

*DAVID ALBERTOVICH FRANK-KAMENETSKIĬ* (1910–1970)

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SOVIET Physics has suffered a great loss: the author of fundamental research studies in the area of physical chemistry and astrophysics and on the theory of plasma, a professor, and a doctor of physical and mathematical sciences, the outstanding theoretical physicist David Albertovich Frank-Kamenetskiĭ passed away on June 2, 1970.

Frank-Kamenetskiĭ began his scientific activity under rather unusual circumstances. He spent his childhood and adolescence in Siberia, was graduated from the Tomsk Technological Institute there with a diploma in metallurgical engineering, and began to work in an ore-concentration plant. At the beginning of 1935 he wrote Academician N. N. Semenov a letter discussing problems of chemical thermodynamics. The talent of the author of this letter was so obvious that he was invited to the Institute of Chemical Physics. A deliberate search for and attraction of capable young people, especially from the periphery, was a device employed widely and with success at that time in the institutions which had separated from the Leningrad Physico-technical Institute.

Frank-Kamenetskiĭ, as a member of a large staff, participated in work on the problem of oxidation and fixation of atmospheric nitrogen during combustion and explosions. References to this problem, for example by Cavendish, appeared immediately after the discovery of nitrogen and following the establishment of the composition of air. Such prominent chemists as Haber and Nernst in Germany and Bone in England turned to research on this process. In connection with the development of the theory of chain reactions the question arose about the possibility of direct use of the energy of combustion for converting nitrogen into nitric acid. Investigations in which Frank-Kamenetskiĭ<sup>[1]</sup> participated showed that the process is connected with a chain reaction mechanism involving the atoms N and O, but that in this process the amount of nitric oxide produced is limited by the conditions of the thermodynamic equilibrium. The directions of subsequent work by Frank-Kamenetskiĭ were quite naturally mapped out: on the one hand—the theory of combustion and explosion, on the other—the general foundations of chemical technology.

In his basic work of 1939<sup>[2]</sup> Frank-Kamenetskiĭ posed the problem of thermal explosion with allowance for the spatial distribution of the temperature in the medium in which the chemical reaction occurs. The solution of this problem concluded almost a century of research. It became possible to predict exactly the conditions of occurrence of an explosion. Numerous experiments completely corroborated the theory of D. A. Frank-Kamenetskiĭ. Thanks to this theory, important results were obtained in chemical kinetics.

In his cited work<sup>[2]</sup>, however, there were contained matters of a more profound nature beyond the question



of explosion. Only after many years did we come to understand the fruitfulness of his formulation of the problem about critical conditions as a problem about the limit of the existence of a solution. Proceeding on the example of thermal explosion, Frank-Kamenetskiĭ developed a similarity theory for the processes of release and removal of energy. He proposed an asymptotic expression to replace the exponential dependence ( $A \exp(T - T_0)/\theta$  instead of  $B \exp Q/RT$ ), whereby the solution for a certain temperature is obtained by a similarity transformation from the solution for another temperature. According to contemporary terminology, he used the group properties of the equations and consciously selected the approximation needed for the occurrence of a group that is additive in the temperature and multiplicative in the coordinates.

These general ideas of physics and mathematics were widely used in studies of the theory of combustion which were carried out both with the direct participation of D. A. Frank-Kamenetskiĭ<sup>[3]</sup> and also as a continuation of his investigations.

His investigations on the principles of chemical technology have been summed up in an outstanding monograph "Diffuziya i teploperedacha v khimicheskoi kinetike" (Diffusion and Heat Transfer in Chemical Kinetics)<sup>[4]</sup>, reissued in East Germany and twice in the USA. For this book D. A. Frank-Kamenetskiĭ was awarded the D. I. Mendeleev Prize of the USSR Academy of Sciences in 1949.

Readers of our journal do not need to be reminded that heat transfer, diffusion, and hydrodynamics constitute divisions of classical physics. In a remarkable manner this monograph<sup>[4]</sup> combines analytic solutions, the theory of similarity, and a semi-empirical approach to phenomena and processes of a varying degree of complexity. The broad scientific program of a mathematical-physics approach to technology which now exists makes great use of the profound ideas and the methods set forth in this work.

The scientific interests of Frank-Kamenetskiĭ shifted soon after the war to the field of astrophysics. Problems of quiescent evolution of stars were masterfully expounded in his monograph "Fizicheskie protsessy vnutri zvezd" (Physical Processes Inside Stars)<sup>[5]</sup>. Frank-Kamenetskiĭ also solved the problem of how a shock wave builds up in the outer layers during the explosion of a star.<sup>[6]</sup> This phenomenon is closely linked with the laws of the change in brilliance of supernova stars, and also perhaps with the process of the primary acceleration of cosmic rays. Frank-Kamenetskiĭ was one of the first to understand, as evidenced by his work on "epiplasma,"<sup>[7,8]</sup> the role played in astrophysics and particularly in cosmology by the process of production of pairs of particles and antiparticles under extremal conditions. In 1956, at the invitation of I. V. Kurchatov, Frank-Kamenetskiĭ transferred to the Institute of Atomic Energy, where he headed a new line of research—research on the interaction of waves with plasma. Here he was the first to formulate clearly the problem of heating plasma at the expense of the dissipation of waves excited in it by an external source of oscillations.

