

VLADIMIR YAKOVLEVICH KURBATOV
AND HIS PHYSICO-CHEMICAL INVESTIGATIONS

(on his 75th Birthday)

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Professor Vladimir Yakovlevich Kurbatov is one of the oldest of the physical chemists, a student of D. I. Mendeleev and D. P. Kononov. For 45 years V. Ya. has headed the Chair of Physical Chemistry in the Leningrad Technological Institute; he is its originator. The successful and very fruitful creative duties of V. Ya. Kurbatov have extended for a half century in the field of physical chemistry, continuing and developing the scientific aims of his great teachers. Blazing new trails in the study of the properties and internal structures of liquids, colloids, and gels, V. Ya. enriched his native chemical science with many extensive generalizations and discoveries.

V. Ya. Kurbatov was born on January 24, 1878 in St. Petersburg into a servant's family. In 1896, on finishing the primary government school and the 7th St. Petersburg Gymnasium, he entered the Natural Science Division of the Physico-Mathematical Faculty of St. Petersburg University. In 1897, Vladimir Yakovlevich began to conduct scientific investigations in D. P. Kononov's laboratory. In 1900 he finished at the St. Petersburg University, and was allowed to remain for preparation for professorship. He very often met D. I. Mendeleev in D. P. Kononov's laboratory, whose assistant V. Ya. Kurbatov was from 1900-1907, and he often discussed problems in chemical science and the results of his own experimental investigations with him at gatherings.

In 1905, V. Ya. began to teach the course in general chemistry for the St. Petersburg Agronomic Courses, where he also organized the first chemical laboratory. The summer of that year he worked in Henri Le Chatelier's laboratory in Paris. In this laboratory he discovered reagents which made possible the correct differentiation of the constituents of quenched steels.

In 1907, V. Ya. Kurbatov was invited to teach the first complete course in physical chemistry at the St. Petersburg Technological Institute, in which he created the Chair of Physical Chemistry. In 1908 he participated in the organization of the chemical faculty of the Womens' Polytechnical Institute, begun by P. N. Ariyan, and from 1908 to 1923, he taught the course in Physical Chemistry for the future first Russian women engineers.

In 1913, V. Ya. was a member of the commission and main consultant for the construction of a cyanamide plant. Later, it must be mentioned that other factories, in particular potassium hydroxide factories, were constructed with his consultation. In 1915, V. Ya. headed the materials testing laboratory for the Ministry of Agriculture, in which he conducted a series of investigations on the preparation of flexible cast iron, cementation of steel, while studying materials and steels for agricultural implements and machines.

V. Ya. Kurbatov adopted the Great October Socialist Revolution completely and without reservation. From the start of the revolution, he was an active participant in the construction of Soviet higher schools, in the construction of a new socialist culture. Even in 1917, he was designated consultant to the Peoples Commissariat for Education of the young Soviet republic. In 1918, a state museum was created by the Soviet government in Moscow on the proposal and plan of V. Ya. Kurbatov. A course in commercial economics was organized at the museum, which was then reorganized into the Institute of Communal Economics.

In 1919, V. Ya. was designated a member of the Soviet of Peoples Economy for the Northern Section. V. Ya. Kurbatov was one of the most important of the chemists and scientists advising the government on questions of the chemization of the country for the Sovnarkam of the USSR. V. Ya. contributed great scientific pedagogic, and organizational effort during the first years of the Soviet Rule to the higher institutions of learning in Leningrad, served as professor of Physical and General Chemistry at the Photochemical, Agronomic, and Pedagogic Institutes. In 1924, he taught a course in physical and colloidal chemistry at the War Economy Academy of the Workers' and Peasants' Red Army. In the following years, he participated actively in the organization of teaching in the Workers' University, served as a member of the Commission on Self Education for LOSPS,* and was the organizer of the Chemical Section of the Leningrad Industrial Academy.

During the years of the Stalin five year plans, V. Ya. Kurbatov directed his activities at the development of chemical industry in our country, to the organization of new chemical plants. He served as a member of scientific counsels and as a consultant to the Scientific Research Institute for Plastics, the All-Union Scientific Institute for Fats, Central Laboratory of the "Red Triangle" Factory, the All-Union Aluminum Magnesium Institute, the Central Accumulative Laboratory. In all of these years, V. Ya. conducted an extremely large amount of consultant work on production in work shops and laboratories of Leningrad plants and factories. Discoveries during industrial and laboratory experiments for the solution of actual industrial problems enabled him to formulate new physico-chemical laws and theories.

