



Places and chemistry: Mulhouse. Chemists in Werner's birth city up to the 1st half of the 20th century

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ARTICLE INFO

Article history:

Available online 7 February 2013

Dedicated to Professor Pierre Braunstein

Keywords:

Mulhouse
Alsace
Werner
Noelting
Dyestuffs industry

ABSTRACT

The Alsatian city Mulhouse, Alfred Werner's birthplace, has a fascinating chemical history and has hosted numerous chemical personalities who are briefly presented in this paper.

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1. Introduction

A birth, on December 12th, 1866, in Mulhouse, was that of the man who would become considered the founder of coordination chemistry: Alfred Werner (Fig. 1), Nobel laureate in Chemistry in 1913. Many papers [1] and a book [2] have been written about Werner and his essential contributions to the advancement of chemical science, most of which came from his work during his academic life at the University of Zurich following his early scientific training in Mulhouse (see ahead). Werner's birthplace, Mulhouse, however, also has a remarkable chemical and industrial [3] history associated with numerous other significant chemical personalities. The aim of this paper is to briefly present these chemists [4], focusing our attention on the academics. The presentation is of course far from being exhaustive.

Mulhouse is today an Alsatian city located in the French "département du Haut-Rhin" (Upper Rhine province) but its history is complex [5]. In the first half of the 14th century, the city was granted the right to have its burgomaster elected by the council and by the representatives of the corporations, thus introducing republican features in the functioning of the city administration. From 1354 to 1515, Mulhouse belonged to an alliance of 10 cities along the Rhine valley called the Décapole. In 1515, Mulhouse left

the Décapole and allied itself with the Swiss cantons, greatly enhancing its independence. In 1798, Mulhouse became part of France [6]. From 1871 to 1918 it was annexed, as being a part of Alsace, to the German Empire, and went back to France at the end of World War I. From 1940 to 1944 the city was, like Alsace, annexed de facto by the 3rd Reich. After its liberation in November 1944, it went back to France.

2. Chemists in Mulhouse before the Franco-Prussian War

In 1746, a calico printing factory was founded in Mulhouse by Jean-Henri Dollfus, Samuel Koechlin and Jean-Jacques Schmalzer. Textile printing necessitates chemicals and chemical knowledge. Many other "indienne" (printed fabric) manufacturers later established themselves in Mulhouse, Anthès, Feer and coworkers (1754), Hofer, Risler and coworkers (1756), J.J. Feer and Huguenin (1758), Eck, Schwartz and coworkers (1762), Heilmann, Blech and coworkers (1764), Thierry l'Aîné and coworkers (1764), Feer and coworkers (1764), Dollfus and Hofer (1764), Schoen, Huguenin, Zuber and coworkers (1765), Hartmann and sons (1767) being examples [7].

It has been argued that the development of Mulhouse during the 19th century provides one of the most richly complex illustrations of the path of the industrial revolution in France [8]. The industrial and commercial growth of the city, largely based on 18th century textile industry and its use of natural dyes, became increasingly dependent on, amongst other factors, the chemistry of dye synthesis and dyeing processes. Of the many chemical

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Fig. 1. Portraits of several Mulhouse-connected chemists.

enterprises [9] established in Mulhouse during the 19th century, special mention should be made of those of Frauger and Baumgartner, founded in 1823 and producing cerussite (lead carbonate), of Laederich-Brustlein, established in 1825 at Mulhouse and producing starch and dextrin (soluble oligosaccharides), of Simon Grosjean, created in 1833 and producing chloride of lime (a mixture of calcium chloride and calcium hypochlorite), of J.D. Schuller, founded in 1839 and producing tin compounds and gelatine, of R. Bleyer, founded in 1840 and producing cerussite, of Steinbach and Laedrich, founded in 1842 and making starch and dextrin, of Léonard Schwartz and Edouard Thierry-Mieg, founded in 1843 and producing madder-root-based dyes, of Gerber and Schirmer, created in 1844 and making animal charcoal, of Bertrand, created in 1852 and producing starch and dextrin, of Bleyer and Cacheux, founded in 1855, of Beck, created in 1856 and making chloride of lime, and of Gros, founded in 1857 and producing orseille (a violet dye extracted from lichen).

In 1859, Jean Gerber-Keller and his son Armand from a factory in Dornach, a village close to Mulhouse (and incorporated into it in 1914), found a method of making a red dye by treating aniline with mercuric nitrate. They called this dye «azaléine». In fact «azaléine» proved to have the same composition as fuchsin. It was cheaper than the fuchsin that was already patented and produced by the factory «Renard frères et Franc» in Lyon. However, at the time the apparent identity of the two materials was taken to mean that the production of azaléine was a form of counterfeiting of fuchsin. Extended patent litigation resulted in a decision in favour of Renard frères [10].

