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The Dye Collection

◄ Opened display cabinet of the Dye Collection

For thousands of years, coloring agents have been employed to dye textiles and other materials. Apart from the time-honored use of colors in many fields of design, research into colors has increased considerably as regards function and importance, particularly in recent years. The material witnesses associated with these processes have also found their way into the Dye Collection of the TUD Dresden University of Technology, one of the most comprehensive and significant collections of its kind in Europe. The inventory currently includes around 1,500 natural dyes of plant or animal origin, more than 20,000 synthetic dye samples and over 3,000 sample cards and books, as well as numerous samples of dyes prepared in the Institute of Colour Chemistry, the domicile of the Dye Collection. It also contains coal and tar products, various fiber materials, earth and mineral colors, and a collection of the Institute's scientific papers and specimens from 1897 onwards. The Collection documents the development of color chemistry and the dye industry from the mid-19th century onwards and is still used today as a source of visual aids and as a reference work in teaching and for scientific purposes.

Instruction in chemistry subjects during early industrialization

The origins of the Dye Collection can be traced back to the middle of the 19th century, when dyes and pigments became the subject of research and teaching at the Technical School in Dresden – the original precursor of the TUD. Instruction in chemistry had been part of the curriculum since the Institute's foundation in 1828 and was taught, as was still customary at the time, by the physician Heinrich Ficinus and later by his successor Ferdinand Jaehkel. In Saxony, industrialization of the chemical industry had started primarily in metallurgy and in the production of paper and glass. Nevertheless, Saxony lagged behind developments in England, where at this time coke for smelting iron, for example, and essential basic chemicals such as sulfuric acid, chlorine and soda ash were already being produced in large quantities.

Decisive stimuli for the booming chemical industry came from the textile sector, the dominant branch of early industrialization. The growing demand for bleaching, dyeing and cleaning agents led to a significant increase in the relevance of chemistry from the middle of the 19th century. This was also reflected in the way the subject prospered at the universities and institutions of technical education. As a consequence, the curriculum of the Technical School soon focused not only on training engineers and technicians for mechanical engineering and transportation, but also on a new breed of specialists capable of designing and controlling chemical processes and manufacturing methods.

For the most part, the coloring agents used in the textile industry, which to begin with were natural substances obtained exclusively from animals or plants, had to be imported from far away. Crucial dyes such as indigo came from India and other English overseas colonies. The monopolist prices were in line with demand and therefore subject to speculation. Driven by a growing need for artificial dyes, their production became the focal point of research from the 1830s onwards. In the German industrial regions, science-oriented education conveying in-depth knowledge of the natural sciences was supposed to close the gap to the advanced industrial nations of England and France, and to promote economic development in competition with them. The chemical industry, then still in its infancy, was highly dependent on reproducible and verifiable findings that were not based on the random results typical of pure empiricism. Instead, theoretical knowledge about the composition of substances at the molecular level was supposed to lead to an understanding of the causes of chemical reactions and to their targeted application. Chemists such as Justus von Liebig and Friedrich Wöhler established a science-based chemical education that placed great emphasis on experiments while also focusing on practical application. This educational concept was to prove advantageous during the extremely successful advance of color chemistry in Germany.

The young Technical School in Dresden also gradually developed a differentiated chemistry curriculum, taking account of scientific developments and, at the same time, increasingly seeking to meet the needs of industry. From 1830, during early industrialization, it was mainly the emerging large-scale inorganic production that necessitated knowledge of chemical technology and created a demand for chemists and chemical engineers. The first stage of development was the empirical formation of prototypes of devices for processes involving substance changes. This was followed by the substance-oriented depiction of overall processes. In this way, chemical technology established itself at the Polytechnical Schools as a practice-oriented science, providing chemists and engineers with basic technological knowledge.

From 1832, technical chemistry was introduced into the curriculum, alongside practical, theoretical and analytical chemistry. Due to the lack of necessary facilities, Ficinus taught practical chemistry for a time in his own laboratory in the “Mohren” Pharmacy. In 1846, the department moved into the new building on Antonsplatz, which was equipped with a chemistry lecture hall and suitable laboratories, providing, at least temporarily, acceptable working conditions for teaching and laboratory work.

