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***IN HONOR OF THE 300TH ANNIVERSARY OF THE BIRTH OF M V LOMONOSOV***

# "Geniuses like this are very rare today..."*

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## Contents



**Abstract.** **This paper gives insight into the context of how Lomonosov developed into a scientist and a physicist; reviews his major achievements in physics; discusses his epistemological method, and explores the major reasons for his tragedy as a physicist. The role of the poetically interpreted knowledge and science of nature in Lomonosov's popularization activities is emphasized. The paper traces Lomonosov's route from science and its popularization to the organization of higher and secondary education in Russia. How the perception of his genius changes with time is discussed.**

## 1. Introduction

Mikhail Vasil'evich Lomonosov, a polymath scientist and educator of the 18th century, is a symbol of Russian state and society, of national science and culture. The lasting significance of Lomonosov for physical science in this country also lies in the fact that he was, by reason of circumstances, its first and most illustrious physicist.

Lomonosov's versatile and harmonious personality attracts the attention of both 'physicists' and 'lyrics', actors in all spheres of science, culture, and education. A great volume of literature devoted to Lomonosov includes, among other things, accounts of his work in the fields of physics and astronomy.

Of special interest in this context are publications in which prominent scientists of different times give a professional and ideologically unprejudiced assessment of Lomonosov's physical works. The most relevant facts can be found in articles written by P N Lebedev [1], P P Lazarev [2], S I Vavilov [3], P L Kapitza [4], and some other Russian physicists and astronomers (see, e.g., Refs [5, 6]).

In 1950 and 1961, two papers by B I Spasskii [7, 8] appeared in *Uspekhi Fizicheskikh Nauk* (*Physics–Uspekhi*); they contained a deep and detailed analysis of the role of Lomonosov as the founder of Russian science and his achievements in the development of physics. Even earlier (1947), M I Radovskii published a review [9] of the book about Lomonosov by B N Menshutkin that was very popular in the first half of the 20th century.

The overall objective assessment of the place of Lomonosov in Russian physics by the above authors greatly promoted the formation of public opinion among native scientists as regards his services to science, his crearive path, and his personality. Popularization of his works shaped the public image of Lomonosov as the brightest mind of 18th century Russia.

The present article focuses on the personal aspect of Lomonosov's creative work. For all his scientific achievements, his fate as a physics researcher was sad rather than happy. P N Lebedev wrote that "it did not allow him to realize even a thousandth part of the capabilities he was endowed with; his own misfortunes typify the tragic fate of a scientist in Russia" [1, p. 354].

An analysis of the discrepancy between the exceptional intellectual potential of Lomonosov as a scientist and the ultimate results of his work in physics continues to be relevant today, not only in terms of the logic of development of science at the time, but also with respect to the circumstances that interfered with the recognition his genius deserves and that could or can just as well affect anyone anywhere at any time.

For us, the tragic fate of Lomonosov is instructive in that it was to a large extent due to the contradictory conditions of Russian life, with its frequent social cataclysms and apparently insurmountable troubles. Under such conditions, one

* L Euler's quote characterizing M V Lomonosov. (*Editor's note*.)

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cannot do better than follow Descartes's maxim: "to try always to master myself rather than fortune, and to be as firm and decisive in my actions and opinions as I could once I had adopted them" [10].

Those who dream of 'becoming Lomonosov' or wish to be like him should remember that we, like him, continue to live in Russia with its long-standing traditions and mentality. By learning the lessons of this great man, we acquire some sort of psychological immunity against misfortunes on the way to the unique goal of penetrating into the secrets of nature.

## 2. Lomonosov's formation as a scientist

The social and educational status of M V Lomonosov (1711–1765) could hardly have given him the hope to seriously study natural science, especially physics, that just at that time had begun to be influenced by Newton's doctrine with its system of concepts and notions, basic theories, and mechanical — mechanistic — research program.

The fact that Lomonosov became the first Russian physicist who suggested a number of breakthrough scientific ideas despite highly unfavorable conditions for the development of science in Russia in his time is first and foremost attributable to his genius, insatiable interest in everything around him, and unremitting zeal for penetrating into the secrets of nature, coupled with a serendipitous circumstance that in the end enabled him to engage in numerous scientific activities.

M V Lomonosov was born on November 19, 1711 into the family of a coast-dwelling peasant in the White Sea region. In the youth, he made a careful study of the material of two textbooks, the Slavic *Grammar* of Smotritskii, and the *Arithmetic* of Magnitskii. The latter included a survey of many sciences of the day, such as mathematics, astronomy, physics, geodesy, and navigation. When he was nineteen, Lomonosov resolved to go to Moscow to seek further education. He represented himself as the son of a nobleman and was admitted to the Slavic-Greek-Latin Academy.

