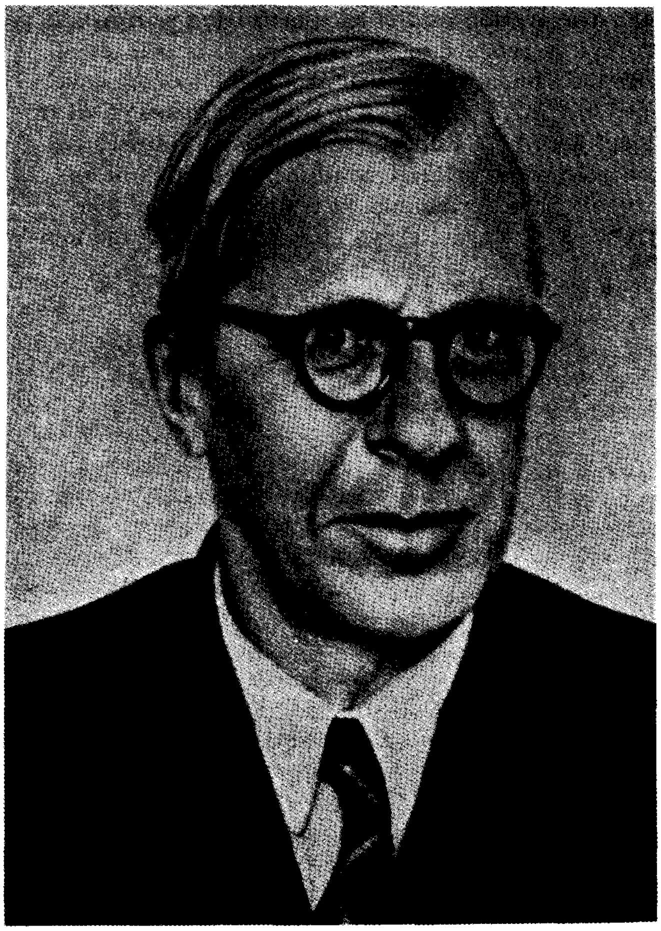
Personalia

SERGEĬ TIKHONOVICH KONOBEEVSKIĬ

(on his seventieth birthday)

G. S. ZHDANOV

Usp. Fiz. Nauk 71, 161-165 (May, 1960)



On April 27, 1960 seventy years passed since the birth of one of the most distinguished Soviet physicists-crystallographers, Corresponding Member of the U.S.S.R. Academy of Sciences, Sergeĭ Tikhonovich Konobeevskiĭ.

The life of S. T. Konobeevskiĭ is the brilliant creative path of a Soviet scientist who contributed greatly to physical metallurgy and promoted its development. It is remarkable that the young scientist's entry into science (he was graduated from the department of natural sciences at the physico-mathematical faculty of the Moscow University, where he specialized in animal physiology) coincided with a period of rapid development and wide application of a new physical method of studying the atomic structure of substances. As is well known, in 1912 von Laue in Germany discovered the diffraction of x rays by crystals. In 1913, Bragg in England and the professor of the Moscow University Yu. V. Vul'f in Russia proposed an elegant interpretation of three-dimensional diffraction as the selective reflection by planes of a three-dimensional lattice. An essential stage in the practical application of x-ray diffraction was the obtaining of the first x-ray patterns of polycrystalline and amorphous substances by Debye and Scherrer in 1916. Soon a new diffraction effect was discovered in x-ray patterns of metals, in a technologically important state, in the form of wires and rolled discs — the falling apart of the Debye rings into a series of symmetrically distributed maxima. The interpretation of these patterns, especially from rolled metals, presented considerable difficulties.

The credit and priority for the interpretation of x-ray patterns of rolled metals, a fact noted by the world's scientific press, belongs to two Soviet scientists — professor N. E. Uspenskiĭ and the young Konobeevskiĭ, at that time unknown to the physics world. This distinguished work carried out at the outbreak of the civil war and of disturbances was possible because of the great attention and assistance which the Soviet government accorded the development of science already in the first stages of its activity. In 1920, at a meeting of the P. N. Lebedev Scientific Society, Uspenskiĭ and Konobeevskiĭ read a paper in which they showed that the special features of the interference pattern of rolled metals are explained by the ordered arrangement of the micro-crystallites. The mathematical theory of this phenomenon, based on calculating the pattern of rays reflected by a rotating mirror, made it possible to determine the directions of the crystallographic axes of the structure quantitatively. This theory was worked out by Konobeevskiĭ. Thus, already in his first crystallographic work the special feature of his creative work — not to limit himself to a qualitative interpretation of the observed phenomena but to give them if possible a full mathematical treatment — manifests itself. During the following years Konobeevskiĭ headed the large x-ray laboratory at the State Experimental Electrotechnical Institute, continuing the investigation of the structures of plastically deformed metals. This laboratory contained a very interesting device for the visual observation of the Laue diffraction pattern from a single crystal on a fluorescent screen; this made it possible to follow the kinematics of the movement of diffraction spots as a function of the angle of rotation and inclination of the crystal.