The Dye Collection amid the growing significance of the chemical industry

The appointment of Wilhelm Stein as Professor of Technical Chemistry in 1850 was a decisive event in the history of the Dye Collection. He took charge of Section C for Chemistry, established during the reorganization measures that occurred in 1851. Stein had received his doctorate under Justus Liebig in Giessen and was deeply committed to making the education as hands-on as possible. In addition to his many duties in technical chemistry, he was particularly interested in the composition of natural dyes such as the inorganic pigment ultramarine or the organic dyes of the berries of rhamnus and *Rubus xanthocarpus* from China. Stein used these and other natural dyes to establish a teaching collection that provided a good overview of the most important chemical substances and devices of the time.

In 1853, Director Julius Ambrosius Hülsse described the chemical collections of the Royal Polytechnical School as containing “29 preparations for teaching theoretical chemistry and 783 objects for technical chemistry”. (Hülsse 1853, p. 13) A fully equipped laboratory with 29 workstations was attached to these collections. The devices of this laboratory can no longer be found in today’s inventories of TUD. It can be assumed, though, that some of the dye samples examined by Stein have survived in Dresden to this day. The Dye Collection contains numerous natural dyes together with the plants from which they were obtained at the time. It is possible to deduce from the file marks present on some of the samples that they were acquired around 1850. This includes dyes from tropical dyewoods such as yellowwood, redwood or bluewood, various dyes from lichens such as litmus, and crucial plant dyes such as

Oldest color sample chart, Neubarth company, handmade, 1851, as a record of early forms of sales promotion

blue indigo or rose madder. There are also various animal dyes, such as purple and carmine, that were obtained from snails and cochineal respectively, as well as a very rare sample of Indian Yellow. This color pigment was obtained from the urine of Indian cows whose diet consisted exclusively of leaves of the mango tree and who were given only small amounts of liquid. The process was banned by the Indian colonial government at the beginning of the 20th century in order to protect the animals.

Apart from these samples, today's Dye Collection also contains a number of dyes whose origins can be traced back to the great world or trade exhibitions of the 19th century, and as such to the international transfer of knowledge. These include a bottle of "red cudbear", a red dye extracted from lichen and originating from the British firm Wood & Bedford, which distributed high-quality natural dyes in Leeds from the mid-1920s. (Whitworth 2008) The label identifies the bottle as an exhibit of the "Collection of Samples of Produce of Great Britain" at the Great Exhibition of 1851 in London, which took place one year after Stein's appointment, suggesting he had brought this bottle back with him from London.

The historical alliance between chemical research and the coal tar dyes industry

In the second half of the 19th century, coal and crude oil gave rise to a large-scale organic chemical industry, which became the basis of the modern energy and materials economy. The groundbreaking discovery of artificial dyes made from constituents of coal tar was to completely revolutionize color chemistry and, as a consequence, the chemical industry in Germany as a field of research and work. Coal tar accrued in large quantities as a waste product during the manufacture of coke, which was needed to extract iron. In 1930s Germany, Ferdinand Runge had studied the composition of coal tar and had managed to isolate various substances that today are defined as aromatic compounds. Of these, kyanol, later called aniline, became particularly significant.

Natural dyes cochineal, madder, natural indigo, Indian yellow, around 1900

Alongside Runge, August Wilhelm von Hofmann, a student of Liebig's who taught in London from 1845 and was tasked with establishing the Royal College of Chemistry, was one of the protagonists of researching synthetic dyes. Hofmann investigated the chemical properties of coal tar and, based on its constituents, attempted to develop a manufacturing process for quinine, which was urgently needed as an antipyretic, especially in the treatment of yellow fever. While these – unsuccessful – experiments were being conducted in 1856, Runge's student William Henry Perkin succeeded in discovering an interesting dye that was capable of dyeing wool and silk in brilliant violet hues. Initially, he named this substance Aniline Purple. A short time later, he had the substance produced by a company he founded specifically for this purpose and had it marketed under the name "Mauveine". An original sample of this dye still remains in the Collection today. In 1906, it was presented to Richard Möhlau, Director of the Institute for Dye and Textile Chemistry at the Royal Saxon Technical College, during the celebrations of the 50^{th} anniversary of the discovery of Mauveine held in Perkin's honor by the Chemical Society in London (Hennings 1906).