In the Great Patriotic War of 1941-1945, V. Ya. conducted a series of important experimental investigations for industry, consulted for many plants and factories, developed technical conditions for the storage of artistic memorials (bronze monuments) during the war and blockade of Leningrad. The work of V. Ya. on the preparation of engineers and scientific staffs of the Naval Forces of the USSR deserves mention.

V. Ya. Kurbatov conducted his great general work from the first days of the Great October Socialist Revolution. From 1917 up to the present time, he gave more than two thousand lectures at plants, factories, at military posts, warships, clubs, hospitals, lecture halls, and Courses of Culture on various sciences and scientific technical themes. V. Ya. Kurbatov was one of the organizers and a member of the presidium of the All-Union Scientific Engineering Technical Society of Chemists in its Leningrad Section (1930-1938), a member of the Educational Council of the Scientific Chemical Technical Press (from 1918-1938), a member of the organization committee for the V. I. Mendeleev Congress (1932), a member of the editorial staff of the Journal "Chemistry and Economy" (1929), a member of the presidium of the Society for the Welfare of the Soviet Union and for the Development of the Aviation and Chemical Industries, Leningrad Region (1927). He did varied and very useful work as a deputy of the Leningrad State Counsel during its session (1930-1938).

During his years as professor, V. Ya. educated several generations of Soviet engineers and technologists, many of whom became builders and inventors of the Soviet chemical industry. Among the students of V. Ya. Kurbatov are heads of scientific research institutes and enterprises of the chemical industry, heads of the chairs of higher institutions, and chief engineers of the great plants.

The Soviet authorities honored highly the many years of the great creative work of the scientist inventor, patriot of the Motherland, by awarding the Order of Lenin, the Red Banner of Labor, the medals "For Victory over Germany", and "For Valiant Effort in the Great National War of 1941-1945", and awarded him the honorary title "one distinguished in science and technology".

I

For 50 years (1902-1952) the scientific efforts of professor V. Ya. Kurbatov were directed at the study of the properties and internal structure of liquids. The first investigation of liquids, "On the Relation of Latent Heat of Evaporation and the Density of the Vapor" [1] was on the determination of the heat capacity, latent heat of evaporation, and the compressibility of aniline hydrochloride vapors. V. Ya. established that dissociation varies to a considerable degree with the temperature, as well as the pressure. This first scientific investigation of V. Ya. Kurbatov was honored in 1903 by the Russian Physical Chemical Society by a small prize in the name of A. M. Butlerov.

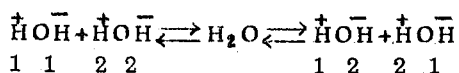
In 1902, V. Ya. published, for the first time in the history of chemistry, the determination of the latent heat of evaporation of mercury and its heat capacity [2]. This investigation showed the preferential application of mercury vapor over water vapor in heat engines, and served as the stimulus for the designing of heat electrical centers on the mercury water cycle.

* Leningrad Oblast Trade-Union Council.

In his work on the determination of the latent heat of evaporation of mercury, and on the study of the heat capacity and the latent heat of evaporation of aniline, V. Ya. overcame many great experimental difficulties, and obtained such accurate results that they were entered into the basic reference books on physico-chemical values.

In 1907, on the basis of the study of heat capacity and heat of evaporation of a large number of different organic liquids, V. Ya. Kurbatov came to the conclusion that "the forces of crystal formation affect the properties of substances in the liquid state" [3]. "If not all, then some properties of the amorphous state are related to the ability of the given substance to form a crystal lattice" [4]. Although the above theoretical conclusions of V. Ya. Kurbatov are now not doubted at all, at that time they were met with sharp objections and furious attacks from the side of the defenders of the outmoded and reactionary factions in science. These theoretical generalizations and experimental investigations of over 30 organic liquids were published by V. Ya. in his first monograph, "On Molecules Formed by Compounds with Similar Groups. The Appearance of Association" (St. Petersburg, 1908).

Up to 1916 V. Ya. Kurbatov had investigated more than 150 liquids [5]. As a result of the many investigations, he first showed that the degree of ionic exchange between their molecules had a great effect upon the properties of liquids. According to Kurbatov's suggestions, particles of liquids are not only attracted to each other as a whole, but even exchange ions to a certain extent:



This type of transformation depends, according to V. Ya. Kurbatov, on the ease of transition of molecules from the non-ionic to the ionic state, which is aided by the asymmetry of the surrounding molecules and the molecular interaction.