However, his interests lay in the direction of natural sciences and mathematics. Luck came after 5 years of eager studies. When the Moscow school was requested to send its 12 best students to learn at the Academy of Sciences in St. Peterburg in 1736, Lomonosov was the first choice. There, the future scientist started familiarizing with the elements of mathematics and physics at the lectures of the well-known physics experimentalist G W Krafft; simultaneously, he developed his own experimental skills.

Eight months later, Lomonosov was sent to Marburg University to study chemistry and acquire a profession of 'skilful mining physicist' under Christian Wolff, who taught students exact natural sciences and familiarized them with the works of classics. Then, Lomonosov had to proceed to Freiburg to study the fundamentals of mineralogy, mining, and metallurgy. For 5 years, he acquired knowledge of physics, chemistry, philosophy, linguistics, and poetry.

But the most valuable acquisition was understanding the essence of the Cartesian and Newtonian method and its applicability to the formation and rationale of scientific knowledge. In addition, he was influenced by the ideas of Leibniz–Wolff scientific school, even though he did not strictly follow their teachings in his subsequent papers (P L Kapitza once noted that "creative disobedience is an intrinsic trait of a man of genius" [11]). Indeed, Lomonosov pursued his own path in science, not hesitating to incidentally pick up 'tasty morsels' from the teachings of his predecessors on which to base his own original ideas.

At the same time, Lomonosov bathed in Germany in the atmosphere of science and education that prompted him to choose those main areas of creative activity that he thought would be most needed in his own country. At that time, he was determined to create a consistent system of physics that would rationally explain the phenomena of 'this visible world' and to apply his personal knowledge and scientific achievements to the benefit and prosperity of the Russian Empire.

## 3. His work as a physics scientist

Lomonosov was early distinguished from most of his companions by characteristic features that shaped his creative disposition. His family's life and the conditions under which he had been raised made him a self-absorbed youth concentrated on his own thoughts; to these qualities he owed much of the love for learning that he displayed throughout his life (in keeping with Pushkin's aphorism: "The Muses' service brooks no vanity").

He was at the mercy of mental uneasiness, some inner strain and the desire to change his fate, intellectual excitement constantly requiring new food for mental pabulum, and the capacity to become enamoured of all new knowledge and interests. But Lomonosov's most distinctive quality was his unsurpassed natural abilities. "One can hardly say why they manifested themselves to such a great extent in him rather than in anyone else" [12].

When 28-year-old Lomonosov returned to Russia in 1741, he immediately became engaged in versatile activities within the walls of the St. Petersburg Academy of Sciences, where some foreign scholars, both physicists and mathematicians, still worked (J Delille, G Krafft, and G Richman being the same age with him). However, G Bilfinger, D Bernoulli, and L Euler had already left Russia by that time. Soon, G Krafft and J Delille followed them.

In the end, only two successful physicists remained at the Academy, Richman and, of course, Lomonosov. The latter became adjunct of the 'physical class', and thereafter professor of chemistry and member of the Academy (1745) to which he brought fame through many important achievements. Moreover, he organized the chemistry laboratory (1748) and built a factory to manufacture colored glass (1753).

Lomonosov contributed to the formation of the majority of spheres of science and culture in Russia. His studies in the fields of physics, chemistry, physical chemistry, astronomy, mineralogy, mining, and instrument engineering, geography, the humanities and social sciences, and public education laid a solid basis for the further development of science and culture in the country.

By that time, European scientists had realized the possibility of attracting public attention to science by demonstrating its benefits to society. In turn, Lomonosov tried to persuade his compatriots that "there is not a single place in Russia enlightened by Peter the Great, where sciences could not bring fruits, and not a single man who could not expect to benefit from them" [12]. In this regard, he gave primacy to basic sciences in the process of mindset formation and a variety of practical applications.

Lomonosov made his greatest discoveries in physics, chemistry, and astronomy. According to his most fruitful achievement — development of atomic-kinetic conception — matter is composed of corpuscles (molecules) made of elements (atoms), the corpuscles being in continuous motion responsible for most of the thermal properties of bodies. In other words, he believed that heat is due to the motion of particles of a substance [7, 8].

By his own admission, Lomonosov pondered this concept over many years but its first postulates had been formulated when he was still a student in "Fizicheskaya dissertatsiya o razlichii smeshannykh tel, sostoyashchem v stseplenii korpuskul..." ("Physical thesis on the distinction between mixed bodies, consisting in the coupling of corpuscles"). This work was reviewed by G Krafft, L Euler, and J Weitbrecht. The theory was consistently expounded in the "Elementy matematicheskoi khimii" ("Elements of mathematical chemistry") (1741) [13]. In his subsequent years, Lomonosov supplemented this theory and applied it to the explanation of a variety of natural phenomena.