Perkin's discovery triggered a wave of research focusing on the conversion of aniline and other coal tar constituents into viable dyes. By 1858, the Frenchman Emanuel Verguin was successfully producing Fuchsine from aniline. He was followed by Johann Peter Grieß, who in 1861 obtained diazonium salts from aniline. These formed the basis for the production of azo dyes, which quickly advanced to become the most important class of the new aniline or coal tar dyes. They could be easily prepared from derivatives of aniline, which were usually readily accessible, and converted into dyes of practical value by simple modification reactions. The in-depth exploration of coal tar dyes was also the driving force behind the discovery of many more significant principles of synthesis in organic chemistry.

The new aniline dyes were given an enthusiastic reception at the 1862 International Exhibition in London. This rapid development in coal tar dye production primarily benefited the textile industry, which was able to use the new synthetic dyes to produce textiles of unprecedented brilliance and color fastness that sold like hot cakes. Colorful, fashionable clothes and colored textiles for the home set the trend, and demand for cheap coloring agents rose steadily. This was particularly true of alizarin, which was obtained from the red dye of the madder root and had already been synthesized in 1869 by Carl Graebe and Carl Liebermann, at the newly founded "Badische Anilin und Sodafabrik" (BASF) in Ludwigshafen. This ushered in the decline in the cultivation of plants for the manufacture of natural dyes. Red fuchsine, patented by Verguin in 1858 and produced on an industrial scale, also became a fashionable color and formed the economic basis for the later "Farbwerke Hoechst AG". The displacement of natural dyes continued after BASF chemists succeeded in 1878 in synthesizing the previous

Early synthetic dyes from various manufacturers with an original mauveine sample, from 1860

"king of natural dyes", deep blue indigo, and producing it cheaply a few years later. As a result of this development, the market share of natural indigo had fallen to approx. 4 % by the beginning of the 20th century.

Establishing color chemistry as a subject in its own right

In Dresden, still under Wilhelm Stein's direction in 1870, a further differentiation of subjects came about. Stein effected the separation of the subject into technical chemistry, which he represented until 1879, and a new Chair of Theoretical Chemistry, to which Rudolf Schmitt was appointed. Educated in Marburg as a student of Hermann Kolbe and Robert Bunsen, he introduced experimental chemistry lectures in Dresden and took charge of the organic chemistry laboratory. Among other things, he conducted research in the field of azo dyes, which still form one of the most crucial classes of synthetic dyes today. One of Schmitt's greatest successes, however, was the synthesis of salicylic acid, which had been developed by Kolbe in Leipzig, but which Schmitt brought to technical maturity. In addition to its application in the dyeing industry, for example to obtain azo-based mordant dyes, it was primarily used to produce acetylsalicylic acid (Aspirin).

The first salicylic acid factory, where Schmitt was also scientific director for a time, was built in Radebeul by Schmitt's student Friedrich von Heyden in 1875. The factory was one of the first spin-offs to emerge from the College and illustrates how closely science and industry of that time cooperated from the very beginning. Research findings were immediately applied in industrial production and instantly commercialized. This path from theory to practice can be observed mainly in coal tar dye chemistry, whose successful industrial implementation was from the outset grounded in science, guaranteeing sustainable economic success. For Germany, thanks to its outstanding potential regarding chemists, the scientific approach proved to be sound strategy for compensating for the shortage of resources. In this way, the coal tar dye industry initiated a general boom in the chemical industry by means of a previously unknown linking of chemical science and production. It was not least due to this development that within a few decades, England and France lost their initial leading role in the dye industry. At the turn of the century, the world market share of coal tar dyes produced in Germany stood at over 80 %.