In 1928 the Soviet Government sent a number of scientists on scientific missions abroad; among them was Konobeevskiĭ who worked for half a year in Stuttgart at the X-ray Institute of professor Richard Glocker. During this mission he carried out, in a field new to him, an interesting investigation of the structure of the amorphous variety of the carbon mineral shungite, in which he observed the presence of twin groups of iron atoms.

In 1930 he was called upon to direct the X-ray Laboratory at the reorganized State Central Institute for Nonferrous Metals. Among the researches under his direction can be mentioned the structure investigation of plastically deformed single crystals (with I. I. Mirer), papers on rising diffusion (with Ya. P. Selisskiĭ), a paper on the determination of the true limits of solubility in alloys (with V. P. Tarasova), and on the mechanism of phase transformations in metals (with M. I. Zakharova).

According to widely known concepts, diffusion leading to a leveling of concentrations should occur during the annealing of an alloy. However, during the annealing of deformed alloys, as a result of inner stresses, the direction of the diffusion processes is substantially changed. The appearance of a "triplet," instead of the doublet well known to x-ray crystallographers, was observed on the x-ray patterns of the magnesium alloy Elektron after annealing. As it turned out, the triplet consists in actual fact of two superimposed doublets; this was explained by the formation of regions of solid solution in the alloy with higher and lower concentrations of the second component respectively, resulting from the diffusion redistribution of the atoms of the components. The increase of the gradient of concentration during the annealing of "Elektron" is possible because in this alloy the temperature necessary to remove the inner stresses is higher than the temperature for which diffusion becomes considerable. Under these conditions, the energy decrease of the inner stresses, and consequently also of the inner energy of the alloy, takes place through the migration of the smaller atoms into the compressed regions of the solid solution, and vice versa through the migration of the larger atoms into the expanded regions. The theory of rising diffusion was worked out by Konobeevskiĭ on the basis of the generalized Fick equations with an additional term to account for the presence of an inhomogeneous field of inner stresses in the alloy.

The theoretical and practical value of phase diagrams is well known. The dependence of the properties on the composition was widely used by N. S. Kurnakov and his school in their work on physico-chemical analysis. In studying the phase diagrams of some alloys the attention was drawn by a peculiar feature, which consisted in the approach of the phase boundaries to the vertical as one went over to lower temperatures. Such a vertical position of the boundaries would indicate that the solubility is temperature independent, while both from thermodynamics and statistical mechanics it follows as a rule that the solubility increases with temperature. The reason for this inconsistency is explained by the decrease of diffusion with a lowering of the temperature as a result of which the time during which the alloy approaches equilibrium is increased. Therefore, the practically attainable annealing times are insufficient at low temperatures to bring the alloy into equilibrium and the phase boundaries determined by the usual methods are those of alloys which are not in equilibrium. A considerable increase in the rate of diffusion can be attained by working with cold-deformed alloys, for instance in the form of filings. In the work of Konobeevskiĭ and Tarasova it was shown by x-ray methods that under these conditions the phase boundaries deviate considerably from the vertical. Thus it was shown in the case of bronze that at 300°C the true solubility of tin in copper does not exceed 2% instead of 10% as was previously noted on phase diagrams. Such a strong temperature dependence of the solubility indicates that the aging of these alloys is possible in principle.

The attention of many investigators was drawn by the problem of aging, or amelioration, of alloys which is of great practical significance. Heat treatment of such alloys, a typical example of which is duraluminum, leads to a considerable change of their mechanical properties. The aging process may continue a long time after annealing, and is not accompanied by any significant structural changes. When conditions are not optimal, the strength of an alloy may reach a maximum and then start to decrease. X-ray investigations carried out in Tsgintsvetmet disclosed the changes which take place during the decomposition of supersaturated solid solutions. The analysis of the experimental data enabled Konobeevskiĭ to work out a thermodynamic theory of aging, which was based on the notions of colloidal equilibrium of submicroscopic precipitates of the new phase with the solid matrix. This equilibrium turned out to be possible only for a definite particle-size range of the new phase. Outside these particle sizes the equilibrium was disturbed and a coagulation of the precipitates, which led to a decrease in the mechanical strength, took place.

