# Nikolaĭ Nikolaevich Semenov (on his eightieth birthday)

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A talented scientist, the founder of a new branch of science, the greatest organizer in Soviet science, recipient of USSR State Prizes and the Nobel Prize, a man who is purposeful and at the same time personable, and indefatiguable worker. Each of these phrases, taken alone, could be applied to persons other than Nikolaĭ Nikolaevich Semenov. However, the organic blending of all of these qualities is in the highest degree characteristic for Nikolaĭ Nikolaevich, whose eightieth birthday is being marked on the 16th of April not only by our country's chemists and physicists, but by the entire Soviet people.

At first glance, the celebrant's biography might appear somewhat terse. Semenov was born at Saratov into the family of a clerk. He graduated from St. Petersburg University in 1917, having begun while still a student to participate actively in the work of the famous seminar headed by Abram Fedorovish Ioffe.

Beginning in 1920, he headed the Laboratory of Electronic Phenomena in the Physico-technical Institute ("Fiztekh"), which had been founded two years earlier by his teacher Ioffe and was to play such a prominent role in the emergence of Soviet Physics. Semenov has been director of the USSR Academy of Sciences Institute of Physical Chemistry since the day of its creation, having moved over in 1931 from the "Fiztekh."

Thus, Semenov spent 55 years—nearly his entire adult life—in the same scientific collective, whose rapid growth and expansion was stimulated to a substantial degree by the ideas and organizational activity of Semenov himself.

To this we might add that Semenov taught for many decades—from 1920 to 1932 as an Instructor and then as a Professor at the Leningrad Polytechnic Institute, and from 1944 as head of the Chemical Kinetics Department of the Moscow State University Chemistry Faculty and concurrently as one of the founders of the Moscow Physical-technical Institute.

From 1958 to 1963, Semenov was Academician-Secretary of the Division of Chemical Sciences, from 1963 to 1971 a Vice President of the USSR Academy of Sciences, and from 1971 a member of its Presidium.

Let us now give a cursory listing of at least the most important marks of worldwide recognition that have been accorded Semenov's career.

In 1929, he was elected a Corresponding Member of the USSR Academy of Sciences, and in 1932 an Academician. In 1941, Semenov's name appeared on the list of the first USSR State Prize Laureates, and in 1956 he became the first Soviet scientist to be awarded a nobel prize. Semenov was elected an honorary member of the British Chemical Society (1943) and a Foreign Member of the British Royal Society (1958), an Honorary Member of the New York Academy of Sciences (1962) and a Foreign Member of the U. S. National Academy of Sciences (1963), a Member of the German Leopoldine Academy (1959) and an Honorary Member of the Indian Academy of Sciences (1959); he is a Member of the Hungarian (1961), Rumanian (1965), Czechoslovak (1965), East German (1966), Bulgarian (1969) and Polish (1975) Academies of Sciences, holds honorary doctorate degrees from Milan Polytechnic University (1964), Budapest Technical University (1965), the Charles University at Prague (1965), and the University of London (1965), as well as a doctorate from the Humboldt University at Berlin, an honorary membership in the Royal Society at Edinburgh, etc.

In 1970, Semenov was awarded the highest scientific honor of the USSR Academy of Sciences—the M. V. Lomonosov gold medal.

Semenov is a Hero of Socialist Labor and twice a USSR State Prize Laureate; he holds seven orders of Lenin and other orders and medals of the USSR.

What stands behind this uncommonly wide recognition—why is Semenov's name known today not only to scientists in all countries of the world, but even to schoolboys in the upper classes; to what does Semenov owe his genuinely nationwide recognition in our country and his exceptional popularity in the international scientific community?

Semenov's life's work came to be the discovery and theoretical explanation of branched chain chemical reactions, the creation of a chain theory of combustion and a theory of the thermal explosion. The phrase "chain reaction" is now quite commonplace and appears in every household and political dictionary and is encountered in fiction and in the pages of newspapers. For this the world owes much to none other than Semenov.

The fundamental idea of the chain theory can be stated quite concisely: a chemical reaction is, as rule, the fastest way through a sequence ("chain") of conversions that include atoms, free radicals, and ener-

getically excited molecules. The individual links of this chain bear no resemblance at all to the over-all outcome of the reaction, which includes only the initial and final stable products. The laws under which the branched chain reaction unfolds in time with a characteristic buildup of reaction rate also bear no resemblance to the trivial kinetic "law of mass action."