In his main theory, Lomonosov proceeded from the principle of the material unity of the world, and the continuous motion of matter and its constituent elements. He believed that the whole variety of visible natural phenomena and processes obey a few fundamental laws. This belief in the unity and simplicity of physical reality to a large degree determined his choice of the subject matters and problems of research, as well as success in solving the problems of interest.

Guided by the principle of simplicity of physical reality, Lomonosov arrived at the conclusion that "seeing as the central motion of corpuscles alone is sufficient for explaining heat, there is no need to invent other causes". And somewhat below, "Specific heat-generating matter is just a fiction because fire and heat result from the internal rotary motion of particles" [13]. Therefore, Lomonosov denied the existence of a hypothetical heat matter (weightless liquid).

Based on his atomic-kinetic concept, Lomonosov could make several predictions important at the time. Specifically, he deduced that heat is the motion of corpuscles and that "the highest degree of cold" is possible when complete cessation of movement occurs [6]; also, he revealed that the Boyle–Mariotte law becomes increasingly inaccurate at high pressures. Next, Lomonosov studied aggregate states of matter and the thermometric properties of bodies, determined several gas expansion coefficients, and proposed rather accurate methods of weighing.

Lomonosov tried to apply his corpuscular approach to explaining gravity. He assumed the existence of a peculiar "gravity matter" with specific properties, having no weight and consisting of impenetrable inertial particles. Interactions between bodies occur due to the presence of these particles. He verified the theory in time-consuming experiments with a specially constructed "pendulum centroscopicum".

In the work entitled "Opyt teorii uprugosti vozdukha" ("An attempt at the theory of air elasticity") (1748), Lomonosov proposed for the example of air a kinetic theory of gases, stating that the property of elasticity is intrinsic not to individual atoms but to atoms in their totality. According to him, "the elastic force results from the tendency of air to expand every which way" [13]. This theory enabled Lomonosov to find a rational explanation of the relationship between gas pressure, volume, and temperature.

Even with regard to isolated errors, e.g., the statement that the rotary motion of corpuscles is the cause of the thermal properties of bodies, supported by H Davy and J Joule already in the 19th century, the basic tenets of Lomonosov's corpuscular theory seem as if they were borrowed from treatises on molecular physics in the early 20th century (see P P Lazarev [2, p. 1356]).

However, the main disadvantage of Lomonosov's theory, similar to the preceding theories devised by L Euler and D Bernoulli, probably lay in its essentially qualitative, descriptive character, which precluded its experimental verification and any practical application. In this respect, bis kinetic theory of heat continued to cede to a caloric theory.

Another big discovery Lomonosov made before A Lavoisier was the enunciation of the law of matter (mass) conservation [14]. In his regular letter to L Euler (1748), Lomonosov broadly interpreted this law as follows: "All changes occurring in nature proceed so that if something is added to one object, it is taken from another" [11].

Lomonosov also extended his universal law of conservation to motion. In his paper "Rassuzhdenie o tverdosti i zhidkosti tel" ("Reflection on the solidity and liquidity of bodies") (1760), he argued that "an object moving the other by its own force in fact imparts to another object the force it loses" [13]. This conjecture, actually implying what is known as the law of conservation of force, appears to have anticipated the law of conservation of energy.

By this discovery, hence, Lomonosov valuably contributed to the origin and development of our concepts concerning the laws of conservation of different types and significance and their role in the processes underlying physical phenomena on Earth and in the Universe. And if modern physics is based on the generally known laws of conservation of energy and momentum, therein is also Lomonosov's merit even if it has been somewhat obscured by time.

The scholars of the 18th century actively explored electrical phenomena. Important experiments were conducted by S Gray, C Du Fay, P Musschenbroek, and J-A Nollet. Lomonosov also participated enthusiastically in experiments on atmospheric electricity carried out by G Richman. After the latter's tragic death, Lomonosov developed in 1756 a mathematical theory of electricity expounded in his article "Teoriya elektrichestva, izlozhennaya matematicheski" ("The theory of electricity expressed mathematically") [13]. However, this theory was essentially electrostatic, unlike that of Benjamin Franklin, who left room for electric current [15].

In the field of optics, Lomonosov supported Huygens' wave theory of light but rejected Newtonian corpuscles. Also, he proposed the theory of colors regarding red, yellow, and blue as primary ones ("from which all other colors can be mixed"). As far as the nature of light is concerned, Lomonosov believed it to be "a surging motion of ether" [13] (meaning Descartes' ether). Moreover, he tried to establish the relationships among thermal, chemical, optical, and electrical processes.

