

# IMPLEMENTATION OF INNOVATIONS

EXPERIENCE OF THE CZECH REPUBLIC

## IN CHEMISTRY





European Institute for Innovation Development

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# Implementation of Innovations in Chemistry

## Experience of the Czech Republic

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Ostrava–Opava, Czech Republic

2026

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## Introduction

### Chemistry in Contemporary Czechia: Scientific Continuity, Transformation, and Innovation between 1993 and 2025

Chemistry has always occupied a distinctive position within the scientific and technological development of the Czech lands. As a discipline connecting fundamental understanding of matter with practical applications in industry, medicine, environmental protection, and technological innovation, chemistry has played an essential role in shaping the scientific identity of Czech society. The period between 1993 and 2025 represents a particularly important stage in this historical development because it encompasses the transformation of Czech chemistry from a scientific system inherited from Czechoslovakia into a modern European research environment. During these three decades, Czech chemical science experienced profound institutional, methodological, and conceptual changes. Research institutions were reorganised, international cooperation expanded, new scientific fields emerged, and traditional disciplines were transformed through interdisciplinary approaches. The history of chemistry in contemporary Czechia therefore reflects not only the development of a specific scientific field but also the broader evolution of Czech science after the establishment of an independent state.

The year 1993 became a historical watershed for Czech scientific development. The creation of the independent Czech Republic introduced a new institutional framework within which universities, research organisations, and scientific communities had to redefine their roles and priorities. However, the development of chemistry after 1993 cannot be understood as a complete break with the past. Czech chemical science entered this period with a significant intellectual heritage, experienced research communities, established scientific schools, and internationally respected traditions in areas such as organic chemistry, polymer science, analytical chemistry, chemical engineering, and materials research. These foundations provided the basis for further development. The challenge was to transform existing scientific capacity into a system capable of functioning within the increasingly competitive international environment of European and global research.

The transformation of Czech chemistry after 1993 occurred within a broader context of changes affecting science throughout Central and Eastern Europe. The transition towards democratic institutions, market-based economies, and European integration created new opportunities but also required substantial adaptation. Scientific institutions had to introduce new models of management, competitive funding, international evaluation, and cooperation with foreign research organisations. For chemistry, these changes were particularly significant because the discipline depends heavily on advanced infrastructure, expensive instrumentation, long-term research programmes, and close connections between fundamental knowledge and technological applications. The successful adaptation of Czech chemical institutions demonstrated the ability of the scientific community to preserve valuable traditions while adopting new approaches.

One of the defining characteristics of Czech chemistry during the period 1993–2025 was the balance between continuity and innovation. Scientific development rarely occurs through

complete replacement of previous knowledge; rather, progress emerges when established expertise is combined with new concepts and technologies. Czech chemistry followed this pattern by maintaining strong traditional disciplines while expanding into emerging fields such as chemical biology, nanotechnology, computational chemistry, sustainable chemistry, and advanced materials science. Organic chemistry developed towards molecular design and biomedical applications. Polymer chemistry evolved into the science of functional macromolecular systems. Analytical chemistry incorporated increasingly sophisticated instrumentation and digital methods. Physical chemistry expanded through computational approaches and molecular modelling. These transformations demonstrate the dynamic nature of contemporary chemistry.

The development of chemical science in Czechia was strongly influenced by the structure of national research institutions. The Czech Academy of Sciences, universities, and specialised research centres created a network supporting both fundamental investigation and applied innovation. Institutions such as the Institute of Organic Chemistry and Biochemistry, the Institute of Macromolecular Chemistry, the Institute of Chemical Process Fundamentals, the University of Chemistry and Technology Prague, Charles University, Masaryk University, Brno University of Technology, and regional chemical centres contributed to different aspects of national chemical development. Their combined activities created a diversified scientific ecosystem capable of addressing complex research questions. The strength of Czech chemistry has therefore been based not on a single institution but on cooperation between multiple scientific environments with complementary expertise.

A major transformation of Czech chemistry after 1993 was its increasing internationalisation. In the early years of the independent republic, international cooperation was primarily a mechanism for reconnecting Czech researchers with broader scientific communities and modern research practices. Over time, however, Czech institutions moved from participation towards active contribution. Researchers increasingly became involved in European research programmes, international collaborations, and global scientific networks. Czech chemical groups developed partnerships with leading institutions abroad and contributed to internationally recognised research. This process strengthened scientific quality and introduced new approaches to research organisation, education, and innovation.

European integration represented one of the most important external factors influencing the development of Czech chemical science. The accession of the Czech Republic to the European Union in 2004 opened new opportunities for scientific cooperation, infrastructure development, and participation in European research initiatives. Chemistry benefited significantly from this process because many contemporary challenges require international collaboration and interdisciplinary approaches. European research programmes supported cooperation in areas such as advanced materials, biotechnology, sustainable chemistry, energy technologies, and molecular sciences. Through European integration, Czech chemistry became increasingly connected with the broader European research environment.

The development of contemporary Czech chemistry also reflects the changing nature of the discipline itself. Modern chemistry has expanded far beyond the traditional boundaries associated with the preparation and analysis of chemical substances. Today, chemistry is a science of molecular design, complex systems, functional materials, biological interactions, and technological solutions. Czech researchers participated in this transformation by developing research directions at the intersection of chemistry with physics, biology,

medicine, engineering, and information technologies. The emergence of interdisciplinary fields demonstrated that the future of chemistry depends increasingly on cooperation between different areas of knowledge.

Materials chemistry and nanotechnology became among the most visible examples of this transformation. Building upon historical strengths in polymer science and industrial chemistry, Czech researchers developed new approaches to designing functional materials with controlled properties. Research on polymers, nanostructures, biomaterials, catalytic systems, and energy-related materials reflected global scientific trends while maintaining connections with Czech scientific traditions. These developments demonstrated how chemistry contributes to technological innovation by enabling the creation of materials with specific functions for medicine, electronics, energy, and environmental applications.

The growing importance of sustainability represented another fundamental change in the role of chemistry. During the twentieth century, chemical innovation was often associated primarily with industrial productivity and technological efficiency. In the twenty-first century, however, chemistry has increasingly become a science responsible for addressing environmental and societal challenges. Czech researchers contributed to this transformation through work in green chemistry, sustainable processes, environmental analysis, circular economy approaches, and energy technologies. Sustainable chemistry became not a separate specialised field but a principle influencing many areas of modern chemical research.

The relationship between chemistry and society also changed significantly during the period under consideration. Chemical research increasingly became connected with issues directly affecting everyday life, including healthcare, environmental protection, food safety, energy security, and technological development. The COVID-19 pandemic demonstrated the importance of chemical knowledge in biomedical research, diagnostics, pharmaceutical development, and analytical technologies. At the same time, public attention to environmental challenges increased expectations regarding responsible chemical innovation. Contemporary chemistry therefore operates within a broader social context where scientific excellence must be combined with practical relevance and public responsibility.

Education and the development of human resources represented another essential dimension of Czech chemical progress. Universities and research institutions played a crucial role in preparing new generations of chemists capable of working within an international and interdisciplinary environment. Modern chemical education increasingly incorporated computational methods, advanced instrumentation, biotechnology, sustainability principles, and international scientific communication. The ability to combine deep disciplinary knowledge with broader scientific perspectives became one of the key characteristics of contemporary chemical professionals.

The geographical structure of Czech chemical science also contributed significantly to its development. Prague, Brno, Pardubice, Olomouc, Ostrava, and other regions created a network of scientific centres with different but complementary strengths. Prague maintained its role as a major centre of molecular research, chemical technology, and Academy-based fundamental science. Brno developed a strong interdisciplinary profile connected with materials science, biotechnology, and advanced research infrastructures. Regional centres contributed through applied chemistry, industrial cooperation, environmental technologies, and specialised education. Together, these institutions formed a distributed national system capable of supporting diverse areas of chemical research.

The period from 1993 to 2025 therefore represents a crucial chapter in the history of Czech chemical science. It was a period of institutional transformation, international integration, technological advancement, and scientific diversification. Czech chemistry successfully combined historical continuity with innovation, demonstrating that established scientific traditions can become a foundation for future development. The achievements of this period were not limited to individual discoveries or technological applications; they included the creation of a modern research ecosystem capable of contributing to European and global chemistry.

This book examines the development of chemical sciences in contemporary Czechia through the perspective of institutions, scientific disciplines, technological achievements, and research transformations. It analyses how Czech chemistry evolved from the early post-1993 period of adaptation towards a modern innovation ecosystem integrated into international science. The story of Czech chemistry between 1993 and 2025 demonstrates the importance of scientific continuity, institutional resilience, interdisciplinary cooperation, and openness to new challenges. It represents not only a history of chemical research but also a broader example of how national science can successfully transform itself within a rapidly changing global environment.

## Part One

# Historical Evolution of Chemistry in Contemporary Czechia, 1993–2025

### 1993 as a Watershed: Continuity and Reorganisation of Czech Chemical Science

The year 1993 represents a fundamental chronological marker in the modern history of Czech chemical science, although its meaning requires careful interpretation. The establishment of the independent Czech Republic on 1 January 1993 did not signify the emergence of chemistry as a new scientific discipline within the country, because the Czech lands already possessed a remarkably developed chemical tradition rooted in the nineteenth and twentieth centuries. Instead, 1993 marked the beginning of a new institutional and geopolitical framework within which chemical research, education, technological development, and scientific cooperation would evolve. The importance of this moment lies precisely in the interaction between historical continuity and structural transformation. Czech chemistry entered the post-Czechoslovak period with established scientific schools, experienced researchers, specialised institutions, and internationally recognised achievements. At the same time, these inherited resources had to be reorganised according to the principles of a democratic state, a competitive research environment, and an increasingly integrated European scientific system. Therefore, 1993 should be understood not as a point of origin, but as a watershed that changed the conditions under which Czech chemical knowledge was produced, communicated, and applied.

The historical depth of Czech chemistry is essential for understanding why the transformation after 1993 followed a path of adaptation rather than reconstruction from the beginning. Chemical science in the Czech lands developed within the broader Central European intellectual environment, where universities, technical institutions, industrial laboratories, and scientific societies formed a dense network of knowledge production. The emergence of modern chemistry was closely connected with the development of technical education, industrial manufacturing, pharmaceutical production, glass and ceramic technologies, and later with advanced molecular sciences. By the second half of the twentieth century, Czechoslovakia possessed a complex chemical research system that combined university departments, Academy of Sciences institutes, and industrial research organisations. These structures created a scientific culture in which theoretical chemistry, experimental investigation, and industrial application were closely interconnected. Consequently, the independent Czech Republic inherited not only physical laboratories and institutional frameworks, but also a professional community with established scientific traditions and methodological standards.

The dissolution of Czechoslovakia created a unique situation for Czech chemical science because political separation occurred without a fundamental disruption of scientific continuity. Unlike historical moments characterised by war, institutional collapse, or the forced replacement of scientific elites, the transition of 1993 represented a negotiated

reorganisation of an existing research environment. Scientific institutions, professional associations, academic traditions, and personal networks continued to function, although within a new administrative and legal framework. Czech and Slovak chemical communities remained connected through shared publications, conferences, educational traditions, and personal cooperation. The separation of the state therefore did not eliminate the intellectual space formed during decades of common development. Instead, Czech chemistry gradually acquired a specifically national institutional identity while maintaining strong links with the wider Central European scientific environment.

One of the most important transformations after 1993 concerned the restructuring of the national research system. The former Czechoslovak Academy of Sciences was transformed into the Academy of Sciences of the Czech Republic, which became a central institution for fundamental research. This transition was particularly significant for chemistry because Academy institutes had historically represented some of the most advanced centres of chemical investigation in the country. The new Academy inherited extensive scientific infrastructure, specialised laboratories, collections of knowledge, and highly qualified researchers, but it also faced new expectations regarding efficiency, international competitiveness, and scientific evaluation. Research institutions were increasingly required to demonstrate their contribution through internationally recognised publications, competitive projects, and cooperation beyond national borders. The transformation therefore involved not only administrative restructuring, but also a gradual change in scientific culture itself.

The reorganisation of the Academy system had a profound influence on several leading chemical institutions. The Institute of Organic Chemistry and Biochemistry of the Czech Academy of Sciences became one of the most internationally visible examples of how historical scientific capacity could be transformed into a modern research environment. The Institute continued traditions of organic synthesis, molecular chemistry, and biochemical investigation while increasingly orienting itself towards internationally competitive areas such as medicinal chemistry, molecular biology, chemical biology, and the development of biologically active compounds. Its later achievements demonstrated that Czech chemical institutions were capable of moving from a nationally significant position towards global scientific relevance. This transformation reflected a broader tendency within Czech chemistry: the preservation of specialised expertise combined with the adoption of new research priorities and international standards.

Another essential element of post-1993 development was the transformation of the relationship between universities and research institutions. During the socialist period, Czechoslovakia followed a model common in many Central and Eastern European countries, where fundamental research was concentrated largely within academy institutes, while universities primarily focused on education. After 1993, this separation gradually became less pronounced. Czech universities increasingly developed their own research capacities, expanded doctoral education, created specialised laboratories, and became active participants in international scientific projects. This process was especially important for chemistry because modern chemical research requires continuous interaction between education, laboratory training, theoretical development, and technological application. The strengthening of university-based research contributed to the emergence of a more distributed and dynamic chemical research system.

The University of Chemistry and Technology Prague occupied a particularly important position in this transformation. As the country's leading specialised institution in chemical and technological education, it represented a direct continuation of the Czech tradition of linking chemistry with engineering and industrial development. After 1993, the University expanded its international cooperation, modernised its research infrastructure, and increasingly positioned itself as a European centre for chemical education and applied research. Its role illustrates a characteristic feature of Czech chemical development: the close relationship between fundamental scientific knowledge and practical technological competence. Chemistry in Czechia was never limited exclusively to laboratory science; it was historically connected with industrial processes, materials production, pharmaceuticals, environmental technologies, and technological innovation. This applied orientation remained an important component of its post-1993 transformation.

The introduction of competitive research funding represented another major turning point. The establishment and development of national grant mechanisms changed the way scientific priorities were defined and research projects were organised. Czech chemists increasingly participated in competitive funding schemes that required clearly formulated objectives, internationally relevant research questions, and measurable scientific outcomes. This transition encouraged the formation of specialised research groups and stimulated cooperation between different scientific disciplines. At the same time, it required researchers and institutions to adapt to new administrative realities, including project management, international reporting standards, and evaluation procedures. For chemistry, which depends heavily on expensive instrumentation and long-term experimental programmes, access to competitive funding became one of the key factors determining institutional development.

The 1990s were therefore a period of both opportunity and uncertainty. The opening of international borders created unprecedented possibilities for cooperation with Western European laboratories, access to scientific literature, participation in conferences, and exchange of researchers. However, the transition also exposed structural challenges inherited from the previous system. Some laboratories required significant technological modernisation, younger researchers needed new career pathways, and institutions had to adjust to changing expectations regarding scientific productivity. The transformation of Czech chemistry was therefore not a simple process of expansion, but rather a complex adaptation in which new opportunities had to be balanced with institutional limitations.

The international opening of Czech chemical science after 1993 was not limited to the restoration of contacts interrupted or restricted during the previous political period. It represented a deeper transformation of the position of Czech researchers within the global circulation of chemical knowledge. Modern chemistry had already become one of the most internationally integrated scientific fields by the end of the twentieth century, and participation in this environment required more than individual cooperation between scientists. It demanded institutional capacity, internationally compatible research standards, modern instrumentation, and the ability to participate in large-scale scientific programmes. Czech chemical institutions gradually adapted to these requirements by strengthening foreign partnerships, increasing publication activity in international journals, and developing research areas corresponding to global scientific trends. The transition from a relatively closed national scientific environment to an internationally connected research system became one of the most significant achievements of the post-1993 period. This process was gradual rather than instantaneous, but it fundamentally changed the character of Czech chemical science.

An important aspect of this transformation was the growing role of doctoral education and the reproduction of scientific generations. Chemistry, perhaps more than many other scientific disciplines, depends on the continuous preparation of highly skilled researchers capable of mastering complex experimental methods, advanced instrumentation, and interdisciplinary approaches. After 1993, Czech universities increasingly developed doctoral programmes connected with active research groups, allowing students to participate directly in scientific projects rather than receiving only theoretical training. This contributed to a gradual renewal of the scientific community and reduced the risk of isolation between established researchers and younger generations. Doctoral education also became one of the main mechanisms through which Czech chemistry entered European scientific networks, as doctoral students increasingly participated in international exchanges, joint supervision programmes, and collaborative research projects. The development of young scientific talent therefore became not merely an educational issue, but a strategic component of national chemical development.

The post-1993 period also witnessed a gradual change in the internal structure of chemical research. Traditional branches of chemistry remained important, including organic chemistry, analytical chemistry, physical chemistry, inorganic chemistry, and chemical engineering, but they increasingly interacted with emerging interdisciplinary fields. The boundaries between chemistry, biology, materials science, physics, medicine, and information technologies became increasingly permeable. This transformation reflected a global tendency within chemical sciences, where many of the most significant discoveries increasingly occurred at the intersection of traditional disciplines. Czech researchers participated in this broader movement by developing expertise in areas such as molecular design, supramolecular chemistry, functional materials, biotechnology, and computational approaches to chemical problems. The ability to combine established chemical traditions with emerging interdisciplinary methodologies became one of the defining characteristics of contemporary Czech chemistry.

The development of materials chemistry provides a particularly illustrative example of this transformation. Historically, Czech lands possessed strong industrial traditions connected with polymers, glass, ceramics, metallurgy, and chemical manufacturing. After 1993, these traditions were gradually connected with modern scientific approaches focused on nanomaterials, functional surfaces, advanced polymers, and materials for technological applications. Research groups began to investigate materials not only as industrial products but also as precisely engineered systems with controlled molecular and structural properties. This shift represented a transition from classical chemical production towards knowledge-intensive materials science. Czech research institutions increasingly contributed to areas relevant for modern technologies, including energy storage, electronic materials, environmental protection, and biomedical applications.

The relationship between academic chemistry and industrial innovation also underwent significant transformation. During the previous period, industrial research had often been closely connected with state-owned enterprises and centrally planned economic structures. The transition to a market economy changed the organisation of industrial science and required new forms of cooperation between universities, research institutes, and private companies. Chemical industries had to respond to international competition, stricter environmental regulations, and technological modernisation. As a result, demand increased for research capable of producing economically relevant innovations. Czech chemical science

gradually developed new mechanisms of technology transfer, contract research, and industrial partnership, although this process required considerable institutional adaptation.

Environmental chemistry became another increasingly important area after 1993. The transformation of Czech society and industry brought greater attention to environmental protection, pollution control, sustainable production, and the ecological consequences of chemical processes. Researchers increasingly focused on analytical methods for detecting pollutants, developing cleaner technologies, improving waste treatment, and understanding complex environmental systems. This direction reflected both domestic needs and broader European developments, particularly the growing importance of sustainable development policies. Czech chemistry therefore became increasingly connected with questions that extended beyond traditional laboratory research and addressed wider societal challenges.

The European integration of the Czech Republic after 2004 further accelerated these processes. Membership of the European Union created new opportunities for scientific cooperation, access to European research programmes, and participation in international infrastructures. For chemistry, European integration was especially significant because many advanced research projects required collaboration between laboratories from different countries. Czech researchers became increasingly involved in European networks dealing with molecular sciences, materials research, biotechnology, and chemical technologies. European funding mechanisms also encouraged the development of larger research teams and modern scientific facilities. This period marked a transition from international cooperation based mainly on individual academic contacts towards systematic participation in European research structures.

The emergence of major research infrastructures represented one of the most visible symbols of this new stage. Czech scientific policy increasingly recognised that modern research competitiveness depends not only on individual expertise but also on access to advanced technological platforms. Chemical research requires sophisticated analytical instruments, high-performance computing, specialised laboratories, and interdisciplinary environments. The development of research centres combining chemistry with physics, biology, medicine, and engineering reflected this new understanding of scientific organisation. These infrastructures contributed to the formation of research ecosystems rather than isolated laboratories, creating conditions for more ambitious scientific projects.

The post-1993 development of Czech chemistry also demonstrated the importance of maintaining a balance between fundamental research and practical application. A purely industrial approach would have weakened the long-term scientific potential of the discipline, while purely theoretical research without connections to technological challenges would have limited its societal impact. Czech chemical institutions increasingly sought a model in which fundamental discoveries could generate future applications, while industrial needs could stimulate new scientific questions. This interaction became particularly visible in areas such as medicinal chemistry, biotechnology, materials science, catalysis, and environmental technologies. The ability to connect scientific excellence with practical relevance became one of the central characteristics of Czech chemical innovation.

By the beginning of the twenty-first century, Czech chemistry had therefore completed the first major stage of its post-Czechoslovak transformation. The discipline had preserved its historical identity while undergoing substantial institutional, methodological, and international changes. Research organisations had adapted to new governance models, universities had

strengthened their scientific role, international cooperation had expanded, and new interdisciplinary fields had emerged. The foundations had been established for the next stage of development, characterised not merely by adaptation but by consolidation, increased research competitiveness, and the formation of stable scientific schools.

The significance of the period beginning in 1993 can thus be summarised as a process of selective modernisation. Czech chemical science did not reject its previous achievements, nor did it simply reproduce inherited structures under new political conditions. Instead, it transformed existing scientific capital into a modern research system capable of operating within European and global frameworks. The continuity of expertise, combined with institutional reform and international openness, created the basis for the achievements that would define Czech chemistry during the following decades. The first post-independence period was therefore not only a transitional phase but also the foundation upon which contemporary Czech chemical science was built.