The dye industry, with its influence on the textile sector, had by the mid-1880s become a significant economic factor that now also received particular attention in scientific training. While smaller chemical companies for specialized products tended to set up business in the Dresden area, the expanding large companies of the dye industry such as BASF or Bayer AG, founded in 1865 and 1863 respectively, were highly dependent on well-trained specialist staff. The growing demand generated an increased influx of students interested in this branch of industry and created new requirements for the availability of sufficient training places. In Dresden, the desire for a new building had already arisen in the 1860s, due to the proliferating number of students and the need for more space for teaching materials and laboratories. The Polytechical School was elevated to the status of a Polytechnic in 1871, and the associated restructuring of the subjects according to the departmental principle, meant that public funding for such a building was now available. The growing relevance of chemistry was taken into account during the planning for the new institution at Bismarckplatz: The chemical laboratories were given their own building in the gardens behind the main building along Schnorrstraße, which was inaugurated in 1875.

When Walther Hempel succeeded Stein in 1879, and following a proposal by Director Gustav Anton Zeuner, chemistry was divided into two independent subject areas: theoretical and technical chemistry. Hempel took over as head of the Laboratory of Technical Chemistry. He was primarily active in the field of inorganic technical chemistry and achieved great scientific successes, particularly in gas analysis and technical electrochemistry. This explains why various devices he developed, including his gas burette, are components of a comprehensive collection of devices used in inorganic technology, which is still housed at the Faculty of Chemistry and Food Chemistry of TUD today.

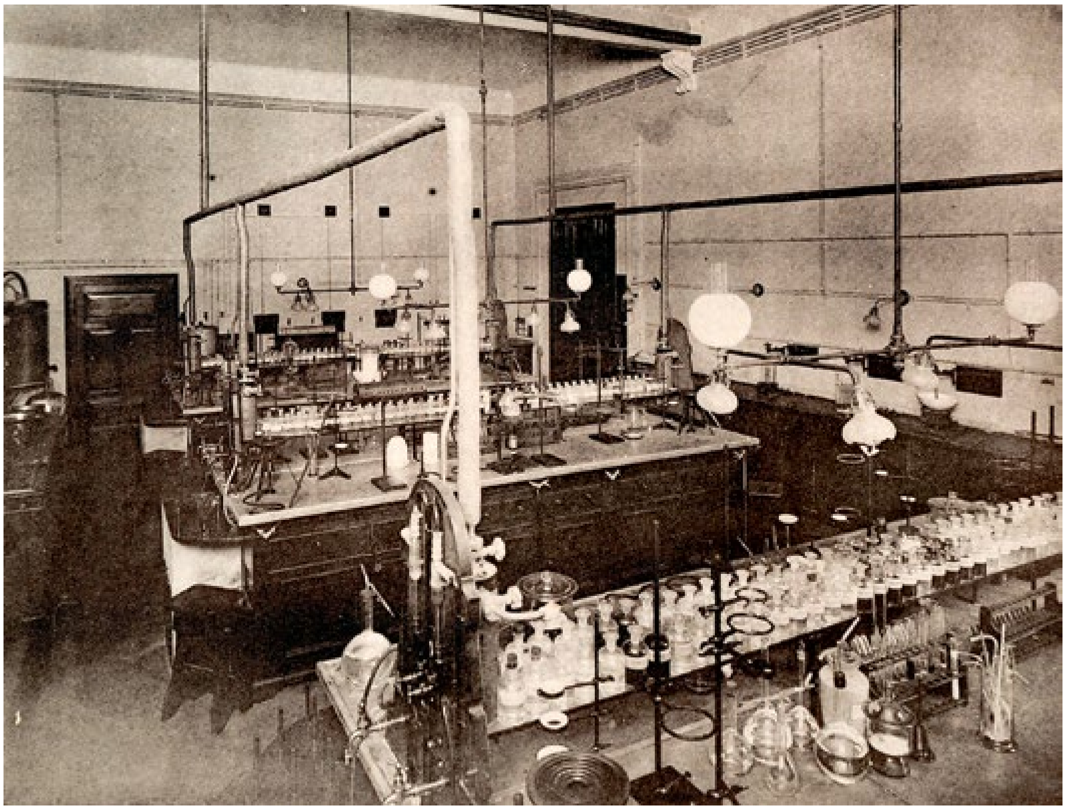
Richard Möhlau (1857–1940)
Professor of chemistry of the textile industry, color chemistry and dyeing technology, and Director of the Laboratory for Color Chemistry and Dyeing Technology from 1886 to 1911; Rector of the Technical College 1908/09

