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СТРАНИЦЫ ИСТОРИИ

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REVIEW ARTICLE

Department of Physical Chemistry in M.V. Lomonosov Institute of Fine Chemical Technologies at the RTU MIREA: From the beginning to the present

To the 120th anniversary of the Department

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Abstract

Objectives. *To review the prerequisites for the origin of physical chemistry at the turn of the 19th–20th centuries and to evaluate the contribution of the Department of Physical Chemistry at the M.V. Lomonosov Institute of Fine Chemical Technologies in the development of the main areas of chemical science.*

Results. *The study considers the historical retrospective of the appearance of the Department of Physical Chemistry at the beginning of the 20th century. The main areas of scientific activity over the past 120 years are shown.*

Conclusions. *The Department of Physical Chemistry has made a significant contribution to the formation of physical and chemical knowledge among specialists in wide areas of chemical science and chemical technology. The Department of Physical Chemistry through its pedagogical and scientific activities maintains and expands the areas development, based on the unity of theory and practice, established by its founders. The decisive role of fundamental research in the development of new technologies is also shown.*

Keywords: *physical chemistry, thermodynamics, kinetics, catalysis, molecular theory and nature of chemical bonds, N.D. Zelinsky, S.G. Krapivin, Ya.K. Syrkin*

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ОБЗОРНАЯ СТАТЬЯ

Кафедра физической химии Института тонких химических технологий имени М.В. Ломоносова РТУ МИРЭА: От истоков до наших дней

К 120-летию кафедры

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Аннотация

Цели. *Рассмотрение предпосылок возникновения физико-химического направления на рубеже XIX–XX веков. Оценка вклада кафедры физической химии им. Я.К. Сыркина Института тонких химических технологий имени М.В. Ломоносова в развитие основных направлений химической науки.*
Результаты. *Освещена историческая ретроспектива возникновения кафедры физической химии в начале XX века. Приведены основные направления ее функционирования на протяжении 120 лет.*
Выводы. *Кафедра внесла значительный вклад в формирование физико-химического мышления специалистов в различных направлениях химической науки и химических технологий. На протяжении всей своей педагогической и научной деятельности кафедра сохраняет и преумножает вектор развития, базирующийся на единстве теории и практики, заложенный ее основателями. Показана определяющая роль фундаментальных исследований при разработке новых технологий.*

Ключевые слова: *физическая химия, термодинамика, кинетика, катализ, теория строения молекул и природа химической связи, Н.Д. Зелинский, С.Г. Крапивин, Я.К. Сыркин*

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INTRODUCTION

The establishment of the Physical Chemistry Laboratory at the Moscow Higher Women's Courses (MHWC) coincided with the global tectonic shifts in world history. The same global changes are characteristic of the development of science at the turn of the 19th and 20th centuries when new areas of research were established based on the outstanding achievements in physics, chemistry, biology, and other natural sciences.

Physical chemistry is an advanced, continuously, and intensively developing field of chemical sciences, now taught as an independent discipline in the specialized departments of many higher educational institutions in Russia and the world. In 2023, one of the oldest in Russia departments,

the Department of Physical Chemistry of the M.V. Lomonosov Institute of Fine Chemical Technologies (IFCT), celebrates its 120th anniversary.

HOW IT ALL STARTED. THE FIRST PHYSICAL CHEMISTRY LABORATORIES

It is interesting that the formation of physical chemistry as a branch of science and as a subject of teaching went on in parallel for several centuries. The first separate course of lectures on this discipline was presented in 1752–1753 to students of the Academic University in St. Petersburg by Mikhail Vasilievich Lomonosov. He was convinced that chemistry and physics would develop more successfully only as a result of "mutual assistance" [1–4].

Although M.V. Lomonosov considered physical chemistry to be the leading direction in the development of chemical science, he did not establish a separate department or a specialized laboratory for systematic research in this field. This was natural. Lomonosov's scientific thinking was far ahead of his time: 18th century chemistry and physics possessed neither theoretical nor experimental data upon which physical chemistry could develop independently [5].