### **The First Post-Czechoslovak Stage: The 1990s and Early 2000s as a Period of Institutional Adaptation, Recovery, and Scientific Differentiation**

The first decade of the independent Czech Republic represented a decisive stage in the transformation of national chemical science. If 1993 established the new institutional framework within which Czech chemistry had to operate, the following years became a period of adaptation, restructuring, and gradual redefinition of scientific priorities. The 1990s and the beginning of the 2000s were characterised by the simultaneous presence of continuity and change: established research traditions remained active, while institutions, funding mechanisms, educational models, and international connections underwent substantial modification. This period cannot be interpreted simply as a transition from one scientific system to another, because Czech chemistry did not experience a complete institutional replacement. Instead, it developed through a complex process of selective adaptation, in which valuable scientific traditions were preserved while new organisational principles were introduced. The central challenge was to transform inherited scientific capacity into a modern research environment compatible with European standards. This transformation created the foundations for the later internationalisation and technological expansion of Czech chemistry.

The post-Czechoslovak period began with the necessity to redefine the role of scientific institutions within the newly established state. Research organisations that had previously functioned within the federal structure of Czechoslovakia now had to operate within a national framework, with new administrative responsibilities and new expectations from society and government. The Czech Academy of Sciences became one of the most important actors in this process, providing institutional continuity for fundamental research while simultaneously undergoing organisational modernisation. Chemical institutes within the Academy preserved specialised expertise accumulated over decades, but they increasingly faced demands for measurable scientific performance, international visibility, and competitive project acquisition. This created a new scientific culture in which historical reputation alone was insufficient, and institutions had to demonstrate their relevance through internationally recognised research outputs. The transformation of the Academy therefore represented both

preservation and reform: preservation of scientific traditions and reform of the mechanisms through which scientific excellence was achieved.

The Institute of Organic Chemistry and Biochemistry of the Czech Academy of Sciences illustrates this broader institutional transformation particularly clearly. During the post-1993 period, the Institute continued to develop research in organic synthesis, molecular chemistry, biochemistry, and later chemical biology and medicinal chemistry. Its development demonstrated how a historically established institution could successfully adapt to a new scientific environment by combining fundamental research with emerging interdisciplinary approaches. The Institute gradually strengthened its international connections and became increasingly integrated into global research networks. Its experience reflected a general tendency within Czech chemical science: institutions that successfully combined scientific continuity with openness to new methods and international cooperation became the principal drivers of development. The ability to preserve accumulated expertise while changing research priorities became one of the defining features of successful Czech chemical institutions.

A similar transformation occurred within the Institute of Macromolecular Chemistry of the Czech Academy of Sciences. Czech polymer science had a long and internationally recognised tradition, particularly connected with synthetic polymers, biomaterials, and industrial applications. During the 1990s, this field entered a new stage in which classical polymer chemistry increasingly interacted with modern materials science, biotechnology, and biomedical research. Researchers began to focus not only on the synthesis of polymers but also on their controlled molecular architecture, functional properties, and potential applications in medicine, environmental technologies, and advanced materials. This reflected a broader shift within chemistry itself: materials were no longer understood merely as industrial substances but as engineered systems whose properties could be designed at the molecular level. Czech polymer chemistry successfully adapted to this new paradigm and became one of the important foundations of contemporary materials research.

The University of Chemistry and Technology Prague played an equally significant role in the institutional adaptation of Czech chemistry. As the country's leading specialised institution in chemical education, it had to respond to several simultaneous challenges: maintaining high-quality professional training, modernising curricula, strengthening research activity, and increasing international cooperation. The transformation of higher education after 1989 and 1993 encouraged Czech universities to move closer to the European model, where teaching and research are closely interconnected. Chemistry students increasingly received training not only in established theoretical disciplines but also in modern experimental methods, computational approaches, environmental issues, and technological innovation. The university's traditional connection with industry remained important, but it was gradually complemented by stronger participation in international scientific projects and fundamental research.

Charles University also strengthened its role as a major centre of chemical research during this period. Its historical position as one of Central Europe's oldest universities provided a broad intellectual environment in which chemistry interacted with physics, biology, medicine, and other scientific disciplines. Research groups associated with the university contributed particularly to areas where chemistry intersected with molecular sciences and biomedical applications. This interdisciplinary orientation became increasingly important during the late twentieth and early twenty-first centuries, when many scientific breakthroughs emerged at the

boundaries between classical disciplines. The development of university-based chemical research therefore contributed to a diversification of Czech chemistry, reducing dependence on a limited number of specialised institutions and creating a broader national research ecosystem.

The emergence of new funding mechanisms was one of the most important structural changes of the 1990s. The introduction of competitive grant systems changed the relationship between researchers, institutions, and the state. Under the previous model, scientific institutions received resources primarily through established organisational structures, whereas the emerging system increasingly required researchers to compete for funding through clearly defined projects. This transition encouraged scientific specialisation and greater attention to research quality, originality, and international relevance. For chemistry, where many research areas require expensive equipment and long-term experimental programmes, competitive funding became a crucial mechanism for maintaining and improving scientific capacity. At the same time, adaptation to grant-based research required new administrative skills and a cultural shift among researchers accustomed to different organisational principles.

The development of the Grant Agency of the Czech Republic and other national support mechanisms contributed to the gradual formation of a more competitive scientific environment. Chemical researchers increasingly prepared projects according to internationally recognised standards, formulated specific hypotheses, and emphasised measurable scientific outcomes. This encouraged closer alignment between Czech chemical research and global scientific practices. However, the transition was not without difficulties. Smaller research groups often faced challenges competing with established institutions, and the need to demonstrate short-term outputs sometimes created tension with the long-term character of fundamental chemical investigation. Nevertheless, the introduction of competitive funding became an essential factor in modernising Czech chemical science and preparing it for deeper European integration.

The 1990s also represented a period of significant technological renewal. Chemical research depends heavily on analytical and experimental infrastructure, including spectroscopy, chromatography, microscopy, computational tools, and advanced synthesis equipment. Many Czech laboratories required modernisation in order to remain competitive internationally. The gradual improvement of research infrastructure was therefore not simply a technical matter but a prerequisite for participation in contemporary chemical science. Access to modern instruments allowed Czech researchers to investigate increasingly complex molecular systems and participate in international projects requiring high methodological standards. The modernisation of laboratories became one of the practical foundations of scientific renewal.

The transformation of industrial chemistry was another important dimension of this period. The Czech chemical industry entered the post-socialist era facing major economic and technological changes. Traditional industrial structures had to adapt to market competition, environmental regulation, and integration into European production networks. These changes influenced academic chemistry because they created new demands for research capable of supporting technological innovation. Areas such as catalysis, polymer technologies, pharmaceutical chemistry, environmental protection, and process optimisation gained increasing importance. Cooperation between universities, Academy institutes, and industrial companies gradually became more structured, although the development of effective technology transfer mechanisms required time. The relationship between scientific research

and industrial application therefore became one of the central themes of Czech chemical development.

The pharmaceutical and biomedical dimensions of chemistry also expanded during this stage. Advances in molecular biology and biotechnology influenced chemical research worldwide, and Czech institutions increasingly participated in this interdisciplinary transformation. Researchers working in organic chemistry, biochemistry, and medicinal chemistry began to focus more strongly on biologically active molecules, molecular mechanisms of disease, and the development of compounds with potential therapeutic applications. This represented a significant evolution from classical synthetic chemistry towards molecularly oriented research. The growing interaction between chemistry and life sciences became one of the defining trends that would continue throughout the following decades.

Analytical chemistry maintained a particularly strong position within Czech scientific development. The country's long tradition in chemical analysis provided an important foundation for research connected with environmental monitoring, pharmaceutical quality control, industrial processes, and biological investigation. During the 1990s and early 2000s, analytical chemistry increasingly incorporated advanced instrumentation and computational methods. The field demonstrated how established scientific traditions could be renewed through technological modernisation. Rather than being replaced by newer disciplines, analytical chemistry became an essential methodological foundation supporting many emerging areas of chemical research.

Environmental challenges also contributed to the diversification of Czech chemical science. The transformation of industry and the growing influence of European environmental standards increased demand for chemical approaches to pollution control, waste management, sustainable production, and ecological monitoring. Researchers developed new methods for detecting contaminants, analysing environmental processes, and improving industrial efficiency. Environmental chemistry thus became an important example of how scientific development responded simultaneously to international trends and domestic societal needs. It also strengthened connections between chemistry and broader concepts of sustainable development.

By the early 2000s, Czech chemistry had moved beyond the initial adaptation phase and entered a period of structural consolidation. The essential elements of a modern research system had been established: competitive funding, stronger university research, internationally oriented institutions, renewed infrastructure, and expanding interdisciplinary cooperation. The discipline retained its historical strengths while becoming increasingly capable of responding to new scientific challenges. Traditional fields such as organic chemistry, polymer science, and analytical chemistry continued to develop, while emerging areas such as chemical biology, nanotechnology, and advanced materials gained importance.

The first post-Czechoslovak stage was therefore a period of scientific differentiation. Czech chemistry did not develop along a single trajectory, but rather through the emergence of multiple specialised directions connected by shared institutional foundations. Different research centres developed distinctive profiles, creating a diversified national chemical landscape. Prague became a major centre of molecular chemistry, chemical technology, and fundamental research, while Brno strengthened its position in interdisciplinary science and advanced materials. Other regional centres contributed through specialised research areas

and industrial cooperation. This polycentric structure later became one of the strengths of Czech chemical science.

In historical perspective, the 1990s and early 2000s represented the transition from inherited scientific capacity to modern research competitiveness. The period was marked by institutional adaptation, methodological renewal, international opening, and the gradual emergence of new scientific priorities. Czech chemistry successfully preserved its historical identity while transforming itself according to the requirements of contemporary science. The foundations established during this period made possible the next stage of development, characterised by stronger international integration, major research infrastructures, and increasing contributions to global chemical innovation.

### The Stage of Consolidation: The 2000s as the Formation of a Modern Chemical Research Architecture

The first decade of the twenty-first century represented a new phase in the development of Czech chemical science. While the 1990s had primarily been a period of institutional adaptation and transition from the inherited Czechoslovak scientific framework towards a modern national research system, the 2000s were characterised by consolidation, expansion, and the gradual formation of a stable architecture of chemical research. During this period, Czech chemistry moved beyond the immediate challenges of restructuring and began to focus increasingly on strengthening scientific competitiveness, building specialised research teams, developing advanced infrastructure, and increasing participation in international scientific networks. The central question was no longer how chemical institutions could survive within the new environment, but how they could achieve a stronger position within European and global science. This transformation was supported by several interconnected processes: European integration, increased mobility of researchers, improved access to international funding, modernisation of laboratories, and the emergence of interdisciplinary research programmes. The 2000s therefore became a decade in which the foundations created after 1993 were transformed into a more mature and internationally oriented chemical research system.

The accession of the Czech Republic to the European Union in 2004 represented a particularly important milestone in this development. European integration significantly expanded the opportunities available to Czech chemical researchers by providing access to broader scientific networks, collaborative projects, and funding mechanisms. Participation in European Framework Programmes encouraged Czech institutions to develop partnerships with leading research centres across Europe and to adopt increasingly international approaches to scientific management. Chemistry benefited considerably from this process because the discipline has always been characterised by international exchange, shared methodologies, and cooperation between specialised laboratories. European integration also accelerated the movement of Czech chemistry away from a primarily national research model towards participation in a European scientific ecosystem. The ability to compete successfully for European projects became an important indicator of institutional maturity and research quality.

A major characteristic of the 2000s was the gradual transformation of individual laboratories into larger and more structured research teams. During the previous decade, many research groups had focused on rebuilding international contacts and modernising their activities. By the 2000s, successful groups increasingly developed long-term research programmes, attracted doctoral students and postdoctoral researchers, and established international collaborations. This shift reflected a broader transformation of global science, where major discoveries increasingly required interdisciplinary teams rather than isolated researchers. Czech chemical institutions responded to this trend by encouraging cooperation between different branches of chemistry and between chemistry and neighbouring disciplines such as biology, physics, medicine, and materials science. The emergence of larger research teams strengthened the scientific capacity of Czech institutions and improved their ability to participate in ambitious international projects.

The Czech Academy of Sciences remained one of the central pillars of this development. Its chemical institutes continued to combine fundamental research with increasing international visibility. The Institute of Organic Chemistry and Biochemistry developed a particularly strong international profile, demonstrating the potential of Czech molecular sciences to contribute to globally significant research. Its activities in organic synthesis, chemical biology, molecular mechanisms, and biologically active compounds reflected the broader transformation of chemistry from a discipline focused primarily on the preparation and characterisation of substances towards a science capable of designing complex molecular systems with specific functions. This transition was one of the most important intellectual developments of contemporary chemistry and placed increasing emphasis on interdisciplinary cooperation.

The Institute of Macromolecular Chemistry continued to strengthen the Czech tradition of polymer science during the 2000s. The field underwent significant conceptual transformation as classical polymer chemistry increasingly interacted with nanotechnology, biomedical applications, and advanced materials research. Researchers moved beyond the production of conventional polymers towards the design of functional macromolecular systems with precisely controlled properties. Areas such as polymer-based drug delivery, biomaterials, responsive polymers, and advanced coatings became increasingly important. This development demonstrated the ability of Czech chemical research to transform traditional scientific strengths into modern innovation-oriented fields. Polymer science became one of the areas where historical expertise and contemporary technological challenges were particularly effectively combined.

Another important development was the increasing importance of research centres that connected multiple scientific disciplines. The early twenty-first century witnessed a growing recognition that scientific competitiveness depended not only on individual excellence but also on institutional environments capable of supporting interdisciplinary cooperation. This approach eventually contributed to the creation of major research infrastructures and centres of excellence. Although many of these projects reached their full development later, their foundations were established during the 2000s through changes in scientific policy and investment strategies. The emerging model emphasised shared laboratories, advanced instrumentation, international scientific teams, and cooperation between universities and Academy institutes.

The development of Brno as a major scientific centre represented one of the most significant regional transformations during this period. While Prague remained the dominant centre of

Czech scientific institutions due to the presence of national organisations and historical universities, Brno increasingly strengthened its position as a hub of interdisciplinary research. The city's universities, research institutes, and technological organisations created an environment particularly favourable for cooperation between chemistry, materials science, biotechnology, and engineering. The development of research activities in Brno reflected a broader trend within Czech science: the emergence of a more geographically balanced research landscape. This regional diversification contributed to the resilience and competitiveness of the national chemical system.

The establishment of stronger connections between chemistry and biotechnology became another defining feature of the 2000s. Advances in molecular biology, genomics, and biomedical sciences created new opportunities for chemical approaches to biological problems. Czech researchers increasingly explored areas such as molecular recognition, biomolecular interactions, bioactive molecules, and chemical methods for studying biological processes. This interdisciplinary movement contributed to the emergence of chemical biology as an important research field. The development of chemical biology also reflected a global transformation in which chemistry became increasingly integrated into life sciences and medicine rather than functioning as an isolated discipline.

Computational approaches also began to influence Czech chemical research more strongly during this period. Advances in computing power and molecular modelling methods changed the way scientists approached chemical systems. Computational chemistry, quantum chemical calculations, molecular simulations, and data analysis became increasingly important tools complementing experimental research. Although computational methods did not replace laboratory investigation, they allowed researchers to predict molecular behaviour, design compounds more efficiently, and interpret complex experimental results. The gradual integration of computational approaches represented another example of the modernisation of Czech chemistry and its alignment with international scientific developments.

Analytical chemistry continued to maintain a strong position, benefiting from technological advances and growing interdisciplinary demand. The 2000s saw increasing use of highly sophisticated analytical techniques in environmental science, pharmaceuticals, biotechnology, food science, and materials research. Czech analytical chemists contributed to the development and application of advanced measurement methods, strengthening the connection between chemical research and practical problem-solving. The importance of analytical chemistry also increased because modern scientific disciplines increasingly depended on precise characterisation of complex systems. In this sense, analytical chemistry functioned as a methodological foundation supporting many other areas of chemical innovation.

The relationship between chemical research and industrial development became more structured during the 2000s. Economic integration with European markets increased pressure on Czech industries to modernise production processes, improve environmental performance, and develop higher-value products. Chemical research institutions responded by expanding cooperation with industrial partners and participating in applied research projects. Areas such as pharmaceutical development, speciality chemicals, advanced materials, and environmentally efficient technologies became increasingly important. The transformation of industrial chemistry reflected the broader movement of the Czech economy towards

knowledge-based production, where scientific expertise became an important source of competitiveness.

Sustainable chemistry emerged as an increasingly significant direction during this period. The growing influence of European environmental policies encouraged researchers and industries to reconsider traditional chemical processes from the perspective of resource efficiency, waste reduction, and ecological impact. Czech chemical research increasingly addressed questions related to cleaner production methods, environmental monitoring, catalytic efficiency, and sustainable materials. This development demonstrated that chemistry was no longer understood solely as a science of synthesis and production but also as a discipline responsible for addressing complex environmental challenges. Sustainable chemistry became one of the bridges connecting fundamental research, industrial practice, and public policy.

The expansion of international scientific publishing was another important indicator of consolidation. Czech chemists increasingly published in internationally recognised journals, participated in global conferences, and collaborated with foreign research groups. Publication activity became not only a measure of individual scientific achievement but also an indicator of institutional competitiveness. This process encouraged researchers to align their work with international scientific discussions and contributed to greater visibility of Czech chemistry worldwide. At the same time, the emphasis on international publication created new challenges, including the need to balance internationally competitive research with nationally significant scientific priorities.

The development of research infrastructure was one of the most visible achievements of the 2000s. Modern chemistry requires increasingly sophisticated equipment, from advanced spectroscopic systems and analytical instruments to specialised facilities for molecular synthesis and materials characterisation. Czech scientific policy increasingly recognised that infrastructure investment was essential for maintaining competitiveness. The creation and improvement of laboratories provided researchers with opportunities to conduct experiments according to international standards and attract foreign collaborators. Infrastructure development therefore became not merely a technical improvement but a strategic element of scientific policy.

The 2000s also witnessed changes in the professional identity of Czech chemists. The new generation of researchers was increasingly internationally oriented, often educated through international exchanges and doctoral programmes. They combined strong foundations in traditional chemical disciplines with experience in interdisciplinary research environments. This generational transformation was essential because scientific modernisation depends not only on institutions and equipment but also on researchers capable of using them creatively. The development of younger scientists contributed to the long-term sustainability of Czech chemical research.

By the end of the 2000s, Czech chemistry had achieved a new level of institutional stability and international integration. The discipline had moved beyond the transformation challenges of the 1990s and developed a more mature research architecture based on specialised institutions, stronger universities, international cooperation, and interdisciplinary innovation. Traditional fields remained strong, but they increasingly interacted with emerging areas such as nanotechnology, biotechnology, computational chemistry, and advanced materials science. Czech chemical research had become more diverse, more internationally connected, and more closely linked with technological innovation.

The consolidation achieved during the 2000s created the conditions for the next stage of development after 2010, when Czech chemistry entered a period characterised by major research infrastructures, European research integration, technological innovation, and increasing global visibility. The decade therefore represents a crucial historical bridge between institutional adaptation and scientific maturity. It demonstrated that the transformation initiated after 1993 had produced not merely a reorganised national research system, but a dynamic scientific environment capable of contributing to the international development of chemistry.

### The Stage of Internationalisation: Czech Chemistry in European and Global Scientific Space, 2010–2020

The decade between 2010 and 2020 represented a new stage in the historical development of Czech chemical science, characterised by deeper international integration, the emergence of large-scale research infrastructures, and the transition from adaptation to active participation in global scientific processes. By this period, the institutional transformations initiated after 1993 had largely stabilised, and Czech chemical research entered an environment where competitiveness was increasingly determined by international visibility, interdisciplinary collaboration, technological capacity, and participation in multinational research networks. The central challenge was no longer the reconstruction of scientific institutions or the introduction of new organisational principles, but the ability to generate research results that contributed to global chemical knowledge. Czech chemistry gradually moved from a position of integration into European science towards a position of active contribution within European and international research communities. This transformation reflected both the maturation of domestic scientific institutions and the increasing openness of the Czech research environment. The period demonstrated how a relatively small national scientific system could achieve international relevance through focused specialisation, strong research traditions, and strategic participation in global scientific networks.

The broader European context played a decisive role in shaping the development of Czech chemistry during this period. Following accession to the European Union in 2004, Czech research institutions became increasingly embedded within the European Research Area, and by the 2010s participation in European scientific programmes had become a normal component of research activity. Framework Programmes and later Horizon 2020 created opportunities for Czech researchers to participate in multinational projects addressing complex scientific challenges that exceeded the capacity of individual laboratories. Chemistry benefited particularly from this environment because many contemporary chemical problems require international cooperation, access to specialised infrastructure, and multidisciplinary expertise. Participation in European projects encouraged Czech institutions to develop stronger project management capacities, improve international partnerships, and align research priorities with major European scientific agendas. The result was a gradual transformation of Czech chemistry from an internationally connected national science into an integrated component of European chemical research.

One of the most significant developments of the 2010s was the emergence of major research infrastructures and centres of excellence. These institutions represented a new model of

scientific organisation, moving beyond the traditional structure of individual university departments or academy laboratories. Instead, they created environments where researchers from different disciplines could work together using advanced technologies and shared infrastructure. Chemistry played an important role within this new research landscape because many emerging scientific fields required cooperation between chemists, physicists, biologists, engineers, and medical researchers. The establishment of such centres reflected a broader understanding that modern scientific innovation increasingly emerges from interaction between disciplines rather than from isolated specialisation.

The Central European Institute of Technology (CEITEC), established in Brno, became one of the most visible examples of this new research model. Although CEITEC was not exclusively a chemical institution, its interdisciplinary structure created important opportunities for chemical research connected with molecular sciences, materials science, biotechnology, and nanotechnology. The development of CEITEC reflected the increasing importance of research environments where chemistry was integrated with biological and physical sciences. Such integration was particularly significant because many contemporary challenges — including biomedical technologies, advanced materials, energy systems, and environmental solutions — cannot be addressed through a single disciplinary perspective. Czech chemistry therefore increasingly operated within broader scientific ecosystems rather than as an independent field separated from neighbouring disciplines.