For example, he planned to elucidate the interplay between optical and electrical phenomena in his article "127 zametok k teorii sveta i elektrichestva" ("127 notes on the theory of light and electricity") and "to make an experiment to explore if a light beam is refracted differently in electricized glass or water" [13]. It is unknown whether he performed such experiment or not. Only in 1875 did Scottish physicist J Kerr observe birefringence in an isotropic substance placed in an electric field (the Kerr effect).

Convinced of the common physical nature of terrestrial and celestial matter, already at that time Lomonosov considered it beneficial to make astrophysical studies and necessary observations. He advocated the electrical nature of auroras being always of interest for him and certainly hypothesized about the origin of solar thermal emission. He explained the nature of a comet's tail glow in terms of his theory of atmospheric electricity.

Lomonosov designed a number of instruments for his experiments, including a night-vision telescope to facilitate night-time observations of celestial bodies. Using this tool to observe the transit of Venus across the solar disk ("and interested largely in the accompanying physical phenomena"), he discovered the "great air atmosphere" of this planet. He expressed his idea of the infinite and diverse Universe in these inspired lines: "An abyss has opened, full of stars, the stars numberless, the abyss bottomless".

To sum up, Lomonosov left very important physical works that cover the kinetic theory of gases and the theory of heat, optics, electricity, gravity, and the atmospheric physics. It being apparent that he did these works practically at a qualitative level and usually in the form of separate fragments involving sometimes the description of his own experiments, either performed or yet designed. Many of them, however, were not completed for a variety of reasons.

Lomonosov reported the results of his physical and chemical research at meetings of St. Petersburg Academy of Sciences, publishing them in Academy's proceedings *Kommentarii* (*Commentaries*) or *Novye Kommentarii* (*New Commentaries*). However, in-depth scientific discussions within the walls of the Academy were rare and unproductive since as before only few of their participants were able to fully appreciate Lomonosov's physical ideas (G Krafft and G Richman were among them for a short time, as was F Aepinus during the last 8 years).

Lomonosov was convinced that Nature was cognizable and described the process of scientific cognition as "a trying to get the truth from it." He considered experiment to be the main criterion for testing any his theory or hypothesis: "I rank a single experiment above a thousand opinions prompted only by the imagination" [13]. He emphasized that a hypothesis must only be based on the conducted experiment to be applicable to the theoretical explanation of a phenomenon of interest.

These arguments were not mere abstract philosophical speculations. Lomonosov came to them from personal experience. In different periods, his experiments were designed to measure the heats of absorption and melting of various materials, check the law of conservation of mass, elucidate the interplay between electric and magnetic forces, determine the measure of color variations in objects, confirm his theory of gravity, and many others.

Lomonosov carried out his experiments using instruments he had collected in the Physics Cabinet of the Academy [forerunner of the present P N Lebedev Physical Institute, RAS (FIAN)]. He also demonstrated them at lectures on experimental physics for the university students. Later on, when he found himself in acute need of tools for optical studies, Lomonosov, like some of his foreign colleagues, created his own home laboratory/workshop.

Practically speaking, there was no solid basis for serious experimental studies in Russia at that time. Although Lomonosov, jointly with Bilfinger, Krafft, and Richman, did his best to keep the Physics Cabinet running efficiently, he could not turn it into a national center of serious physical research. This led him to constantly apply to the Academy authorities for funds to build a specialized physicochemical laboratory.

It should be noted that Lomonosov began his physics and astronomical research as early as 1738 during his stay in Germany. When a student, he wrote the article "O prevrashchenii tverdogo tela v zhidkoe..." ("On the conversion of a solid body into a liquid"). In a quarter of a century, he finished the last work "Ob usovershenstvovanii zritel'nykh trub" ("On the improvement of observation tubes") (1762) in which he proposed the design of a reflecting telescope, the precursor of W Herschel's telescope design.

In January 1764, Lomonosov prepared "Otchet o zavershennykh i nezavershennykh nauchnykh i literaturnykh rabotakh" ("The report on finished and unfinished scientific and literary works") for the Academy of Sciences in Bologna. It appears that he was still working on "a new and correctly proved system of entire physics." He had actually begun thinking of this theory when a young man in Germany. In May 1764, Lomonosov summarized the results of his fruitful scientific work in "Obzor vazhneishikh otkrytii" ("Survey of the most important discoveries").

## 4. Methodological principles of the scientist

Lomonosov was for the rest of his life grateful to his teacher Ch Wolff for the lessons in critical thinking. Nevertheless, very early (when in Germany) he started to regard the physical world from a somewhat different standpoint than did Wolffian natural philosophy, which recognized God's primacy in Nature. In conflict with this view, Lomonosov argued that matter is what constitutes natural bodies and their movements and changes.