Not long before the second world war S. A. Vekshinskiĭ proposed an interesting idea of preparing alloys with a continuously varying concentration, and worked out a method for preparing such alloys and investigating their properties. The method of preparing alloys of varying concentration consisted in the condensation of two atomic beams of different metals on a cold backing. It was found that the thin condensed layer of alloy had a sharply defined structure. The x-ray investigation carried out by M. M. Umanskiĭ under Konobeevskiĭ's direction, showed the complex character of this structure. The plane of orientation of the crystallites was determined both by the position of the plane of the backing, and also by the direction of the atomic beam. Konobeevskiĭ proposed a mathematical theory based on the formation of condensation centers already in the beam, whose oriented settling made it possible to explain the observed structure.

Among his theoretical works, that in the field of the domain theory of alloys should also be noted. Earlier, with the help of this theory Jones explained the laws observed in the group of electron compounds, which had been determined experimentally by Hume-Rothery. Using Jones' quantum-mechanical theory, Konobeevskiĭ gave an interpretation of the interesting phenomenon of the formation of residual solid solutions in the alloys of nickel and aluminum at certain concentrations.

The breadth and versatility of his interests is indicated in particular by his investigation of the symmetry and form of atoms in crystals, carried out with the aid of x-ray data for diamond obtained by Mamedov.

Konobeevskiĭ's most recent period of scientific activity is devoted to the study of a completely new field of solid state physics, namely the effect of radiation on the structure and properties of solids, and also to the study of phase diagrams of heavy-metal (uranium, plutonium) alloys. New and interesting facts were discovered in these investigations: radiation hardening, the growth of uranium, and phase transformations at temperatures considerably lower than the transition point. Radiation hardening is the name given to the increase in the dimensions of the crystalline metal grains (recrystallization) during neutron irradiation; this is accompanied by an increase in the hardness of the metal, and not by the decrease that takes place during the usual recrystallization. On irradiating rolled samples of uranium possessing structure, and also strongly anisotropic single crystals of uranium, a large increase in the linear dimensions and volume were observed (uranium growth), a phenomenon of great practical significance. The methods of investigating the structure and properties of irradiated substances, and also a series of results were published in the papers read by Konobeevskiĭ, Pravdyuk, and Kutaĭtsev at the first Geneva Conference on the Peaceful Uses of Atomic Energy, and evoked general interest.

The greater part of Konobeevskiĭ's life and activity were connected with the Moscow State University; it was also here that his gift as pedagogue came to light. His work at the Moscow State University was of great value for the education of Soviet x-ray physicists and for the preparation of specialists in the field of physical metallurgy. Konobeevskiĭ was able to attract and educate a substantial group of young coworkers, many of whom subsequently became professors and prominent scientists in the fields of x-ray analysis and physical metallurgy. In 1926 professor Yu. V. Vul'f proposed to establish at the Moscow State University a special chair for x-ray structure analysis whose value for the investigation of the atomic structure of matter grew steadily. The need for x-ray specialists grew likewise, especially during the period when the large-scale program of the industrialization of the Soviet economy was being implemented.

In 1927, after Vul'f's death, Konobeevskiĭ was appointed to the vacated post of lecturer to organize and direct the new department. In the course of a few years this department established a special x-ray clinic in which all contemporary methods of analysis were represented, work on the construction of new types of x-ray apparatus, which later developed greatly, was started, and scientific investigation concentrating on contemporary problems in physical metallurgy was developed. The chair for x-ray structure analysis, later renamed as the chair for physical metallurgy, headed by Konobeevskiĭ successfully trained qualified specialists in the field of x-ray structure analysis. Soon the physics faculty of the Moscow State University became one of the main centers for the training of Soviet x-ray specialists. During its existence more than 200 qualified physicists graduated from it. Its graduates head large x-ray laboratories in scientific research institutions, departments in colleges, and also work in many plant laboratories of leading industrial branches in the various parts of our vast country.

In 1946 the U.S.S.R. Academy of Sciences elected S. T. Konobeevskiĭ a corresponding member. The Soviet government rewarded him with two Orders of Lenin, the Order of the Red Banner of Labor, and with medals.