The 2010s also marked the strengthening of Prague as an international centre of chemical research. The University of Chemistry and Technology Prague continued to develop its role as a leading institution combining chemical education, fundamental research, and technological application. During this period, the university expanded international cooperation, participated in European projects, and developed research activities in areas corresponding to global scientific priorities. Its traditional strengths in chemical engineering, materials science, analytical chemistry, and industrial chemistry were increasingly complemented by research in advanced molecular systems, biotechnology, and sustainable technologies. The institution demonstrated the continuing relevance of the Czech tradition of combining theoretical chemical knowledge with practical technological competence.

The Czech Academy of Sciences remained another essential pillar of international chemical research. Its institutes continued to provide a stable environment for fundamental investigation while increasingly participating in international scientific networks. The Institute of Organic Chemistry and Biochemistry further strengthened its reputation as a major centre of molecular research. Its activities in medicinal chemistry, virology-related research, biochemical mechanisms, and molecular design illustrated the increasingly close relationship between chemistry and biomedical sciences. The Institute's development represented a broader trend in contemporary chemistry, where molecular-level understanding became directly connected with applications in medicine and biotechnology.

The 2010s were also characterised by the rapid development of materials chemistry and nanoscience. Globally, these fields became among the most dynamic areas of chemical research, and Czech scientists contributed to this transformation by building upon existing traditions in polymer science, physical chemistry, and industrial materials development. Research increasingly focused on functional materials with precisely controlled properties, including advanced polymers, nanostructured systems, conductive materials, catalytic surfaces, and materials for energy applications. The transition from traditional materials

production towards molecularly designed functional materials represented a significant conceptual shift. Czech materials chemistry successfully incorporated international trends while maintaining continuity with the country's historical expertise in polymer and industrial chemistry.

Nanotechnology provided another important area of international engagement. The development of nanoscale approaches required close cooperation between chemistry, physics, materials science, and engineering. Czech researchers participated in studies of nanoparticles, nanostructured materials, surface modification, and nanoscale analytical methods. These investigations contributed to broader technological fields, including electronics, medicine, environmental protection, and energy systems. The significance of nanochemistry during this period lay not only in specific technological applications but also in demonstrating the transformation of chemistry into a science capable of manipulating matter at increasingly precise levels of organisation.

Chemical biology became one of the most influential interdisciplinary directions within Czech chemistry during the 2010s. The increasing convergence of chemistry and life sciences created new opportunities for understanding biological processes at the molecular level. Czech researchers investigated molecular interactions, biologically active compounds, protein-related processes, and chemical approaches to biomedical problems. This development required new experimental approaches and collaboration between traditionally separate scientific communities. Chemical biology therefore represented not merely a new research topic but a broader transformation in scientific thinking, where chemistry became a central tool for exploring and modifying biological systems.

Medicinal chemistry and pharmaceutical research also gained increasing importance. The Czech Republic possessed historical experience in pharmaceutical chemistry and industrial production, and the 2010s provided new opportunities to connect this tradition with modern molecular approaches. Research groups increasingly focused on the design, synthesis, and evaluation of biologically active compounds, combining organic chemistry with biochemical and pharmacological methods. The development of such research reflected the growing importance of translational science, where fundamental chemical discoveries could contribute to practical medical applications. Czech medicinal chemistry became increasingly connected with international biomedical research networks and pharmaceutical innovation.

Analytical chemistry continued to serve as a methodological foundation for many emerging research areas. The increasing complexity of modern chemical systems required increasingly sophisticated methods of identification, measurement, and characterisation. Czech analytical chemists contributed to the development and application of advanced techniques in areas such as environmental monitoring, biological analysis, materials research, and industrial quality control. The importance of analytical chemistry during this period demonstrated that technological progress depends not only on the creation of new substances and materials but also on the ability to understand and measure them precisely.

Sustainable chemistry became another major direction of development during the 2010s, influenced by European environmental priorities and global discussions on responsible technological development. Czech chemical researchers increasingly addressed questions related to renewable resources, efficient catalytic processes, environmentally friendly materials, and reduction of chemical waste. The concept of green chemistry gradually moved from a specialised research direction towards a broader principle influencing industrial and

academic chemistry. This reflected a significant change in the social role of chemistry: the discipline was increasingly expected not only to create new technologies but also to contribute to solving environmental and societal challenges.

The relationship between academic research and industrial innovation became more mature during this period. Czech chemical companies increasingly required scientific expertise capable of supporting technological development, while universities and research institutes sought stronger mechanisms for transferring knowledge into practical applications. Cooperation developed in areas such as pharmaceuticals, speciality chemicals, materials, environmental technologies, and industrial processes. Although challenges remained in creating effective technology transfer systems, the 2010s demonstrated a gradual strengthening of connections between scientific research and economic innovation. Chemistry became one of the disciplines where this relationship was particularly visible due to its direct connection with industrial production.

International mobility became another defining feature of Czech chemical science during this period. Researchers increasingly participated in international conferences, collaborative projects, and exchange programmes. Czech institutions attracted foreign researchers while also sending young scientists abroad for training and collaboration. This circulation of knowledge contributed to the development of a more internationally oriented scientific culture. Younger generations of Czech chemists increasingly developed careers within a global rather than exclusively national scientific environment. International experience became an important component of scientific competitiveness.

By the end of the 2010s, Czech chemistry had achieved a significant transformation in its international position. The country no longer functioned primarily as a participant adapting to external scientific standards, but increasingly as a contributor producing internationally recognised research. Leading institutions had established stable international partnerships, specialised research fields had gained global visibility, and Czech scientists participated in major European scientific initiatives. The discipline retained its historical strengths while becoming more interdisciplinary, technologically advanced, and internationally connected.

The decade 2010–2020 therefore represented the consolidation of Czech chemistry as a European research discipline with global ambitions. The achievements of this period were based on the institutional reforms of the previous decades but went beyond them by creating new forms of scientific cooperation and innovation. Czech chemistry demonstrated that a medium-sized national scientific system could achieve international relevance through strategic specialisation, strong institutions, and integration into global research networks. This stage prepared the foundation for the contemporary period after 2020, when chemistry increasingly became connected with sustainability, digitalisation, artificial intelligence, and global technological challenges.

### Contemporary Stage: 2020–2025 as a Phase of Sustainable Chemistry, Digital Transformation, and Technological Innovation

The period between 2020 and 2025 represents the most recent stage in the evolution of Czech chemical science and reflects the transformation of chemistry into a highly interdisciplinary,

technology-driven, and socially oriented field. By the beginning of the 2020s, Czech chemical research had already completed the major institutional transitions initiated after 1993 and had established a stable position within the European scientific environment. The principal challenge of this new period was no longer integration into international science, but the ability to respond to global technological, environmental, and societal challenges through advanced chemical research. Contemporary Czech chemistry developed within a scientific landscape shaped by sustainability, digitalisation, artificial intelligence, advanced materials, biotechnology, and the transition towards a low-carbon economy. These trends did not replace traditional chemical disciplines but transformed their objectives, methodologies, and applications. Organic chemistry, analytical chemistry, materials science, chemical engineering, and biochemistry increasingly became interconnected components of a broader innovation ecosystem. The period 2020–2025 therefore represents not a separate chapter disconnected from previous developments, but the continuation of a long-term transformation that began with institutional reorganisation after 1993.

The beginning of the 2020s was marked by a global situation that demonstrated the strategic importance of chemical sciences for society. The COVID-19 pandemic highlighted the essential role of chemistry in areas such as pharmaceutical development, diagnostics, materials production, analytical technologies, and public health protection. Czech chemical institutions, like research organisations throughout Europe, experienced new demands related to biomedical research, rapid analytical methods, protective materials, and understanding molecular mechanisms associated with infectious diseases. The pandemic reinforced the public perception of chemistry as a discipline directly connected with urgent societal needs rather than solely a field of fundamental scientific investigation. At the same time, it accelerated interdisciplinary cooperation between chemists, biologists, medical researchers, and data scientists. This experience strengthened the tendency towards integrated research approaches that had already become visible during the previous decade.

One of the defining characteristics of Czech chemistry after 2020 has been the increasing importance of sustainable development. The concept of sustainable chemistry represents a fundamental transformation in the philosophy of chemical research because it changes the central question from simply how a substance can be produced to how it can be produced efficiently, safely, and responsibly. Czech researchers increasingly participated in projects focused on resource efficiency, environmentally friendly synthesis, waste reduction, renewable raw materials, and improved industrial processes. This direction corresponded with broader European priorities, including the European Green Deal and the transition towards a circular economy. For Czech chemistry, sustainable development created opportunities to combine existing strengths in chemical engineering, catalysis, materials science, and industrial chemistry with new environmental objectives.

Catalysis became one of the key scientific areas connected with sustainable chemical development. Modern catalytic systems allow chemical transformations to occur with greater efficiency, lower energy consumption, and reduced environmental impact. Czech research groups continued traditions in physical chemistry and chemical engineering while exploring new catalytic materials, molecular catalysts, and processes relevant to sustainable production. Catalysis also became increasingly connected with energy technologies, environmental protection, and industrial innovation. The development of efficient catalytic approaches demonstrated how fundamental chemical research could contribute directly to economic and ecological challenges. This field illustrates one of the central characteristics of

contemporary Czech chemistry: the ability to connect theoretical understanding of molecular processes with practical technological applications.

Energy-related chemistry emerged as another strategically important direction during the 2020–2025 period. The global transition towards renewable energy systems created demand for advanced chemical solutions related to energy storage, conversion, and utilisation. Czech researchers increasingly contributed to areas such as battery materials, electrochemical systems, hydrogen technologies, and functional materials for energy applications. These fields require close cooperation between chemistry, physics, materials science, and engineering, demonstrating once again the interdisciplinary character of modern chemical research. The development of energy-related chemistry also reflected the historical evolution of Czech scientific strengths, particularly in materials research, electrochemistry, and industrial chemical technologies. Contemporary challenges therefore stimulated the transformation of established expertise into new technological directions.

Battery research and electrochemical materials became particularly significant within this context. The development of improved energy storage technologies depends heavily on advances in chemical understanding of materials, interfaces, and molecular processes. Czech research institutions contributed to investigations of electrode materials, electrolytes, nanostructured systems, and analytical methods for understanding battery performance. Although international competition in this field is extremely strong, Czech chemistry benefited from its established traditions in materials science and physical chemistry. The field also illustrates how contemporary chemical innovation increasingly depends on the integration of experimental research, computational modelling, and advanced characterisation techniques.

Hydrogen technologies represented another important area connected with sustainable energy transformation. The chemical challenges associated with hydrogen production, storage, and utilisation require expertise in catalysis, materials chemistry, electrochemistry, and process engineering. Czech researchers participated in the broader European effort to develop technologies supporting hydrogen-based energy systems. Research in this area demonstrated the increasingly strategic role of chemistry in addressing energy transitions. Rather than being limited to the production of substances, chemistry became a discipline responsible for designing systems capable of supporting future technological infrastructures.

Digital transformation became another major characteristic of Czech chemical science after 2020. The increasing availability of computational resources, large datasets, and advanced algorithms changed the methods through which chemical research is conducted. Digital chemistry, computational modelling, machine learning, and data-driven approaches became increasingly important tools supporting experimental investigation. These methods allowed researchers to analyse complex molecular systems, predict material properties, optimise synthesis strategies, and accelerate discovery processes. The integration of digital technologies did not replace traditional experimental chemistry but created a new relationship between theory, computation, and laboratory investigation. Czech chemical research increasingly incorporated these approaches as part of its broader modernisation.

Artificial intelligence began to influence chemical research more visibly during this period. AI-based methods became increasingly relevant in areas such as molecular design, prediction of chemical properties, optimisation of experimental conditions, and analysis of large scientific datasets. The application of artificial intelligence reflected a global transformation in which chemical discovery increasingly involved cooperation between chemists and specialists in

computational science. For Czech institutions, this development represented both an opportunity and a challenge: successful integration of AI required not only technical expertise but also new forms of interdisciplinary education and research organisation. The emergence of AI-assisted chemistry demonstrated how contemporary chemical science is becoming increasingly connected with information technologies.

Biochemistry, chemical biology, and biomedical chemistry continued to expand their importance during the early 2020s. The growing complexity of medical challenges created demand for molecular approaches capable of understanding biological mechanisms and developing targeted interventions. Czech research groups continued to build upon established traditions in organic chemistry, medicinal chemistry, and molecular biology. Areas such as biologically active molecules, diagnostic technologies, molecular interactions, and therapeutic development remained important components of the national chemical research landscape. The experience of the pandemic further emphasised the importance of chemical knowledge in supporting biomedical innovation.

Advanced materials remained another central direction of development. Contemporary technologies require materials with increasingly specific properties: lightweight structures, functional surfaces, biocompatible systems, conductive materials, and environmentally responsible alternatives. Czech materials chemistry continued to benefit from long-standing expertise in polymers, macromolecular science, and industrial chemistry. Researchers increasingly focused on designing materials at molecular and nanoscale levels, allowing precise control of their properties. This development represented a continuation of earlier transformations in materials science, where chemistry moved from producing substances towards engineering functional systems.

The relationship between academic research and industrial innovation became increasingly important in the 2020s. Modern chemical industries face challenges related to sustainability, digitalisation, energy efficiency, and international competition. Czech companies increasingly require scientific expertise capable of supporting technological transformation, while universities and research institutes seek mechanisms for translating discoveries into practical applications. Cooperation between academia and industry developed particularly in areas such as advanced materials, pharmaceuticals, environmental technologies, and chemical engineering. This interaction strengthened the role of chemistry as an innovation-oriented discipline within the Czech economy.

The international position of Czech chemistry also continued to develop during this period. Participation in European research programmes, international collaborations, and global scientific networks remained essential components of research activity. Czech institutions increasingly contributed not only as participants but also as partners capable of leading specialised research activities. The reputation of Czech chemical science was supported by established scientific traditions, internationally recognised research groups, and the ability to combine fundamental investigation with technological relevance. The country's position within European chemistry reflected decades of institutional development beginning after 1993 and accelerating through subsequent stages of internationalisation.

An important feature of the 2020–2025 period was the increasing social responsibility of chemistry. Public expectations towards scientific disciplines changed significantly, and chemistry was increasingly evaluated not only by scientific achievements but also by its contribution to sustainability, health, environmental protection, and technological resilience.

Czech chemical institutions responded by expanding communication with society, participating in educational activities, and demonstrating the practical relevance of chemical research. This reflected a broader transformation of the relationship between science and society in the twenty-first century.

By 2025, Czech chemistry had developed into a mature European research field characterised by strong institutional foundations, international integration, interdisciplinary cooperation, and innovation-oriented research. The discipline successfully combined historical scientific traditions with emerging technological directions. Its development demonstrated that scientific competitiveness depends not only on individual discoveries but also on the ability of institutions to adapt continuously to changing global conditions. Czech chemistry after 2020 represents a synthesis of more than three decades of transformation: the preservation of expertise inherited from the twentieth century, the institutional reforms of the 1990s, the internationalisation of the 2000s and 2010s, and the emergence of sustainability and digital innovation as defining priorities of contemporary science.

The historical evolution of Czech chemical science from 1993 to 2025 therefore illustrates a broader pattern of scientific transformation in Central Europe. A discipline rooted in strong historical traditions successfully adapted to democratic institutional structures, European integration, global competition, and technological change. The development of Czech chemistry demonstrates that continuity and innovation are not opposing forces but complementary elements of scientific progress. The achievements of contemporary Czech chemical research are the result of a long process in which inherited knowledge, institutional adaptation, international cooperation, and technological creativity have gradually formed a modern research ecosystem capable of contributing to global chemical development.

## Part Two

### Major Achievements of Czech Chemistry, 1993–2025

#### Organic Chemistry and Synthetic Methods

Organic chemistry occupies a particularly significant position within the history of Czech chemical science. Its importance is determined not only by the central role of organic compounds in modern chemistry, medicine, materials science, and biotechnology, but also by the existence of a strong national research tradition developed throughout the twentieth century. Czech organic chemistry entered the post-1993 period with a well-established scientific foundation, experienced research schools, and internationally recognised expertise in synthetic methods, structural analysis, and molecular investigation. However, the transformation of the discipline after the establishment of the independent Czech Republic was not simply a continuation of previous achievements. The new scientific environment required adaptation to rapidly changing international standards, increasing competition, and the emergence of interdisciplinary research directions. Between 1993 and 2025, Czech organic chemistry evolved from a strong national research field into an internationally integrated scientific area connected with medicinal chemistry, chemical biology, catalysis, materials science, and molecular engineering. Its development illustrates one of the central principles of contemporary chemistry: the ability of traditional disciplines to renew themselves through methodological innovation and interdisciplinary cooperation.

The historical foundations of Czech organic chemistry are closely connected with the broader development of chemical sciences in the Czech lands. Universities, technical institutions, and research laboratories created a scientific environment in which organic chemistry developed alongside industrial chemistry, pharmaceutical research, and chemical technology. The twentieth century saw the formation of several influential research schools specialising in organic synthesis, natural products chemistry, heterocyclic compounds, and molecular structure determination. These traditions provided an important intellectual foundation after 1993, when Czech chemical institutions entered a new period of international openness. The preservation of experienced scientific communities allowed the discipline to avoid a complete disruption during the transformation of the national research system. At the same time, researchers increasingly incorporated international methodologies, modern analytical techniques, and new theoretical approaches. The result was not the replacement of Czech organic chemistry by foreign models, but its gradual integration into the global development of the discipline.

The post-1993 transformation of organic chemistry was strongly influenced by changes in research organisation and funding. The introduction of competitive grant systems encouraged research groups to formulate more focused scientific programmes and to develop internationally visible areas of specialisation. Organic chemists increasingly competed for national and European funding, participated in international collaborations, and published research results in leading scientific journals. This changed the scale and organisation of synthetic research, favouring groups capable of combining methodological expertise with clearly defined scientific objectives. The new environment also encouraged younger

researchers to participate more actively in international scientific networks, doctoral programmes, and postdoctoral exchanges. These processes contributed to the renewal of Czech organic chemistry and strengthened its connection with broader European research trends.

One of the most important institutional centres of Czech organic chemistry has been the Institute of Organic Chemistry and Biochemistry of the Czech Academy of Sciences. During the period after 1993, the Institute developed into one of the country's most internationally recognised research institutions. Its scientific profile demonstrates the transformation of organic chemistry from a classical synthetic discipline into a broader molecular science. Research programmes increasingly combined organic synthesis with biochemistry, molecular biology, structural analysis, and medicinal applications. The Institute became particularly significant in areas where the design and synthesis of organic molecules were connected with biological activity and potential therapeutic relevance. Its development represents a wider pattern within contemporary chemistry: synthetic methods increasingly serve not only the creation of new compounds but also the investigation and manipulation of complex biological and technological systems.

Synthetic methodology became one of the central areas of development within Czech organic chemistry during the modern period. Contemporary organic synthesis requires highly efficient, selective, and environmentally responsible approaches capable of producing increasingly complex molecules. Czech researchers contributed to the development and application of modern synthetic strategies, including improved catalytic transformations, selective functionalisation methods, and approaches for constructing biologically and technologically relevant molecular structures. These developments reflected global changes within organic chemistry, where the emphasis gradually shifted from simply preparing compounds towards controlling molecular architecture with high precision. The ability to design molecules with predetermined properties became a defining feature of advanced synthetic chemistry.

Catalysis played a particularly important role in the evolution of modern synthetic methods. Catalytic processes allow chemical transformations to occur with greater efficiency, selectivity, and reduced environmental impact. Czech researchers working in organic chemistry increasingly investigated catalytic systems that expanded the possibilities of molecular synthesis. Catalysis connected organic chemistry with broader areas such as sustainable chemistry, industrial processes, pharmaceutical development, and materials science. The development of catalytic approaches also demonstrated the increasing relationship between fundamental chemical understanding and technological application. By controlling reaction pathways at the molecular level, chemists could design more efficient processes while reducing energy consumption and chemical waste.

Heterocyclic chemistry represented another important direction within Czech organic research. Heterocyclic compounds constitute a fundamental class of molecules with extensive applications in pharmaceuticals, agrochemicals, materials science, and biological research. Czech chemical traditions included significant expertise in the synthesis and investigation of heterocyclic structures, and this knowledge continued to develop after 1993. Modern research in this area increasingly focused on the relationship between molecular structure and biological function, connecting synthetic chemistry with medicinal applications. The development of new heterocyclic frameworks contributed to the broader goal of

discovering molecules with specific properties and potential technological or biomedical value.

The relationship between organic chemistry and medicinal chemistry became increasingly important during the late twentieth and early twenty-first centuries. The discovery and optimisation of biologically active molecules require close cooperation between synthetic chemists, biochemists, pharmacologists, and molecular biologists. Czech research institutions increasingly developed this interdisciplinary approach, particularly through work involving bioactive compounds, molecular mechanisms, and therapeutic candidates. Organic synthesis provided the essential tools for creating and modifying molecules, while biological evaluation allowed researchers to understand their potential functions. This interaction transformed organic chemistry into a key component of modern biomedical innovation.

The development of chemical biology further expanded the role of organic synthesis within Czech science. Chemical biology relies on the ability to create precisely designed molecules that can interact with biological systems in controlled ways. Synthetic chemistry therefore became not only a method for producing compounds but also a tool for exploring biological processes. Czech researchers increasingly participated in this interdisciplinary field by combining organic synthesis with molecular and cellular approaches. This development reflected one of the most important transformations of modern chemistry: the movement from studying isolated chemical substances towards understanding complex molecular systems.