During his studies in Germany, Lomonosov started to conceive and use for his own purposes the major methodological principles of scientific cognition formulated by Bacon, Galileo, Descartes (whose ideas influenced Lomonosov greatly), and Newton that prevailed among advanced European minds of that time and governed their research activities.

Most of them, as a rule, believed that the world of physical phenomena is material and cognizable insofar as the causes of the processes or phenomena of interest are known; the number of such causes must be as small as possible and they must be accessible to experimental exploration and theoretical interpretation of appropriate inferences; finally, the truth must be simple and conform to prior knowledge about the phenomena.

Lomonosov had a clear idea of how to plan and carry out research, interpret experimental findings, and propose a hypothesis based on analysis, synthesis, and own intuition. From his experience in the natural sciences and other fields, Lomonosov thought it beneficial to use the entire scope of methods and means available at his time. Such an approach "makes it easier to obtain insight into the occult nature of bodies" [13].

The early unfinished work "Elementy matematicheskoi khimii" ("Elements of mathematical chemistry") published in 1741, where chemical phenomena are explained by physical (mechanical) conditions, exemplifies Lomonosov's complex method of cognition of the world ("my chemistry is physical"). He wrote in this regard that "the theory of solutions is the first example and model on which to base true physical chemistry" [11].

Lomonosow argued that all natural phenomena may be described in terms of measure, weight, and number, which makes mathematics indispensable for their study. According to him, experiment and mathematical method are the main instruments by which scientific information is obtained. However, the quantitative approach found wide application in the works of European researchers only in the late 18th century.

Lomonosov emphasized the close connection between theory and experiment in the research work: "The best way to reveal the truth is to deduce theory from experiment and to verify experimental findings with the theory." However, intuition ("a sort of revelation") is just as important for a scientific discovery. By intuition, the greatest scientists arrived at bold hypotheses and this was "the sole way the most important discoveries came to them" [13].

Lomonosov accentuated that God gave two books to humanity, one (about the world) for "physicists, mathematicians, and astronomers," the other (the Holy Scripture) for "prophets, apostles, and fathers of the church." He insisted on the distinction between science and religion with its mysticism, and argued that science is the sole and exclusive source of truth. The question of the relation between science and religion is still with us [16].

It follows from the above that the methodological 'picture' of Lomonosov as a physicist matched in principle and general outline the requirements of his scientific epoch. They would be equally well acceptable at our time if supplemented by the norms and standards set by modern science. However, Lomonosov was unable to fully realize these ideal principles in his practical activities.

## 5. The tragedy of Lomonosov's genius

George Sarton, a French historian of the 20th century science, once noticed that "scientific discovery marches on and today's truth will become tomorrow's anecdotes. Science is important but individual human fates are infinitely more important" [17]. In the socio-cultural context, most people obviously have little or no concern about the drama of scientific ideas, whereas a personal drama appeals to a much wider audience.

Indeed, it is impossible to gain a complete and objective understanding of the history of scientific ideas without knowing the individual qualities of their authors. The analysis itself of a creative personality, motives of his or her deeds, behavior, moral standards and aims was always no easy matter, especially without regard to his or her socio-cultural milieu.

To recall, the high place accorded to Lomonosov's achievements by Soviet historians of the 20th century (in the vein of Marxism–Leninism theory) [7] and the tacit prohibition against objective assessment of the true meaning of his creative activities has long precluded the ideologically unbiased analysis of the discrepancy between the unsurpassed genius of Lomonosov and the lack of his tangible influence on world science.

P L Kapitza was the first to break the ban at the session of the Division of Physico-Mathematical Sciences, USSR Academy of Sciences, dedicated to the 250th anniversary of the birth of M V Lomonosov (November 17, 1961). Even then, however, his report was not published in the journals *Priroda* and *Uspekhi Fizicheskikh Nauk* (Editor-in-Chief: E V Shpol'sky). Kapitza submitted the report to *Physics–Uspekhi* in 1962 but it could be published only in an abridged form to which the author did not give consent (see book [11] p. 337). It appeared in the journal only 4 years later [4].

There is nothing surprising about this natural, even if deplorable, historical fact. It was always difficult and painful to part with illusions ingrained in social consciousness by the contemporary life order. We are proud of Lomonosov and his achievements, with which he glorified Russia, and we deeply regret that he could not accomplish all of his goals: some of them were not in fact realized or completed, while the others did not lead to positive results.

Lomonosov himself summarized the research work he had done during his lifetime in May 1764, i.e., a year and a half before his death, in the list of discoveries that he believed enriched natural sciences of his time, such as the corpuscular concept, the kinetic theory of gases and the theory of light, works in mineralogy, geology, electricity, and gravimetry, etc. (a total of nine 'discoveries').