The idea of the chain reaction can be compared with Darwin's theory of the evolution of species and survival of the fittest. The chain theory is as important in chemistry as Darwin's influence was in biology.

Generalization on the scale of the chain theory required the opening of research on a broad front. It was necessary to make concrete studies of the combustion reaction of hydrogen and reactions in organic chemistry, biochemical processes, and the detonation of explosives.

In 1931, a separate Institute of Chemical Physics was formed within the framework of a combine of physico-technical institutes.

During the Second World War, the Institute operated out of Kazan' with emphasis on work of direct military importance. Even before the end of the war, the Institute moved back to Moscow from Kazan', and it is now one of the largest institutes of the USSR Academy of Sciences.

In 1955, Semenov advanced the idea of setting up a branch (now a Division) of the Institute of Chemical Physics. This Division of the Institute has become the "center of crystallization" of one of the largest scientific centers of the Moscow area—the Noginsk Scientific Center. Here chemists and physicists in various specialties work in close communication and collaboration.

Semenov is Chairman of the Council of Directors of the Noginsk Scientific Center.

An extensive reorganization of projects at the Institute of Chemical Physics was necessary to realize the full depth of its scientific ideas, to demonstrate their generality, and especially to apply them to problems of the country's national economy.

But talented individuals are more important than mere buildings and equipment. Semenov gave enormous interest and attention to the recruiting of bright people for the Institute, making a nationwide search for them. He has also shown a constant concern for staff living conditions at Leningrad and Kazan', Moscow and Chernogolovka, during both peacetime and wartime.

Semenov never complains that his organizational duties are interfering with his scientific work. This is not simply a matter of his enormous capacity for work, which he enjoys to this day. More importantly, he recognizes organizational work as a necessary part of the development of his favorite concern, science. He also conveys his sense of belonging to science in a larger sense to his assistants. He stimulates everyone that comes into contact with him.

Semenov's dedication to purpose has been responsible for his major successful accomplishments. The Institutes that he was instrumental in creating also develop science in areas that are farther from Semenov's personal interests. Semenov supports new trends with the modesty of a genuine scientist, with a real appreciation of their promise, and without petty jealousy.

Semenov's entire scientific career can be followed to the present day by moving along the bookshelves.

Here are the yellowed pages of Semenov's first scientific publication, which was devoted to the intearction of slow electrons with molecules (1916).

Here is the paper by Semenov and P. L. Kapitza (1921) in which they proposed an experiment in which an inhomogeneous magnetic field would act on a beam of paramagnetic particles. Later, this famous experiment was also proposed and carried out independently in Germany by Stern and Gerlach. They were rightly awarded a Nobel Prize for this work.

The following papers by Semenov demonstrate his rapdily rising interest in the problems of chemical processes.

In a paper "On Certain Chemical Reactions" (1926), Semenov describes experimental data that he and his colleagues had obtained on the oxidation of phosphorus vapor. It was in this and subsequent studies that new chemical-reaction phenomena that did not fit into the framework of conventional concepts of chemical reaction mechanisms were discovered. The extremely sharp transitions from the practical absence of reaction to exceptionally fast reaction, spontaneous ignition on a slight change in external conditions, the strong dependence of the reaction rate on the material and state of the walls of the reaction vessel and on what would appear to be totally inert additives were among these effects. To explain them, Semenov advanced the idea of the branched chain reaction. The theory of these reactions that was originated and developed by Semenov describes quantitatively all of the basic patterns in this large and important class of chemical processes.

Semenov showed back in 1930 that in their initial stages, the rates of such reactions increase exponentially in time as $e^{\varphi t}$, where $t$ is the time and $\varphi$ is the difference between the kinetic coefficients of chain branching and termination. Further development of chemical kinetics showed that this law, like other quantitative relationships formulated by Semenov, is inherent to all branched chain processes, including the reactions with degenerate branching that he discovered later.

This law also describes the development of chain atomic fission reactions in time and laser stimulated emission (it is noteworthy that the first branched chain reaction chemical laser was developed precisely at the Institute of Chemical Physics).

There are visible "tracks" that we may follow to retrace the life of a single individual. There are also milestones that map out the history of scientific life, the life of society. Semenov's 1934 book "Chain Re-

actions" is one of the basic milestones of Twentieth Century science. Without this book, it would be impossible to understand not only the history of modern chemistry, but also the history of man's conquest of atomic energy or the methodology of modern natural science.

