of conservation, which contained ideas that had been widely accepted by both ancient and

[12] The laboratory report apparently was first published in: P. Biliarskii, *Materialy dlia Biografii Lomonosova* (Sanktpeterburg: Tipografiia Imperatorskoi Akademii Nauk, 1865). Hereinafter referred to as *Biliarskii*.

[13] The letter is printed in full in: Lomonosov, *Polnoe Sobranie Sochinenii*, II, pp. 170–193. Both the original Latin text and a Russian translation are provided. In addition, on page 195 of the volume cited there is a reproduction of the manuscript page which contains the alleged law.

[14] Lomonosov was strongly opposed to the idea of force acting at a distance. His argument against Newtonian gravitation immediately preceeds the statement of the principle of conservation, and it is, unless I am mistaken, an example of the *petitio principii*: "First of all, if there exists in bodies a pure force of attraction, then it is necessary to assume that it is innate to them to affect motion. But it is known by all that the motion of bodies is produced by impulse [a push, P.P.]. It follows that for the appearance of one and the same effect in nature there exist two causes, and besides, contradictory to one another . . .". Lomonosov, *Polnoe Sobranie Sochinenii*, II, pp. 181–83.

[15] Lomonosov, *Polnoe Sobranie Sochinenii*, II, pp. 180–5.

modern atomists. As an atomist, Lomonosov believed that matter was indestructible, but that it could be transferred from one body to another. One could hardly call this an original notion, certainly not in the middle of the eighteenth century. Furthermore, the principle of the conservation of motion or momentum that Lomonosov sought to prove by logical demonstration had already been thoroughly demonstrated, experimentally and mathematically, in the combined work of Newton, Leibniz and Huygens. If there is anything original here, it is the law which refers to sleep and wakefulness, and the former president of the Soviet Academy of Sciences felt that it too deserved recognition under the rubric, "the law of the conservation of time"[16].

The ideas that Lomonosov developed in the letter to Euler on 5 July, 1748, were further elaborated in the "Dissertation on the Solidity and Fluidity of Bodies", written in 1760. There was no change worthy of note in his restatement of the law of the conservation of matter[17]. On the basis of these two bits of evidence it is impossible to credit Lomonosov with any significant contribution to an understanding of chemical processes. There is certainly no indication that Lomonosov had experimentally demonstrated the law of the conservation of matter in chemical transformations. There is, however, the third piece of evidence—the laboratory report of 1756. This is the complete text of the relevant section of the report:

> Among various chemical experiments, of which there is a thirteen page journal, there were conducted experiments in tightly sealed vessels in order to investigate whether the weight of metals increases from pure heat. By these experiments it was found that the opinion of the celebrated Robert Bitsie (sic) is false, for without the admission of the external air, the weight of the burned metal remains the same . . .[18].

In his yearly laboratory reports Lomonosov always referred to his laboratory journals. Unfortunately, only one such journal has been preserved, and it is not the journal for 1756[19]. Soviet scholars point to the laboratory inventories for 1757, 1759, and 1760 as evidence of the experiments that Lomonosov presumably conducted in 1756, since they cannot produce the journal of the experiments[20]. The inventories are nothing but lists of reagents and minerals,

[16] S. I. Vavilov, "Zakon Lomonosova", *Pravda*, No. 5, 5 Jan., 1949, p. 2.

[17] Lomonosov, *Polnoe Sobranie Sochinenii*, III, pp. 382–3: "But since all changes occurring in nature are such, that as much is removed from one body, so much is added to another, so if somewhere some matter diminishes, then it increases in another place, as many hours are spent on vigil, so many are taken from slumber. This universal natural law extends to the very laws of motion . . .".

[18] *Biliarskii*, p. 313.

[19] Lomonosov, *Sbornik*, I, pp. 11–12.

[20] Lomonosov, *Polnoe Sobranie Sochinenii*, X, p. 785. See footnote 35 to Document 516.

some of which had been dissolved, others burned under a variety of conditions. There are several hundred entries, and a number of them are metals that had been burned in kilns, glass furnaces, sealed clay retorts, and glass phials[21]. What kind of conclusions can be drawn from these lists? We may conclude that Lomonosov had been busy burning and dissolving things, and that he had been seeking answers to questions by burning and dissolving things, but we do not know what questions he asked and what answers he received. We can only speculate. The laboratory inventories were not even Lomonosov's own work. The first inventory was drawn up in 1757 by his pupil and collaborator, V. I. Klement'ev, the second one in 1759 by the new director of the laboratory, U. K. Sal'khov, and the third in 1760 by I. M. Klembken[22]. These inventories cannot be accepted as evidence of experiments conducted by Lomonosov in 1756. The only genuine evidence that we have is the laboratory report printed above. It is impossible to misinterpret that simple document. Lomonosov simply states that metals burned in sealed glass vessels do not increase in weight if external air is not admitted. Soviet scholars claim that Lomonosov weighed the retort with the metal in it both before and after burning and found that the weight of the entire system was the same[23]. Nowhere does Lomonosov state that he weighed the retort with the metal in it. Let us assume for the sake of argument that he did. It would have been rather shocking if he had found that the weight of the retort and metal taken together had increased while the weight of the metal itself remained constant. It is better to assume that for some reason an oxidation reaction did not occur, or that the gain in weight was so small due to the size of the vessel, the amount of heat applied, the type of metal used, the duration of heating, or any possible combination of these factors, that Lomonosov could not measure it. It is possible that Lomonosov did not measure accurately. In a word, our speculations are as good as those of Soviet scholars in the absence of a description of the experiments, and unless they can produce a fuller description of Lomonosov's

