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Internationally Important Achievements of Polish Chemists and Pharmacists

When chemistry was viewed as a mere subdiscipline of applied alchemy, and pharmacy was treated as a craft, the scientific knowledge of nature was the domain of philosophers. Later, in Renaissance Europe, alchemy, though officially prohibited, continued to be supported by patrons and pursued at royal courts, sometimes also in monasteries and at universities. Among the alchemists of that period, Michał Sędziwój (1566-1636) was probably the most famous. He was a Polish nobleman, secretary to King Sigismund III Vasa, advisor to Emperors Rudolf II and Ferdinand II, diplomat and philosopher. His Latinate name Michael Sendivogius was mentioned in esoteric and scientific treatises by various authors until the end of the 18th century. Sędziwój's writings were composed mainly in Latin and then translated into almost all European vernacular languages, and had several editions. It is estimated that they went into over eighty editions within two hundred years. Sędziwój's works were studied by Isaac Newton and Antoine L. Lavoisier. As they contained original theories and a huge portion of experimental knowledge, they had to exert a strong impact on the development of modern chemistry. At the same time, pharmacists' circles were affected by iatrochemistry, which presented new materials and new methods in drug production. Its renowned, controversial proponent, Paracelsus (1493-1541), who wrote in German, left behind some writings that soon proved pivotal for the advances of natural sciences and medicine. But for one book, the rest were printed posthumously. The world historiography states that the first, Latin edition of Paracelsus' *Opera omnia* had ten volumes and two supplements, and was published in Basel in the years 1589-1591. However, it is little known that two decades later, in Kraków, Paracelsus' most important books were translated into Latin and printed, the funds having been provided by Olbracht Łaski (*De preparationibus* and *Archidoxae libri X*, Kraków 1569).

The era of the Enlightenment changed human outlook on the world. Man no longer felt an integral element of the macrocosm, but began to perceive nature as his gift, an inexhaustible treasury of resources. Thus learning acquired a strictly utilitarian motivation. Alchemy had to retreat, leaving space to its opponent, chemistry. The latter was quick to propagate its own analytical methods in order to answer questions posed by the remaining natural sciences. However, the advances of chemistry were the most crucial for progress in biological sciences, medicine and pharmacy. The eternal mystery of life was to be solved thanks to man's acquaintance with chemical transformations of substances.

An original solution to that mystery was proposed by a physician, professor of chemistry and pharmacy at the University of Wilno, Jędrzej Śniadecki (1768-1838). The core of the system of life sciences that was created by Śniadecki was an analysis of correlations between the animate and inanimate matter along with mechanistic views on the structure of chemical compounds and affinity as a characteristic, innate feature of chemical elements. The origin of substances that build up bodies of plants and animals involved a power that was contrary to affinity and that was the attribute of life. Śniadecki did not think it was equal either to the soul or any other supernatural factor. His *Teoria jestestw organicznych* [*Theory of organic beings*], which was translated into French and German, influenced European experimental physiology. The German edition can still be found at the University Library in Vienna, and it was used by Johannes Müller. Probably it was also known to Justus Liebig, who, twenty years later, published some writings which contained strikingly similar opinions, comparable to those interpretations of life phenomena that had been voiced by Śniadecki.

In history of chemistry, the first half of the 19th century was halcyon days of analysis. The investigation into the composition of substances that occur in nature became the basic method of acquiring knowledge about the world. Soon enough, that method brought about numerous discoveries, especially in organic chemistry and pharmacy, thanks to which many new substances could be used by chemical factories, and natural dyes and new medicines were invented. In this respect, valuable results were obtained by Filip Neriusz

Walter (1810-1847). Having graduated from the Jagiellonian University and earned his doctorate in Berlin, he took part in the 1830 uprising against the Russians. As the insurrection was suppressed, Walter had to emigrate and started to work as the director of the Chemical Division in the Central School of Arts and Crafts in Paris. Walter was the first scientist who put forward a hypothesis about the plant origin of petroleum. Thanks to dry distillation of pine resin and other substances of vegetable origin, he isolated over twenty previously unknown aromatic compounds. For that achievement, France awarded him with the Grand Cross of the Legion of Honour.