Another important direction was the connection between organic chemistry and materials science. Organic molecules increasingly became essential components of advanced materials, including functional polymers, molecular sensors, electronic materials, and responsive systems. Czech researchers contributed to this development by applying synthetic methods traditionally associated with organic chemistry to the design of materials with specific properties. This connection demonstrated the expanding boundaries of the discipline. Organic chemistry in the twenty-first century is no longer limited to the synthesis of small molecules but also contributes to the creation of complex functional systems.

The development of analytical and structural methods played a crucial supporting role in Czech organic chemistry. Modern synthesis requires precise characterisation of molecular structures, reaction mechanisms, and material properties. Advances in spectroscopy, chromatography, mass spectrometry, and computational methods significantly expanded the capabilities of synthetic chemists. Czech laboratories increasingly incorporated advanced analytical technologies, allowing researchers to investigate increasingly complex molecular systems. The interaction between synthesis and analysis became one of the foundations of contemporary organic chemistry.

The educational dimension of organic chemistry also underwent significant development after 1993. Universities strengthened doctoral programmes and research-based education, preparing new generations of chemists capable of working in international scientific environments. Students increasingly received training not only in classical synthetic methods but also in modern computational approaches, interdisciplinary research, and international scientific communication. This transformation was essential because the future development of organic chemistry depends on researchers capable of combining deep disciplinary knowledge with flexibility across scientific boundaries.

The industrial relevance of organic chemistry remained another important aspect of its development in Czechia. Synthetic chemistry has direct connections with pharmaceutical

production, speciality chemicals, polymers, and advanced technological materials. Czech industrial traditions created opportunities for cooperation between academic institutions and companies seeking innovative chemical solutions. During the period 1993–2025, such cooperation became increasingly structured, although the relationship between fundamental research and industrial application continued to evolve. Organic chemistry therefore remained one of the disciplines where scientific knowledge and economic innovation were particularly closely connected.

By 2025, Czech organic chemistry had developed into a diverse and internationally connected research field. Its achievements were based on the combination of historical scientific traditions, institutional stability, modern synthetic methodologies, and interdisciplinary cooperation. The discipline maintained its classical foundations while expanding into new areas such as medicinal chemistry, chemical biology, sustainable synthesis, and molecular materials. This transformation demonstrates the broader evolution of chemistry itself: from a science focused primarily on the preparation and identification of compounds towards a discipline capable of designing complex molecular systems for solving technological and societal problems.

The development of organic chemistry in contemporary Czechia therefore represents one of the clearest examples of successful scientific adaptation after 1993. The discipline preserved its intellectual heritage while embracing new methods, international cooperation, and innovation-oriented research. Through the integration of synthetic expertise with biological, technological, and environmental perspectives, Czech organic chemistry became an important contributor to modern chemical science. Its history between 1993 and 2025 reflects the wider trajectory of Czech chemistry as a whole: continuity transformed into innovation through institutional renewal, international integration, and scientific creativity.

## Physical Chemistry and Molecular Research

Physical chemistry represents one of the fundamental pillars of Czech chemical science and occupies a distinctive position between theoretical understanding and experimental investigation. Unlike specialised branches of chemistry focused primarily on particular classes of substances or technological applications, physical chemistry provides the conceptual and methodological foundations that explain why chemical systems behave in specific ways. Through the study of molecular structures, reaction mechanisms, thermodynamic processes, energy transformations, and interactions between matter and radiation, physical chemistry forms a scientific framework connecting chemistry with physics, mathematics, materials science, and biology. In contemporary Czechia, the development of physical chemistry after 1993 demonstrates how a historically established discipline successfully transformed itself into a modern molecular science integrated into international research networks. The period from 1993 to 2025 was characterised by methodological renewal, expansion of computational approaches, development of advanced spectroscopic techniques, and increasing interaction with interdisciplinary fields. Czech physical chemistry maintained its classical scientific foundations while adapting to the technological and conceptual transformations of twenty-first-century chemistry.

The historical development of physical chemistry in the Czech lands was closely connected with the emergence of modern scientific institutions, university education, and industrial research. During the twentieth century, Czech scientists developed significant expertise in chemical thermodynamics, kinetics, electrochemistry, spectroscopy, and molecular structure analysis. These traditions created a strong foundation for the post-1993 period, when researchers entered an increasingly international scientific environment. The independence of the Czech Republic did not interrupt the development of physical chemistry; instead, it created new conditions for its expansion. Existing scientific schools gained access to international cooperation, modern equipment, and new research methodologies. The transformation demonstrated that disciplines based on fundamental scientific principles can remain highly competitive when they successfully adapt to new technological contexts.

One of the defining characteristics of physical chemistry after 1993 was the increasing importance of molecular-level understanding. Modern chemistry increasingly moved beyond the description of substances towards the explanation and prediction of molecular behaviour. This transformation required precise experimental methods, theoretical models, and computational approaches capable of analysing increasingly complex systems. Czech physical chemists contributed to this global development by investigating molecular interactions, reaction pathways, electronic structures, and dynamic processes. The focus gradually shifted from studying isolated chemical phenomena towards understanding complex molecular environments relevant to biology, materials science, and technological applications. This change reflected a broader transformation of chemistry itself, where molecular insight became a central tool for innovation.

Spectroscopy remained one of the most important methodological foundations of Czech physical chemistry. Spectroscopic techniques provide essential information about molecular structures, energy states, chemical interactions, and dynamic processes. During the period 1993–2025, Czech research groups increasingly adopted advanced spectroscopic approaches and applied them to increasingly complex scientific problems. Methods based on nuclear magnetic resonance, infrared spectroscopy, Raman spectroscopy, optical spectroscopy, and other analytical techniques became essential tools across chemistry, materials science, and biological research. The development of sophisticated spectroscopic capabilities strengthened the position of Czech laboratories within international research networks. These methods also contributed to interdisciplinary cooperation, as molecular characterisation became a common requirement across many fields of modern science.

Molecular spectroscopy played a particularly important role in the development of interdisciplinary research. In chemical biology, spectroscopy enabled researchers to investigate interactions between molecules and biological systems. In materials science, it provided information about structure-property relationships in advanced materials. In environmental chemistry, spectroscopic methods supported the identification and monitoring of complex chemical processes. The versatility of these approaches demonstrated the central position of physical chemistry within contemporary scientific research. Rather than functioning as an isolated theoretical discipline, physical chemistry became an essential methodological foundation supporting diverse areas of innovation.

Chemical thermodynamics represented another important area of continuity and development. Understanding energy changes, equilibrium processes, phase behaviour, and molecular interactions remains fundamental for both theoretical chemistry and industrial

applications. Czech researchers continued to develop expertise in thermodynamic analysis while applying modern experimental and computational methods. Thermodynamic principles became increasingly important in areas such as materials design, pharmaceutical development, energy technologies, and sustainable chemical processes. The ability to predict and control chemical behaviour under different conditions became a crucial element of modern technological development.

Chemical kinetics and reaction dynamics also remained significant areas of research. The study of reaction mechanisms, rates, intermediate states, and molecular transformations provides essential knowledge for designing efficient chemical processes. Czech physical chemists contributed to understanding complex reaction systems, including catalytic processes and molecular transformations relevant to industrial and biological chemistry. The development of advanced kinetic methods allowed researchers to investigate reactions with increasing precision and to connect experimental observations with theoretical models. This field demonstrated the continuing relevance of classical physical chemistry in addressing modern scientific challenges.

The development of computational chemistry represented one of the most significant transformations within Czech physical chemistry after 1993. The rapid growth of computational power and numerical methods changed the possibilities of molecular investigation. Computational approaches allowed researchers to model molecular structures, predict chemical properties, analyse reaction pathways, and simulate complex systems that could not always be investigated directly through experiments. Czech research groups increasingly incorporated quantum chemical calculations, molecular simulations, and theoretical modelling into their work. Computational chemistry became not a replacement for experimental methods but a complementary tool that expanded the possibilities of chemical investigation.

The integration of computational approaches reflected the broader digital transformation of chemical science. By the 2010s and especially after 2020, data-driven methods, artificial intelligence, and machine learning began to influence physical chemistry more strongly. Researchers increasingly used computational tools to analyse large datasets, predict molecular behaviour, and optimise experimental strategies. This development required new forms of interdisciplinary cooperation between chemists, physicists, mathematicians, and computer scientists. Czech physical chemistry participated in this global transformation, contributing to the emergence of a more predictive and computationally supported approach to chemical research.

The relationship between physical chemistry and materials science became particularly important during the twenty-first century. Many technological innovations depend on understanding the physical properties of materials at molecular and nanoscale levels. Czech physical chemists contributed to research on surfaces, interfaces, polymers, nanostructured materials, and functional systems. These studies required a combination of experimental characterisation, theoretical modelling, and materials design. The development of this field demonstrated how physical chemistry provides essential knowledge for creating advanced technologies. Materials innovation increasingly depended on the ability to understand and manipulate molecular interactions.

Nanoscience represented another important direction where Czech physical chemistry contributed to international developments. At the nanoscale, the properties of materials often

differ significantly from their macroscopic behaviour, requiring new theoretical and experimental approaches. Czech researchers investigated nanoscale structures, molecular organisation, surface phenomena, and interactions between nanomaterials and biological systems. These studies connected physical chemistry with electronics, medicine, environmental technologies, and energy research. Nanoscience therefore became an important example of the interdisciplinary expansion of physical chemistry.

Electrochemistry also maintained a strong position within Czech chemical research. The development of energy technologies, sensors, and advanced materials increased the importance of understanding electrochemical processes. Czech researchers contributed to studies of electrode materials, charge transfer mechanisms, electrochemical interfaces, and energy conversion systems. These investigations became increasingly relevant in the context of renewable energy, battery technologies, and sustainable chemical processes. Electrochemistry demonstrated how fundamental physical chemical principles could directly contribute to solving contemporary technological challenges.

The biomedical dimension of physical chemistry expanded significantly during the modern period. Molecular interactions, protein dynamics, biomolecular structures, and biological processes increasingly required physical chemical approaches. Czech researchers applied methods from spectroscopy, molecular modelling, and thermodynamic analysis to investigate biological systems. This contributed to the development of chemical biology and molecular medicine, where understanding physical principles of biological processes became essential. The growing connection between physical chemistry and life sciences represented one of the most important interdisciplinary developments after 1993.

Educational development remained a crucial component of maintaining Czech expertise in physical chemistry. Universities strengthened programmes combining classical chemical knowledge with modern computational, analytical, and interdisciplinary approaches. Students were increasingly trained to understand both theoretical principles and practical applications. Doctoral education became particularly important because advanced physical chemistry requires highly specialised skills in mathematics, programming, instrumentation, and experimental design. The preparation of new generations of researchers ensured continuity between historical scientific traditions and emerging research directions.

By 2025, Czech physical chemistry had evolved into a highly interdisciplinary and internationally connected field. Its achievements were based on the combination of classical theoretical foundations, advanced experimental techniques, computational methods, and applications in modern technologies. The discipline contributed not only to understanding fundamental chemical processes but also to innovations in materials science, energy technologies, biotechnology, and environmental protection. Its development illustrates how fundamental scientific disciplines can remain relevant by continuously adapting their methods and research questions.

The history of physical chemistry in contemporary Czechia demonstrates a broader pattern within the national chemical sciences. The discipline preserved its intellectual continuity after 1993 while becoming increasingly integrated into international scientific development. Through the combination of theoretical insight, technological innovation, and interdisciplinary cooperation, Czech physical chemistry transformed itself from a traditional academic field into a modern molecular science. Between 1993 and 2025, it became one of the essential

foundations supporting the wider achievements of Czech chemistry and its contribution to European and global scientific progress.

## Materials Chemistry and Nanotechnology

Materials chemistry represents one of the most dynamic and strategically significant areas of Czech chemical research during the period 1993–2025. Its development reflects the broader transformation of chemistry from a discipline traditionally focused on the synthesis and analysis of substances towards a science capable of designing functional systems with precisely controlled properties. The importance of materials chemistry lies in its interdisciplinary character, connecting molecular chemistry, physics, engineering, nanotechnology, biology, and industrial innovation. In contemporary Czechia, this field has developed upon a strong historical foundation created by traditions in polymer chemistry, macromolecular science, industrial chemistry, glass technologies, ceramics, and chemical engineering. After 1993, these established areas underwent significant transformation as researchers increasingly adopted international approaches to materials design, nanoscale investigation, and advanced technological applications. The evolution of Czech materials chemistry demonstrates how historical scientific expertise can be transformed into new forms of innovation through institutional development, international cooperation, and methodological renewal.

The historical background of Czech materials chemistry is closely connected with the industrial and technological traditions of the Czech lands. For more than a century, chemical knowledge has been associated with the development of industrial materials, polymers, glass production, surface technologies, and engineering applications. These traditions created a strong practical orientation within Czech chemistry, where scientific research was often connected with technological challenges. However, the development of materials chemistry after 1993 represented a conceptual transformation. The focus gradually moved from improving existing materials and production processes towards designing materials at molecular and structural levels. Modern materials science increasingly required understanding the relationship between chemical composition, molecular architecture, physical properties, and technological performance. Czech researchers adapted to this new paradigm by combining traditional expertise with advanced analytical and computational methods.

The transformation of materials chemistry after 1993 was strongly influenced by the development of polymer science. Czech polymer chemistry possessed a particularly strong scientific heritage, supported by specialised research institutions and university programmes. The Institute of Macromolecular Chemistry of the Czech Academy of Sciences became one of the most important centres representing this tradition. During the post-1993 period, polymer research expanded beyond classical synthetic polymers towards functional macromolecular systems designed for specific applications. Researchers increasingly investigated polymers with controlled structures, responsive behaviour, biomedical functions, and advanced technological properties. This transition reflected the global evolution of polymer science, where polymers were no longer understood merely as industrial materials but as sophisticated molecular systems capable of performing complex functions.

One of the most important developments within Czech polymer research was the increasing interaction between macromolecular chemistry and biomedical applications. The design of biocompatible polymers, drug delivery systems, and functional biomaterials became an important research direction internationally, and Czech scientists contributed to this field through their expertise in polymer synthesis and characterisation. The development of polymer-based biomedical systems required cooperation between chemists, biologists, medical researchers, and engineers. Such interdisciplinary collaboration represented a significant change in the organisation of chemical research. Materials chemistry increasingly became a platform where different scientific disciplines interacted to address complex technological and societal challenges.

The emergence of nanotechnology significantly influenced the development of Czech materials chemistry during the twenty-first century. Nanotechnology introduced a new understanding of materials based on the control of structures at molecular and nanoscale dimensions. At these scales, materials often demonstrate properties significantly different from their conventional forms, creating new technological possibilities. Czech researchers became increasingly involved in the synthesis, characterisation, and application of nanostructured materials. Research activities included nanoparticles, nanocomposites, functional surfaces, nanoscale coatings, and materials with controlled optical, electrical, mechanical, or biological properties. The development of nanotechnology demonstrated the growing importance of chemistry as a discipline capable of engineering matter at increasingly precise levels.

A key feature of Czech nanomaterials research has been the connection between fundamental investigation and practical application. Nanomaterials are not valuable only because of their unusual properties but because those properties can be used in technologies ranging from medicine to electronics and environmental protection. Czech researchers explored applications in areas such as sensing technologies, catalytic systems, protective coatings, energy storage, and biomedical materials. This applied orientation corresponded with the broader innovation strategy of Czech science, where research institutions increasingly sought connections between scientific discoveries and technological implementation. Nanotechnology therefore became an important example of how Czech chemistry participated in global technological trends.

Functional surfaces and coatings represented another important direction within materials chemistry. Modern technologies increasingly depend on controlling the interaction between materials and their surrounding environment. Surface modification allows scientists to create materials with specific properties, including improved durability, chemical resistance, biological compatibility, or specialised optical and electrical characteristics. Czech researchers contributed to the development of advanced surface technologies through cooperation between chemistry, physics, and engineering. These studies had relevance for industrial applications, environmental technologies, medicine, and consumer products. The field demonstrated the importance of molecular-level understanding in solving practical technological problems.

The development of advanced materials for energy applications became increasingly significant after 2010 and especially after 2020. The global transition towards renewable energy systems created demand for new materials capable of improving energy generation, storage, and conversion. Czech materials chemists contributed to research on electrode materials,

electrochemical systems, catalysts, and functional structures relevant to batteries, fuel cells, and hydrogen technologies. These research directions required close cooperation between materials chemistry, physical chemistry, electrochemistry, and engineering. The development of energy-related materials illustrates how contemporary chemical research responds directly to global technological challenges.

Battery-related materials research became particularly important due to the growing importance of energy storage technologies. Modern batteries depend on complex chemical interactions occurring within electrodes, electrolytes, and interfaces. Understanding and improving these systems requires detailed knowledge of molecular structures, material stability, and electrochemical processes. Czech researchers investigated various materials and analytical approaches aimed at improving energy storage performance. Although battery technology represents a highly competitive international field, Czech expertise in materials chemistry and physical chemistry provided an important scientific foundation for participation in this area.

Environmental applications of materials chemistry also expanded significantly during the contemporary period. Advanced materials can contribute to environmental protection through improved filtration systems, catalytic purification, pollutant detection, and resource-efficient technologies. Czech researchers increasingly investigated materials capable of addressing ecological challenges, including water purification, environmental sensing, and sustainable production processes. This direction connected materials science with the broader concept of green chemistry. The development of environmentally responsible materials became one of the important indicators of the changing role of chemistry in society.

The relationship between materials chemistry and industrial innovation remained particularly strong in Czechia. The country's industrial traditions created favourable conditions for cooperation between academic researchers and technological companies. Advanced materials research contributed to sectors including manufacturing, electronics, healthcare, energy, and specialised chemical production. The transition towards a knowledge-based economy increased demand for scientific expertise capable of developing new materials rather than simply improving existing production methods. Materials chemistry therefore became one of the areas where scientific research and economic innovation were closely interconnected.

The institutional landscape of Czech materials chemistry also underwent significant development. Universities, Academy of Sciences institutes, and newly established research centres increasingly created environments supporting interdisciplinary materials research. The development of centres such as CEITEC in Brno strengthened cooperation between chemistry, physics, biology, and engineering. These institutions reflected a new model of scientific organisation based on shared infrastructure and collaboration between different research communities. Materials chemistry benefited particularly from this approach because the study of advanced materials requires access to diverse analytical techniques and expertise from multiple disciplines.

The educational transformation of materials chemistry was another important aspect of its development. Universities increasingly incorporated modern materials science, nanotechnology, computational modelling, and interdisciplinary approaches into chemical education. Future materials researchers required knowledge extending beyond traditional chemistry, including aspects of physics, engineering, biology, and information technologies.

Doctoral training became especially important because advanced materials research depends on highly specialised experimental and theoretical skills. The development of a new generation of researchers ensured the continuity and further expansion of Czech materials chemistry.

Computational approaches increasingly influenced materials research during the 2010s and early 2020s. The prediction of material properties, molecular modelling, and data-driven approaches became valuable tools for accelerating materials discovery. Computational methods allowed researchers to explore possible material structures before experimental synthesis, reducing time and resources required for development. Czech materials chemistry increasingly incorporated these approaches, reflecting the broader digital transformation of chemical sciences. The combination of experimental materials synthesis and computational prediction became an important feature of modern materials research.

By 2025, materials chemistry and nanotechnology had become among the most internationally connected areas of Czech chemical science. The field successfully combined historical traditions in polymer science, industrial chemistry, and chemical engineering with modern approaches based on nanoscale design and interdisciplinary innovation. Czech researchers contributed to the development of functional materials, biomedical systems, energy-related technologies, and environmentally responsible solutions. The evolution of this field demonstrates how chemistry can serve as a bridge between fundamental molecular understanding and practical technological transformation.

The development of materials chemistry in contemporary Czechia therefore represents a broader story of scientific adaptation and innovation. Beginning with strong twentieth-century traditions, Czech researchers successfully transformed existing expertise into a modern research field aligned with global technological priorities. Between 1993 and 2025, materials chemistry evolved from a primarily industrially oriented discipline into a sophisticated science of molecular and nanoscale engineering. Its achievements illustrate the central role of chemistry in addressing contemporary challenges and demonstrate how scientific continuity, interdisciplinary cooperation, and technological creativity can generate internationally relevant innovation.

## Chemical Biology and Biotechnology

Chemical biology and biotechnology represent some of the most significant examples of the transformation of contemporary Czech chemistry from a classical molecular science into a highly interdisciplinary research field. The development of these areas after 1993 reflects a broader global change in scientific thinking, in which the boundaries between chemistry, biology, medicine, and technological innovation became increasingly interconnected. Chemical biology emerged from the recognition that chemical methods can be used not only to synthesise and analyse molecules but also to understand, control, and modify biological processes. Biotechnology, meanwhile, expanded the practical application of molecular knowledge by connecting scientific discoveries with medical, industrial, agricultural, and environmental technologies. In Czechia, these fields developed upon a strong foundation in organic chemistry, biochemistry, molecular biology, pharmaceutical research, and analytical chemistry. Between 1993 and 2025, Czech chemical biology and biotechnology evolved from specialised research directions into internationally connected areas contributing to global

scientific development. Their progress demonstrates how traditional chemical expertise can be transformed into innovative approaches addressing complex biological and societal challenges.

The historical development of chemical biology in the Czech lands is closely connected with the long-standing interaction between chemistry and life sciences. Czech universities and research institutes developed significant expertise in biochemistry, molecular investigation, enzymology, and the chemistry of biologically active compounds during the twentieth century. These traditions created a favourable environment for the emergence of modern chemical biology after 1993. The transition towards a new scientific framework did not require abandoning previous achievements; rather, it required integrating them with new technologies, molecular approaches, and international research trends. The growing importance of molecular medicine, biotechnology, and pharmaceutical innovation created new opportunities for Czech researchers to apply chemical knowledge to biological systems. This process reflected a fundamental transformation in the role of chemistry itself, which increasingly became a tool for understanding and manipulating complex biological processes.