While the English chemist Sir William Perkin is credited with the discovery of mauveine, development of aniline-based dyes in Mulhouse, as a consequence of some rather particular cultural and economic factors, proved to be as well of economic significance. In 1863, factories for the production of aniline-based dyes were founded at Mulhouse by Adolphe d'Andiran and Gustave Wegelin, and by Clément Courtois. Both factories were bought by the Thann factory in 1884 [11]. Another chemical enterprise was founded by Louis Roesler [12] in 1870 at Dornach and produced oils, greases and dyes.

The interest of Mulhousians in applied sciences as well as the expansion of the chemical industry (including dye production) in Mulhouse and in Alsace [13] had as a consequence the initiation in March 1822 of a course of applied chemistry, firstly given by L. Degenne, and the construction of a chemistry laboratory within the Collège communal (municipal) of Mulhouse. This is considered as the beginning of what is nowadays the Ecole Nationale Supérieure de Chimie Mulhouse (ENSCMu; the National Advanced School of Chemistry of Mulhouse, hereafter “the Ecole”) [14].

After Degenne, Achille Penot [15] (1801–1886; Fig. 1) took over the chemistry course from 1825 to 1854. Penot was a chemist and also a statistician. He attended lectures at the Collège de France and passed a doctorate at Strasbourg. Penot wrote papers on subjects including acidimetry and alkalimetry [16], chloride of lime [17], cotton [18] etc. He was vice president (1851–1871) of the Société Industrielle de Mulhouse (Mulhouse Industrial Society). A strong force in the industrial and scientific life in Alsace, the Société Industrielle de Mulhouse [19] (SIM), was founded in 1826. Amongst the founder members of the SIM were chemists Daniel Koechlin-Schouch (1785–1871), Daniel Dollfus-Ausset (1797–1780), Edouard Schwartz (1798–1861) and Léonard Schwartz (1802–1885) as well as several “indienneurs” (indienne makers). Chemistry was clearly a priority for the SIM. The committee of chemistry (1826–1939) of the SIM played important roles by arousing and encouraging the chemical research for the industry, by spreading the chemical knowledge, by sustaining the chemical education [20].

In 1854, the Ecole Professionnelle de Mulhouse (Professional School of Mulhouse), which ran the industrial chemistry classes of the Collège communal (municipal), and the Ecole Supérieure de Sciences Appliquées (ESSA; the Higher School of Applied Sciences), operational in 1855, were created. Appointed as professor of chemistry in 1854, Paul Schützenberger [21] (1829–1897; Fig. 1) was in charge of the chemistry courses at Mulhouse until 1865. Schützenberger was born in Strasbourg, became a medical doctor of Strasbourg university and obtained also a “licence ès sciences physiques” there. He was an assistant in medical chemistry under Caillot in Strasbourg, then assistant in the Conservatoire des Arts et Métiers in Paris under Persoz, after which he came at Mulhouse. After his Mulhouse period, he was an assistant of Balard at the Collège de France, then Deputy Director of the laboratory of the Ecole Pratique des Hautes Etudes at La Sorbonne. From 1876 until his death, he was professor at the Collège de France, and from 1882 he was the Director of the Ecole Supérieure de Physique et de Chimie Industrielles de la ville de Paris (ESPCI). His wide-ranging research included the syntheses of the platinum (II) complex $[\text{Pt}(\text{CO})\text{Cl}_2]_2$, the first metal carbonyl compound [22] and cellulose acetate [23], the discovery of dithionous acid [24] and the study of dithionites [25], and albumins.

After Schützenberger left Mulhouse, the classes of chemistry became an independent section attached to the ESSA. The professor in charge of chemistry from 1865 to 1868, Daniel Auguste Rosenstiehl [26] (1839–1916; Fig. 1), was again native from and educated in Strasbourg. Rosenstiehl also worked in the chemical industry and ended his career as a professor at the Conservatoire National des Arts et Métiers in Paris. He was a renowned specialist in dye chemistry and worked on aniline black, on triphenylmethane-derived dyes, on nitroalizarin, on anthraflavone [27], on azoic dyes and others. His books on colours, amongst which was *Les premiers éléments de la science de la couleur* (Introduction to the science of colours), were famous.

From 1868 to 1871 the chemical courses were held by Perrey. After the 1870–1871 war, the ESSA was closed, but the Ecole Professionnelle continued to function. The independent chemical section became the Ecole Municipale de Chimie Industrielle (Municipal School of Industrial Chemistry) in 1871.

Other chemists, not necessarily professors at the Ecole de Chimie, are connected with Mulhouse. Born in Mulhouse, Auguste Scheurer-Kestner [28] (1833–1899; Fig. 1) was a chemist, industrialist and politician, and he supported Alfred Dreyfus during the Dreyfus Affair. As a chemist, he worked on several industrial processes for the production of chemicals, as well as on the calorific power of fuels [29]. His father-in-law was Charles Kestner [30] (1803–1870), a chemist, native of Strasbourg, who discovered [31] racemic acid.