At that time petroleum was rather rarely used, sometimes to grease cart axles or to tan hides, in veterinary practice or in pharmacies as medicinal raw material. It could not be used as fuel because, when burned, it produced too much acrid smoke and soot. Therefore the idea to use petroleum in lamps, as a source of light, must have appeared absolutely preposterous. Yet the problem of lighting proved to be of utmost importance in everyday life. Although in large cities some streets were lit with gas lamps, others were submerged in darkness. Public edifices, hospitals, schools and dwelling houses could rely on expensive candles or slightly cheaper lamps and cressets, where liquid vegetable oil or animal fat were burned.

The first man in the world who distilled petroleum to obtain a fraction that could be used for illumination and to utilise it in lamps was a pharmacist, Ignacy Łukasiewicz (1822-1882). Kerosene, obtained from petroleum, was not explosive and burned with clear, bright light. The only thing that had to be done was to modify the design of the common oil lamp and the result was a new source of light, much more efficient than all the previous ones.

The first building that was illuminated with kerosene lamps was the hospital in Lwów (now Lviv, Ukraine). That occurred in 1853. One year later, the first street kerosene lamp was lit in Gorlice, Subcarpathia. Another achievement of Ignacy Łukasiewicz was the exploitation of the oil field in Bóbrka, where petroleum was taken from drilled oil wells. It began in 1854. From 1856, the first large-scale petroleum distillery was operative. Kerosene lamps were adopted very quickly. For instance, in 1858 the Board of the Austrian Northern Railways issued a decision that such lamps should be installed in trains and railway stations.

The importance of production of oil and oil processing was rightly appreciated by the American *Standard Oil Company*. Its representatives approached Łukasiewicz with an offer of 20% of stock in exchange for the technology of obtaining oil products. Łukasiewicz answered that he had enough money and showed the guests all the relevant documentation as well as all the oil field and distillery machinery.

Five years later than in Poland, in the United States there appeared first oil wells and petroleum processing plants. In a short time, *Standard Oil Company* was transformed into Rockefeller's financial empire.

Other natural resources that were fairly frequently investigated by chemists and pharmacists were curative waters. From the mid-19th century, spa treatments were undergoing a pan-European revival. There was a growing demand for scientific data concerning the elements present in particular springs and for the classification of spas alongside medical recommendations. In this field, a meritorious figure was a pharmacist, Teodor Torosiewicz (1789-1876), who analysed and described many springs of curative mineral water, especially those located in the then Austrian territories of Galicia and Bukovina. In the majority of cases, that was ground-breaking research. Torosiewicz published all his papers in Polish and German. He was most satisfied with the fact that some of his findings and suggestions were immediately taken advantage of in European countries; those results concerned the influence of particular bands of diffracted white light on various substances that were used in pharmacies. For instance, he found out that mercury chloride does not turn black in red and orange light. Then he researched the impact of sun rays on photosensitive materials placed in transparent yellow containers. Among the analysed substances, there were chlorine water, Prussic acid, vegetable oils and animal fat with an admixture of mercurous iodide. After some time, only animal fat was changed due to the presence of light. Therefore Torosiewicz recommended that pharmacists should use yellow, orange and red glass vessels. His paper on the subject was published in 1836. Afterwards, coloured glass jars began to appear in pharmacies, at first in Germany.

Fifty years later, the problem of the influence of light on the course of chemical processes inspired research studies of Julian Schramm (1852-1926), who graduated from the university in Lwów, where later he worked as professor. Schramm investigated the fluorination of aromatic and aliphatic hydrocarbons, which was one of topical issues. Even towards the end of the 1860s it was known that the process may be regulated by temperature: the substitution in the aromatic ring or aliphatic side chain depended on whether the reaction occurred in cold temperature or at the boiling temperature of the hydrocarbon. Julian Schramm demonstrated that the substitution with the halogen takes a quantitative course in the side aliphatic chain even at reduced temperatures on condition that the reaction occurs in the presence of sunlight. His first paper discussing the phenomenon and providing its theoretical explanation was published in 1885. Schramm's discovery was a crucial one and gave rise to a new subdiscipline: photochemistry.