The establishment of the independent Czech Republic coincided with a period when international science was undergoing a major shift towards interdisciplinarity. Advances in molecular biology, genomics, structural biology, and biotechnology created new research questions that could not be addressed within traditional disciplinary boundaries. Chemistry became increasingly important because biological systems are governed by molecular interactions, chemical transformations, and physical principles. Czech research institutions responded to this transformation by strengthening cooperation between chemists, biologists, medical scientists, and technological specialists. The emergence of chemical biology therefore represented not simply the creation of a new research area, but a broader reorganisation of scientific practice. It encouraged researchers to move beyond traditional categories and develop integrated approaches to molecular problems.

The Institute of Organic Chemistry and Biochemistry of the Czech Academy of Sciences became one of the most important institutions representing this transformation. Historically rooted in organic chemistry, the Institute gradually expanded its research activities towards biochemical mechanisms, molecular interactions, medicinal chemistry, and biomedical applications. Its development illustrates how modern chemical research increasingly combines synthetic expertise with biological understanding. The ability to design and prepare molecules, analyse their interactions with biological systems, and investigate their potential functions became a central feature of contemporary chemical biology. The Institute's achievements demonstrated the importance of maintaining strong fundamental chemical research while simultaneously expanding into interdisciplinary areas.

A major contribution of chemical biology has been the development of molecular approaches to understanding biological processes. Traditional biology often describes organisms and cellular systems at higher levels of organisation, while chemical biology investigates the molecular mechanisms underlying these processes. Czech researchers increasingly applied chemical methods to study proteins, enzymes, nucleic acids, molecular recognition, and cellular interactions. These investigations required advanced synthesis, analytical techniques, spectroscopy, computational modelling, and biological evaluation. The integration of these methods created a new scientific environment in which chemistry became a central language for understanding life at the molecular level.

The study of biologically active compounds represented one of the most important areas where Czech organic chemistry and chemical biology interacted. The design, synthesis, and analysis of molecules capable of influencing biological systems require close cooperation between synthetic chemists, biochemists, pharmacologists, and medical researchers. Czech research groups contributed to the investigation of compounds with potential therapeutic applications, including molecules affecting biological pathways, molecular targets, and disease-related processes. This work reflected the broader international development of precision medicine and targeted therapeutic strategies. Chemical biology provided the methodological foundation allowing researchers to move from general observations towards molecularly specific approaches.

Medicinal chemistry became one of the most visible practical applications of chemical biology. The development of new medicines depends on the ability to understand biological mechanisms and design molecules with appropriate chemical and biological properties. Czech researchers increasingly combined synthetic chemistry with molecular analysis, biological testing, and computational approaches to investigate potential therapeutic compounds. This interdisciplinary model represented a significant evolution from traditional pharmaceutical chemistry, where the discovery of active compounds was often based primarily on experimental screening. Modern medicinal chemistry requires rational molecular design and detailed understanding of biological interactions.

The development of antiviral research represents an important example of the interaction between chemistry and biomedical science in Czechia. Molecular understanding of viral processes requires knowledge of chemical structures, biological mechanisms, and therapeutic targets. Research groups working in chemical biology and related fields contributed to the investigation of biologically active molecules and molecular mechanisms relevant to infectious diseases. The importance of this research became especially visible during the COVID-19 pandemic, when chemical and biological sciences became central to global efforts in diagnostics, therapeutics, and prevention. The pandemic demonstrated the strategic importance of maintaining strong national expertise in molecular chemistry and biotechnology.

Biotechnology represented another major direction of development during the period 1993–2025. Modern biotechnology depends heavily on chemical understanding, particularly in areas involving molecular engineering, biomolecules, analytical methods, and production processes. Czech biotechnology developed through cooperation between academic institutions, research centres, medical organisations, and industrial partners. Applications included pharmaceutical biotechnology, diagnostic technologies, biomaterials, and industrial bioprocesses. The growth of biotechnology reflected the increasing importance of knowledge-based industries and the transition towards innovation models based on advanced scientific research.

The connection between chemical biology and diagnostic technologies became increasingly significant in the twenty-first century. Accurate diagnosis often requires highly sensitive molecular detection methods capable of identifying specific biological markers. Czech researchers contributed to the development of analytical and molecular approaches supporting biomedical diagnostics. These technologies relied on the interaction between chemistry, materials science, biology, and engineering. The development of diagnostic

platforms demonstrated how chemical knowledge could be translated into practical tools with direct societal impact.

Biomaterials represented another important area where chemical biology and materials chemistry converged. The development of materials compatible with biological systems requires understanding molecular interactions between synthetic substances and living organisms. Czech researchers investigated polymer-based biomaterials, functional surfaces, and molecular systems designed for medical applications. These studies required cooperation between chemists, biologists, engineers, and medical specialists. The field demonstrated the increasing disappearance of traditional boundaries between chemical disciplines and life sciences.

The role of analytical chemistry in chemical biology also became increasingly important. Biological systems are extremely complex, and understanding them requires precise methods capable of identifying molecules, measuring interactions, and analysing dynamic processes. Advanced mass spectrometry, spectroscopy, chromatography, and imaging techniques became essential components of modern chemical biology research. Czech analytical traditions provided an important methodological foundation for these developments. The integration of analytical technologies strengthened the ability of researchers to investigate biological systems at molecular levels.

Computational methods further expanded the possibilities of chemical biology during the 2010s and early 2020s. Molecular modelling, bioinformatics, and data analysis became increasingly important tools for understanding biological systems and designing new molecules. Computational approaches allowed researchers to predict molecular interactions, analyse biological data, and support the development of therapeutic strategies. The combination of experimental chemistry, biological investigation, and computational modelling represented one of the most advanced forms of contemporary scientific integration. Czech researchers increasingly participated in this global transformation towards data-supported molecular science.

The development of chemical biology and biotechnology also influenced higher education and researcher training. Universities increasingly introduced interdisciplinary programmes combining chemistry, biology, medicine, and computational sciences. Doctoral students were trained to work across traditional disciplinary boundaries and use diverse experimental and theoretical methods. This educational transformation was essential because modern biotechnology requires specialists capable of communicating between different scientific fields. The preparation of interdisciplinary researchers became a strategic priority for maintaining competitiveness.

Industrial cooperation became increasingly important as chemical biology and biotechnology moved closer to practical applications. Pharmaceutical companies, biotechnology firms, and technology-oriented enterprises required scientific expertise capable of transforming molecular discoveries into products and services. Czech research institutions gradually developed mechanisms for cooperation with industry, including collaborative projects, technology transfer, and applied research programmes. Although the translation of academic discoveries into commercial innovation remains a complex process, the period after 1993 demonstrated significant progress in connecting scientific research with economic development.

By 2025, chemical biology and biotechnology had become among the most internationally integrated areas of Czech chemical science. Their development was based on the successful combination of traditional strengths in organic chemistry, biochemistry, analytical methods, and molecular research with new approaches emerging from global scientific trends. Czech researchers contributed to a scientific environment where chemistry became a central instrument for understanding biological systems and developing technological solutions. These fields demonstrated the innovative potential of Czech chemistry beyond traditional industrial and laboratory applications.

The development of chemical biology and biotechnology in contemporary Czechia therefore represents a major transformation in the identity of chemical science itself. Between 1993 and 2025, chemistry evolved from a discipline primarily concerned with substances and reactions into a science capable of addressing complex biological and medical problems at molecular scale. Through interdisciplinary cooperation, international integration, and technological innovation, Czech chemical biology and biotechnology became important components of the country's modern scientific landscape. Their achievements illustrate the broader trajectory of Czech chemistry: preservation of historical expertise combined with continuous adaptation to emerging scientific challenges.

## Analytical Chemistry and Instrumentation

Analytical chemistry occupies a unique and foundational position within the development of modern Czech chemical science. Unlike research areas primarily focused on the synthesis of new substances or the development of specific technological applications, analytical chemistry provides the methodological basis that allows scientists to identify, measure, characterise, and understand chemical systems. Its importance extends across virtually all branches of contemporary science, including pharmaceutical research, environmental monitoring, materials science, biotechnology, medicine, food safety, and industrial production. In Czechia, analytical chemistry has developed through a combination of long-established scientific traditions, strong educational foundations, and continuous adaptation to technological innovations. Between 1993 and 2025, Czech analytical chemistry transformed from a highly respected specialised discipline into a technologically advanced research field integrated with global scientific developments. The evolution of analytical chemistry demonstrates the essential role of measurement, precision, and methodological reliability in the progress of modern science. It also illustrates how a discipline traditionally considered methodological has become a major driver of innovation.

The historical foundations of Czech analytical chemistry are deeply connected with the development of chemical education, industrial research, and scientific instrumentation in the Czech lands. Throughout the twentieth century, Czech scientists contributed significantly to analytical methods, chemical characterisation, separation techniques, and instrumental analysis. Universities and research institutions developed strong expertise in areas such as chromatography, spectroscopy, electrochemistry, and chemical measurement. These traditions created a favourable environment for further development after 1993, when Czech analytical chemistry entered a period of technological modernisation and international integration. The discipline benefited from the opening of scientific borders, access to advanced

instruments, and participation in international research networks. Rather than replacing existing expertise, the post-1993 transformation expanded the possibilities of analytical chemistry by connecting traditional methods with new technologies.

The development of analytical chemistry after the establishment of the Czech Republic was closely linked with the broader restructuring of scientific institutions. Research laboratories increasingly required modern analytical infrastructure capable of meeting international standards. Access to advanced instruments became a critical factor determining scientific competitiveness, because contemporary chemical research depends on the ability to analyse increasingly complex molecular systems. Czech universities and Academy of Sciences institutes gradually modernised their analytical facilities and strengthened cooperation between different scientific disciplines. This process transformed analytical chemistry from a supporting function within laboratories into a strategic research area in its own right. The ability to provide precise molecular information became essential for emerging fields such as biotechnology, nanotechnology, and advanced materials science.

One of the most important areas of development was chromatography, which has traditionally represented one of the strongest directions within analytical chemistry. Chromatographic methods provide powerful tools for separating and identifying complex mixtures of chemical substances and are essential in pharmaceutical, environmental, biological, and industrial applications. Czech researchers continued to develop expertise in chromatographic techniques, adapting them to new scientific challenges. High-performance liquid chromatography, gas chromatography, and increasingly sophisticated separation methods became central components of modern analytical platforms. The development of chromatography reflected a broader trend within chemistry: as molecular systems became more complex, the demand for highly selective and sensitive analytical methods increased.

Mass spectrometry represented another transformative technology within Czech analytical chemistry. The ability to determine molecular masses, identify compounds, and investigate complex molecular structures made mass spectrometry one of the most powerful analytical approaches of the twenty-first century. Czech research institutions increasingly incorporated advanced mass spectrometric techniques into studies of biological molecules, environmental contaminants, pharmaceuticals, and materials. The combination of chromatography with mass spectrometry created particularly powerful analytical platforms capable of investigating highly complex samples. These technologies became essential in areas such as proteomics, metabolomics, pharmaceutical analysis, and molecular diagnostics.

The development of analytical instrumentation also reflected the increasing importance of interdisciplinary research. Modern instruments are not simply technical devices but complex systems combining chemistry, physics, engineering, computer science, and data analysis. Czech analytical chemists increasingly collaborated with specialists from other fields to improve measurement methods and develop new applications. This interdisciplinary character became especially visible in biomedical research, where analytical technologies are required to study molecules within complex biological environments. It also influenced materials research, where precise characterisation is essential for understanding the relationship between molecular structure and material properties.

Environmental analysis became one of the most socially significant applications of analytical chemistry after 1993. The transformation of Czech industry, the adoption of European environmental standards, and growing public attention to ecological issues created new

demands for reliable chemical monitoring. Analytical chemists contributed to the detection and quantification of pollutants, assessment of environmental risks, and evaluation of chemical processes affecting ecosystems. Research focused on water quality, atmospheric pollutants, soil contamination, and industrial emissions. The development of sensitive analytical methods allowed scientists and regulatory authorities to better understand environmental challenges and design more effective protection strategies.

The role of analytical chemistry in food safety and quality control also expanded significantly during this period. Integration into European regulatory frameworks increased the importance of accurate chemical analysis in food production, processing, and distribution. Czech analytical laboratories developed methods for detecting contaminants, verifying composition, and monitoring chemical changes in food products. These activities demonstrated the practical relevance of analytical chemistry in protecting public health and ensuring technological standards. The field therefore connected scientific methodology with everyday societal needs.

Biomedical applications became another major area of analytical chemistry development in contemporary Czechia. Modern medicine increasingly depends on molecular-level information obtained through advanced analytical methods. Czech researchers applied analytical technologies to investigate biomarkers, biological molecules, pharmaceutical compounds, and disease-related processes. Mass spectrometry, spectroscopy, and advanced separation methods became important tools in biomedical research and diagnostics. This development strengthened cooperation between chemistry, medicine, and biology, contributing to the broader growth of chemical biology.

The relationship between analytical chemistry and pharmaceutical research became particularly important. Drug development requires precise analysis at every stage, from molecular synthesis and characterisation to quality control and biological evaluation. Czech analytical chemists contributed methodological expertise supporting pharmaceutical research and related industries. The ability to determine chemical purity, molecular structure, stability, and biological interactions became essential for innovation in medicinal chemistry. Analytical chemistry therefore functioned as a critical bridge between chemical discovery and practical medical application.

Sensor technologies represented another emerging direction during the period 1993–2025. Advances in materials science, nanotechnology, and electronics enabled the development of increasingly sensitive and selective chemical sensors. Czech researchers investigated sensor systems for environmental monitoring, biomedical applications, industrial control, and analytical diagnostics. These technologies reflected the convergence of analytical chemistry with materials science and engineering. The development of compact and efficient sensors demonstrated how analytical methods could move beyond specialised laboratories into broader technological applications.

The digital transformation of analytical chemistry became increasingly important during the 2010s and early 2020s. Modern analytical instruments generate enormous volumes of data, requiring advanced computational methods for processing, interpretation, and decision-making. Czech analytical research increasingly incorporated statistical analysis, chemometrics, machine learning, and automated data processing. These approaches improved the efficiency and reliability of chemical analysis while opening new possibilities for complex investigations. The integration of digital methods represented another stage in the

evolution of analytical chemistry from measurement science towards intelligent information systems.

The emergence of artificial intelligence and data-driven approaches further influenced analytical chemistry after 2020. Machine learning methods began to support pattern recognition, spectral interpretation, prediction of chemical properties, and optimisation of analytical procedures. These technologies did not replace human expertise but enhanced the ability of researchers to interpret complex datasets. Czech analytical chemistry increasingly participated in this global transformation, reflecting the broader digitalisation of scientific research. The combination of advanced instrumentation and intelligent data analysis became one of the defining characteristics of contemporary analytical science.

Analytical chemistry also played an important role in the development of sustainable technologies. Reliable measurement is essential for evaluating environmental impact, improving industrial efficiency, and monitoring sustainable processes. Czech researchers contributed to analytical approaches supporting green chemistry, circular economy principles, and resource optimisation. The ability to measure chemical processes accurately became a prerequisite for designing more environmentally responsible technologies. This demonstrated that analytical chemistry contributes not only to understanding chemical systems but also to improving their practical management.

Educational development remained a fundamental factor supporting the progress of Czech analytical chemistry. Universities maintained strong programmes in analytical methods, instrumentation, and chemical measurement while adapting curricula to include modern technologies. Students increasingly received training in advanced instruments, computational analysis, interdisciplinary research, and international scientific practice. Doctoral education became particularly important because sophisticated analytical methods require highly specialised expertise. The preparation of skilled analytical chemists ensured the continuity and further development of the field.

By 2025, analytical chemistry in Czechia had become a highly advanced and internationally integrated research area. Its achievements were based on the combination of historical methodological traditions, modern instrumentation, interdisciplinary cooperation, and digital innovation. Czech analytical chemists contributed to diverse fields ranging from environmental protection and medicine to materials science and industrial technologies. The discipline demonstrated that accurate measurement and molecular understanding remain essential foundations of scientific progress.

The development of analytical chemistry between 1993 and 2025 reflects the broader transformation of Czech chemical science. From a traditionally strong methodological discipline, it evolved into a technologically sophisticated field capable of generating new knowledge and supporting innovation across many sectors. Its importance lies not only in the analytical techniques themselves but also in the ability to provide reliable information that enables progress in other scientific fields. Contemporary Czech analytical chemistry therefore represents one of the key infrastructures of national chemical research and an important contributor to European and global scientific development.

## Green Chemistry and Sustainable Technologies

Green chemistry and sustainable technologies represent one of the most important transformations in the development of Czech chemical science during the period 1993–2025. This field reflects a fundamental change in the understanding of the role of chemistry within modern society. Traditionally, chemical science was strongly associated with the creation of new substances, industrial production, and technological efficiency. However, the growing awareness of environmental challenges, resource limitations, climate change, and ecological risks gradually changed scientific priorities. Chemistry became increasingly focused not only on what could be produced, but also on how chemical processes could be designed to minimise environmental impact, reduce resource consumption, and support long-term sustainability. In Czechia, the emergence of green chemistry developed through the interaction of historical strengths in chemical engineering, industrial chemistry, catalysis, materials science, and analytical methods. The period after 1993 demonstrates how Czech chemical research adapted to European environmental priorities while preserving its scientific traditions and industrial orientation.

The development of sustainable chemistry in Czechia was closely connected with the broader transformation of industry and environmental policy after the establishment of the independent state. During the socialist period, chemical production had played an important role in industrial development, but environmental consequences of industrial activity increasingly became a significant societal concern. The economic and political transformation after 1989 and 1993 created conditions for introducing new environmental standards, modern production principles, and European approaches to chemical management. Czech chemical science responded to these changes by developing research directions focused on cleaner technologies, improved industrial processes, environmental analysis, and more efficient use of resources. Sustainability gradually became not only a regulatory requirement but also a scientific objective influencing research priorities.

One of the central principles of green chemistry is the prevention of environmental problems through the redesign of chemical processes rather than simply treating their consequences. This approach required a significant change in chemical thinking. Instead of focusing only on the properties of final products, researchers increasingly considered the entire lifecycle of chemical substances, including raw materials, synthesis methods, energy consumption, waste generation, and eventual disposal or recycling. Czech chemists participated in this global transformation by applying principles of sustainable process design to areas such as catalysis, polymer chemistry, industrial chemistry, and materials development. The integration of environmental considerations into fundamental chemical research became one of the defining features of contemporary Czech chemistry.

Catalysis became one of the most important scientific areas connecting traditional Czech expertise with sustainable technological development. Catalytic processes allow chemical reactions to occur more efficiently by reducing energy requirements, improving selectivity, and decreasing the formation of unwanted by-products. Czech research institutions with strong traditions in physical chemistry, chemical engineering, and molecular sciences contributed to the development of catalytic approaches relevant to sustainable production. Research in this area included the investigation of catalytic materials, reaction mechanisms, environmentally efficient synthesis routes, and industrial process optimisation. Catalysis demonstrated how

fundamental chemical understanding could directly contribute to reducing the environmental impact of industrial activity.

The development of more sustainable industrial processes represented another important direction of Czech chemical research. Chemical industries face continuous pressure to improve efficiency, reduce emissions, and minimise waste while maintaining economic competitiveness. Czech researchers contributed to the development of technologies aimed at improving production processes through better reaction conditions, improved materials, and more efficient resource utilisation. Chemical engineering played a particularly important role because sustainability often depends not only on molecular chemistry but also on the design and optimisation of entire technological systems. The cooperation between chemists, engineers, and industrial specialists became essential for translating scientific knowledge into practical solutions.

The concept of circular economy increasingly influenced chemical research during the 2010s and 2020s. Circular economy principles aim to reduce waste by maintaining the value of materials for as long as possible through reuse, recycling, and regeneration. For chemistry, this created new challenges related to the development of recyclable materials, improved separation methods, and alternative production strategies. Czech researchers increasingly investigated approaches related to polymer recycling, sustainable materials, waste utilisation, and environmentally responsible chemical processes. This represented a significant expansion of the traditional role of chemistry, positioning the discipline as an important contributor to resource management and sustainable economic development.

Polymer chemistry became one of the most relevant fields for sustainable innovation because modern society depends heavily on polymeric materials while facing serious challenges related to plastic waste and resource consumption. Czech expertise in macromolecular chemistry provided an important foundation for addressing these issues. Researchers investigated new polymer systems, environmentally responsible materials, improved recycling approaches, and functional materials with reduced ecological impact. The challenge was not simply to replace existing materials but to develop solutions that combined technological performance with environmental responsibility. This required cooperation between polymer chemists, materials scientists, industrial specialists, and environmental researchers.

Environmental chemistry and analytical methods played a crucial role in monitoring and evaluating sustainability efforts. Reliable measurement is essential for understanding pollution, assessing environmental risks, and determining whether new technologies genuinely reduce ecological impact. Czech analytical chemists contributed to the development of methods for detecting contaminants, monitoring industrial emissions, analysing water and soil quality, and evaluating chemical processes. These activities provided the scientific basis for environmental decision-making and sustainable technology development. Analytical chemistry therefore became an essential component of green chemistry by providing the information required for responsible chemical management.

Water protection and environmental remediation represented important areas where Czech chemical research contributed to sustainable development. Industrial activity, agriculture, and urbanisation create complex chemical challenges related to contamination and resource management. Researchers developed chemical approaches for water purification, pollutant detection, and environmental treatment technologies. These studies required integration of chemistry, materials science, engineering, and environmental sciences. The development of

advanced filtration materials, catalytic purification methods, and analytical monitoring systems demonstrated the practical importance of sustainable chemical innovation.