He predicted theoretically the important phenomenon of magnetosonic resonance,<sup>[9,10]</sup> which was later detected experimentally with his direct participation.<sup>[11]</sup> Later on he and his students did detailed theoretical and experimental research on this phenomenon.<sup>[12-21]</sup> They studied the dispersion properties of a vast class of oscillations, viz., direct and indirect magnetosonic waves. They demonstrated experimentally the occurrence of resonant buildup of electromagnetic fields in a plasma during magnetosonic resonance ("the spatial magnetic-field amplification effect"). Finally they discovered the anomalous dissipation of magnetosonic oscillations and, as a consequence, they demonstrated experimentally the possibility of heating plasma during magnetosonic resonance to high temperatures. In particular, with the help of this method they succeeded in heating dense hydrogen and helium plasma to temperatures of  $5 \times 10^6 - 10^7$  °K.

In recent years, along with research on this topic, Frank-Kamenetskiĭ undertook research on the instability of plasma during electron-cyclotron heating<sup>[22-23]</sup> and also expanded his work on the study of plasma phenomena in solid-state physics.<sup>[24,25]</sup>

It should be noted that Frank-Kamenetskiĭ had enormous influence on creative young people. Back in 1956-57 he called for research on collective processes in plasma and on phenomena in which they should appear, such as nonlinear and collisionless shock waves,  $\theta$ -pinch, etc. His ideas doubtless have played a fundamental role in the formation of plasma physics.

The breadth of his erudition, the encyclopedic range of his knowledge, and his extraordinary literary talent and his ability to speak simply and clearly about very complicated matters won for Frank-Kamenetskiĭ fame as one of the most prominent popularizers in the area of the natural sciences. He was the author of a series of popular scientific books on various areas of physics: "Energiya v prirode i tekhnike" (Energy in Nature and in Technology), "Obrazovanie khimicheskikh élementov v nedrax zvezd" (Formation of Chemical Elements in the Interior of Stars), and "Yadernaya astrofizika" (Nuclear Astrophysics). The greatest fame was achieved by his book written at the suggestion of I. V. Kurchatov, "Plasma—chetvertoe sostoyanie veshchestva" (Plasma—the Fourth State of Matter). This book has been reprinted repeatedly and it has been translated into Bulgarian, Polish, Czech, German, and Japanese.

Frank-Kamenetskiĭ was one of the most competent specialists on a huge set of questions in physics, chemistry, astrophysics, and biophysics. His sincere and completely unselfish desire to help everyone who turned to him for advice, his colossal erudition and his constant readiness to plunge enthusiastically into the resolution of scientific problems—even when they lay outside the circle of his interests of the day—made him an irreplaceable creative consultant. A clear idea about the unique breadth of his scientific interests, and also about his characteristic style of exposition and his sense of humor is conveyed by reviews printed in the course of many years in the bulletin "Novye knigi za rubezhom" (New Books Abroad), and by his articles and notes in the journal "Priroda" (Nature)<sup>[26-30]</sup> concerning the latest achievements of Soviet and world science and concerning a series of fundamental philosophical problems. Under the editorial direction of D. A. Frank-Kamenetskiĭ, many scientific and popular scientific books of famous scientists abroad have been published in Russian. Great fame has been achieved by his public lectures on the most vital problems in contemporary science and by his brilliant performances on radio and television.

D. A. Frank-Kamenetskiĭ's activities as a teacher, begun back in the early thirties at Chita Technical School and Irkutsk University, continued almost without interruption all his life. In recent years he headed the department of plasma physics that he had organized at Moscow Physico-technical Institute. He was the author of the textbook "Lektsii po fizike plazmy" (Lectures on Plasma Physics).

The Soviet Government held the service of D. A. Frank-Kamenetskiĭ in high esteem: he was awarded Orders of Lenin and of the Red Labor Banner and three time State Prizes.

A simple enumeration of the scientific works of D. A. Frank-Kamenetskiĭ still does not give a complete idea of his authority and scientific influence, both of which depended to a great degree on his personal attributes

and on the generosity with which he passed along his own original ideas not only to his students and fellow workers, but also to anyone at all who turned to him for advice.

His tremendous optimism and kindness, the nobility of his spirit, and his attentiveness—these are qualities of Frank-Kamenetskiĭ's that are well known not only to his fellow workers and students, but also to a wide circle of physicists and chemists. He was distinguished by a complete lack of jealousy or envy of the results of others. The active desire that is natural for a scientist to display his talents and to get important results merged harmoniously in this man with an interest in the essence of matter and with an interest in nature.

Frank-Kamenetskiĭ lived a bright and happy life. The memory of him will remain in our hearts forever.

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