A huge impact on the development of another speciality, called cryogenics, was exerted by the research output of two professors of the Jagiellonian University in Kraków: the physicist Zygmunt Wróblewski (1845-1888) and the chemist Karol Olszewski (1846-1915). Using the cascade method, which they had invented, they were the first to obtain such low temperatures that allowed them, while the pressure was appropriately increased, to liquefy gases that were considered stable. In 1883 they liquefied oxygen and hydrogen. Later on they managed to liquefy and solidify carbon dioxide. After Wróblewski's sudden death, following an accident in the laboratory, Olszewski proceeded with that research on his own. He obtained solid chlorine, hydrogen chloride and arsine, as well as liquid and solid argon. In the 1880s, Kraków was the most important centre of cryogenics in the world.

Although liquefaction and solidification of gases are physical processes, yet the progress of cryogenics had a considerable significance for the advances in chemistry as it preconditioned the development of low temperature chemistry and cryometry.

In history of chemistry, the second half of the 19th century was marked by fascination with carbon compounds. The object of research was natural substances isolated from vegetable and animal material as well as artificial substances obtained in laboratories. However, it was not enough to provide the empirical formula. In order to identify and characterise a new compound, it became necessary to construct and prove the structural formula. That was achieved by means of substitution and synthesis reactions.

In Polish territories at that time, the most active organic chemistry research centre was Lwów. An important school of organic chemistry originated there, which had considerable research achievements. Its traditions are currently continued by the University of Wrocław. The founder of the school was Bronisław Radziszewski (1838-1914). Earlier, he was prosecuted as a political offender as he co-organised and actively participated in the 1830 uprising against the Russians. After the suppression of the uprising, he had to emigrate, and intended to proceed with his chemical studies. Radziszewski succeeded in securing a place at the laboratory of August Kekulé in Ghent. There, he received a doctoral degree and then for a short time was a trainee at the University of Louvain. Later he returned to stay in those Polish territories that were occupied by Austria, where he could feel safe. In 1872, he became professor at the university in Lwów. He took pleasure in analysing mineral waters that were used in medical treatment. The presence of methane in the Iwonicz springs confirmed, in his opinion, the hypothesis which had been proposed forty years earlier by Walter and which said that petroleum was of vegetable origin. Radziszewski elaborated on that hypothesis and was the first to create a theory to explicate the genesis of petroleum, which was gaining more and more importance as a raw material. However, Radziszewski's main research interest was aromatic compounds. He observed that some of those substances in basic medium with hydrogen peroxide are able to emit light. Next, he found out that chemiluminescence is characteristic not only of aromatic hydrocarbons, but also of aldehydes, alcohols, fats, fatty acids, and soaps. While carrying out experiments concerning this interesting feature of organic compounds, he observed that nitriles, when in basic medium, react with hydrogen peroxide and form amides. That was tantamount to the discovery of how to transform nitriles into amids derived from carboxylic acids. Thus Radziszewski went down in general history of chemistry. Nowadays, the reaction scheme for what specialist literature calls the *Radziszewski reaction* is the following:

$$R - CN + 2H_2O_2 = R - CONH_2 + H_2O + O_2$$

Those chemical reactions that are distinguished by the name of the discoverer are usually of fundamental value. They are termed "name reactions". Almost all of them refer to organic chemistry, and the majority of them had appeared in the literature by the end of the 19th century. Among the documented name reactions that are mentioned in handbooks and scientific publications, twenty-two are named after the Poles.

In Switzerland and elsewhere

Historical circumstances at the turn of the 19th and 20th century made it necessary for a large group of Polish chemists to emigrate. Sometimes they were forced to take such a decision by political reasons or otherwise they sought better education and academic opportunities. That was often the case with Poles who lived in Russian-occupied territories, where all Polish institutions of higher education had been liquidated. Young people had to go abroad to study in Germany, France, Britain or Italy. Switzerland proved to be a particularly hospitable country and Polish migrants formed a substantial portion both among the students and the faculty.

One of those migrants was Marceli Nencki (1847-1901). Since he had taken part in the anti-Russian uprising (as so many of his compatriots), he had to leave his native land, so first he went to study in Kraków, then in Jena and Berlin. In 1872 he found employment at Bern University, where he was professor for nearly two decades and established a research institute that investigated the most topical problems of organic chemistry, which currently belong to physiological chemistry and biochemistry. That period saw the origin of Nencki's vital works on putrefactive processes in proteins. From proteins, Nencki isolated a substance that was identical to synthetic indole. Treating the substance with ozone, in 1875 he obtained synthetic indigo dye, a blue dye that is used even nowadays, especially to colour cotton textiles. It was the first indigo dye synthesis in the world. Nencki's achievements in Switzerland include also his ground-breaking research on the chemistry of amino acids and phenyl esters. One of the results was that in 1886 the first synthetic antiseptic, *salol*, was obtained. For many years, until antibiotics were invented, *salol* was a valuable medicine, prescribed in the diseases of the urinary tract and the alimentary tract.