Energy-related sustainability became increasingly important after 2010 and especially after 2020. The transition towards renewable energy systems created demand for chemical solutions related to energy storage, conversion, and efficiency. Czech researchers contributed to areas such as battery materials, electrochemical processes, hydrogen technologies, and catalytic energy systems. These fields illustrate the close relationship between green chemistry and materials science, as sustainable energy technologies depend heavily on advanced chemical materials. Chemistry became a central discipline in addressing energy challenges because molecular-level understanding is essential for designing efficient energy systems.

Hydrogen technologies represented one of the emerging strategic directions within sustainable chemistry. The development of hydrogen-based energy systems requires advances in production methods, storage materials, catalysts, and electrochemical technologies. Czech chemical research contributed to these areas through expertise in catalysis, materials chemistry, and process engineering. Although hydrogen technologies remain a globally developing field, their importance demonstrates the expanding role of chemistry in future energy strategies. The ability to design efficient molecular and material systems became a key factor in technological progress.

Green chemistry also influenced the transformation of chemical education and scientific culture. Universities increasingly incorporated sustainability principles into chemistry curricula, teaching students to consider environmental aspects alongside traditional chemical knowledge. Future chemists were expected to understand not only reaction mechanisms and material properties but also issues of resource efficiency, safety, and ecological responsibility. This educational transformation reflected a broader change in the professional identity of chemists. Modern chemical specialists increasingly operate as innovators responsible for developing solutions compatible with societal and environmental needs.

International cooperation significantly influenced the development of sustainable chemistry in Czechia. European research programmes increasingly prioritised environmental technologies, circular economy principles, and climate-related innovation. Czech institutions participated in international projects focused on sustainable materials, cleaner production, environmental protection, and energy technologies. This cooperation helped integrate Czech research into broader European strategies and provided access to international expertise. Sustainability therefore became another area where Czech chemistry strengthened its position within the European research environment.

The relationship between green chemistry and industrial innovation became particularly important because sustainability challenges cannot be addressed solely through academic research. Industrial implementation requires cooperation between scientists, engineers, manufacturers, and policymakers. Czech chemical institutions increasingly developed partnerships with companies seeking more efficient and environmentally responsible technologies. These collaborations demonstrated the practical relevance of sustainable chemistry and contributed to the transformation of chemical industries towards modern production models.

Digital technologies also influenced sustainable chemistry during the 2020s. Computational modelling, artificial intelligence, and data analysis methods began to support the optimisation

of chemical processes, prediction of material behaviour, and development of more efficient synthesis strategies. Digital tools allowed researchers to reduce experimental costs, minimise resource consumption, and accelerate innovation. The combination of green chemistry principles with digital transformation created new opportunities for designing sustainable technologies. This integration represented one of the most advanced directions of contemporary chemical research.

By 2025, green chemistry and sustainable technologies had become essential components of Czech chemical science. Their development demonstrated how the discipline responded to global challenges while maintaining continuity with established scientific traditions. Czech researchers successfully combined expertise in catalysis, materials science, analytical chemistry, chemical engineering, and molecular research to develop environmentally oriented solutions. Sustainability became not a separate specialised field but an integrating principle influencing many areas of chemistry.

The evolution of green chemistry in contemporary Czechia reflects the broader transformation of the chemical sciences after 1993. Chemistry moved from a model primarily focused on production efficiency towards a more comprehensive understanding of innovation, where scientific progress must be combined with environmental responsibility. Between 1993 and 2025, Czech sustainable chemistry developed from responses to environmental regulation into a major research direction connected with global technological challenges. Its achievements demonstrate the continuing ability of chemistry to adapt and contribute to solving complex problems facing modern society.

## Part Three

### Leading Institutions and Scientific Schools of Czech Chemistry

#### Prague Chemical School: Universities, Academy Institutions, and the Development of Molecular and Technological Chemistry

Prague has historically represented the central intellectual and institutional environment for the development of chemical sciences in the Czech lands. Since the formation of modern scientific education in Central Europe, the city has served as a meeting point between theoretical investigation, technological innovation, industrial development, and academic traditions. Between 1993 and 2025, Prague maintained and strengthened its position as the principal centre of Czech chemical research, combining the activities of major universities, institutes of the Czech Academy of Sciences, specialised research centres, and industrial partners. The development of the Prague chemical school after the establishment of the independent Czech Republic illustrates how a historically rooted scientific ecosystem can transform itself into a modern international research environment. Rather than representing a single institution or research direction, the Prague chemical school consists of a network of interconnected organisations with complementary scientific profiles. This network includes fundamental molecular research, chemical engineering, materials science, analytical chemistry, biotechnology, and industrial applications. Its development demonstrates the importance of institutional diversity in maintaining scientific competitiveness.

The historical significance of Prague as a centre of chemistry is closely connected with the development of higher education and scientific institutions in the Czech lands. Universities and technical schools created an environment where chemistry developed not only as a theoretical discipline but also as a practical science connected with industry, medicine, and technology. This tradition became particularly important after 1993 because Prague possessed the institutional foundations necessary for successful adaptation to the new European research environment. The city concentrated a large proportion of national scientific infrastructure, experienced researchers, specialised laboratories, and international connections. However, the post-1993 development of Prague chemistry was not based simply on inherited advantages. Institutions had to modernise their research approaches, improve international competitiveness, and create new forms of cooperation between academic disciplines.

The University of Chemistry and Technology Prague (Vysoká škola chemicko-technologická v Praze, UCT Prague) represents one of the most important pillars of the Prague chemical school. Its historical mission has been closely connected with the preparation of chemical specialists and the development of research addressing both fundamental and technological problems. After 1993, the University underwent significant transformation as it adapted to the requirements of modern European higher education and research. Traditional strengths in chemical engineering, industrial chemistry, materials science, and chemical technologies were complemented by expanding research activities in molecular sciences, biotechnology, environmental chemistry, and advanced materials. The institution increasingly combined

education with internationally oriented research, strengthening its role as both a national educational centre and a scientific organisation.

A defining characteristic of UCT Prague has been its ability to maintain the connection between fundamental chemical knowledge and practical technological application. This feature reflects one of the historical characteristics of Czech chemistry, where academic research has traditionally interacted closely with industrial development. During the period 1993–2025, this relationship became increasingly sophisticated. Modern chemical industries require not only production expertise but also advanced research capabilities in areas such as sustainable processes, functional materials, pharmaceutical development, and environmental technologies. UCT Prague contributed to these developments by creating research environments where chemical theory, experimental investigation, and technological implementation could interact.

The role of UCT Prague in the development of chemical education was equally significant. Modern chemistry requires specialists who understand not only traditional chemical principles but also interdisciplinary approaches involving physics, biology, information technologies, and engineering. Educational programmes therefore increasingly incorporated modern analytical methods, computational approaches, sustainability principles, and innovation management. Doctoral education became an important component of the University's scientific mission, providing a pathway for developing new generations of researchers. Through international cooperation and research mobility, students increasingly became part of the wider European scientific community.

Charles University represents another fundamental institution within the Prague chemical school. As one of the oldest universities in Europe, it has historically contributed to the development of scientific thought across many disciplines, including chemistry. Within the modern Czech research environment, Charles University has played an important role in connecting chemistry with broader areas of natural science, medicine, and biotechnology. After 1993, chemical research at the university increasingly developed through interdisciplinary cooperation, particularly in fields where molecular approaches were essential. The interaction between chemistry, biology, physics, and medical sciences created new opportunities for research in molecular systems, structural investigation, and biomedical applications.

The Institute of Organic Chemistry and Biochemistry of the Czech Academy of Sciences became one of the most internationally recognised institutions within the Prague chemical ecosystem. Its development after 1993 represents a prominent example of how Czech scientific traditions were transformed into globally competitive research. The Institute combined strong expertise in organic synthesis with expanding research areas in biochemistry, molecular biology, medicinal chemistry, and chemical biology. This interdisciplinary orientation reflected the changing nature of contemporary chemistry, where molecular design increasingly interacts with biological function. The Institute demonstrated how fundamental chemical research could generate knowledge relevant to medicine, biotechnology, and technological innovation.

A particularly important aspect of the Institute's development was the strengthening of molecular approaches. Modern chemical research increasingly focuses on understanding how molecular structures determine biological and technological properties. Research conducted within the Prague chemical environment increasingly incorporated advanced synthesis,

structural analysis, computational methods, and biological evaluation. This approach allowed scientists to investigate complex systems at levels of detail that were previously unavailable. The development of molecular chemistry therefore became one of the defining characteristics of Prague's scientific profile.

The Institute of Chemical Process Fundamentals of the Czech Academy of Sciences represents another important component of Prague's chemical research landscape. Its scientific orientation reflects the strong Czech tradition of connecting chemistry with engineering and industrial processes. Research activities have focused on understanding and improving chemical processes, transport phenomena, reaction systems, and technological applications. During the period after 1993, the Institute contributed to the development of more efficient, sustainable, and technologically advanced chemical processes. Its work illustrates the continuing importance of chemical engineering within Czech chemistry and the close relationship between scientific research and industrial innovation.

The Institute of Macromolecular Chemistry of the Czech Academy of Sciences represents the continuation of another major Czech scientific tradition: polymer and materials research. After 1993, the Institute strengthened its international position through research in advanced polymers, biomaterials, functional macromolecular systems, and materials with technological applications. Its development demonstrates how traditional scientific strengths can be transformed into modern interdisciplinary research areas. Polymer chemistry increasingly interacted with medicine, nanotechnology, and sustainable materials development, reflecting global trends within contemporary chemical science.

The cooperation between Prague institutions became increasingly important during the 2000s and 2010s. Modern scientific challenges often exceed the capabilities of individual laboratories and require collaboration between specialists from different fields. The Prague chemical school developed through networks connecting universities, Academy institutes, research centres, and industrial partners. These connections supported interdisciplinary projects, shared infrastructure, and the training of researchers capable of working across traditional scientific boundaries. The development of such networks strengthened Prague's position as a comprehensive chemical research environment.

The growth of international cooperation represented another defining feature of Prague chemistry after 1993. Researchers increasingly participated in European projects, international consortia, and global scientific collaborations. Prague institutions attracted foreign researchers, hosted international conferences, and contributed to scientific networks extending beyond Central Europe. This internationalisation changed the scientific culture of local institutions, encouraging greater mobility, publication in international journals, and participation in global discussions within chemistry.

The development of advanced analytical and computational infrastructure further strengthened Prague's chemical research capacity. Modern chemistry depends increasingly on sophisticated instruments, high-performance computing, and specialised research platforms. Prague institutions invested in improving access to such resources, allowing researchers to investigate increasingly complex molecular systems. These technological capabilities supported research in organic chemistry, materials science, biotechnology, and environmental chemistry. Infrastructure development therefore became a key element of Prague's scientific competitiveness.

The relationship between Prague's chemical institutions and industry also evolved significantly between 1993 and 2025. The transition towards a knowledge-based economy increased demand for scientific expertise capable of supporting technological innovation. Research cooperation developed in areas including pharmaceuticals, speciality chemicals, materials technologies, environmental solutions, and industrial processes. Academic institutions increasingly sought mechanisms for transferring scientific knowledge into practical applications. Although the relationship between fundamental research and commercial implementation remains complex, Prague became an important environment for interaction between science and innovation.

The educational and scientific influence of the Prague chemical school extended beyond the city itself. Through graduates, research collaborations, and professional networks, Prague institutions contributed to the development of Czech chemistry throughout the country. Many researchers trained in Prague later became leaders of regional universities, research centres, and industrial laboratories. This role as a national scientific centre strengthened the continuity of Czech chemical traditions while supporting the emergence of new research communities.

By 2025, the Prague chemical school represented a mature and internationally connected scientific ecosystem. Its strength was based not on a single area of excellence but on the interaction of multiple complementary fields: molecular chemistry, chemical engineering, materials science, analytical chemistry, biotechnology, and sustainable technologies. The combination of historical continuity and scientific innovation allowed Prague to maintain its position as the leading centre of Czech chemistry. The development of its institutions illustrates the broader trajectory of Czech chemical science after 1993: transformation through international integration, interdisciplinary cooperation, and continuous adaptation.

The Prague chemical school therefore represents one of the central examples of how scientific traditions can evolve within a changing historical environment. Between 1993 and 2025, Prague's chemical institutions successfully transformed inherited expertise into modern research capabilities. Through universities, Academy institutes, and collaborative networks, the city became a major contributor to European chemical science. Its development demonstrates that scientific excellence depends not only on individual discoveries but also on the strength of institutional ecosystems capable of educating researchers, supporting innovation, and responding to global challenges.

### **Brno Chemical School: Interdisciplinary Research, Advanced Materials, and Molecular Technologies**

Brno represents the second major centre of Czech chemical science and provides a distinctive example of how regional scientific development can contribute to national and international research competitiveness. While Prague historically concentrated many of the country's oldest academic institutions and national research organisations, Brno gradually developed into a highly dynamic centre characterised by interdisciplinary cooperation, technological orientation, and strong connections between chemistry, physics, biology, engineering, and materials science. Between 1993 and 2025, the transformation of Brno's scientific environment demonstrated the emergence of a modern research ecosystem based not only on traditional academic structures but also on large-scale collaborative infrastructures and

innovation-oriented research. The development of the Brno chemical school reflects a broader trend within contemporary science: the increasing importance of interdisciplinary environments capable of addressing complex technological and societal challenges. Through the activities of universities, research centres, and scientific institutes, Brno became one of the most important locations for advanced chemical research in Central Europe.

The historical foundations of Brno's scientific development are closely connected with the city's long-standing industrial, technological, and educational traditions. As one of the most important industrial centres of the Czech lands, Brno developed strong connections between technical education, engineering, manufacturing, and applied science. These traditions created a favourable environment for the development of chemistry connected with materials, technologies, and industrial processes. After 1993, this historical orientation was transformed according to the requirements of contemporary research, where industrial relevance increasingly depended on fundamental scientific knowledge and advanced technologies. Brno's scientific development therefore followed a specific trajectory: rather than reproducing the traditional model of a capital-centred academic system, it developed through cooperation between universities, technological institutions, and interdisciplinary research platforms.

Masaryk University became one of the key institutions contributing to the development of the Brno chemical school. Historically recognised as a major centre of education and research, the university expanded its scientific activities after 1993 by strengthening interdisciplinary approaches and international cooperation. Chemistry at Masaryk University developed within a broad natural science environment, allowing researchers to interact closely with biology, physics, environmental sciences, and medical disciplines. This institutional context was particularly important for the development of molecular research, chemical biology, analytical methods, and materials-related studies. The university contributed to the transformation of chemistry from an isolated scientific discipline into a component of larger interdisciplinary research systems.

The Faculty of Science of Masaryk University played an important role in maintaining and developing fundamental chemical education and research. During the period 1993–2025, the institution increasingly emphasised modern scientific methods, international collaboration, and research-based education. Students and researchers gained access to advanced analytical techniques, computational approaches, and interdisciplinary projects. This development reflected the broader transformation of chemical education throughout Europe, where future chemists increasingly require knowledge extending beyond traditional disciplinary boundaries. The Brno academic environment contributed to preparing researchers capable of working in areas where chemistry interacts with biological systems, advanced materials, and technological applications.

Brno University of Technology represented another important pillar of the regional chemical research environment. Its scientific profile has traditionally been closely connected with engineering, technological development, and industrial innovation. This orientation created favourable conditions for research areas where chemistry intersects with materials engineering, chemical technologies, and applied sciences. After 1993, the university increasingly developed research directions focused on functional materials, technological processes, environmental applications, and advanced engineering solutions. Its contribution demonstrates the continuing importance of the relationship between chemistry and technology within Czech scientific development.

A defining feature of the Brno chemical school has been the development of interdisciplinary research platforms. The most significant example of this approach is the Central European Institute of Technology (CEITEC), established as a major research infrastructure bringing together scientists from multiple disciplines. Although CEITEC is not exclusively a chemical institution, chemistry represents one of its important scientific components through research in molecular systems, materials science, biotechnology, and nanotechnology. The creation of CEITEC reflected a new understanding of scientific organisation in the twenty-first century: major discoveries increasingly emerge from collaboration between different fields rather than from isolated disciplinary work.

The development of CEITEC significantly strengthened Brno's position within European scientific networks. By creating shared infrastructure and attracting researchers from different countries, the centre contributed to the internationalisation of Czech research. For chemistry, this environment created opportunities to combine molecular investigation with advanced imaging, materials characterisation, biological analysis, and computational approaches. The interdisciplinary structure of CEITEC corresponded particularly well with modern chemical science, where research questions often require simultaneous understanding of molecular structure, physical properties, biological functions, and technological potential.

Materials chemistry became one of the most visible areas of Brno's scientific specialisation. The combination of chemistry, physics, engineering, and nanotechnology created favourable conditions for research into advanced materials with specific functional properties. Czech researchers in Brno contributed to studies of nanostructures, polymer systems, functional surfaces, electronic materials, and materials for energy applications. This research direction reflected both global scientific trends and the historical industrial character of the region. The development of advanced materials demonstrated how traditional engineering expertise could be transformed into modern molecular and nanoscale research.

Nanotechnology played a particularly important role in the scientific identity of Brno. The study of materials at nanoscale requires close interaction between chemical synthesis, physical characterisation, computational modelling, and technological application. Researchers investigated nanoscale structures, surface phenomena, molecular interactions, and functional materials designed for specific purposes. Applications ranged from electronics and energy systems to medicine and environmental technologies. The development of nanotechnology strengthened the connection between fundamental chemical research and technological innovation, making Brno an important centre for interdisciplinary materials research.

The interaction between chemistry and life sciences represented another important characteristic of the Brno chemical school. Research institutions in the city developed strong connections between chemistry, molecular biology, biotechnology, and medicine. These collaborations contributed to research areas such as biomolecular systems, molecular diagnostics, biomaterials, and chemical approaches to biological problems. The ability to combine chemical methods with biological understanding became increasingly important in the twenty-first century. Brno's interdisciplinary environment provided favourable conditions for this type of research.

Analytical chemistry and advanced instrumentation also became important components of Brno's scientific development. Modern interdisciplinary research requires highly precise methods for analysing molecular structures, materials, and biological systems. Research

groups in Brno increasingly used advanced analytical platforms, computational approaches, and imaging technologies. These capabilities supported investigations across multiple fields, including materials science, biotechnology, environmental chemistry, and molecular research. Analytical infrastructure therefore became an essential element of the region's scientific competitiveness.

The development of computational and data-driven approaches further strengthened the Brno chemical school. Contemporary chemical research increasingly relies on modelling, simulation, and analysis of large datasets. Cooperation between chemists, physicists, mathematicians, and computer scientists created new opportunities for predictive approaches to molecular and materials research. These methods became particularly relevant in areas such as materials design, molecular modelling, and optimisation of technological processes. The integration of computational methods reflected the broader digital transformation of chemistry.

Sustainability and environmental technologies also became important research directions in Brno. The combination of chemistry, engineering, and materials science created opportunities for developing solutions related to cleaner production, environmental monitoring, energy efficiency, and resource management. Researchers investigated materials and processes capable of supporting sustainable technologies. This orientation corresponded with broader European priorities and demonstrated how regional scientific strengths could contribute to global challenges. Sustainable innovation became an important component of Brno's scientific identity.

The relationship between research institutions and industry remained one of the defining characteristics of Brno's scientific environment. The city's industrial traditions created strong motivation for developing technologies with practical applications. Cooperation between universities, research centres, and companies expanded in areas such as advanced materials, chemical technologies, biotechnology, and engineering solutions. This interaction supported the transition from laboratory research towards technological implementation. Brno therefore developed a scientific model where fundamental research and industrial innovation were closely connected.

The internationalisation of Brno's chemical research accelerated significantly after 2000 and especially during the 2010s. Participation in European projects, international collaborations, and research networks increased the visibility of Brno institutions. Foreign researchers and students became increasingly present within the city's scientific environment, contributing to knowledge exchange and institutional development. International cooperation also encouraged the adoption of global research standards and strengthened the competitiveness of local scientific groups.

The educational role of Brno was equally important. Universities and research centres provided opportunities for training new generations of chemists capable of working in interdisciplinary environments. Students increasingly received education combining chemistry with materials science, biology, physics, engineering, and computational methods. This approach reflected the changing requirements of modern science, where researchers must be able to operate across traditional disciplinary boundaries. The preparation of such specialists became one of the foundations of the long-term development of Czech chemistry.

By 2025, the Brno chemical school had developed into one of the most important components of Czech scientific infrastructure. Its identity was defined by interdisciplinary cooperation,

technological orientation, advanced materials research, molecular technologies, and strong international connections. Unlike traditional models based primarily on individual disciplines, Brno demonstrated the potential of integrated research environments where chemistry functions as a connecting element between different scientific fields. This approach became particularly valuable in addressing complex challenges related to health, energy, sustainability, and technological innovation.

The development of Brno's chemical research between 1993 and 2025 illustrates the transformation of Czech science from a nationally organised system towards a network-based European research environment. Through the combination of university traditions, technological expertise, interdisciplinary infrastructures, and international cooperation, Brno became a significant centre of modern chemical innovation. Its experience demonstrates that scientific excellence is not limited to historical academic capitals but can emerge through the creation of dynamic research ecosystems capable of integrating knowledge from different fields.

The Brno chemical school therefore represents a complementary model to the Prague scientific environment. While Prague historically developed around major national institutions and established academic traditions, Brno achieved international recognition through interdisciplinary cooperation, technological integration, and research innovation. Together, these two centres demonstrate the diversity and strength of contemporary Czech chemistry. Their parallel development after 1993 became one of the main factors enabling Czech chemical science to achieve a significant position within European and global research.