L Euler, who knew Lomonosov's works very well, did him justice by saying that "he is endowed with the most fortunate ingenuity in explaining physical and chemical phenomena." He later added: "Geniuses like him are very rare today..." [17]. Lomonosov's discoveries in the natural sciences became known outside the borders of his country. He was elected a member of the Swedish Academy of Sciences (1760) and a member of the Academy of Bologna (1764).

However, the lack of a proper mathematical background for making thorough investigations and adequate experimental facilities, not to mention the strength and time needed to check his hypotheses and inferences from them, did not allow Lomonosov, a truly romantic scientist with a strain of superficiality in his character, to do more than suggest very general (even if sometimes brilliant) ideas. He made quite a number of errors, and many his works remained either fragmentary or uncompleted.

By way of example, Lomonosov regarded rotary motion as the main form of corpuscular motion. He was convinced that bodies interact only through collisions, denied the proportionality of body mass and gravity, assumed the existence of "gravity matter", and so forth. True, delusions of genius mostly arise from the delusions of one's epoch and imperfections of the cognitive process per se.

It should be emphasized that Lomonosov's works did not contain mathematical calculations to support the conducted experiment and its theoretical interpretation. Although he constantly persuaded readers that mathematics provides a powerful tool for understanding natural phenomena, he could not use it properly himself because his studies with the philosopher Wolff did not give him the knowledge and skills necessary for physical research.

Nevertheless, Lomonosov's achievements, for all his mistakes and neglect of the mathematical apparatus, rank him among such pioneers of physical science as Galileo, Descartes, Newton, and some others [11, p. 206]. True, he was the only person on this list of homor who failed to fully realize his physical genius for a number of objective and subjective reasons, as outlined above. A few more should be mentioned here.

Lomonosov never received due support from his academic Russian colleagues. According to B N Menshutkin, they "simply could not appreciate the importance of his chemical and physical works and did not give them the attention they deserved" [18]. In academic circles, Lomonosov was mostly known as a poet laureate, while his research activities were considered to be just a bit of fun for him. Moreover, they were seriously hindered, according to

P N Lebedev, by his official duties, not infrequently useless and even absurd [1, p. 354].

Lomonosov had no direct contact with foreign colleagues except Wolff and Euler, with whom he maintained correspondence. He communicated to them some of his most important results, and thus they reached Europe, where they were well known; otherwise, he would not have been elected a member of the Swedish and Bolognese academies. However, his theories and ideas were not widely acknowledged, because in many papers Lomonosov did not appeal directly to experiment but rather to general experience and common knowledge. It hampered their integration into the world of Western science.

Lomonosov's theories and ideas continued to be extensively exploited into the 19th century, with its enormous industrial boom and rapid scientific progress (especially in physics). They were further developed and updated, but the name of the author sank into oblivion. Only a few classics (A Volta, T Young, and some others) incidentally reminded their colleagues of the breakthrough achievements of the Russian genius.

Taken together, these circumstances precluded Lomonosov's works from exerting an appreciable influence on the progress of world science "nor did they allow him to experience the joy of creation his genius deserved" (P L Kapitza [11, p. 337]). The discoveries of his contemporaries continued to 'feed' physics, and one comes across their names in any monograph and textbook, whereas the services of Lomonosov are hardly mentioned (see, for instance, *Obshchii Kurs Fiziki* (*General Course of Physics*) by D V Sivukhin [14]); hence, his great tragedy.

From what has been said, in might be assumed that insufficient access to professional education typical of scientist in these days, the lack of support from the State and scientific community, isolation from the world of European science, superficiality and disconnectedness of character, domestic problems, and day-to-day routine collectively account for the unhappy fate that befell M V Lomonosov.

## 6. Science and poetry in Lomonosov's popularization activities

In the last decade of his life, Lomonosov combined research and teaching activities, devoting much attention to the creation of a basis for the teaching process at institutions of higher and secondary education, designing curriculums, and prepairing necessary textbooks. He was the initiator and organizer of the work that eventually led to the foundation in 1755 of Moscow University — the contemporary center of Russian science.

Lomonosov appears to have been born to perform this mission. Having an essentially humanitarian turn of mind, he had adopted by that time the rationalism of European culture. While the intrinsic humanitarian side of his character inspired in him strong feelings of patriotism and instilled faith in a better future and greatness for Russia, the acquired rationalism dictated the logic of behavior in addressing the problems pertinent to the development of science and education in the country [12].

Lomonosov considered science as an effective tool with which to modify the lifestyle of Russian society. He was convinced that "science is a clear cognition of truth, enlightenment of mind, harmless entertainment in life, praise of youth and support in old age, a means for building cities and reinforcing armies, comforting a grieving heart and adorning happiness; in a word, it is a faithful and reliable companion everywhere and at any time" [13].