However, the world-famous attainments of Marceli Nencki involved research on haem, which is responsible for the red tincture of blood and is an ingredient of haemoglobin. Nencki studied and described the spectroscopic properties of haematoporphyrin. That research, started in Bern, was continued by Nencki in Saint Petersburg, where he moved in 1891 to become head of the Department of Chemistry (in the Institute of Experimental Medicine), which was designed and equipped according to his guidelines.

In 1896 another Polish chemist, Leon Marchlewski (1869-1946), who worked in Manchester on synthetic dyes, observed that spectroscopic properties of haematoporphyrin are similar to those of phylloporphyrin, which he had isolated from chlorophyll, present in green parts of plants. He informed Necki about this finding in a letter. Both researchers, co-operating and corresponding, demonstrated chemical analogies between haem and chlorophyll. Their discovery confirmed the chemical uniformity of the plant and animal kingdoms, the unity of all animate nature.

One of Nencki's colleagues at Bern University was Stanisław Kostanecki (1860-1910). Before he was offered a professorial position in Bern, he had graduated in chemistry from the university in Berlin, earned a doctor's degree in Basel and achieved many crucial research successes. His speciality was dyes.

Since mauveine had been discovered, dyes attracted the attention of a great number of researchers, both as to their structure and easy and efficient production methods. Besides cognitive motives of these pursuits, there appeared a global demand of textile industries for various permanent, inexpensive dyeing preparations.

Stanisław Kostanecki examined natural vegetable dyes and attempted to identify their chemical structure. To that end, he analysed yellow substances derived from poplar buds (chrysin), the oak *Quercus tinctoria* (quercetin), the Hungarian tree *Rhus cosinus* (fisetin), parsley (apigenin), the *Reseda lutea* (luteolin), and others. Having compared the results, he observed that all those dyes had a similar, characteristic atomic structure. Kostanecki called it the flavone structure. That happened in 1895. Four years later he confirmed empirically his conclusions as to the structure of vegetable yellow pigments, performing a lab analysis of the flavone structure. Kostanecki's accomplishments marked the beginning of the chemistry of flavonoids, a new subdiscipline of great importance for biochemistry and drug sciences. As Filip Walter before, also Kostanecki, in recognition of his scientific success, was awarded the Grand Cross of the Legion of Honour by the French government.

Now a century has passed since Kostanecki's discovery, and in that time about 7,000 such substances have been identified. It turned out that many of them are present in plants in the form of glycosides. It was also proved that flavone compounds are characterised by comprehensive biological activity and therefore they have become basic ingredients of a large group of drugs. Currently, the fast developing chemistry of flavonoids is one of the most important branches of pharmacognosy.

One of Kostanecki's Bernese students was Kazimierz Funk (1884-1967), a biologist and chemist, who went down in history as the founder of vitamin science. In 1911, from rice bran, he isolated a substance that proved efficient in fighting beri-beri, a dangerous disease that was widespread among poor populations of the tropics. He called this substance "vitamin" and stated that the cause of the symptoms of beri-beri was avitaminosis. Both these names were widely adopted and soon their meaning became broader. The substance which had been isolated by Funk was marked with the symbol B_1. Later experiments showed that it contained admixtures of other B vitamins. Funk continued his research into the impact of nutrition deficiencies on the etiology of various diseases. Apart from vitamins, he was also interested in hormones, especially insulin ones, and in the ways they affect metabolic processes. He collaborated with pharmaceutical companies in Poland, France and the United States. In order to honour his scientific output, in 1947 the Funk Foundation for Medical Research was established in New York.

Switzerland was a place of residence, for over twenty years, for an outstanding chemist, engineer and inventor, the future President of the Republic of Poland, Ignacy Mościcki (1867-1946). His numerous inventions and patents belong to history of technology, while his important achievements in chemistry include the technology of obtaining nitric acid from air and water.