In view of the great amount of experimental difficulties for the determination of the heat capacity of poor conductor liquids, V. Ya. Kurbatov used intermolecular coupling to study their nature. The calculation of the intermolecular coupling of liquids by means of Kurbatov's equations required a knowledge of the value of the heat capacity of superheated vapors, which was only slightly studied at that time. During experiments on the determination of the heat capacity of superheated vapors for 16 substances, he showed: 1) at constant temperatures, the heat capacity of superheated vapors is equal to half the heat capacity of the liquid; 2) the relation between the heat capacity and temperature for superheated vapors, as well as for liquids, is expressed by a straight line, or curves closely resembling straight lines; 3) the molecular weight of liquids with sufficiently large ionic interchange is equal to the weight of the given mass of liquid, whether it is a drop or an ocean. The last suggestion of V. Ya. Kurbatov was debated for a long time in the scientific literature, but after two generations, it found complete experimental basis and was proven by Langmuir at the International Physico-Chemical Conference in 1936 at Edinburgh.

Yearly increasing the number of investigated liquids and the temperature ranges of the experiments, up to 1927 V. Ya. Kurbatov had determined: 1) the heat capacity of 136 liquids at temperatures from 60-350°; 2) the heat capacities of five liquid metals at wide temperature intervals, Hg (from 35 to 346°), Na (99-304°), K (79-150°), Cd (353-562°), Pb (351-446°); 3) the latent heat of evaporation of 125 liquids, for most cases the determinations were made at temperature intervals of 60° (at pressures from 760-100 mm); 4) heat capacities of vapors of 18 substances at various temperatures within intervals of about 60°; 5) boiling points of 194 liquids at 25-900 mm; 6) surface tension and capillary constants of 36 liquids at 0-300°. All of these experimental results and theoretical generalizations composed V. Ya. Kurbatov's third monograph [6].

The later investigations of V. Ya. Kurbatov and his students were directed at the determination of the heat capacity of 450 organic liquids, and to see the effect of various functional groups on their properties. The main results of the scientific investigations of the last quarter century (1927-1952) were presented by him at the 1st International Congress on Physical Chemistry in Paris, at the meetings of the Mendeleev All-Union Chemical Society. A compilation of these investigation was published in monograph form [7-9].

In all of his published papers on liquids, V. Ya. Kurbatov established important laws of the liquid and gaseous states of substances: 1) linear relationship of the heat capacity of gases (super heated vapors) with the temperature; 2) the similarity between the above temperature coefficient of heat exchange of gases and the coefficient of expansion of gases; 3) the equality of the given temperature coefficient of heat capacity of weakly ionized liquids to 0.0022 and its decrease upon going to liquids of greater ionizability; 4) additivity of the molecular heat capacity of liquids; 5) the equality of the given volume of all liquids at a corresponding temperature. All of these laws enabled V. Ya. Kurbatov to propose a new complete association theory of liquids, which, in

relation to the degree of ionization, classifies all liquids into a finely divided series from the least ionic liquid, helium II, to molten metals and salts [10].

Using these equations, V. Ya. Kurbatov calculated the intermolecular association for 50 liquids. The parallelism, shown by him, between the increase in the intermolecular association of liquids and their electroconductivity, dielectric constant, and chemical activity resulted in convincing and thorough verification for the polyionic theory of association, according to which the liquid state is a continuously forming and dissociating crystal.

The experimental data of V. Ya. Kurbatov on the determination of the properties of liquids were published as standards by the Inter-Peoples Bureau of Standards and are widely used in Soviet chemical literature, and in particular, in M. Kh. Karapetyants' book on chemical thermodynamics which earned the Stalin prize in 1951. V. Ya. Kurbatov's representation of water, as well as of substances with latent crystalline structure, is the basis for the study of the structure of water in the paper of O. A. Alekina "General Hydrochemistry," the first national course in hydrochemistry which earned the Stalin prize in 1950.

Theoretical and experimental papers of V. Ya. Kurbatov in the field of physico-chemical properties resulted in the development of methods: 1) for the intensive purification of natural waters from organic substances, iron, and manganese; 2) for the softening of mineralized waters with deionizers; and 3) for the conservation of drinking water.