Those who begin to familiarize themselves with Lomonosov's writings cannot help being amazed at both the diversity and depth of his scientific ideas and the poetical form in which they were presented to the readers. The rich poetic heritage of Lomonosov reflects his keen interest in philosophical and applied issues. Even his laudatory odes may be considered a peculiar civil lirics dedicated to the popularization of scientific knowledge.

For Lomonosov, the poetical language was as good as any other for exposing his views of natural phenomena and scientific problems. His characteristically rich figurative language was equally suitable for the rational explanation of the surrounding world and the infinite Universe, the physical nature of the solar radiation and auroras, the useful properties of glass, weather forecasting, and numerous phenomena and objects of common interest. His poetic imagination guided by faith in the future of Russia served to enlighten its people.

He believed popularization of scientific knowledge to be the best way to achieve this goal and actively and constantly indulged in it first promoting natural sciences. His 'Words' and 'Speeches' contained numerous examples illustrating the importance of science for society. They were designed to stir interest in science, and to overcome ignorance and prejudices.

His "Slovo o pol'ze khimii" ("A word on the benefits of chemistry") exemplifies one of the best specimens of popular science writings illustrating the universal character of this discipline. "Whatever one looks at and wherever one turns, everywhere are noticeable the results of its application" [13]. Lomonosov's arguments carried increasingly greater weight since his contemporaries began to pay him tribute as a man of 'low' origin, who rose to become a polymath and deep thinker.

The vivid illustration of the intrinsic relationship between science and art of those times and the accurate expression of scientific ideas in the poetical form characteristic of Lomonosov's writings attracted the attention of S I Vavilov: "It would not be an exaggeration to say that Lomonosov was a scientist in poetry and art, a poet and artist in science," his poetry popularizing science becoming for us, his compatriots, "a soul-stirring call to true patriotism" [3].

Lomonosov popularized scientific knowledge not only in his verses but also in public lectures, which, apart from their cognitive value, were characterized by genuine concern about further progress in science and education, the faith in a great future for the country and its people. Lomonosov was known for the honest and responsible attitude toward the preparation of his public lectures [19].

Lomonosov was equally concerned about the education of young people and training research workers and technical specialists within the walls of the Academy. Being convinced that "sciences feed young men," he wrote in the very beginning of his career: "I am intended to serve my country to the best of my ability by promoting both the development of sciences and the improvement of youth education" [13].

Having been appointed Rector of the University and gymnasium of the St. Petersburg Academy of Sciences in 1760, Lomonosov proposed a comprehensive program for the development of science and its popularization through print media, library, public lectures, and forums, along with training specialists for future research work, organization and control of the teaching process in educational institutions of Russia.

Lomonosov's efforts were not in vain. His lectures with demonstrations of chemical and physical experiments laid a basis for the rise of such known Russian scientists as V F Zuev, P B Inokhodtsev, S K Kotel'nikov, I I Lepekhin, A P Protasov, and many others who, in turn, greatly contributed to political, economic, and cultural developments in Russia.

Lomonosov did much to improve the system of secondary education. The university without a gymnasium is like "a tilled field unsown." Pupils of the gymnasium "must be given an insight into all sciences studied at the Academy", and "young people must be taught the right mode of thinking and good morals" [13]. In the 20th century, similar schools were organized at Moscow and Novosibirsk State Universities, and the A F Ioffe Physical-Technical Institute.

In 1746, Lomonosov translated into Russian the book by his teacher Wolff, *Experimental Physics*; its creatively revised version was published under the title *Volfianskaya Fizika* (*Wolffian Physics*). He introduced new Russian terms for certain widely used notions, e.g., thermometer, elasticity, barometer, etc., and thereby gave impetus to the development and use of scientific terminology in the Russian language. He supplemented the second edition of this book with information on new discoveries.

The book by Wolff–Lomonosov was the first guide to experimental physics in the Russian language. For several decades it remained the main textbook for secondary schools and served as a pattern for later authors. The Russian terms for cognition and knowledge, teaching and education, gymnasium, class, lesson, etc. coined by Lomonosov entered common usage.

In a letter to Count I I Shuvalov dated 1754, Lomonosov proposed a project for the organization of Moscow University as a means to facilitate access to higher education for young people. The university was to have philosophical department (also for students in the natural sciences), a department of law, and a medical department. Lomonosov was against setting up a theological department. In addition, he thought it necessary to hold public lectures to popularize scientific knowledge.

Lomonosov was sure that "Russian land can give birth to its own Platos and quick-witted Newtons" [13]. He backed these words by his own deeds. In a century, Lomonosov's prophecy came true: Russia did give birth to a pleiad of eminent scientists, such as N I Lobachevsky, I M Sechenov, D I Mendeleev, P N Lebedev, and many others, whose works marked the appearance of Russian science with its characteristic features and traditions on the world stage.