Only 100 years later, in the second half of the 19th century, physical chemistry was established as its own scientific field and academic discipline. The development of this branch of chemistry at that time and the identification of its tasks were primarily associated with the names of Wilhelm Friedrich Ostwald and Jacobus Henricus van't Hoff, who worked in Germany.

In 1871, the world's first department of physical chemistry was established at the University of Leipzig. The head of the new department was the physicist Gustav Heinrich Wiedemann who took up the post in the same year[1] [6]. The cofounder of the department and its second head (from 1887) was Ostwald. In 1885, he gave a separate course on physical chemistry at the University of Leipzig [6–8]. In 1898, the first independent Institute of Physical and Theoretical Chemistry in Europe and the world was opened on the basis of the University of Leipzig, and Ostwald became the first director of the new institution [9].

The second center for the development of physical chemistry was the University of Berlin, where in 1878 a specialized department was founded.[2] Particularly intensive research in physical chemistry began here in 1896, when J.H. van't Hoff started working at the university. In 1901, he was awarded the first Nobel Prize in Chemistry for the development of the theory of solutions [6].

Later, at the beginning of the 20th century, physical chemistry departments and laboratories began to appear in other European countries.

In Russia, the development of physical chemistry was more rapid. The creation of this scientific discipline was directly connected with the name of the great Russian scientist andencyclopedist M.V. Lomonosov, who worked at the Academic University—the predecessor of St. Petersburg State University. However, although the history of physical chemistry in this educational institution began at the very moment of its foundation, it was not until 1914 when a specialized department was established.[3]

In the second half of the 19th century, physical chemistry began to be taught in a number of Russian universities, for example in Kazan and Moscow, but without separate departments and laboratories [2, 10].

The eminent Russian physical chemist, Ivan Alekseevich Kablukov, had been lecturing on physical chemistry at the Chemical Department of the Faculty of Physics and Mathematics at the Moscow University, since 1886. From 1921, I.A. Kablukov was appointed as the head of the new Laboratory of Inorganic and Physical Chemistry. In 1925, the Physical Chemistry Laboratory was separated from the Inorganic Chemistry Laboratory and Professor Evgeny Ivanovich Shpitalsky[4] was appointed its head. In 1929, the independent Department of Physical Chemistry was established simultaneously with the formation of the Faculty of Chemistry of the Moscow State University. This is now considered the official year of birth of the Department of Physical Chemistry of the Moscow State University [11, 12].

One of the oldest independent departments of physical chemistry in Russia is that of the St. Petersburg State Electrotechnical University.

[1] Universität Leipzig: Geschichte. URL: https://www.chemie.uni-leipzig.de/en/faculty/history. Accessed February 25, 2023.

[2] Humboldt-Universität zu Berlin. Geschichte des Instituts für Chemie. URL: https://www.chemie.hu-berlin.de/en/department-en/geschichte. Accessed February 25, 2023.

[3] From the history of the Institute of Chemistry of St. Petersburg State University. Department of Physical Chemistry. Updated on March 21, 2017. URL: https://chem.spbu.ru/phys/42-sectiondepartment/phischem/1971-istoriya-kafedry.html. Accessed February 25, 2023.

[4] Pentin Yu.A. About the Department of Physical Chemistry (Chemical Faculty of Moscow State University and its departments (history and current state)). URL: https://www.chem.msu.su/rus/teaching/zorkii/12(pentin).html. Accessed April 14, 2023.