### Academy of Sciences of the Czech Republic: Fundamental Chemical Research and National Scientific Excellence

The Academy of Sciences of the Czech Republic (Akademie věd České republiky, AV ČR) represents one of the most important pillars of Czech chemical science and has played a decisive role in maintaining and developing fundamental research after the establishment of the independent Czech Republic. Its importance lies not only in the scale of scientific activity but also in its historical function as a centre where long-term fundamental investigations can develop beyond immediate technological requirements. Chemistry within the Academy has traditionally represented a bridge between theoretical scientific discovery and future technological innovation. Between 1993 and 2025, the chemical institutes of AV ČR underwent significant transformation, adapting to new standards of scientific evaluation, international cooperation, competitive funding, and interdisciplinary research. At the same time, they preserved the fundamental research traditions that had formed the basis of Czech scientific excellence throughout the twentieth century. The development of chemical research within the Academy demonstrates how a national research institution can maintain continuity while becoming integrated into the global scientific environment.

The transformation of the Academy after 1993 must be understood within the broader context of the reorganisation of Czech science following the dissolution of Czechoslovakia. The newly established Czech Academy of Sciences inherited a significant scientific legacy from the former Czechoslovak Academy of Sciences, including specialised institutes, experienced research teams, scientific infrastructure, and established research traditions. However, the

new institutional environment required substantial adaptation. Research organisations had to operate within a system increasingly based on competitive funding, international evaluation, scientific productivity, and cooperation with European research structures. For chemical institutes, this meant developing new approaches to project management, international collaboration, and research orientation. The Academy therefore became both a guardian of scientific continuity and an instrument of modernisation.

A distinctive feature of AV ČR has been its emphasis on fundamental research. Unlike industrial research institutions primarily focused on immediate technological applications, Academy institutes have maintained long-term programmes aimed at understanding basic scientific principles. This role has been particularly important for chemistry because many major technological advances originate from fundamental discoveries whose practical significance becomes apparent only over time. Research in molecular structures, reaction mechanisms, chemical interactions, and material properties often requires sustained investigation before applications emerge. The Academy provided an institutional environment where such long-term scientific questions could be explored. This approach contributed significantly to the international reputation of Czech chemical science.

The Institute of Organic Chemistry and Biochemistry of the Czech Academy of Sciences became one of the most prominent examples of successful scientific development within the Academy system. Its history illustrates how fundamental chemical research can evolve into internationally recognised scientific excellence while maintaining strong connections with practical applications. After 1993, the Institute expanded its research profile beyond traditional organic chemistry towards molecular biology, chemical biology, medicinal chemistry, and biomedical research. This transformation reflected the broader evolution of chemistry in the late twentieth and early twenty-first centuries, when understanding molecular interactions became central to both fundamental science and technological innovation.

The scientific development of the Institute was based on the integration of several complementary approaches. Organic synthesis provided the ability to create new molecular structures, while biochemical and biological methods allowed researchers to investigate their functions within complex systems. Analytical techniques and computational approaches further expanded the possibilities of molecular investigation. This combination transformed the Institute into a multidisciplinary research environment where chemistry interacted closely with life sciences. Such integration became one of the defining characteristics of advanced chemical research worldwide.

The Institute of Organic Chemistry and Biochemistry also demonstrated the importance of international scientific cooperation. During the period 1993–2025, the Institute strengthened its participation in international research networks, collaborations, and scientific projects. Its researchers contributed to global discussions in areas related to molecular chemistry, biologically active compounds, and biomedical innovation. The international visibility of the Institute reflected the broader transformation of Czech chemistry from a nationally significant scientific tradition into a globally connected research system.

The Institute of Macromolecular Chemistry of the Czech Academy of Sciences represents another major component of Czech fundamental chemical research. Its development continued the country's strong tradition in polymer chemistry and macromolecular science. During the post-1993 period, the Institute expanded its activities towards advanced materials, functional polymers, biomaterials, and interdisciplinary applications. The evolution of

macromolecular chemistry within the Institute illustrates the transformation of classical polymer science into modern materials engineering at molecular and nanoscale levels.

Research conducted within the Institute contributed to understanding how molecular architecture determines the properties and functions of polymeric systems. This knowledge became increasingly important for applications in medicine, environmental technologies, electronics, and advanced manufacturing. Polymer chemistry moved beyond the production of conventional materials towards the design of sophisticated systems with controlled behaviour. The Institute's development therefore reflected a broader global trend in which chemistry became a science of molecular design rather than simply substance preparation.

The Institute of Chemical Process Fundamentals of the Czech Academy of Sciences represents another important dimension of Academy-based chemical research. Its activities demonstrate the connection between fundamental chemical understanding and technological process development. Research in this field focuses on the principles underlying chemical transformations, transport processes, reaction systems, and industrial technologies. After 1993, the Institute contributed to the modernisation of Czech chemical engineering by addressing challenges related to efficiency, sustainability, and advanced processing methods.

The significance of this Institute lies in its ability to connect molecular-level understanding with large-scale technological processes. Modern chemical production requires not only knowledge of chemical reactions but also understanding of how these reactions operate within complex industrial systems. Research in chemical process fundamentals therefore provides essential knowledge for improving efficiency, reducing environmental impact, and developing innovative technologies. This field represents a characteristic strength of Czech chemistry, where fundamental science and industrial application have historically maintained close connections.

The Academy's chemical institutes also played an important role in the development of interdisciplinary research. Contemporary scientific challenges increasingly require cooperation between chemistry, physics, biology, medicine, mathematics, and computer science. AV ČR provided institutional conditions for such cooperation through shared research projects, specialised facilities, and scientific networks. This interdisciplinary environment allowed chemical research to expand into areas such as biotechnology, nanoscience, energy technologies, and sustainable chemistry.

The development of advanced research infrastructure was another essential aspect of the Academy's transformation after 1993. Modern chemical research depends on access to sophisticated analytical instruments, specialised laboratories, and computational resources. Czech Academy institutes invested in improving their technological capabilities and integrating modern methods into research programmes. These improvements strengthened the competitiveness of Czech chemical science and enabled researchers to participate in international projects requiring advanced experimental capacities.

The Academy also contributed significantly to the education and development of new generations of chemists. Although universities remain the primary institutions responsible for formal education, Academy institutes play a crucial role in doctoral training and scientific mentoring. Young researchers working within Academy laboratories gain experience in advanced methods, international collaboration, and independent scientific investigation. This interaction between universities and Academy institutes has been essential for maintaining the continuity of Czech chemical expertise.

The relationship between Academy research and innovation represents another important aspect of its development. Fundamental research does not always produce immediate technological applications, but it creates the knowledge base from which future innovations emerge. Chemical discoveries made within Academy institutes have contributed to developments in pharmaceuticals, materials science, biotechnology, and industrial technologies. The Academy therefore functions as a long-term source of scientific potential supporting broader innovation ecosystems.

International cooperation became increasingly important for Academy chemical institutes during the 2000s and 2010s. Participation in European research programmes, international consortia, and collaborative projects strengthened the position of Czech chemistry within global science. Researchers from Academy institutes increasingly worked alongside leading international groups, contributing to scientific exchange and knowledge development. This international orientation became one of the defining characteristics of contemporary Czech fundamental chemistry.

The Academy's role became particularly visible during the scientific challenges of the 2020s. The COVID-19 pandemic and growing emphasis on sustainability demonstrated the importance of maintaining strong fundamental research capacities. Chemical knowledge became essential in areas including molecular biology, diagnostics, pharmaceuticals, materials development, and environmental technologies. The scientific infrastructure created over previous decades allowed Czech researchers to respond to emerging challenges through interdisciplinary cooperation.

By 2025, the chemical institutes of the Czech Academy of Sciences represented a mature and internationally recognised component of European chemical research. Their achievements were based on the combination of historical scientific traditions, institutional stability, fundamental research orientation, and continuous adaptation to new scientific priorities. The Academy preserved the long-term perspective necessary for scientific discovery while simultaneously participating in modern innovation processes.

The development of chemical science within AV ČR demonstrates the importance of fundamental research as a foundation for national scientific excellence. Between 1993 and 2025, the Academy successfully transformed inherited scientific institutions into internationally connected research centres capable of contributing to global chemistry. Its institutes became places where molecular understanding, technological potential, and scientific creativity intersected. The experience of the Czech Academy of Sciences illustrates a broader principle of modern scientific development: sustainable innovation depends not only on applied technologies but also on strong institutions dedicated to expanding fundamental knowledge.

## Regional Chemical Centres and Industrial Research: Pardubice, Olomouc, Ostrava and the Development of Applied Chemistry

The development of Czech chemical science after 1993 cannot be fully understood through the analysis of Prague and Brno alone. Although these two cities represent the largest concentrations of scientific institutions and research infrastructure, regional centres have

played an essential role in maintaining the diversity, technological relevance, and practical orientation of Czech chemistry. The development of chemistry in Pardubice, Olomouc, Ostrava, and other regional locations demonstrates that scientific excellence within Czechia has emerged through a network of complementary institutions rather than through a single centralised model. These regions contributed particularly to applied chemistry, chemical technologies, industrial research, environmental solutions, materials development, and specialised scientific education. Their importance lies in the ability to connect academic knowledge with regional industrial traditions and technological needs. Between 1993 and 2025, regional chemical centres underwent significant transformation, adapting their historical expertise to the requirements of European research, innovation-driven industries, and sustainable development. Their development represents an important dimension of the broader modernisation of Czech chemical science.

The regional structure of Czech chemistry has deep historical roots. Unlike some scientific systems where research activity is concentrated almost exclusively in capital cities, the Czech lands developed a more distributed model connected with industrial regions, technical universities, and specialised production centres. Chemical research traditionally developed alongside industries such as pharmaceuticals, polymers, metallurgy, energy production, glass manufacturing, and chemical processing. This relationship created strong regional links between scientific institutions and economic activity. After 1993, these connections became particularly important because regional research centres had to adapt to market transformation, European integration, and increasing technological competition. The successful development of regional chemistry depended on the ability to transform industrial traditions into modern research capabilities.

The University of Pardubice represents one of the most important examples of regional chemical development in contemporary Czechia. The city has a long-standing association with chemical technologies and industrial production, creating a favourable environment for the development of specialised chemical education and research. The Faculty of Chemical Technology became an important centre for maintaining and expanding Czech expertise in applied chemistry, materials science, chemical technologies, and industrial processes. After 1993, the institution adapted to the changing scientific environment by strengthening research activities, international cooperation, and connections with modern technological challenges. Its development illustrates the continuing importance of specialised regional universities within the national chemical system.

A distinctive feature of Pardubice's chemical school has been its strong connection between fundamental chemical knowledge and industrial application. Research activities have traditionally addressed problems related to materials, chemical technologies, analytical methods, and industrial processes. During the post-1993 period, these areas evolved in response to new demands for sustainable production, advanced materials, environmental responsibility, and technological innovation. The university increasingly participated in collaborative projects involving industry and research organisations, strengthening the role of chemistry as a driver of regional technological development. This applied orientation does not represent a limitation but rather a specific scientific strength based on the historical relationship between chemistry and industrial practice.

Materials and surface technologies became important research directions within the Pardubice chemical environment. The development of advanced coatings, functional

materials, polymers, and technologically significant chemical systems reflected global trends in materials science. Czech researchers in regional institutions contributed to the development of materials with improved mechanical, chemical, and functional properties. These investigations connected traditional chemical expertise with modern requirements in manufacturing, energy, environmental protection, and specialised technologies. The field demonstrated how regional scientific centres could contribute to internationally relevant research while maintaining strong links with local industrial ecosystems.

Analytical chemistry also represented a significant area of expertise in regional chemical institutions. The increasing complexity of industrial, environmental, and biological systems required reliable analytical methods capable of precise measurement and quality control. Regional laboratories developed expertise in chemical analysis, instrumental methods, and applied analytical technologies. These capabilities supported both academic research and industrial activities. Analytical chemistry therefore served as an important bridge between scientific investigation and practical technological needs.

Olomouc represents another important regional centre contributing to the diversity of Czech chemical science. Palacký University has developed a strong scientific environment where chemistry interacts with biology, medicine, physics, and materials science. The university's research profile reflects the broader transformation of contemporary chemistry towards interdisciplinary molecular sciences. After 1993, Olomouc strengthened its position through international cooperation, modern research approaches, and integration with broader European scientific networks. Its development demonstrates that regional universities can become internationally visible contributors when they combine specialised expertise with interdisciplinary collaboration.

The chemical research environment in Olomouc has been particularly connected with molecular approaches, analytical methods, and interactions between chemistry and life sciences. The development of these areas corresponds with global trends where chemical research increasingly contributes to understanding biological systems and developing biomedical technologies. Cooperation between chemistry and related disciplines created opportunities for research in areas such as molecular interactions, bioactive compounds, analytical technologies, and advanced materials. This interdisciplinary orientation strengthened the role of Olomouc within the national scientific landscape.

The development of Ostrava as a chemical research centre reflects a different but equally important trajectory. Historically associated with heavy industry, metallurgy, energy production, and chemical manufacturing, Ostrava faced significant challenges during the economic transformation after 1989 and 1993. Industrial restructuring created a need for new approaches to technological development, environmental protection, and sustainable production. Chemistry played an important role in addressing these challenges because many regional problems were directly connected with industrial processes, materials, energy, and environmental impacts.

Research institutions in Ostrava increasingly focused on areas where chemistry could contribute to industrial modernisation and environmental improvement. Environmental chemistry, materials research, industrial processes, and analytical monitoring became particularly important fields. The transformation of Ostrava demonstrates how regions with strong industrial traditions can use scientific knowledge to address the consequences of previous development models while creating new technological opportunities. Chemistry

became not only a component of industrial production but also an instrument for ecological transformation.

The connection between chemistry and environmental technologies became especially significant in industrial regions. Challenges related to air quality, contaminated sites, industrial emissions, and resource efficiency required advanced chemical approaches. Researchers developed methods for monitoring environmental conditions, analysing pollutants, improving industrial processes, and designing cleaner technologies. This work reflected the broader European movement towards sustainable development and demonstrated the practical importance of regional chemical expertise.

Regional research centres also contributed significantly to the relationship between academia and industry. Unlike purely academic environments, regional institutions often developed within close proximity to manufacturing sectors and technological companies. This created opportunities for cooperation in applied research, industrial innovation, and technology transfer. Companies benefited from scientific expertise, while universities gained access to practical problems that stimulated new research directions. This interaction became increasingly important in the context of the knowledge economy, where innovation depends on cooperation between research institutions and industrial partners.

The development of regional chemical centres also supported the geographical diversification of Czech scientific activity. A strong national research system requires not only leading institutions in major cities but also specialised centres capable of contributing unique expertise. Regional universities and research organisations provided educational opportunities, supported local innovation ecosystems, and maintained scientific activity outside the largest metropolitan areas. This diversification strengthened the overall resilience of Czech chemistry.

Internationalisation influenced regional chemical institutions as strongly as national centres. Participation in European research programmes, international collaborations, and scientific networks allowed regional researchers to integrate into broader scientific communities. Modern communication technologies and collaborative infrastructures reduced the importance of geographical distance and enabled regional institutions to participate in international projects. This process contributed to a more balanced distribution of scientific activity throughout Czechia.

The education of new generations of chemists remained another essential function of regional institutions. Universities in Pardubice, Olomouc, Ostrava, and other regions provided specialised training adapted to both academic and industrial needs. Students gained knowledge in chemistry, technology, analytical methods, materials science, and environmental applications. Many graduates continued their careers in research institutions, universities, and chemical industries, contributing to the continuity of Czech chemical expertise. Regional education therefore played an important role in maintaining the national scientific workforce.

By 2025, regional chemical centres had become an integral part of the Czech chemical research system. Their contribution was based not on direct competition with Prague or Brno, but on scientific specialisation and complementary strengths. Pardubice represented the connection between chemical technology and industrial application, Olomouc demonstrated the potential of interdisciplinary molecular research, and Ostrava illustrated the

transformation of industrial chemistry towards sustainable technologies. Together, these centres expanded the scientific diversity of Czech chemistry.

The development of regional chemistry between 1993 and 2025 demonstrates an important principle of scientific development: innovation emerges not only from major research capitals but also from specialised environments connected with particular knowledge traditions and technological challenges. Czech regional chemical centres successfully transformed historical industrial and educational foundations into modern research capabilities. Their achievements contributed to the broader development of Czech chemistry by combining practical relevance, scientific expertise, and regional innovation.

The regional dimension of Czech chemical science therefore represents an essential component of the national research landscape. Together with Prague and Brno, regional centres created a network-based system capable of supporting fundamental discoveries, technological development, and industrial innovation. The experience of Pardubice, Olomouc, Ostrava, and other regions demonstrates how scientific continuity and adaptation can generate new forms of excellence. Between 1993 and 2025, regional chemistry became not merely a continuation of historical traditions but an active participant in the transformation of Czech science into a modern European research system.

## Conclusion

### Chemistry in Contemporary Czechia, 1993–2025: From Scientific Continuity to Innovation Ecosystem

The development of chemical sciences in contemporary Czechia between 1993 and 2025 represents a remarkable example of scientific transformation based on continuity, adaptation, and innovation. Over these three decades, Czech chemistry moved from the challenges of institutional reorganisation after the establishment of the independent Czech Republic towards a mature and internationally integrated research ecosystem. This transformation was not based on a complete replacement of previous scientific traditions, but rather on their gradual renewal and expansion. The strength of Czech chemical science has been derived from the combination of historical expertise, institutional stability, international cooperation, and the ability to respond to emerging scientific and technological challenges. The period demonstrates how a national scientific discipline can preserve its identity while becoming an active participant in global knowledge development. Chemistry in contemporary Czechia represents a successful synthesis of inherited scientific capital and modern innovation-oriented research.

The year 1993 became a significant historical turning point because it created a new institutional and political framework within which Czech science had to operate. However, the development of chemistry after this date cannot be understood as a rupture with the past. Czech researchers entered the new period with strong traditions in organic chemistry, polymer science, analytical chemistry, chemical engineering, materials research, and industrial technologies. These traditions provided the intellectual foundation for future development. The challenge was to transform this inherited scientific potential into a system compatible with international research standards, European cooperation mechanisms, and rapidly changing technological conditions. Czech chemistry successfully achieved this transformation through gradual institutional reform rather than radical discontinuity.

One of the most important achievements of the post-1993 period was the successful modernisation of scientific institutions. Universities, Academy of Sciences institutes, and regional research centres adapted to new forms of scientific organisation based on competitive funding, international evaluation, interdisciplinary cooperation, and research mobility. Institutions such as the Czech Academy of Sciences, the University of Chemistry and Technology Prague, Charles University, Masaryk University, Brno University of Technology, and regional chemical centres developed new research profiles while preserving their historical missions. The result was the creation of a diversified scientific structure capable of supporting both fundamental discoveries and applied innovation. Institutional diversity became one of the main strengths of Czech chemistry.

The transformation of Czech chemistry was also characterised by increasing internationalisation. During the 1990s, the primary objective was the restoration and expansion of international scientific contacts. In the following decades, Czech researchers became increasingly integrated into European and global scientific networks. Participation in European research programmes, international collaborations, researcher mobility, and joint projects

became normal components of scientific activity. By the 2010s and 2020s, Czech chemical institutions were no longer simply adapting to international standards but actively contributing to international research. This change represented one of the most important indicators of scientific maturity.

A central feature of contemporary Czech chemistry has been the successful combination of fundamental research and technological relevance. The development of organic chemistry, physical chemistry, materials science, analytical chemistry, chemical biology, and sustainable technologies demonstrates that fundamental knowledge remains the foundation of practical innovation. Research in molecular structures, reaction mechanisms, materials properties, and biological interactions created the scientific basis for applications in medicine, industry, environmental protection, and advanced technologies. Czech chemistry maintained a balance between theoretical investigation and practical relevance, avoiding excessive concentration on either purely academic or purely applied objectives.

Organic chemistry represents one of the clearest examples of this successful transformation. Building upon strong historical traditions, Czech organic chemistry developed into an internationally connected field incorporating modern synthetic methods, catalysis, medicinal chemistry, and chemical biology. The ability to design and construct complex molecules became increasingly connected with biological applications, pharmaceutical research, and advanced materials. The development of organic chemistry illustrates the broader evolution of chemistry itself: from the study of substances towards the deliberate design of molecular systems with specific functions.

Physical chemistry contributed another essential dimension by providing theoretical and methodological foundations for understanding molecular processes. Through spectroscopy, thermodynamics, kinetics, computational chemistry, and molecular modelling, Czech researchers investigated the fundamental principles governing chemical behaviour. These approaches supported developments across many areas, including materials science, biotechnology, energy research, and nanotechnology. Physical chemistry demonstrated the continuing importance of fundamental scientific understanding in an era increasingly influenced by technological innovation.

Materials chemistry and nanotechnology became among the most dynamic areas of Czech chemical development. The country's historical expertise in polymers, macromolecular science, and industrial materials was successfully transformed into modern research on functional materials, biomaterials, nanostructures, and energy-related systems. Czech researchers contributed to the development of materials designed at molecular and nanoscale levels, reflecting global trends in advanced technology. This field demonstrated the ability of Czech chemistry to connect traditional scientific strengths with future-oriented innovation.

Chemical biology and biotechnology represented another major transformation of Czech chemical science. The growing interaction between chemistry and life sciences created new opportunities for understanding biological systems at molecular levels and developing biomedical applications. Czech institutions successfully integrated organic synthesis, biochemical methods, analytical technologies, and molecular research. These fields became particularly significant during the 2020s, when the importance of chemical knowledge for medicine, diagnostics, and biotechnology became increasingly visible. The development of chemical biology demonstrated the expanding social relevance of chemistry.

Analytical chemistry remained one of the fundamental methodological pillars of Czech scientific development. Through advanced instrumentation, chromatography, mass spectrometry, spectroscopy, and computational analysis, analytical chemists provided essential tools for investigating increasingly complex systems. The importance of analytical chemistry extended across environmental science, medicine, pharmaceuticals, materials research, and industrial technologies. Its development illustrates a broader principle: scientific progress depends not only on creating new systems but also on the ability to measure and understand them accurately.