II

The establishment and development of industry in Leningrad: food, leather, fat, cellulose-paper, and laquer pigment, after the first World and Civil War, made the planned study of colloidal phenomena most important. In the period from 1919 to 1923, V. Ya. Kurbatov investigated, in relation to industrial problems, properties of colloidal solutions and gels. In 1924, on the basis of experimental material obtained, he proposed the crystalline polyamphion theory. This theory holds that colloids and gels, whose external appearance shows the absence of crystallization, can exist only in the presence of a microskelton of seed crystals within them which develops sufficiently slowly. This proposed theory of Kurbatov is being confirmed by all experimental material from 1924 up to the present time. It must be especially mentioned that Kurbatov's theory speaks of the presence of a seed crystal skeleton within gels or colloidal emulsions, and not of the crystallization of the entire gel. The formation and the preservation of gels and colloids is then determined by the following laws established by V. Ya. Kurbatov: 1) the rate of crystallization decreases with increase in the valency of the ions, decreasing with especial rapidity upon going from bivalent to trivalent ions; 2) the stability of the crystals increases on going from ions of low valency to those of high valency, and especially sharply upon going from bivalent to trivalent ions.

According to the suggestions of V. Ya., each ion is a cation in a sufficiently acidic medium, and an anion in a sufficiently basic one; and in the transition state, an amphion. Amphions carry positive and negative charges simultaneously, and at the equal charge state, as a result of the neutralization of the opposing charges and the separation of water, form one general polyamphion. Upon the appearance of seed crystals in the polyamphion, it changes into a crystallo-polyamphion [10-13, 28]. Kurbatov's crystallo-polyamphionic theory resulted in the successful solution of many industrial problems for the Leningrad industry. In particular, the rapid and successful solution of the production of cellulose and motion picture film, control of emulsions for phototechnique, problems of blending of rubber and textiles for shoes, the problem of the production of water proof cartons for the acetonitrile industry, of the thickening of glycerine, of mass corrosion of aluminum products, etc.

The crystallo-polyamphionic theory was changed and developed for the physico-chemical explanations and the study of the phenomenon of life [14]. The recognition of the presence of amphions and polyamphions in electrolytes, led V. Ya. Kurbatov to the polyionic-galilate theory of electrolytes [15-17]. The polyionic-galilate theory not only states that water hydrolyzed electrolytes, but that the electrolyte dissolved in the water simultaneously "galilates", i.e. ionizes the water. The polyionic galilate theory, in particular, explains the different degrees of ionization (dissociation) for the same electrolyte, determining the various properties. (Thus for example, for an 0.5 N solution of MgSO_4 these differences are close to 50%).

For the past few years, V. Ya. Kurbatov and his students have conducted the experimental and theoretical development of the basic proposals of the polyionic-galilate theory of solutions.

A large part of the scientific creative effort of V. Ya. Kurbatov was occupied in the continuation of the scientific legacy of D. I. Mendeleev, in the development of his great ideas. "We will continue the studies of D. I. Mendeleev", wrote V. Ya. Kurbatov in 1908, "somewhat further. At the present time, we know of two finite individualisms, the lower limits of smallness, the electrons, the upper limit of greatness, the galaxies". As a scientific materialist and dialectic he believed, "There is no reason for thinking that individualisms cannot exist which are composed of galaxies as these are composed of solar systems. It is important also not to think of electrons as limits of fineness. If the whole universe is infinite, then electrons can be subdivided" [18]. He notes the transfer of the individualism of the macrocosmos (star systems) to those of the microcosmos (electrons of a smaller order). V. Ya. Kurbatov [19] predicted the discovery of super galaxies-meta galaxies, the existence of which was shown 22 years after his prediction by Hubble and Shapley (1930).

Other important conclusions from his work (1905-1908) is the recognition of the infinite division of the atom itself. Examining the principle of increase in entropy, V. Ya. Kurbatov stated that the increase in entropy counteracts the opposite process, the formation of particles from atoms. "If we generalize the basic principles of thermodynamics for equilibrium of all conditions, tendency for maximum entropy, then it is comprehensible that all similar violations of equilibrium, all individualisms will tend to repel one another, since the further they are from each other, the least is the disturbance of equilibrium in the given position. Conversely, two opposing disturbances will tend to destroy one another, and therefore, tend to approach each other. The appearance of individualisms", continues V. Ya. Kurbatov, "atoms with a defined period of life, disturb the general tendency for equilibrium. The reason for this we do not know; we can only say that such an individualism is more stable than the scattered individualisms of a lower order" [20].