In 1891, Professor Aleksandr Aleksandrovich Krakau founded the Department of Chemistry at the Electrotechnical Institute of Emperor Alexander III. Here, special courses in electrochemistry and physical chemistry were taught in addition to lectures on inorganic and analytical chemistry. In 1906, the Electrochemistry Department was created at the Institute. It was later to become the Electrochemistry Faculty, comprising the Departments of Inorganic Chemistry, Theoretical and Applied Electrochemistry, and a separate Department of Physical Chemistry.[5]

At the same time, physical chemistry was successfully developed at the Empress Catherine II Mining Institute (now St. Petersburg Mining University) This educational institution was founded in 1773 [13] and in 1774 it began offering chemical classes and laboratories for the analysis of mineral raw materials. An independent course in physical chemistry and a separate department appeared at the Institute in 1908. The first professor in the Department of Physical Chemistry (1908–1919) was Peter Petrovich von Weymarn, one of the founders of colloidal chemistry.[6]

AT THE ORIGINS OF THE DEPARTMENT OF PHYSICAL CHEMISTRY IN IFCT. THE APPEARANCE OF THE LABORATORY OF PHYSICAL CHEMISTRY AT THE MHWC

N.D. Zelinsky and S.G. Krapivin

The history of the IFCT dates back to the MHWC established in 1900 by Vladimir Ivanovich Guerrier [14–18], where a few years later the teaching of physical chemistry began in the format of a separate educational cycle. Thus, the Department of Physical Chemistry, now bearing the name of Ya.K. Syrkin, can be considered the oldest in Russia.

In this section, we will focus in more detail on little-known archival materials being published for the first time.

The study of chemistry was provided at the Courses of the Physics and Mathematics Faculty by the 1900 "Regulations on the MHWC". The leading chemists of the time, Alexander Nikolaevich Reformatsky and later Nikolai Dmitrievich Zelinsky, were invited to establish laboratories and teach classes, introducing students to the basics of general, inorganic, and organic chemistry. It soon became clear, however, that the initial scope of the course was insufficient to cover all the problems of the rapidly developing chemical sciences.

In the 1903–1904 academic year at the initiative of N.D. Zelinsky, the future academician, the study of a new discipline—physical chemistry—was included in the curriculum of the IV course at the Mathematical and Natural Departments of the Faculty of Physics and Mathematics of Moscow State University (Fig. 1). Sergey Gavrilovich Krapivin, a private Associate Professor at Moscow State University, was invited to teach this subject (Fig. 2).

Although at that time the MHWC provided students with an education of almost university level, the Courses did not have university status or the appropriate organizational structure [16–18]. The teaching of scientific subjects was carried out in laboratories, the directors of which usually gave lectures, conducted practical classes, and provided comprehensive support for the educational process, i.e., the laboratory performed functions similar to those of a university department.

Thus, just as the Lomonosov IFCT became the successor of MHWC [14, 15], so did the Ya.K. Syrkin Department of Physical Chemistry, which became the successor of the Laboratory of Physical Chemistry and Quantitative Analysis, the first head of which was S.G. Krapivin. The outstanding scientist N.D. Zelinsky (1861–1953) was the initiator and ideological inspirer of the

Fig. 1. N.D. Zelinsky[7]
(photo from the beginning of 1900s).

[5] V.I. Ulyanov (Lenin) St. Petersburg State Electrotechnical University LETI. History of the Department of Physical Chemistry. URL: https://etu.ru/ru/fakultety/ifio/sostav-instituta/kafedra-fizicheskoy-himii/istoriya-kafedry. Accessed April 14, 2023.

[6] St. Petersburg Mining University. History of the Department of Physical Chemistry. URL: https://spmi.ru/istoriya-kafedry-fizicheskoy-khimii. Accessed April 14, 2023.

[7] N.D. Zelinsky. URL: https://permneft-portal.ru/upload/medialibrary/a58/a58de474fe619089f4e9ec3450405840.jpg. Accessed April 14, 2023.

Fig. 2. S.G. Krapivin[8]
(photo of 1925).

creation of such a laboratory. He was already world-renowned in those years. In 1901, N.D. Zelinsky established a laboratory of organic chemistry at the Department of Chemistry, which he headed until 1911. However, his interests also extended to other rapidly developing areas of science and technology, far beyond the boundaries of traditional organic synthesis. In fact, N.D. Zelinsky was one of the founders of organic catalysis, petrochemistry, and adsorption. He foresaw and was well aware of the timeliness of the organization of the physicochemical direction in the MHWC and the training of specialists in this direction (Figs. 3–5).