[21] Lomonosov, *Sbornik*, III, pp. 265–318. On page 268 there is a list of most of the entries that deal with burned metals. The entries themselves appear for the most part on pp. 298–302.

[22] *Ibid.*, pp. 265–6.

[23] This claim is put forward by a number of Soviet authors. See, for example: B. S. Kuznetsov, *Lomonosov, Lobachevskii, Mendeleev* (Moskva: Izdatel'stvo Akademii Nauk SSSR, 1945), p. 80; A. F. Kapustinskii, *Ocherki po Istorii Neorganicheskoi i Fizicheskoi Khimii v Rossii* (Moskva, 1949), p. 23; the article by S. I. Vavilov in *Pravda*, 5 Jan., 1949; the note to the "Dissertation et the Solidity and Fluidity of Bodies", in: Lomonosov, *Polnoe Sobranie Sochinenii*, III, p. 563; B. B. Kudriavtsov, *The Life and Work of Mikhail Vasilyevich Lomonosov* (Moscow: Foreign Languages Publishing House, 1954), pp. 61–2. The lastest work that I have seen that makes this claim is: A. F. Kononkov i B.I. Spaskii, *M. V. Lomonosov kak Fizik* (Moskva: Izdatel'stvo Moskovskogo Universiteta, 1961), p. 102.

experiments on the calcination of metals, plus evidence that he drew the correct conclusions from his experimental observations, there is no reason to believe that Lomonosov discovered the law of the conservation of matter in chemical transformations.

Although there is no evidence that he did discover the law, there is clear and indisputable evidence that Lomonosov did not at all comprehend that metals burned in closed vessels combined with a constituent of the air inside the vessels. This is revealed in at least three of his works. Since it is a law of chemistry that we are concerned with, some of Lomonosov's remarks about oxidation, or calcination, should prove more valuable than general statements about conservation ancillary to his theory of motion. Lomonosov's ideas about calcination appear in "Reflections on the Causes of Heat and Cold", written in 1749[24]. The ideas expressed in this work were also contained in an earlier paper, "On the Reasons of Heat and Cold", written by a student of Lomonosov in 1744. It contains amendments and corrections made by Lomonosov, and is apparently the prototype of the 1749 paper[25]. The ideas in both papers are developed in the course of an attack upon Robert Boyle's belief that stable and ponderable fire particles existed. Lomonosov did not believe in the existence of these particles. An inspection of the two papers reveals that Lomonosov attributed the gain in weight of calcined metals to the "acid of sulphur, which it is possible to liberate from phlegiston, to collect and trap under a bell jar. It penetrates into the pores of copper and silver, and uniting with them, produces an increase in weight"[26]. This quotation was taken from the 1749 paper. In the 1744 paper the same idea was expressed in another way:

> Indeed, among other experiments, a copper plate, burned in the flame of sulphur, acquired the additional weight of 32 grains; such an increase in weight was revealed in silver, burned in a like manner. I am surprised that a scholar, in other instances circumspect, here did not think of the acid spirit, which is drawn by the flame from sulphur and penetrates into the metal, which swells and increases in weight from its adhesion . . .[27].

In both papers, Lomonosov referred to an acid substance, the "acid of sulphur" liberated from phlogiston, or the "acid spirit" drawn by flame from sulphur. Apparently, he used "phlogiston" and "sulphur" interchangeably. Lomonosov had not yet discarded the heritage of seventeenth-century chemistry.

[24] Printed in full in: Lomonosov, *Polnoe Sobranie Sochinenii*, II, pp. 8–55. Latin and Russian.

[25] Printed in full in: *Ibid.*, pp. 64–103. Latin and Russian. See *Ibid.*, p. 653, the note to the work under heading 3.

[26] *Ibid.*, pp. 46–7.

[27] *Ibid.*, pp. 96–9.