Formation of research networks, expansion and consolidation of the Dye Collection under Walter König

Industrial research assumed a certain prominence as the relationship between science, technology and industry changed, helping research findings to permeate into industrial practice. The evolution of specific expert knowledge, especially in “young” industries such as coal tar dye chemistry, created a sound foundation for the increasingly dense network of transfer relationships between industrial, governmental and academic research. The great significance of color chemistry also led to a steady expansion of disciplinary boundaries and a growing demand for teaching and research activities. Presumably as a reaction to this development, color chemistry was introduced as the first specialist field at the Chemistry Department in 1886. Richard Möhlau, who had been an assistant in the Analytical Chemistry Laboratory at the Dresden Polytechnic since 1881, was appointed to the new Chair (later the Chair for Chemistry of the Textile Industry, Color Chemistry and Dyeing Technology), first as associate professor, then as full professor from 1893. He had studied under Schmitt in Dresden and had been awarded his doctorate in Freiburg im Breisgau. After continuing his studies in Hofmann’s laboratory in Berlin, he qualified as a professor in Dresden in 1882. His inaugural lecture dealt with “The development and national economic significance of the coal tar dye industry” and his research also focused primarily on the chemistry of dyes.

In 1891, he was appointed Director of the “Laboratory for Color Chemistry and Dyeing Technology”, founded by him as the first of its kind in Germany. In 1895, this laboratory moved into a purpose-built extension on the east side of the chemistry laboratory on Schnorrstrasse. The Technical College, as it was called from 1890, had now become an extremely attractive educational center for color chemists, for decades exerting a great pull and achieving international renown. The Institute’s teaching covered three sub-areas: the chemistry of dyes, spun fibers and dyeing technology. It also trained factory engineers – in theory and practice – who could manage larger companies. Under Möhlau’s leadership, the Collection was expanded substantially, and the dye samples ordered systematically according to a principle developed by Gustav Schultz in Germany in 1888 and later adopted by the British Society of Dyers and Colourists in the shape of the Color Index, a standard reference work of all common dyes published in 1925.

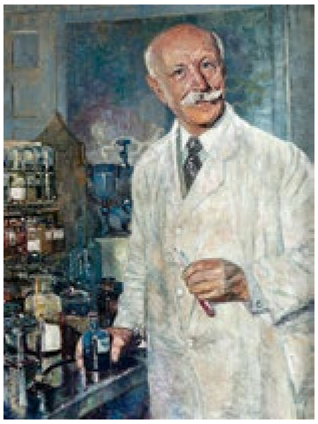
East wing of the Chemical Institute on Schnorrstraße with the Laboratory for Color Chemistry and Dyeing Technology
(Möhlau 1896)



Color laboratory of the Chemical Institute on Schnorrstraße
(Möhlau 1896)

Möhlau retired in 1911 and was succeeded by his former assistant Hans Theodor Bucherer. He made a valuable contribution to the development of color chemistry at the Technical College with his fundamental works on the reversible conversion of naphthols into naphthylamines. Both types of compounds achieved outstanding significance as starting components for the manufacture of azo dyes, the most important class of synthetic dyes in technical