S.G. Krapivin (1868–1927) was an outstanding individual. In 1889, he graduated with honors from Novorossiysk University in Odessa. While still a student, he began scientific research in the field of physical chemistry under the guidance of N.D. Zelinsky, who at that time was a private lecturer at the University of Novorossiysk [19] (Fig. 6).

In order to deepen his theoretical knowledge and improve his practical skills, in 1890–1892 Sergey Gavrilovich went to Germany to study in the laboratories of Nernst, Ostwald, and van't Hoff. Upon his return to Russia, Krapivin passed his Master's examination which allowed him to teach at the university. In 1896, he moved to Moscow at the invitation of N.D. Zelinsky where he worked as a laboratory assistant and private lecturer in the organic chemistry laboratory of Moscow University [20].

[8] S.G. Krapivin. URL: http://encyclopedia.tversu.ru/index.php?title=Krapivin,_sergey_gavrilovich. Accessed April 14, 2023

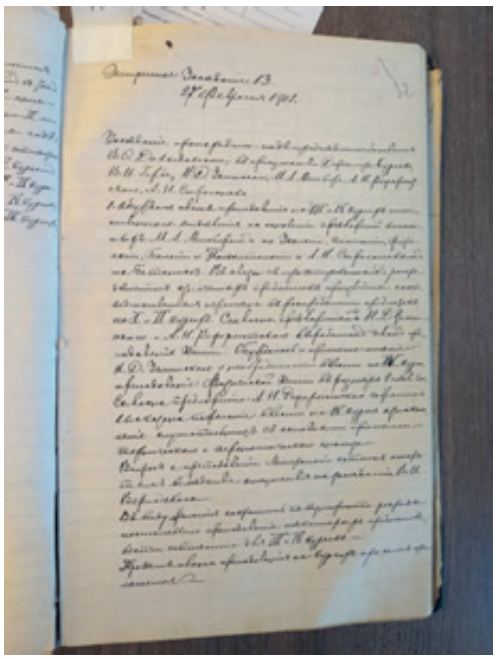

Fig. 3. A page of the protocol of the February 27, 1902 emergency meeting of teachers of the Physico-Chemical Institute of the MHWC with a proposal by N.D. Zelinsky to introduce the teaching of physical chemistry in the 4th year of the Natural Department. Central Archive of Moscow. F. 363. In. 1. N. 6.

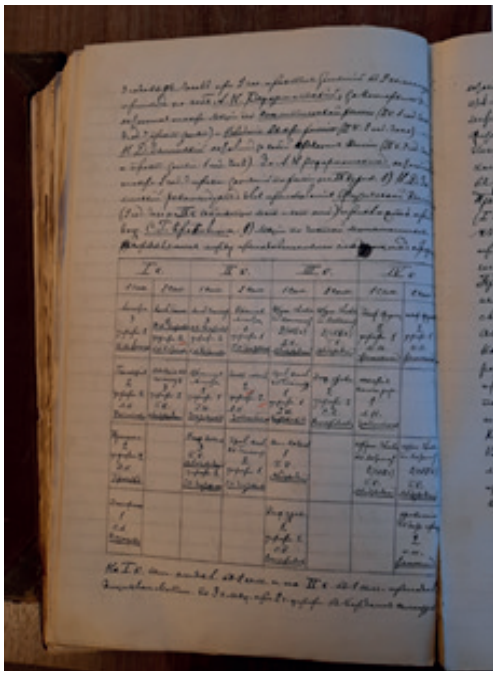

Fig. 4. A page of the protocol of the meeting 15.04.1903 at which N.D. Zelinsky proposes to invite S.G. Krapivin as a teacher of physical chemistry. Central Archive of Moscow. F. 363. In. 1. N. 8.