Lomonosov referred to experiments conducted by Boerhaave and Duclos, but not to any of his own, in both papers:

> Finally, the famous Boerhaave and Duclos conducted these experiments, evidently with contradictory [to Boyle, P.P.] results. The first weighed five pounds and eight ounces of iron before burning, and then again after burning and cooling, but did not find any kind of increment or diminution in weight. The second attributed the increase in the weight of minerals by burning to sulphur particles floating (as we said above) in the air, which incessantly flow over the mineral subjected to burning. . . . This he shows in an experiment, namely: he observed that from regulus of antimony *burned in the open air* [my italics, P.P.] there is extracted with the help of wine spirits a red extract, upon whose separation the remaining mass possesses the weight of the regulus before burning; that regulus of antimony, *burned differently* [my italics, P.P.] without gaining weight, does not provide such an extract. Thus, that evidence which is based upon the increase in weight of burnt bodies, and is presented in the defense of a special, peculiar fire of matter, is not convincing . . .[28].

Lomonosov distinguished between metals burned in the open air and those "burned differently". In the former case, the sulphur particles floating in the air that constantly flowed around the burning metal contributed matter to the metal, and caused an increase in weight. In the latter case, an increase in weight did not occur. Metals, therefore, did not always increase in weight when they were burned. Lomonosov believed that under certain conditions the metal's weight would remain constant. Metals burned in sealed vessels presented a special problem for Lomonosov. This is revealed in two documents, the letter to Euler of 5 July, 1748, and a paper written in 1757–58, *after* he had allegedly proven his law by experiments. The paper was entitled, "On the Relationships of the Quantity of Matter and Weight"[29]. In both the letter to Euler and the paper written ten years later, Lomonosov revealed beyond doubt that he was reluctant to accept the idea that metals could gain weight in sealed vessels, but that the gain in weight could nonetheless be explained without resorting to Boyle's fire particles. He repeated his belief that metals burned in the open air gained weight due to floating particles and added:

> . . . Yet, if we take into account experiments which cannot be doubted, done in closed vessels, in which the weight of a calcined metal also increases, then it will be possible to answer that *in consequence of a destruction of the linkages of the particles* [of the metal, P.P.] *by calcination,*

[28] *Ibid.*, pp. 48–9. This is the 1749 version. In the 1744 version it is clearer that Lomonosov was underwriting the experiments and conclusions of Boerhaave and Duclos. He wrote· "Their results evidently sooner confirm my theory than the opposing one". See, *Ibid.*, pp. 98–9.

[29] Lomonosov, *Polnoe Sobranie Sochinenii,* III, pp. 350–371. Latin and Russian. See the note in *ibid.*, p. 556 for dating of work.

> *their surfaces, earlier closed by mutual contact, are rendered freely exposed to the gravitational fluid. Therefore, the same bodies are driven more strongly towards the centre of the earth . . .*[30].

Here is a curious explanation indeed. Rather than an anticipation of Lavoisier, it is a reversion to a Cartesian explanation, purely mechanical, without any indication that the author realized that a chemical combination occurs when metals are burned in sealed vessels, assuming that correct conditions for an oxidation reaction are present. The laboratory report of 1756 only confirms the conclusion that Lomonosov did not believe that metals burned in sealed vessels combined with a constituent of the air in the vessels. He believed that the basic particles of the metals separated, and were consequently subjected to greater pressure by a "gravitational fluid". The wording of Lomonosov's remarks about calcination in closed vessels reveals his reluctance to believe that any kind of combination occurred, either physical or chemical, despite the evidence of "experiments which cannot be doubted". His gravitational theory of calcination in closed vessels appears to be a last resort. There is no need to dwell upon the peculiar consequences of such a theory.

It is remarkable that Soviet scholars could misinterpret this kind of evidence. There is no reason to believe that Lomonosov anticipated Lavoisier in the solution of the problem of oxidation, and there is weighty evidence that he did not.

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Lomonosov's greatness consisted in the enormous scope of his intellect, and in the vast reservoir of creative vigour that inspired him to undertake numerous ambitious projects, and to complete many of them successfully. But if any single work of Lomonosov is viewed together with that of a great eighteenth-century thinker in a given field, the Russian scholar's work may well suffer by comparison. Lomonosov was an exceptional human being, but he was not superhuman, despite the exaggerations of Soviet historians of science. His work should be judged in its totality, always with the awareness that many flaws and lapses will appear. It was not at all my intention to put Lomonosov in a bad light in this paper. Soviet scholars may call Lomonosov a genius and an innovator without calling forth any protest on my part. However, the attribution of certain specific scientific discoveries to him is quite a different circumstance, and historians of science must ascertain whether or not Soviet claims are well founded. If there is more evidence that can be brought to bear upon this problem discussed in this paper, it would be a service to historians of science if it were published, so that Lomonosov might receive his just reward—general recognition. If there is none, then it is impossible to credit Lomonosov with the discovery and experimental demonstration of the law of the conservation of matter in chemical transformations.

[30] *Ibid.*, pp. 368–9.