Institute of Dye and Textile Chemistry (König Building since 1953), around 1935



Walter König (1878–1964)
Painting by Ernst Hassebrauk, 1954 (TUD Art Collections) Professor of Dye and Textile Chemistry and Director of the laboratory of the same name from 1913 to 1954

terms. The "Bucherer reaction" that is named after him still plays an important role today in the production of certain dye intermediates. In 1913, when Bucherer accepted a call to the Technical College in Berlin, Walter König was appointed Professor of Color Chemistry and Dyeing Technology and Director of the laboratory of the same name. König had also studied in Dresden and had received his doctorate at the Organic Chemistry Institute under Hempel in 1906. He, too, had gained experience in industry in the laboratory of the dye factory, formerly Friedrich Bayer & Co., and was at the cutting edge of chemical practice. König had a significant influence on color and textile chemistry research and made a name for himself internationally through a large number of scientific papers. Within the field of color chemistry, he was particularly interested in researching polymethine dyes, a class of dyes with particular luminosity, for whose synthetic access he made important discoveries. König worked at the Technical College for more than 40 years. Under his stewardship, fundamental work was done in the field of synthetic dyes, which found wide-spread application not only in the textile industry, but also, critically, in the photographic industry. Here, they were employed as sensitizing dyes for the light-sensitive silver halide and are mostly still in use today. During his tenure, König supervised more than 100 dissertations. These are kept in the Collection together with their substances and are frequently requested as valuable reference samples for research projects.

The number of students continued to rise after the Technical College was granted the right to award doctorates in 1900. In 1912, 205 students crowded into the laboratories, at less than half that number of workplaces. The application for a new building for the chemical institutes on the Südvorstadt campus became more and more urgent and was received positively by the government. However, the outbreak of World War I put a stop to all further measures. It was not until 1921 that construction of the new institute building on Mommsenstraße could begin, based on plans by Martin Dülfer, the professor in charge of building design at the Technical College.

Funding difficulties, triggered by the hyperinflation during the economic crisis of the 1920s, almost sank the project. Following an appeal by the "Association of Friends and Sponsors of the Technical College", industry expressed its great interest in continuing the construction of the new building. The Ministry ultimately provided the funds for the building, while the equipment for the laboratories was to be acquired through donations in kind and grants from the chemical industry. The files of the University Archives provide information regarding