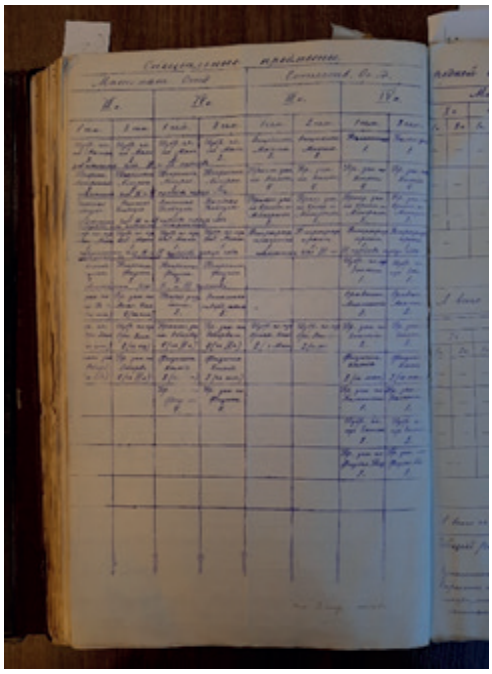

Fig. 5. Draft of a new teaching plan at the Mathematical and Natural Departments of the MHWC (Explanatory note to the draft change in the teaching plan, meeting of the Faculty of Physics and Mathematics on 08.09.1903). The decision to open in the 4th year and introduce the teaching of physical chemistry from the 1903–1904 academic year among the special subjects in both departments (on 3 sheets). Central Archive of Moscow. F. 363. In. 1. N. 8.

In 1903, S.G. Krapivin began to teach at the MHWC. At the same time, he was given the opportunity to set up his own laboratory. The pedagogical and scientific activity of S.G. Krapivin was very fruitful during his management of the Laboratory of Physical Chemistry and Quantitative Analysis of the MHWC. This was despite the heavy administrative burden associated with the purchase of the necessary equipment and reagents, recruitment, and participation in the work of the Chemical Commission of the Faculty. In the space of 15 years, he published a number of basic and applied works, textbooks, and translations of foreign works (Figs. 7 and 8).

S.G. Krapivin's scientific interests during this period were connected with the study of the effect of neutral salts present in solutions on the rate of chemical reactions, and determining electric conductivity of salt solutions in methanol. He also continued his research in organic chemistry which he had commenced at the Moscow State University. He applied the condensation reaction in the presence of aluminum chloride to unsaturated hydrocarbons, obtaining a number α,β of unsaturated ketones (Darzens–Krapivin reaction). The scientific achievements of S.G. Krapivin also include the development of a method for the determination of ammonia in waste water [20–22].

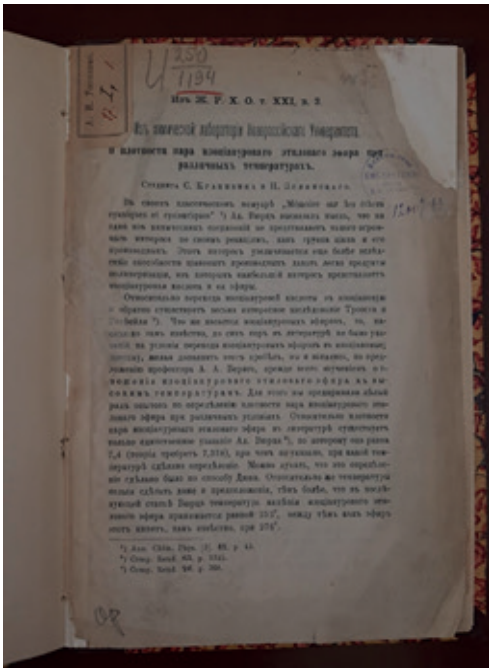

Fig. 6. Article written by the student S.G. Krapivin and N.D. Zelinsky "About the vapor density of isocyanuric ethyl ether at various temperatures," 1888.