In view of the fact that Chile saltpetere deposits were running out while other regions of the world did not hold sufficient resources of that material, the synthetic production of nitrogen compounds became a major issue at the turn of the 19th and 20th century. Saltpetere and other nitrogen compounds were indispensable to manufacture various types of explosives for the military. They were also necessary in the production of artificial fertilizers, dyes, synthetic silk and many other goods offered by chemical plants. Hence many researchers in the world carried out independent research to invent an industrial method of nitrogen oxidation. The cheapest substrate was the air in the atmosphere, containing oxygen and nitrogen in enormous amounts. Attempts were made to activate the reaction using electric arc energy.

Ignacy Mościcki followed the same procedure. His achievement was to design and construct an innovative, sufficiently powerful electric furnace as well as absorption columns to obtain concentrated nitric acid (98%) in an efficient manner. The technological process of producing nitric oxide, as worked out by Mościcki, was implemented in Swiss industry. In 1910 the Chippis factory, which had been constructed under Mościcki's supervision, turned out the world's first tanker of concentrated nitric acid. The plant provided supplies to all chemical works in Switzerland, while the surplus was exported to other European countries. As the market demand was high, the Chippis plant, as designed and overseen by Mościcki, was considerably extended. It played a significant part during the First World War, when imports of saltpetere were hindered due to the blockade of Central Powers. Switzerland was able to satisfy its own demand for nitrogen compounds thanks to domestic produce.

Ignacy Mościcki's contemporary was Maria Skłodowska-Curie (1867-1934), who received the Nobel Prize twice. Having completed her secondary education and chemistry courses in Warszawa, she went to Paris so as to study and develop her academic career. At La Sorbonne, she graduated from the Faculty of Physics and Chemistry and received her BSc in mathematics. Over a decade later, she became professor of that university. The first Nobel Prize was received by her jointly with her husband. It was awarded in 1903 in physics for the discovery of two previously unknown radioactive elements: polonium and radium, which were found in uranium ores. The second Nobel Prize was granted in 1911 for her individual achievement in chemistry, mainly for isolating radium in metallic form and identifying physical and chemical properties of the element. The second Prize was assigned by

Maria Skłodowska-Curie to found the Radium Institute in Paris. Under her guidance, the Institute conducted research in physics, chemistry and applications of radioactivity in medicine, especially in fighting cancer. The Radium Institute educated many eminent scientists, among them four Nobel Prize winners. During the First World War, Maria Skłodowska-Curie organised mobile radiography units in trucks that travelled along the front-line and proved immensely helpful in diagnosing injuries. Maria Skłodowska-Curie drove the trucks herself and she also X-rayed soldiers.

She was convinced that radium could be used in medical treatment and believed that with radium it was possible to cure otherwise incurable cancer. Therefore she was an ardent supporter of establishing similar radium institutes in every country. Thanks to her initiative and the support of President Ignacy Mościcki, in 1935 the Radium Institute was opened in Warszawa.

Recent history and the present day

The 20th century, and particularly its first half, was exceptionally tragic for Europe. Two world wars and two malevolent totalitarian systems, cruelty and homicide on an unprecedented scale clearly had to exert their impact on all domains of human activity, including science. Chemistry, which evolved very dynamically, included a wide range of generously financed secret research for military purposes where pharmaceutical sciences played a role too. The number and the character of important discoveries in that area will be revealed only to historians of future generations.

Nevertheless, some of those achievements were made public, e.g. those by Osman Achmatowicz (1899-1988), who graduated in chemistry from Wilno University and then worked as a trainee at the Dyson Perrins Laboratory in Oxford. Between the world wars, as commissioned by the army, Achmatowicz studied the properties of carbonyl cyanide CO(CN), a compound that structurally resembles phosgene, a gas that is ranked among chemical weapons. Achmatowicz and his colleagues investigated that strongly toxic, highly volatile and explosive substance and managed to define its physical and chemical properties. That knowledge constituted his contribution to organic chemistry.

After the Second World War, Osman Achmatowicz returned to his earlier interests in alkaloids contained in green parts of the *Lycopodium* and roots of the waterlily. During the decades following the discovery of morphine, alkaloids, studied within pharmaceutical chemistry and toxicology, had been attracting the attention of many researchers. All poisonous plants and all bitter-tasting vegetable substances were potential sources of those compounds that affect the human body so strongly. Alkaloids were soon applied in medicine.