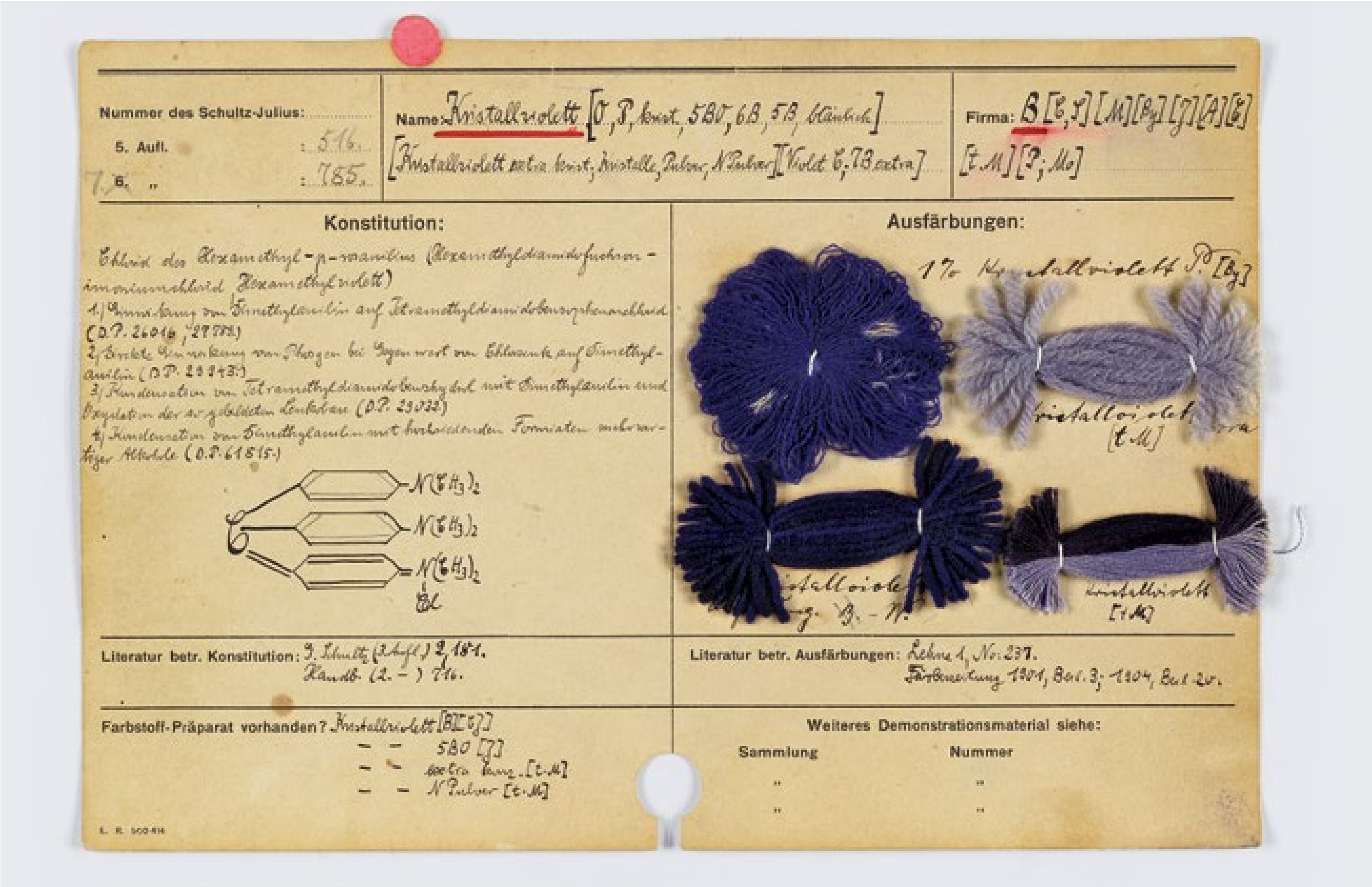
Collection room of the Dye Collection in the König Building
with the historical interior from 1926 (Photo: Till Schuster)

the transfer of various collections, including cabinets and display cases, effected by the Wilhelm and Ella Kaufmann Foundation in October 1924. These included a coal tar dye collection (136 bottles), a tanning agent collection, a detergent and bleaching agent collection, materials for Ostwald's color theory and a collection of various textile materials (UA 167, p. 150). In addition, Walter König procured illustrative instruction materials that were obtained from special teaching material workshops. Among them were biology showcases for Asian silk spinners, which can still be found in the Collection today. After some delay, the new building for the Institutes of Chemistry was inaugurated in June 1926.

The Laboratory for Dye and Textile Chemistry, as it had been called since 1926, was expanded to include a special teaching and research laboratory for the synthesis of dyes and a separate textile chemistry laboratory. The Institute now had a two-story collection room with a wide variety of light-proof cabinets, directly adjacent to the room assigned for preparing lectures. The fact that the Dye Collection is still housed in these cabinets and rooms today constitutes a rare exception among the University collections.

In the 1920s, the Dye Collection experienced yet more growth of its inventory, again due to close collaboration with industry. The research activities of the chemistry departments were of great interest to the large chemical companies such as BASF and other IG Farben companies. These enterprises maintained close ties with the scientists at the universities and concluded staff contracts to secure the use of research findings. One individual who deserves a special mention here is Roland Scholl. From 1916 to 1934, he worked at Technical College as a Professor of Organic Chemistry and Organic-Chemical Technology and, from 1921, headed the chemistry department at this institution for a while. His achievements include research into the chemical structure of Indanthrene, the most lightfast vat dye of its day, which made accessible a completely new class of dyes. Scholl collaborated closely with BASF in Ludwigshafen and, for a time, was himself an employee of IG Farben, to whom he offered many of his research findings for exploitation. In return, he received all the substances and chemicals he needed for his research, on top of generous financial support that made him largely independent of government grants. A great number of dyes and the specimens prepared by Scholl and his colleagues are part of the Dye Collection.