The development of a trend as important as the science of combustion and explosion is also linked to Semenov's name. As early as 1928, in the paper "Contribution to the Theory of Combustion Processes," Semenov drew a clear distinction between the concepts of chain ignition and thermal explosion. In this paper, he formulated the critical conditions for the thermal explosion and calculated the pre-explosion superheat on the basis of conceptions pertaining to the laws of heat release and dissipation.

On the basis of this theory, Semenov's school and his students developed a theory of flame propagation, detonation, and combustion in explosives and powders.

Combustion and explosion processes are brought about in fireboxes, in internal-combustion engines, and in jet engines; unwanted explosions also occur in industry, etc. Therefore the further development of these studies, especially in the Institute of Chemical Physics, proved essential for engineering development projects and resulted in important practical achievements.

Semenov's papers typically strive to demonstrate organic relationships between the laws governing the complex reaction, the reactivities of the reagents, and their structure.

Attaching great importance to the development of research in elementary reactions, Semenov also lends active support to the development of new methods for studying them.

In 1972, he set up a laboratory of chain processes in the Institute of Chemical Physics and directed it personally. His devotion to science and his ability to hear out the scientific arguments of even his youngest staff members "among equals" have surrounded Semenov with with a creative atmosphere in this laboratory.

The electron theory and the theory of the atom with a central nucleus made their appearance abroad in the Nineteenth and Twentieth Centuries. Soon a new science of the microscopic universe appeared with its own mathematical formalism—quantum mechanics. It appeared that only one step remained to be taken for all chemical phenomena to be described by a unified electron theory. The title of the 1926 book by Semenov, V. N. Kondrat'ev, and Yu. B. Khariton, "Electronic Chemistry," bears witness to this mood.

However, direct application of electronic ideas to complex chemical reactions proved to be out of reach at the level of the 1920s and 1930s. Many years of persistent and painstaking effort would be required to establish the individual characteristics of chemical compounds and reactions. New generalizing concepts appeared: the covalent bond, $\pi$ and $\sigma$ electrons, resonance, molecular orbits, the hydrogen bond, and intermediate substances (atoms and radicals) in the reactions.

Now, in the 1970s, chemistry has triumphed with its fundamental electronic physical theory. This theory is armed with the methods of modern atomic and nuclear physics, radiospectroscopy, and quantum elecrtonics. One can only envy Semenov, who has participated actively in all of these three stages through which chemistry has lived. Under the name "Chemical Physics," this new science of the structure of matter and the chemical process will forever be linked to Semenov's name.

During the 250th anniversary celebration of the USSR Academy of Sciences, a major foreign scientist, an outstanding theoretician and an emigré from a developing country, asked how it had been possible for Russia, for the USSR, to make such a great leap in science during the short time between the revolution and the war, from a science of a few individuals (some of them geniuses, like Lobachevskiĭ, Mendeleev, Palov, Lebedev) to a broad front of scientific and technical research.

In response, one of the present authors cited the example of the Physico-technical Institute—the work of Abram Fedorovich Ioffe and Nikolaĭ Nikolaevich Semenov.

A conspicous feature of this activity was the search for talented, bright young people in the provincial universities, the organization of this youth into a spirited team, with free rein allowed for their talents. Semenov, like his teacher Ioffe, and indeed like the entire Ioffe–Semenov school, made his own considerable and inimitable contribution to Soviet science and culture.

But, turning our minds back to the 1920s and 1930s, we sense that this answer was not complete.

The development of science during these years was part of the general historic process in our country and was governed by the objective needs of our Motherland.

Semenov's biography is inseparably connected to the life of our country. His youth was contemporary with the birth and exuberant youth of the Soviet Union. He grew and gained in experience and wisdom together with his country. He is not only a great scientist and organzier of science, but also an outstanding social and political activist. Semenov was a Deputy at three conventions of USSR Supreme Soviet, a candidate for membership in the Communist Party of the Soviet Union, and Chairman of the Board of the All-Union Society "Znanie" [Knowledge]. His social commentaries in newspapers and magazines (here it is sufficient to recall his deeply motivated attack on the aberrations in Soviet biological science, which was essentially the first of its kind in the country), which were summarized in the book "Science and Soceity" (1973), met with tremendous popular response.

Semenov's heroic life effort continues even today.

The majority of the authors have personal experience and knowledge of only isolated segments of Semenov's great creative career. But all of us combine a general deep admiration, respect, and appreciation for our teacher and friend, Academician Nikolaĭ Nikolaevich Semenov.

Translated by R. W. Bowers