Naturally, V. Ya. Kurbatov, as a scientist-materialist, was outstanding in the very beginning of our century against one of the various sects of "physical" idealism, the energitism of W. Ostwald. In connection with Ostwaldian energitism, V. Ya. Kurbatov wrote in 1908, "but after these many years it is clear that the energetistic conception of the world, suitable for the expression of discovered facts using different words, cannot in any way explain the nature of the processes which arise" [21].

In 1908 V. Ya. Kurbatov came to the conclusion that two types of chemical compounds existed [22]. According to V. Ya. Kurbatov, "Certain electrons of the atoms separate readily and electrostatic (electrolytic) bonds are formed between atoms as a result, wherein the number of such electrons corresponds to the denomination of the group in the Mendeleev order [in so far as it is not greater than the ability of the atom to add these electrons (4,5,6, and 7 groups)]" [23].

In the first type of chemical compounds, the atoms are bound with each other by the attraction of opposite electrical charges. In the second type, a substitution of one or more electrons of one atom by atoms and groups of atoms occurs.

V. Ya. Kurbatov pointed out that "it is necessary to recognize the existence of special bonds in order to explain compounds not subject to electrolysis, for example SnCl_4 , CH_4 , etc." [22]. These ideas of V. Ya. Kurbatov were of considerable importance for the development of electronic ideas in chemistry, and in many ways, anticipated the theories of Kossel (1916) and Lewis (1916).

V. Ya. Kurbatov had previously discovered the relation between the electroconductivity of metals and their position in the Mendeleev system. The discovery of this relation showed that the electroconductivity decreases upon going from metals of the lower group of the Mendeleev system to those of the upper. Decrease of electroconductivity of metal with increase in temperature was explained by V. Ya. as resulting from the increase in the disordered movement of the metal ions in proportion to the increase in temperature [24]. The increase in electroconductivity of alloys and their very low temperature coefficients of electroconductivity were explained by him as the effect of the formation of local thermocouples between the different atoms. Although all of these generalizations were published by V. Ya. Kurbatov in 1907-1908, after 1916 they began to be assigned to K. Bendix without any basis. We notice, by the way, that the question of the effect of temperature on the electroconductivity of metals was picked up in the foreign scientific literature only in the thirties.

In 1925-1927, V. Ya. Kurbatov proposed a hyperboloid form for D. I. Mendeleev's periodic system of chemical elements [20-27, 10]. Representing the Mendeleev system in the form of a hyperboloid of rotation, he placed the rare earth elements in the center systems, where two spirals unfold, one toward the lighter elements, the other toward the heavier. Such a form representing the periodic system shows the continually

related properties and the interruption of the transition of properties from element to element, naturally distributing the rare earths and the actinides.

The long and fruitful work of V. Ya. Kurbatov on the propagandization of the scientific discoveries and investigations of D. I. Mendeleev by compiling and editing many of the collected papers of the scientific genius must be mentioned. He read the report "General Review of the Scientific Activities of Mendeleev" [25] after Mendeleev's death at the first Mendeleev Congress. In 1925, V. Ya. Kurbatov's monograph, "D. A. Mendeleev's Law," appeared, in which more than 100 properties of chemical elements were compared for the families of the periodic system. A series of generalizations were given in this monograph by V. Ya., which arose from the basic principles of the Mendeleev Law [26].

In V. Ya. Kurbatov's monograph, "The D. I. Mendeleev System of Elements and Classification in Chemistry" [10], presented by the Academician of Science of the USSR on the 100th anniversary of the birth of D. I., are given the materialistic and elemental-dialectic basis of the scientific theoretical views of the great Russian scientist and idealist, and their value for the development of modern chemical science was shown.

In conclusion it must be mentioned that V. Ya. Kurbatov is widely known as an architectural historian, expert on monuments of Russian culture. To his writings belong the great monographs: "St. Petersburg," "Pavlovsk," "Gardens and Parks," "Leningrad," and the brochures: "Detskoe (formerly Tsarskoe) Selo," "Gatchina," "Peterhof," "Strelna and Oranienbaum," and a series of pamphlets on the history of Russian architecture and art [29].

Vladimir Yakovlevich Kurbatov's life's path is the path of a leading scientist-inventor, the path of a fiery patriot of the Motherland who has given all of his knowledge and strength for the service of the Soviet People.

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Received January 25, 1953.