When Osman Achmatowicz's team joined that worldwide research trend, chemists had already known the chemical structure and properties of many alkaloids that had been isolated from natural plant material. Many of those substances were also successfully synthesised. Under such circumstances, scientists were surprised to learn that nature holds compounds whose structure resembles that of alkaloids, yet includes sulphur. The discovery was made by Achmatowicz et al. in the early 1960s, when they investigated nupharidin and other alkaloids present in the rhizome of the spatterdock *Nuphar lutea*. That new class of compounds was called thioalkaloids. The discovery of thioalkaloids, the identification of their structure and the method of synthesising them were of much importance for the development of phytochemistry.

As early as the end of the 19th century, technological innovations, both in chemistry and pharmacy, were more and more commonly protected by patent laws, which was obviously related to the free market and competition. That pertained also to the production and sale of new medicines, one of the most popular being the antiseptic *Salvarsan*. It was the first ever efficient drug in syphilis treatment, a widespread and dangerous sexually transmitted disease. *Salvarsan* was an organoarsenic compound whose medical properties were proven in 1912 by the German physician and Nobel Prize winner, Paul Ehrlich. However, the medicine was difficult to use in its original form as it did not solve in water and had adverse side effects. Two years later an improved preparation was ready which was introduced under the name *Neosalvarsan*.

At that time, organometallic bonds were studied by Stanisław Kiełbasiński (1882-1955). First, having studied in Berlin and Vienna, he worked in Moscow on the method of obtaining synthetic rubber from ethanol. When in Moscow, he was probably inspired by the news about *Neosalvarsan*, and became interested in organoarsenic compounds in medical treatments. Having returned to Poland, he began intense research into that problem. Between 1920-1922 he invented and patented a method to produce a Polish variety of *Neosalvarsan*, which was soon manufactured by chemical plants. The patent rights to Polish *Neosalvarsan* were sold to about twenty countries. Especially Santiago de Chile owes a great deal to Stanisław Kiełbasiński. He went there in 1929 in order to supervise a green-field project of arsenobenzene preparations production. *Neosalvarsan*, when thoroughly studied, proved to be an arsenical amine, and lost its significance only in the 1940s, when it was replaced by penicillin. Between the world wars, Stanisław Kiełbasiński secured several other patents in the technologies of producing various organic compounds that came to be used as drugs.

Following the rapid increment of knowledge, there occurred a change in the ways in which experimental sciences were practised. The results of a researcher's work depended not only on his inventiveness and expertise, but also, or perhaps primarily, on how well his lab was equipped. Individual work in a secluded environment became an anachronism and a thing of the past. Large teams, collaborating on various aspects of the same problem or phenomenon and communicating with other similar teams all over the world, were gaining more and more prominence.

The majority of research trends that had originated before the First World War continued to flourish and generate new subdisciplines; physical chemistry ranked among the most modern.

An excellent representative of the new speciality was Wojciech Alojzy Świętosławski (1881-1968), who was nominated twice for the Nobel Prize. After his chemical studies in Kiev and academic internship at the university in Moscow, in 1919 he became professor of physical chemistry at the Warsaw University of Technology. He focused on termochemistry, especially on calorimetry and measuring the heat of changes in radioactive substances and organic compounds. That was a fundamental problem, pivotal for quantitative research results. Świętosławski built the micro-calorimeter and designed static and dynamic methods of identifying thermal micro-effects, which came to be commonly used. He constantly upgraded his micro-calorimeters and measurement techniques, which made it possible to quantitatively trace energy changes that accompany various processes, e.g. spontaneous radioactive decay, adsorption, cement hydration. Having conducted those measurements, he put forward a hypothesis that some lanthanides and some elements of the nitrogen group are sources of weak neutron radiation.

Świętosławski's accomplishment is also the improvement of the bomb calorimeter, which is a device to measure the heat of combustion of organic substances that are pressurised with oxygen. In 1922 Świętosławski suggested that benzoic acid should be considered a universal standard in thermochemical measurements to allow common calibration of bomb calorimeters. The International Union of Pure and Applied Chemistry (IUPAC) accepted the suggestion and thus benzoic acid became the first approved standard in this category of measurements.