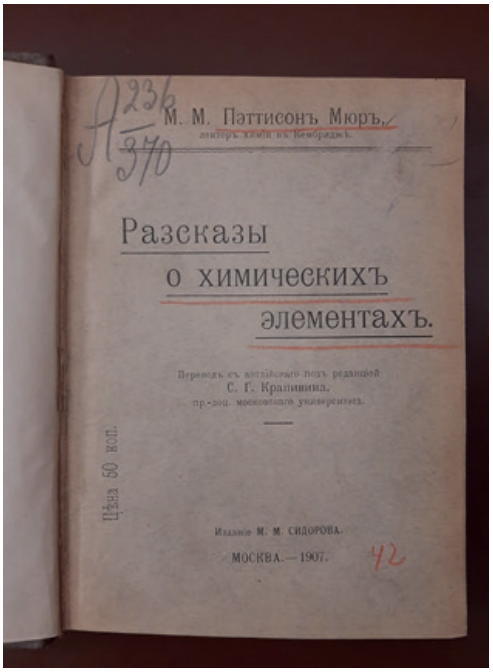

Fig. 7. Pattison Mur M.M. Stories of the Chemical Elements (1907), translation edited by Krapivin S.G. (with a foreword by the editor S.G. Krapivin).

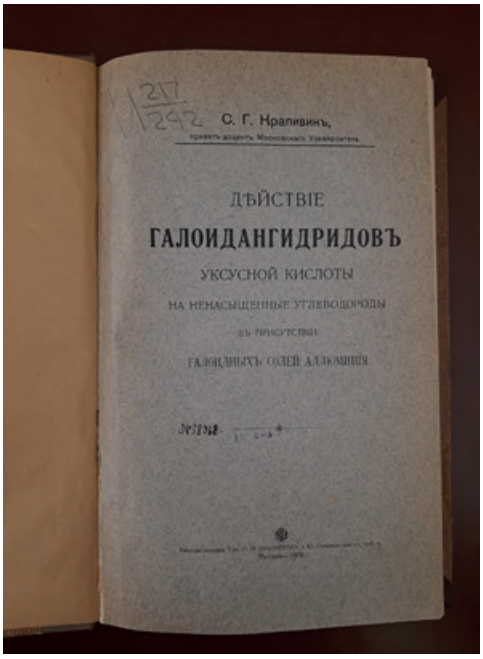

Fig. 8. Krapivin S.G. The action of acetic acid halides on unsaturated hydrocarbons in the presence of aluminum halide salts, Moscow, 1909 (page 1).

We need also to emphasize the pedagogical talent of S.G. Krapivin. He paid great attention to the methodology of teaching chemistry and clearly understood the importance of experimental work by students directly in the laboratory. He wrote, "…Experience has shown that the theoretical foundations, without which practical skills cannot be correctly assimilated, are particularly well absorbed by the students if, during the work itself, theoretical explanations of certain misunderstandings are given," [23]. Therefore, laboratory workshops were an integral part of the study of physical chemistry and quantitative analysis already during the period of his activity at the MHWC. Subsequently, the presentation of courses and lectures for chemistry teachers at higher and secondary educational institutions in various cities in Russia (Tver, Orenburg, Samara, Penza, Smolensk, etc.) made him a well-known methodologist and advocate of science [20–22].

In 1918, after the reorganization of the MHWC into the 2nd Moscow State University, S.G. Krapivin was appointed to the post of Dean of the Chemical and Pharmaceutical Department of the Faculty of Physics and Mathematics [20]. Last but not least, thanks to the efforts of Sergey Gavrilovich, the teaching of physical chemistry was maintained at an independent department, despite the drastic changes in the MHWC. Until 1924, S.G. Krapivin successfully combined administrative and scientific work, continuing to head the laboratory which he had set up.

A knight of science and a true teacher, S.G. Krapivin created, developed and preserved the Department during perhaps the most difficult periods of its existence: during the student riots of the early 20th century, the First World War, the February and October Revolutions, and the Civil War. The colossal expenditure of physical and mental energy could not fail to affect his health, and Sergey Gavrilovich died prematurely before the age of 60.

The development of physical chemistry at IFCT was continued by other national physical chemists [14], but the traditions of teaching this discipline, combining the deep basic training of students with the development of various practical skills, laid down by those who stood at the origins of the department, have always been carefully preserved.