List of the Principal Works of S. T. Konobeevskiĭ

I. Original Works

[1] The Investigation of Microcrystalline Structures with the Aid of X-rays (with N. E. Uspenskiĭ), Научные известия МГУ (Scientific News of the Moscow State University), Collection 3, p. 343, 1922.

[2] The Crystalline Structure of Rolled Iron and Nickel Disks, Журн. прикл. физики (J. Applied Phys.) **2**, Nos. 1–2, 107 (1925).

[3] The Problem of Sliding in Crystallites during Rolling, ibid. **4**, No. 3, 3 (1927).

[4] The Determination of Elastic Stresses in Bent Crystals from Their X-ray Patterns (with I. I. Mirer), Сб. работ рентген. лаб. Гинцветмет (Collection of Works of the Gintsvetmet X-ray Laboratory), p. 17, 1932.

[5] The Broadening of the Debye-Scherrer Lines in the X-ray Patterns of Metals after Cold-working and

Annealing (with Ya. P. Selisskiĭ), GNTI Tsvetmetizdat, p. 1, 1933.

[6] The Limit of the Solubility of the α Phase in the Cu-Sn Alloy (with V. P. Tarasova), JETP **4**, 272 (1934).

[7] Towards a Theory of the Decomposition of Supercooled Solid Solutions and Aging Phenomena, JETP **4**, 1063 (1934).

[8] The Decomposition of the Solid Solution of Copper and Aluminum as a Result of Plastic Deformation and Subsequent Annealing, (with M. I. Zakharova), JETP No. 7, 1134 (1935).

[9] The Problem of the Theoretical Construction of Phase Diagrams of Metal Alloys, Izv. Akad. Nauk SSSR, Ser. Fiz., No. 2, 255 (1936).

[10] Phase and Transformation Diagram during the Decomposition of the α Solid Solution in the Cu-Sn Alloy (with V. P. Tarasova), Журн. физ. хим. (J. Phys. Chem.) **9**, 681 (1937).

[11] The X-ray Determination of the Specific Solubility of the Phase in the Ternary System Copper-Zinc-Tin at Low Temperatures (with V. P. Tarasova and A. A. Stepanova), ibid. **9**, 693 (1937).

[12] Crystallization in Metals during a Solid-State Transformation, Izv. Akad. Nauk SSSR, Ser. Khim., No. 5, 1209 (1937).

[13] The Nature of the Distortion of the Atomic Lattice Appearing during the Plastic Deformation of Crystals, Izv. Akad. Nauk SSSR, Ser. Fiz. No. 5, 845 (1937).

[14] Crystallization on Deformed Rock Salt Crystals (with M. P. Shaskol'skaya), JETP No. 8, 1368 (1938).

[15] The Nature of Solid Solutions and Inner Transformations in Them, Труды ВНИТО металлургов (Trans. of the All-Union Scientific Society of Metallurgical Engineers and Technicians), p. 19, 1940.

[16] The Theory of Phase Transformations, I. The Thermodynamical Theory of Recovery Phenomena during Aging, JETP **13**, 185 (1943).

[17] The Theory of Phase Transformations, II. Diffusion in Solid Solutions in the Presence of a Stress Distribution, JETP **13**, 200 (1943).

[18] The Theory of Phase Transformations, III. Stresses Appearing during the Separation of a Phase from Solid Solution, JETP **13**, 419 (1943).

[19] The Theory of the Structure of Intermetallic Phases of Varying Composition, Ученые записки МГУ (Scientific Notes of the Moscow State University) **14**, 13 (1943).

[20] The Structure of Condensated Metal Layers (With M. M. Umanskiĭ), JETP No. 5, 408 (1947).

[21] Solid Phases of Varying Composition and the Basic Laws of Their Structure, Известия Сектора физ.-хим. анализа АН СССР (Bulletin of the Physico-Chemical Analysis Section of the U.S.S.R. Academy of Sciences) **16**, 19 (1948).

[22] A Method for Making Bragg Projections with the Aid of Quickly Converging Series, Dokl. Akad. Nauk SSSR **59**, 33 (1948).

[23] The Possibility of an Experimental Study of the Form of an Atom in the Crystal Lattice, loc. cit. reference 21, **19**, 19 (1949).

[24] The Anisotropy of the Atomic Scattering Factor of X-rays in Aluminum and Diamond Crystals (with K. P. Mamedov), JETP **21**, 953 (1951).

[25] The Investigation of Atomic Structure in Crystals by the Trial Method, Usp. Fiz. Nauk **14**, 21 (1951).