The team headed by Świętosławski carried out research on ebulliometry, concentrating on the methodology of identifying boiling points of pure substances as well as mixtures and solutions. A very useful device was the differential ebulliometer, which the literature terms Świętosławski's ebulliometer. The device is extremely precise and measures condensation temperatures of contaminated substances, as well as the boiling temperatures and composition of azeotropic mixtures. The use of the device contributed to the development of new branches of physical chemistry: azeotropy and polyazeotropy.

In 1928 Wojciech Świętosławski became the President of the IUPAC. Then from 1934, for two consecutive terms, he chaired the Committee on Physico-Chemical Data and Standards within that international organisation.

During the Second World War Wojciech Świętosławski stayed in the United States, where he was professor at Pittsburgh University, then in Iowa. At that time he invented the cryometer, a device that made it possible to establish the purity of substances and to take measurements in an inexpensive, accurate and quick manner. That it was of utmost practical consequence is corroborated by sheer calculation: previously it had cost about 5,000 dollars to measure the degree of purity of a substance, while Świętosławski's method allowed to obtained equally reliable results for 10 dollars!

After the war, Świętosławski returned to Warszawa, where he was still preoccupied with physical chemistry. In co-operation with Kazimierz Zięborak (1923-2004), he discovered the existence of a four-compound azeotrope. He also invented the terms: *polyazeotropy, homo*- and *heteroazeotropy* as well as *zeotropy*, which were adopted in science.

Some branches of modern physical chemistry have so much converged with physics, due to common research methods and common research area, that it is problematic to draw the demarcation line. That pertains especially to quantum chemistry, whose exceptionally dynamic growth began with the advent of mathematical machines, which could rapidly perform ever more complicated calculations. One of the objectives of quantum chemistry is to build theoretical models of selected objects from the microcosm, in which the considered configurations are described by appropriate function equations with multiple variables.

From among Polish scientists who were active in that field, the greatest success must be ascribed to Włodzimierz Kołos (1928-1996), a chemist and physicist, one of the founders of modern quantum chemistry. His choice of the academic career path was determined by his stay at the University of Chicago in the years 1957-1961. For the first time, Kołos had an opportunity to get acquainted with huge computers and their mathematical potential. After his return to Poland, he concentrated on the electronic structure of small particles and gained fame for his calculation of the dissociation energy for the hydrogen molecule. Kołos's solution was the first case in history when mathematical modelling, recognizing quantum postulates, proved to be more precise than the results of a spectroscopic experiment. Similarly reliable findings were later obtained by Kołos et al. for the excited states of the hydrogen molecule. Kołos was also interested in hydrogen isotopes. When investigating the effects accompanying the beta decay of the tritium molecule, he obtained basic data that were indispensable to define the mass of the neutrino.

Until the end of his life, Włodzimierz Kołos remained faithful to theoretical structural models of small particles. The accomplishments of his team were world-class. The most significant ones include research and calculations concerning muon-catalysed nuclear fusion as well as developments in the theory of intramolecular forces. Włodzimierz Kołos was the first person in the world to receive the medal of the International Academy of Quantum Molecular Science (IAQMS) in 1967, and in 1988 he became a member of that organisation. A similar distinction, i.e. the medal and membership of the IAQMS, was granted later to one more Pole, Kołos's student and long-term working partner, Bogumił Jeziorski.

Today, physico-chemical research forms the core of the majority of studies that have traditionally represented such branches as inorganic chemistry, organic chemistry, physical chemistry, polymer chemistry or technology. Owing to the common research methods, the divisions are no longer clear-cut. The interdisciplinary character of chemical studies, which is manifested both in primary and applied research, is spreading to embrace the specialities that used to be classified as belonging to pharmacy or biochemistry.

What criteria should be adopted in order to assess the most recent achievements of Polish chemists and pharmacists when the best of verifiers, time perspective, is not to be had? If the criterion were technological innovations, then Polish scientists have patented and implemented a considerable number of them, and that number is still growing.

If we take into account the publications presenting the findings of leading-edge research in the best known international specialist journals as well as the citation index, the evaluation might be easier because of the available statistical figures. They state that, annually, chemical papers by Polish authors amount to circa 6% of all the publications in the world. This figure, with slight changes across years and particular subdisiciplines, is continually rising.

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