A BRIEF OVERVIEW OF THE DEPARTMENT'S ACTIVITIES FROM 1925–2023

Much more is known about this period of the Department's life, so we will only briefly consider the main stages of its development.

From 1925 to 1931, the Department was headed by Professor Ya. I. Mikhailenko, a specialist in atomic and molecular spectroscopy [14]. During these years, departments of atomic and molecular theory were added to the traditional sections of the physical chemistry course: chemical thermodynamics, solution theory, and chemical kinetics.

From 1931 to 1974, the department was headed by Yakov Kivovich Syrkin, the greatest scientist, outstanding organizer of science and teacher, later to become Academician of the USSR Academy of Sciences (1964), laureate of the Stalin Prize [14, 24]. He was one of the founders of the most important areas of physical chemistry: the theory of molecular structure and the doctrine of chemical kinetics. His fundamental work on the nature of chemical bonding, thermodynamics and the kinetics of chemical reactions in solutions largely determined the development of many subsequent studies in theoretical chemistry. The contributions of Ya.K. Syrkin to the development of modern methods of quantum chemical calculations of electronic structures of molecules, application of new physical methods for a deeper study of chemical bonding are enormous. He was one of the first to develop the idea of using transition metal

complexes in homogeneous catalysis. Under his leadership (together with I.I. Moiseev, later an Academician of the Russian Academy of Sciences (1929–2021)), the palladium allyl complex, a key intermediate or precursor in many catalytic processes, was first synthesized and characterized (1959). Between 1960–1962, the first series of classical experiments on the homogeneous catalytic oxidation of ethylene and propylene in the presence of palladium complexes was carried out (together with I.I. Moiseev and M.N. Vargaftik). Syrkin's fundamental research in thermodynamics and quantum chemistry is still relevant to the development of coordination chemistry, electrochemistry, molecular biology, and biochemistry [14, 25–29].

At that time (1957), a laboratory for the study of chemical bonding and molecular structure was created, thus greatly increasing the possibilities for research. Full-time researchers appeared, scientific groups were formed and a certain scientific direction was developed. Opportunities for postgraduate study expanded, and students were widely involved in scientific work [27].

Syrkin brilliantly combined his great scientific work with pedagogical activity. His lectures were constantly updated to take account of the latest advances in science. The physical chemistry course which he created was very different from the standard course in the discipline. It was based on the department: "The structure of matter and the nature of chemical bonding". Then the departments of "Chemical kinetics" and "Chemical thermodynamic" were substantially revised [28, 29]. This course structure is currently being maintained.

After the death of Syrkin, the duties of head of department from 1974 to 1976 were performed by Madeleine Grigorievna Shirmazan, his student and closest collaborator. She was an excellent methodologist and teacher and later the scientific secretary of the IFCT [28, 29].

From 1976 to 1983, the department was headed by Academician Vitaly Iosifovich Goldansky, an outstanding physical chemist, [14, 28, 29]. He had an unusually wide range of scientific interests. He predicted the phenomenon of two-proton radioactivity, laid the foundations for the chemical applications of Mesbauer spectroscopy, the physical chemistry of the positron and positronium, and established a temperature criterion for the region of tunnel junctions. He made great contributions to developing the theory of low-temperature polymerization of formaldehyde, conformational transitions in protein globules and other areas. During this period, the Department's scientific contacts both at home and abroad were significantly strengthened and expanded.

From 1983 to 1988, the Department was headed by Prof. Georgii Adrianovich Grigoriev, a specialist in non-equilibrium thermodynamics. During this period, the department moved to a new building on Vernadskii Prospekt. G.A. Grigoriev's organizational and economic skills enabled the department to get through this difficult period practically without affecting the scientific and educational process, and to acquire new modern equipment [14, 29].