[26] Phase Diagrams of Certain Plutonium Systems, Session of the U.S.S.R. Academy of Sciences on the Peaceful Uses of Atomic Energy, July 1–5, 1955, Meetings of the Department of Technical Sciences, p. 362 (1955), Engl. Transl. by Consultants Bureau, vol. 4, p. 207.

[27] Effect of Irradiation on the Structure and Properties of Fissionable Materials (with N. F. Pravdyuk and V. I. Kutaĭtsev), Proc. of the International Conference on the Peaceful Uses of Atomic Energy, Geneva, 1955, vol. 7, 433 (1955).

[28] Effect of Irradiation on the Structure and Properties of Structural Materials (with N. F. Pravdyuk and V. I. Kutaĭtsev), ibid. vol. 7, 479 (1958).

[29] A New Method for the X-ray Structure Analysis of Radioactive Substances (with B. M. Levitskiĭ and Yu. A. Martinyuk), J. Tech. Phys. **26**, 870 (1956), Soviet Phys.-Tech. Phys. **1**, 856 (1956).

[30] The Problem about the Nature of the Radiation Disturbances in Fissionable Materials, Атомная энергия (Atomic Energy) No. 2, 63 (1956).

[31] The Representation of Atoms in Crystals in the Form of Symmetric Figures, Кристаллография (Crystallography) **2**, 447 (1957).

[32] The Investigation of Structural Changes in the Uranium-Molybdenum Alloy under Neutron Irradiation (with K. P. Dubrovin, B. M. Levitskiĭ et al.), loc. cit. reference 30, **4**, 34 (1958).

[33] Diffuse Scattering of X-rays in Irradiated Crystals of Diamond, Corundum, Silicon, and Germanium (with F. P. Butra), ibid. **5**, 572 (1958).

[34] Some Physical Properties of Uranium, Plutonium, and Their Alloys (with A. S. Zamoĭskiĭ et al.), Proc. of the Second International Conference on the Peaceful Uses of Atomic Energy, Geneva, 1958, vol. 6, 194 (1958).

[35] Some Physico-Chemical Processes Taking Place in Fissionable Materials under Irradiation (together with K. P. Dubrovin, B. M. Levitskiĭ et al.) ibid. vol. 5, 574 (1958).

[36] The Effect of Neutron Irradiation on the Mechanical Properties of Structural Materials (with N. F. Pravdyuk, A. D. Amaev and Yu. I. Pokrovskiĭ) ibid. vol. 5, 457, (1958).

II. General and Survey Articles

[1] The Study of the Structure of Metals with the Aid of X Rays (with N. B. Uspenskiĭ), Сообщ. о научн.-техн. работах Республики (Publication of Scientific-technical Works of the Republic) No. 1, 7 (1920).

[2] X Rays and the Structure of Media Consisting of Microcrystallites (with N. E. Uspenskiĭ), ibid. No. 3, 170 (1921).

[3] Crystal Physics and the Problems of Metallurgy, Usp. Fiz. Nauk **5**, No. 6, 433 (1925).

[4] The Structure of Metals and the Problem of the Metal State, SORENA Nos. 2 and 3, 73 (1931).

[5] Main Trends and Means in the Development of X Ray Analysis in Technology, X Ray Diffraction in its Application to the Investigation of Materials, United Scientific and Technical Publishing Houses, p. 5, 1936.

[6] X-ray Diffraction Study of Aging (Amelioration) Phenomena in Alloys, ibid. p. 193, 1936.

[7] The Great Scientist and Thinker M. V. Lomonosov, Ученые записки МГУ (Scientific Notes of the Moscow State University), Jubilee Series, issue 52, physics, p. 7, 1940.

[8] The Role of Russian Investigators in the Development of Solid State Science (Fedorov, Kurnakov, and Chernov), ibid; The Role of Russian Science in the Development of World Science and Culture, vol. I, book 2, p. 46, 1946.

[9] Some New Problems of X-ray Structure Analysis, Izv. Akad. Nauk SSSR, Ser. Fiz. **10**, 371 (1946).

[10] X-ray Analysis and X-ray Spectroscopy after 30 Years, Usp. Fiz. Nauk **33**, 533 (1947).

[11] Металлофизика (Physical Metallurgy), an article for the Large Soviet Encyclopedia.

[12] The Physical Foundations for the Strength of Materials, Вестник АН СССР (Bulletin of the USSR Acad. of Sci.) No. 7, 15 (1955).

Translated by Z. Barnea