All his life, Lomonosov 'worked' to promote education in Russia, putting forward new ideas and substantiating original theories that were included in his *Collected Works* issued in 1751 and 1757. For all that, Russian society, fairly well aware of the unique intellectual abilities of Lomonosov, had no clear idea of his enormous contribution to the development of science.

Lomonosov was equally alone as a public figure and an individual person. He remained misunderstood by his family and peers, felt alien among rich and poor, sometimes inconvenient for academic community and dignitaries, was taken up with bitter recriminations against his scientific and literary opponents, and had no good acquaintances, let alone close friends [12]. The feeling of loneliness further intensified his personal tragedy.

## 7. Conclusion: rebirth from the ashes

A month before his death, Lomonosov wrote: "I see that I must die and I look on death peacefully and indifferently. I know I shall be mourned by the people of my country." However, during his final illness, he gave way to pessimism, saying: "Now, at the end of my life, I realize that all my good intentions will vanish with me" [13].

Most of his genius remained unappreciated in his day. Lomonosov died on April 15, 1765 at the age of 53 and was buried in the Aleksander Nevsky Lavra (Monastery), St. Petersburg. It was only then that the physicochemical ideas of Lomonosov, a large part of which till that time had remained obscure to the learned world, began to receive more general recognition [20]. However, Pushkin already wrote: "Combining an unusual willpower with an unusual power of understanding, Lomonosov embraced all spheres of learning. The thirst for knowledge was the strongest passion of this passionate soul. A historian, orator, mechanic, chemist, mineralogist, artist, and poet, he attempted everything and comprehended everything..." [21].

In the 19th century, Lomonosov's prestige in Russia rose steadily through the efforts of several scientists (D M Perevoshchikov, M F Spasskii, N A Lyubimov, F A Bredikhin) aimed at the recovery of his breakthrough scientific ideas. In the early 20th century, B N Menshutkin began to unearth Lomonosov's writings, and thereby reintroduced him to Europe as a world-renowned scientist. The main physicochemical works of Lomonosov were published in the famous book series *Klassiker der exakten Wissenschaften* (*Classics of the Exact Sciences*) in 1910.

After W Ostwald, the founder of this series (a physical chemist and Nobel Prize winner in Chemistry 1909), had read Menshutkin's *M V Lomonosov Kak Fiziko-Khimik* (*M V Lomonosov As a Physical Chemist*), he noted in his book *Gro'e M'nner* (*Great Men*): "Had he [Lomonosov] been raised under favorable conditions he would very likely have developed into a high-class researcher" [23, p. 311].

In the 20th century, Lomonosov's genius was triumphantly recognized. His scientific services were increasingly more greatly appreciated as the newly discovered aspects of his work demonstrated again and again the depth of his mind and the scope of his personality and deeds. Both historians and physicists of different generations attribute to him the foundation of Russian science. Lomonosov was endowed with "limitless scientific imagination" (P P Lazarev [2, p. 1352], 1925); his genius "was much ahead of both contemporary scholars and scientists of the 19th century" (S I Vavilov [3, p. 583], 1945); he was "the first Russian genius scientist" (P L Kapitza [11, p. 403, 1973), and "his ideas and predictions determined scientific progress for many decades to come" (E P Velikhov [24, p. 8], 1988).

Efforts to recover Lomonosov's great contributions to science and literature initiated by B N Menshutkin and crowned by the publication of his *Complete Collected Works*, along with the subsequent appearance of many foreign editions of his major articles, presented Lomonosov to the world scientific community as a pioneer of that line of cultural developments that led to the explosion of natural sciences in the 19th and 20th centuries.

In 1956, the M V Lomonosov Great Gold Medal was instituted by the Soviet (now Russian) Academy of Sciences as its highest prize awarded to Russian and foreign scientists in the fields of natural sciences and the humanities. Its recipients include P L Kapitza, I E Tamm, A P Aleksandrov, A M Prokhorov, N G Basov, V L Ginzburg, Yu B Khariton, N N Bogoliubov, and other eminent Russian physicists.

The scientific and literary legacy of M V Lomonosov is an integral element of national culture and worldview. His image is printed in our souls and his name heads the list of prominent figures of this country. One cannot think of the history of Russian science and culture without thinking of Lomonosov. Present-day Russia is somehow inconceivable without reference to Lomonosov; his life is a source of inspiration, strength, and steadfastness for its people.

There is a great volume of literature devoted to all phases of Lomonosov's activities in which scientifically-oriented young readers and all those paying tribute to domestic classics of science may find much useful information (see, above all, P L Kapitza [4], E P Karpeev [12], and G E Pavlova and A S Fedorov [24]).

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