Towards the end of World War II, the building housing the Institute of Dye and Textile Chemistry was badly damaged, but the Dye Collection and much of the equipment that was critical for dye research were preserved. Teaching was resumed soon after. In 1949,



Color chart of Crystal Violet, around 1915
From the Institute's extensive collection of index cards for the documentation of important synthetic dyes

exonerated from political charges, König returned to his old position and worked on the development of new dyes that could be used primarily for dyeing the new synthetic fibers, such as Dralon or Orlon. Since Walter König's 75th birthday in 1953, the Institute building has borne his name. He was awarded the August Kekulé Medal of the Chemical Society in the GDR in 1954 and, a few years later, the Emil Fischer Medal of the Society of German Chemists (German abbreviation: GDCh).

Following König's retirement in 1957, the former Institute of Dye and Textile Chemistry was divided into two independent institutes. However, like all other chemical institutes, they lost their autonomy in 1968 as part of the GDR's Third University Reform. Prior to this, the Institute of Textile Chemistry, which had become autonomous in 1965 under its then director Günther von Hornuff, was able – together with the Institute of Technical Chemistry – to move into a new building at the corner of Mommsenstraße and Bergstraße, today's Walther Hempel Building. Here, it was possible to continue to maintain and supplement the color and textile chemistry collections, which had become increasingly extensive in the meantime. Since 2009, the two collections have been reunited in the König Building.

Outlook

Today, the Dresden Dye Collection is an exceptional institution, providing invaluable visual aids for teaching and for communicating contexts related to scientific and economic history. Its preservation as a physical entity in specifically designed rooms demonstrates that those involved in maintaining the Collection are aware of its uniqueness, both in terms of historical significance and as a source and reference material for research. At present, the Dye Collection is integrated into numerous activities related to teaching, research and publicity. The

Collection is open to the public upon request. Regular guided tours for schoolchildren, students and visiting scientists explain the history of dye chemistry in Germany and its significance for industry and science. Some items from the Collection are on loan to museums in Germany and abroad, for instance for the exhibition "The Age of Coal – A European History" (Zeitalter der Kohle — eine europäische Geschichte), held in Essen in 2018 and dedicated to the end of coal mining. More than 3,000 samples from the Dresden Dye Collection document the success story of coal tar dyes obtained from the waste product tar (Brüggemeier 2018).

Art academies and conservators alike benefit from the inventory of rare dye samples that serve as reference points for color comparisons. In recent years, the Dye Collection has participated in various interdisciplinary research projects and has been instrumental in initiating a number of them. These include a project funded by the German Federal Ministry for Education and Research (BMBF) entitled "Color as Actor and Memory" (Farbe als Akteur und Speicher), which has brought together scientists from eight different research institutions, and a research project on the analytical characterization of synthetic organic pigments that are relevant for artistic purposes (Scheurmann 2017). Finally, a "Knowledge Forum Color and Light" (Wissensforum Farbe Licht) at TUD and a student laboratory have been launched. The student lab focuses on dyes, their manufacturing processes and their diverse applications in science, technology and art.

However, in order to ensure the preservation and long-term availability of the Dye Collection, which enjoys a reputation beyond Saxony in terms of the history of science, technology, economics, culture and higher education, a number of challenges will have to be met in the future. The Dye Collection is currently maintained with great commitment, but exclusively by volunteers, and a continuation of the professional supervision of the Collection must be safeguarded in the long run. Nevertheless, the activities mentioned above reflect the continuing topicality of the objects in the Collection against the backdrop of extraordinary success achieved during the history of dye chemistry from early industrialization to the present day. Consequently, the Collection is experiencing an increase in relevance, which is manifested above all in the potential applications of dyes in modern branches of the opto-electronics industry and in medical diagnostics.