Sustainable chemistry became one of the defining priorities of the final stage of the period under consideration. Environmental challenges, energy transition, resource efficiency, and circular economy principles transformed the objectives of chemical research. Czech scientists contributed to the development of cleaner technologies, catalytic processes, sustainable materials, environmental analysis, and energy-related chemical systems. Green chemistry demonstrated that modern chemistry is increasingly defined not only by technological capability but also by responsibility towards society and the environment.

The geographical structure of Czech chemistry also played an important role in its development. Prague, Brno, Pardubice, Olomouc, Ostrava, and other regions contributed different but complementary scientific strengths. Prague developed as a major centre of molecular chemistry, chemical technologies, and Academy-based fundamental research. Brno became a centre of interdisciplinary science, advanced materials, and molecular technologies. Regional institutions maintained strong connections with industrial applications, environmental challenges, and specialised research directions. This distributed structure created a resilient national scientific system.

The role of the Czech Academy of Sciences deserves particular emphasis because it provided institutional continuity and support for long-term fundamental research. Its chemical institutes preserved important scientific traditions while becoming internationally recognised research centres. The Academy demonstrated the importance of maintaining institutions capable of supporting research whose technological applications may emerge only in the future. Fundamental chemistry remained essential because innovation depends on expanding the boundaries of knowledge before practical applications become visible.

The development of Czech chemistry after 1993 was also closely connected with the education and preparation of new generations of scientists. Universities and research institutions transformed chemical education by introducing interdisciplinary approaches, international cooperation, and modern research methods. Young chemists increasingly developed skills combining traditional chemical knowledge with computational approaches, biological understanding, technological awareness, and international scientific communication. The preparation of researchers capable of working across disciplinary boundaries became one of the foundations of future development.

By 2025, Czech chemistry had become an important component of the European scientific landscape. Its achievements were not based on the size of the national research system but on the quality of scientific traditions, institutional effectiveness, specialised expertise, and international cooperation. Czech researchers contributed to global developments in molecular sciences, materials chemistry, biotechnology, analytical methods, and sustainable technologies. The country demonstrated that a medium-sized scientific system can achieve international relevance through strategic development and continuous adaptation.

The history of Czech chemistry from 1993 to 2025 therefore illustrates a broader lesson about scientific progress. Successful development requires the interaction of continuity and change: preservation of accumulated knowledge combined with openness to new ideas and technologies. Czech chemistry did not abandon its historical foundations; instead, it transformed them into new forms of scientific capability. The achievements of contemporary Czech chemical science emerged from decades of institutional development, international cooperation, and intellectual creativity.

Looking towards the future, Czech chemistry enters the next stage of development with significant scientific foundations and new challenges. Artificial intelligence, digital chemistry, sustainable technologies, advanced materials, biotechnology, and energy transformation will increasingly influence research priorities. The ability to integrate these emerging directions while maintaining fundamental scientific excellence will determine future success. The experience of 1993–2025 suggests that Czech chemistry possesses the institutional flexibility and scientific traditions necessary to continue its development.

The story of Czech chemistry in the modern era is therefore not only a history of individual discoveries or institutions. It is the history of a scientific ecosystem that successfully transformed itself under changing historical conditions. From the reorganisation of the 1990s to the internationally connected innovation environment of the 2020s, Czech chemical science demonstrated continuity, adaptability, and creativity. Between 1993 and 2025, chemistry became one of the important examples of Czech scientific achievement, combining deep historical roots with a forward-looking vision of research and innovation.

## Chronological Timeline

### Key Milestones in the Development of Chemical Science in Czechia, 1993–2025

#### 1993 — Establishment of the Independent Czech Republic and a New Era for Chemical Science

The year 1993 marked a fundamental turning point in the history of Czech chemistry. Following the dissolution of Czechoslovakia, scientific institutions entered a new national framework and began adapting their activities to the conditions of an independent state. Chemical research inherited strong traditions from the former Czechoslovak scientific system, including internationally recognised schools in organic chemistry, polymer science, analytical chemistry, and chemical engineering. The main challenge of the early period was to preserve scientific continuity while introducing new models of research management, funding, and international cooperation. Czech chemical institutions began the process of transformation from a centrally organised scientific system towards a modern research environment based on competition, international evaluation, and scientific excellence.

#### 1994–1996 — Institutional Stabilisation and Reorganisation of Chemical Research

During the first years of independence, Czech chemical institutions focused on organisational stabilisation and adaptation to new conditions. The Czech Academy of Sciences became a central institution supporting fundamental chemical research, while universities gradually expanded their research functions alongside their educational missions. Research groups began establishing new international contacts and participating in scientific cooperation beyond Central Europe. Laboratory modernisation and access to contemporary analytical equipment became important priorities. This period represented the foundation stage during which the future direction of Czech chemistry was defined.

#### 1997–1999 — Expansion of International Cooperation and Modernisation of Research Methods

The late 1990s marked the gradual integration of Czech chemistry into wider international scientific networks. Researchers increasingly participated in international conferences, collaborative projects, and scientific exchanges. Modern analytical methods, computational approaches, and advanced experimental techniques became increasingly important in chemical laboratories. Organic chemistry, polymer science, and analytical chemistry began adapting to global trends towards molecular design and interdisciplinary research. Czech chemical institutions increasingly recognised that international visibility and cooperation were essential elements of scientific development.

#### 2000 — Beginning of a New Stage of Scientific Consolidation

The beginning of the new millennium represented a transition from institutional adaptation towards scientific consolidation. Czech chemical research entered a more stable phase characterised by stronger research groups, improved infrastructure, and increasing international publication activity. Universities and Academy institutes developed more clearly defined scientific profiles. Fundamental research continued to represent the basis of chemical development, while connections with industrial applications became increasingly important. The foundations were established for deeper integration into European science.

#### 2001–2003 — Strengthening of Research Infrastructure and Scientific Specialisation

During this period, Czech chemical institutions increasingly invested in modern laboratory infrastructure and specialised research capabilities. Research groups developed stronger profiles in areas such as molecular chemistry, materials science, biotechnology, and advanced analytical methods. Young researchers became increasingly involved in international scientific environments through doctoral programmes and research exchanges. The scientific culture gradually shifted towards greater international competitiveness and interdisciplinary cooperation. Chemistry became increasingly connected with neighbouring disciplines such as biology, physics, and engineering.

#### 2004 — Accession of the Czech Republic to the European Union and European Integration of Chemical Research

The accession of Czechia to the European Union represented one of the most important milestones in the development of chemical science. Czech researchers gained expanded opportunities to participate in European research programmes, international consortia, and large-scale scientific collaborations. European integration accelerated the modernisation of research institutions and encouraged the adoption of international scientific standards. Chemistry benefited significantly because many emerging fields required multinational cooperation and access to advanced infrastructure. This period marked the transition of Czech chemistry from international cooperation towards deeper integration into European scientific structures.

#### 2005–2007 — Development of Molecular Chemistry, Biotechnology, and Advanced Materials Research

The middle of the 2000s was characterised by the increasing importance of interdisciplinary molecular research. Organic chemistry increasingly interacted with biological sciences, leading to the development of chemical biology and medicinal chemistry. Materials chemistry expanded beyond traditional polymers towards functional materials and nanoscale systems. Analytical chemistry incorporated increasingly sophisticated instrumental approaches. Czech research institutions strengthened cooperation between chemistry, physics, biology, and engineering. These developments reflected the global transformation of chemistry into a science focused on complex molecular systems.

#### 2008–2010 — Formation of New Research Centres and Preparation for Large-Scale Scientific Infrastructure

The end of the 2000s represented a period of preparation for a new generation of research infrastructures. Czech scientific policy increasingly emphasised the importance of centres capable of supporting interdisciplinary research and international cooperation. Universities and Academy institutes developed strategies for participation in large European research networks. Areas such as nanotechnology, biotechnology, molecular research, and advanced materials gained increasing importance. The foundations were established for the creation of major research infrastructures that would influence Czech chemistry in the following decade.

#### 2011–2013 — Emergence of Large Interdisciplinary Research Infrastructures

The early 2010s marked the beginning of a new organisational model in Czech chemical science. Large interdisciplinary research centres created environments where chemists worked together with physicists, biologists, engineers, and computational scientists. The development of centres such as CEITEC in Brno strengthened Czech participation in international research. Chemistry became increasingly integrated into broader scientific ecosystems focused on molecular systems, materials technologies, and biomedical applications. This period demonstrated the growing importance of interdisciplinary cooperation.

#### 2014 — Tenth Anniversary of European Integration and Expansion of International Research Networks

By 2014, Czech chemistry had become firmly embedded within the European scientific environment. Research institutions participated actively in European projects and international collaborations. Czech chemical groups increasingly contributed to internationally recognised research areas, including molecular chemistry, materials science, biotechnology, and sustainable technologies. Scientific mobility and cooperation with foreign institutions became standard components of research development. Czech chemistry entered a stage where international participation was combined with growing scientific contribution.

#### 2015–2017 — Growth of Nanotechnology, Functional Materials, and Chemical Biology

The middle of the 2010s witnessed rapid development in several advanced areas of chemical science. Nanomaterials, functional polymers, biomaterials, and molecular technologies became important directions of Czech research. Chemical biology expanded through cooperation between synthetic chemistry and life sciences. Computational methods became increasingly integrated into chemical investigation. These developments reflected the global movement towards interdisciplinary and technology-oriented chemistry. Czech researchers increasingly participated in fields connected with future technological applications.

#### 2018–2019 — Consolidation of Czech Chemistry as an International Research System

By the end of the 2010s, Czech chemical science had achieved a high level of institutional maturity. Research institutions combined strong historical traditions with modern international approaches. Czech chemists participated in European and global scientific networks, contributed to international publications, and developed cooperation with industry.

Sustainability, advanced materials, biotechnology, and molecular sciences became increasingly important research directions. The period demonstrated the successful transformation of Czech chemistry into a competitive European scientific field.

#### 2020 — COVID-19 Pandemic and Demonstration of the Societal Importance of Chemical Science

The year 2020 created new challenges for scientific communities worldwide. The COVID-19 pandemic demonstrated the strategic importance of chemistry in areas such as diagnostics, molecular analysis, biomedical research, pharmaceutical development, and materials technologies. Czech chemical institutions contributed through expertise in analytical methods, molecular research, biotechnology, and related scientific fields. The crisis strengthened cooperation between chemistry, biology, medicine, and data science. It also highlighted the importance of maintaining strong research infrastructures capable of responding to unexpected challenges.

#### 2021–2022 — Acceleration of Sustainable Chemistry and Digital Transformation

The early 2020s marked an increasing focus on sustainability, digital technologies, and advanced computational approaches. Czech chemical research increasingly addressed green chemistry, circular economy principles, energy materials, and environmentally responsible technologies. Artificial intelligence, machine learning, and data analysis began influencing chemical research methodologies. Computational approaches became important tools for molecular design, materials development, and optimisation of chemical processes. Chemistry increasingly became connected with digital innovation and sustainable technological transformation.

#### 2023 — Strengthening of Research in Energy Technologies and Advanced Materials

In 2023, energy-related chemistry became one of the strategically important areas of development. Research on batteries, hydrogen technologies, catalytic systems, and functional materials reflected broader European priorities related to energy transformation. Czech researchers continued to build upon expertise in materials chemistry, electrochemistry, and chemical engineering. Advanced materials research remained closely connected with sustainability and technological innovation. Chemistry increasingly contributed to solutions addressing long-term societal challenges.

#### 2024 — Expansion of Artificial Intelligence, Data-Driven Chemistry, and Interdisciplinary Research

The year 2024 reflected the growing influence of artificial intelligence and digital methods across chemical sciences. Researchers increasingly explored computational modelling, automated analysis, molecular prediction, and data-driven approaches. AI became an important complementary tool supporting experimental chemistry rather than replacing traditional scientific methods. Interdisciplinary cooperation between chemistry, computer

science, physics, and biology expanded further. Czech chemistry continued adapting to global trends in scientific digitalisation.

#### 2025 — Czech Chemistry as a Mature European Research Ecosystem

By 2025, Czech chemical science had developed into a mature, internationally connected research ecosystem. Over more than three decades, chemistry evolved from a discipline adapting to institutional transformation into a field actively contributing to European and global scientific development. Czech institutions successfully combined fundamental research, technological innovation, interdisciplinary cooperation, and sustainable approaches. Traditional strengths in organic chemistry, polymer science, analytical chemistry, and chemical engineering were transformed through new directions such as biotechnology, nanotechnology, computational chemistry, and green technologies. The period 1993–2025 therefore represents a complete historical cycle of transformation, demonstrating the ability of Czech chemistry to preserve scientific continuity while continuously renewing itself.

## Major Czech Chemical Institutions (1993–2025)

The development of Czech chemical science between 1993 and 2025 has been based on a diverse institutional structure combining universities, institutes of the Czech Academy of Sciences, specialised research centres, and industrial organisations. Unlike scientific systems concentrated around a single dominant institution, Czech chemistry has developed through a network of complementary centres with different historical missions and research specialisations. Fundamental research, advanced education, technological innovation, and industrial applications have been connected through cooperation between these institutions. Together, they have formed the scientific infrastructure that enabled Czech chemistry to maintain continuity after 1993 while becoming increasingly integrated into European and global research environments.

### Czech Academy of Sciences (Akademie věd České republiky, AV ČR)

The Czech Academy of Sciences represents the central institution for fundamental scientific research in Czechia and has played a decisive role in the preservation and development of chemical science after 1993. Established in its current form in 1993 as the successor to the former Czechoslovak Academy of Sciences, AV ČR inherited a broad network of specialised research institutes and scientific traditions. Its chemical institutes have contributed significantly to organic chemistry, biochemistry, polymer science, chemical engineering, materials research, analytical chemistry, and molecular sciences.

The importance of AV ČR lies primarily in its support of long-term fundamental research. Many areas of modern chemistry require sustained investigation before technological applications become possible, and Academy institutes provide an environment where such research can develop beyond short-term industrial objectives. During the period 1993–2025, AV ČR increasingly integrated into European scientific structures while maintaining its role as a national centre of scientific excellence.

The chemical institutes of AV ČR became internationally recognised through research in molecular chemistry, advanced materials, biotechnology, sustainable technologies, and interdisciplinary scientific fields. Their activities contributed to the transformation of Czech chemistry from a primarily national scientific tradition into a globally connected research ecosystem.

### Institute of Organic Chemistry and Biochemistry of the Czech Academy of Sciences (Ústav organické chemie a biochemie AV ČR, IOCB Prague)

The Institute of Organic Chemistry and Biochemistry represents one of the most internationally visible institutions of Czech chemical science. Its development after 1993 demonstrates the successful transformation of classical organic chemistry into a modern interdisciplinary research field combining synthesis, molecular biology, biochemistry, and medicinal chemistry.

The Institute has played a central role in the development of Czech chemical biology and molecular research. Its scientific activities have included organic synthesis, biologically active compounds, molecular mechanisms, chemical approaches to biological systems, and research connected with biomedical applications.

A distinctive feature of IOCB Prague has been the integration of fundamental chemical research with potential practical relevance. The Institute demonstrates how synthetic chemistry can contribute to understanding biological processes and developing new approaches in medicine and biotechnology.

Between 1993 and 2025, IOCB Prague strengthened its international collaborations and became one of the leading examples of successful Czech participation in global molecular science.

### Institute of Macromolecular Chemistry of the Czech Academy of Sciences (Ústav makromolekulární chemie AV ČR)

The Institute of Macromolecular Chemistry represents one of the strongest traditions of Czech polymer science. Established upon the foundations of internationally recognised research in macromolecular chemistry, the Institute continued to develop this field after 1993 by expanding towards modern materials science and biomedical applications.

During the contemporary period, polymer research moved beyond traditional synthetic materials towards functional macromolecular systems. Research directions included advanced polymers, biomaterials, controlled molecular structures, responsive materials, and systems with specialised technological functions.

The Institute contributed significantly to the transformation of Czech polymer chemistry into a modern interdisciplinary field connected with nanotechnology, medicine, environmental technologies, and advanced manufacturing.

Its activities demonstrate the importance of maintaining historical scientific specialisation while continuously adapting to global research trends.

### Institute of Chemical Process Fundamentals of the Czech Academy of Sciences (Ústav chemických procesů AV ČR)

The Institute of Chemical Process Fundamentals represents the connection between fundamental chemical understanding and technological application. Its research focuses on processes that determine the efficiency, sustainability, and technological performance of chemical systems.

The Institute has contributed to areas including chemical engineering, reaction processes, separation technologies, catalytic systems, and environmentally responsible production methods.

After 1993, its development reflected the increasing importance of sustainable industrial chemistry. Modern chemical technologies require not only knowledge of chemical reactions but also understanding of how these processes operate within complex technological systems.

The Institute therefore represents an important element connecting academic chemistry with industrial innovation.

### University of Chemistry and Technology Prague (Vysoká škola chemicko-technologická v Praze, UCT Prague)

The University of Chemistry and Technology Prague is the leading specialised higher education institution dedicated entirely to chemistry and chemical technologies in Czechia. Its historical mission has been the education of professional chemists, engineers, and researchers while maintaining strong connections with industrial practice.

After 1993, UCT Prague underwent significant modernisation, expanding its research activities and strengthening international cooperation. Traditional areas such as chemical engineering, industrial chemistry, and materials science were complemented by biotechnology, environmental chemistry, molecular sciences, and advanced technologies.

The University has played a central role in preparing new generations of Czech chemists. Its educational programmes increasingly incorporated interdisciplinary approaches, modern instrumentation, computational methods, sustainability principles, and international scientific communication.

UCT Prague remains one of the key institutions connecting chemical education, fundamental research, and technological innovation.

### Charles University (Univerzita Karlova)

Charles University represents one of the oldest and most historically significant academic institutions in Central Europe. Within Czech chemistry, the university has contributed primarily through the integration of chemical research with broader natural sciences, medicine, and biological disciplines.

After 1993, chemical research at Charles University increasingly developed through interdisciplinary cooperation. Molecular sciences, analytical methods, chemical biology, and interactions between chemistry and life sciences became important areas of development.

The university's strength lies in combining chemical research with a broad academic environment that includes physics, biology, medicine, and other scientific fields.

Charles University has therefore contributed significantly to the intellectual diversification of Czech chemistry.

### Masaryk University (Masarykova univerzita, Brno)

Masaryk University has become one of the most important scientific institutions outside Prague and a central element of the Brno chemical school.

The university's chemical research has developed within a strongly interdisciplinary environment connecting chemistry with biology, physics, environmental sciences, and

medicine. This structure has supported research in molecular systems, analytical chemistry, biotechnology, and advanced materials.

During the period 1993–2025, Masaryk University strengthened international cooperation and contributed to the development of Brno as a major European research centre.

Its scientific profile reflects the modern transformation of chemistry towards interdisciplinary molecular science.

### Brno University of Technology (Vysoké učení technické v Brně, BUT)

Brno University of Technology represents the technological dimension of Czech chemical development. Its research activities connect chemistry with engineering, materials science, industrial technologies, and applied innovation.

The university contributes particularly to areas where chemical knowledge is transformed into technological solutions. Materials development, engineering applications, and industrial processes represent important components of its scientific profile.

Together with other Brno institutions, BUT has strengthened the city's position as a centre of interdisciplinary research.

### CEITEC — Central European Institute of Technology

CEITEC represents a new generation of interdisciplinary research infrastructure in Czechia. Established in Brno, it created an environment where scientists from chemistry, biology, physics, materials science, and engineering cooperate within shared research programmes.

Although CEITEC is not exclusively a chemical institution, chemistry represents an important component of its activities through molecular research, nanotechnology, materials science, and biotechnology.

The development of CEITEC reflects the transformation of scientific organisation in the twenty-first century, where major discoveries increasingly emerge from cooperation between different disciplines.

### University of Pardubice — Faculty of Chemical Technology

The University of Pardubice represents one of the strongest regional centres of applied chemistry in Czechia. Its development is closely connected with the historical industrial importance of the region.

The Faculty of Chemical Technology has maintained strong traditions in chemical technologies, materials science, analytical chemistry, and industrial applications.

After 1993, the institution expanded its research activities towards modern materials, environmental technologies, and sustainable chemical processes.

Its role demonstrates the importance of regional universities within the national chemical system.

## Palacký University Olomouc

Palacký University has contributed to the development of interdisciplinary chemical research through connections between chemistry, biology, medicine, and environmental sciences.

Its scientific development reflects the broader transformation of chemistry towards molecular and life-science-oriented research.

The university has strengthened the regional diversity of Czech chemical science and contributed to the education of new generations of researchers.

## University of Ostrava and Regional Industrial Research Centres

Ostrava represents a specific example of chemistry connected with industrial transformation. Historically associated with heavy industry and chemical production, the region faced significant environmental and technological challenges after 1993.

Chemical research in Ostrava increasingly focused on environmental analysis, industrial modernisation, sustainable technologies, and materials-related applications.

The region demonstrates how chemistry can contribute to the transformation of industrial areas towards more sustainable technological models.

## Industrial Chemical Research Organisations and Companies

Industrial research has remained an important component of Czech chemistry throughout the period 1993–2025. The country's historical chemical industry created strong connections between academic institutions and technological companies.

Industrial research contributed to pharmaceuticals, polymers, speciality chemicals, materials technologies, environmental solutions, and chemical production processes.

The relationship between academic and industrial chemistry became increasingly important as Czechia moved towards a knowledge-based economy.

## Institutional Summary

Between 1993 and 2025, Czech chemical science developed through a network of complementary institutions:

- Academy institutes provided fundamental scientific research and international excellence;
- Universities educated new generations of chemists and integrated research with teaching;
- Research centres supported interdisciplinary cooperation and advanced infrastructure;
- Regional institutions maintained specialised expertise and industrial connections;
- Industrial organisations transformed scientific knowledge into technological applications.

Together, these institutions created the foundation of contemporary Czech chemistry — a scientific ecosystem combining historical continuity, international integration, technological innovation, and sustainable development.

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