In 1988, Professor Aleksandr Anatolievich Ovchinnikov, Corresponding Member of the USSR Academy of Sciences, became Head of the Department. He developed a theory of the structure of large molecules with a system of conjugated bonds which made it possible to predict their physicochemical properties. A.A. Ovchinnikov made a significant contribution to the physical chemistry of organic semiconductors and the theory of redox reactions in polar media [14].

From 1991 to 2004, the department was headed by Professor Andrei Pavlovich Belov, a student of I.I. Moiseev. His research interests included the chemistry and structure of allyl complexes of transition metals, the mechanisms of homogeneous catalytic oxidation reactions of unsaturated compounds, and the chemistry of furan compounds [14]. Despite the difficult economic conditions of the time, the Department managed to maintain much of its scientific and educational potential. At the initiative of A.P. Belov and with his active participation, a Chemistry Department was established for bachelor degree students studying at chemical faculties with a natural science profile. In 1998, the first graduation ceremony for undergraduate students took place. In 2000, the first Master's theses in the Physical Chemistry Master's program were assessed. For the first time, the department had its own graduates! Most of them were postgraduate students and employees of departments or institutes of the Russian Academy of Sciences. Within a short period of time, the department carried out important methodological work, organized new original lecture courses and laboratory workshops.

Since 2005, the department has been headed by Professor Vitaly Rafailovich Flid who continues to develop the traditions of the outstanding IFCT scientific school in the field of physical chemistry and catalysis. Over the past few years, the department has built up a skilled team of like-minded educators and researchers. Under the leadership of Doctors of Sciences, R.S. Shamsiev, O.N. Shishilov, S.M. Pestov, N.A. Yashtulov, and V.R. Flid, traditional scientific directions and groups have been maintained and new ones formed: homogeneous metal complex catalysis and intermediates chemistry; synthesis, structure

and practical application of allylic complexes of transition metals; quantum chemistry as applied to metal complex and heterogeneous catalytic systems; optical sensors and EPR-spectroscopy; heterogeneous catalysis; catalytic chemistry of complex carboxyclic compounds; physics and chemistry of liquid crystals; synthesis and surface properties of photonic crystals; physical chemistry of fuel cells and nano-electro-catalysis; physicochemical bases of qualified biomass processng; new frame polymers and membranes for gas separation; and new materials for implants in cardiovascular surgery. Work is continuing on the frontiers of photochemistry, green chemistry and ecology, as well as the use of chemical converters of solar energy, and hydrogen energy. Research is carried out in small research groups (2–3 staff or teachers, 1–2 postgraduates, and 2–3 students).

The teaching staff of the Department consists of 22 scientists (6 Professors, Doctors of Sciences, 11 Associate Professors, Candidates of Sciences, 3 Senior Lecturers, and 2 Assistants). The scientific staff varies from 5 to 20 people, depending on the current work on grants, contracts, and scientific and technical programs. Each year 8–12 people study in the Postgraduate School and 1 staff member on the Doctoral Program. Bachelor's and Master's students are involved in all scientific work. A Scientific School on Catalysis has been established and registered with the Department. The department was one of the initiators of the creation of the "Center for Catalytic and Mass Transfer Processes," equipped with state-of-the-art facilities. The Center carries out scientific and technological work within the framework of major projects of national economic importance.

CONCLUSIONS

With its considerable human, methodological, and technological potential, the Department of Physical Chemistry at the M.V. Lomonosov IFCT of RTU MIREA is able to resolve some of the most complex theoretical and practical problems. A complex combination of experimental, theoretical, and methodological approaches is successfully implemented through the interaction of different scientific groups, all united by the ambition to resolve matters of common interest. This was what the founding fathers of the Department of Physical Chemistry—N.D. Zelinsky, S.G. Krapivin, and Ya.K. Syrkin—predicted and aspired to in their selfless dedication to science.

Authors' contributions

A.V. Grashkina – analysis of literary sources and Internet resources, investigation of archival materials, writing the text of the review;

V.R. Flid – conceptualization of the review, scientific editing of materials, critical revision with the addition of valuable intellectual content.

The authors declare no conflicts of interest.

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