A native of Mulhouse, the manufacturer and chemist Daniel Koechlin [32] (1785–1781) worked on madder colorants (e.g. on Turkey red (“rouge d’Andrinople”). His son, Camille Koechlin [33] (1811–1890), born in Mulhouse, worked on alizarin, aniline black, aniline red and other dyes. The grandson of Daniel, Horace Koechlin, born in Glasgow, worked, amongst other things, on indo-phenol and on gallocyanin.

René Bohn [34] (1862–1922), born in Dornach-Mulhouse, studied at the Polytechnicum of Zurich and had a fruitful career with the BASF chemical company. One of his important discoveries is the first anthraquinone vat dye: the indanthrene blue.

Other Mulhouse natives included Daniel Dollfus-Ausset [35] (1797–1870) and Léonard Schwartz [36] (1802–1885), who performed studies in the field of textile printing, Gustave Koenig [37] (1804–1891), a member of the commission of the historical museum of Mulhouse [38], and Georges Steinbach [39] (1809–1893), a dyes chemist and vice president of the SIM.

In a nice paper about “the transatlantic voyage of aniline black”, Anthony S. Travis wrote that the Mulhouse-born chemist Alfred Paraf [40] (1844–1885) “was a principal carrier of knowledge about aniline black to North America. He was continuing the traditions of the Mulhouse colorists and chemists, who, for this colorant, remained at the forefront of chemical explanation, technical improvements, and transfer of technology until the late 1880s” [41].

Georges Friedel [42] (1865–1933), the son of the chemist Charles Friedel, was born in Mulhouse. His works of crystallography, as well as those on liquid crystals [43] remain very important. One may notice that the renowned physicist Pierre Weiss (1865–1940) who brought significant contribution to magnetism is also a native of Mulhouse. Both G. Friedel and P. Weiss were born there before the Franco-Prussian War.

3. Chemists in Mulhouse between the Franco-Prussian War and the WWI

After the Franco-Prussian War, Alsace, and so Mulhouse, were annexed to the German Empire. Many well-known chemists worked within the framework of the Ecole de Chimie.

From 1871 to 1879, the Ecole was directed by Friedrich Goppelsroeder (1837–1919). His experimentation on capillary analysis (Kapillaranalyse) can be considered one of the precursors of paper chromatography [44]. His assistant was H. Schmid.

After Goppelsroeder’s departure, the director of the Ecole became, in 1880, Emilio Noelting [45] (1851–1922; Fig. 1) who kept this position for about 35 years. A graduate of the Zurich Polytechnicum (now the ETH), he was for a while there the assistant of Victor Meyer (1848–1897), then of Emile Kopp (1817–1875), an Alsatian professor. An excellent organic chemist [46], Noelting invented dyes including erythrosine, phloxin, and cyanosine. He gave a considerable impetus to the Ecole de Chimie of Mulhouse and amongst other things, introduced into the program of the Ecole an initiation into chemical research.

Alfred Werner met Noelting in Mulhouse and they had an original and interesting discussion, as recounted by G.B. Kauffman in his excellent book about Werner [47]. The eighteen-year-old Werner had “compiled a study of urea compounds” without his own experimental data and believed that it “would reshape all of organ-

ic chemistry”. The young Werner went to show his work to Noelting. Eight days later, Noelting told Werner that with that work he “would not yet achieve a revolution in organic chemistry” and that he “would have to study much more”. Thus, Werner asked Noelting how long it would take for him to become a professor. Smiling, Noelting estimated that patience would be needed for 7 or 8 years. 8 years later, Werner began his career at the University of Zurich, succeeding to Viktor Merz.

From 1886 to 1889, Stanislaus von Kostanecki [48] (1860–1910; Fig. 1), a former assistant of Carl Liebermann, was “chef des travaux” at the Ecole [49]. He later became professor in Bern (1890–1910) and president (1909–1910) of the Swiss Chemical Society. His name has been given to the Kostanecki-Robinson reaction (also known as the Kostanecki acylation) which allows synthesis [50] of coumarins starting from *o*-hydroxy aromatic ketones through acylation with aliphatic anhydrides followed by cyclisation.

From 1894 to 1899, the organic chemist Hans Rupe [51] (1866–1951; Fig. 1) worked at the Ecole as lecturer. He was later professor at the University of Basel (1903–1937) and president of the Swiss Chemical Society (1907–1909). “Rupe nickel” is a hydrogenation catalyst he invented. In Mulhouse, he worked on phenylhydrazine derivatives [52], on guaiacol [53] derivatives, on triazole derivatives [54] etc.

Known for his work on tungstic and molybdic acids, on dyes, for being at the “origin of the theory of steric effects” [55] (steric hindrance), Friedrich Kehrman [56] (1864–1929; Fig. 1), professor at the University of Lausanne (1910–1929), was lecturer at the Ecole [57] from 1907 to 1910. After his departure for Lausanne, Eugène Grandmougin [58], a former professor (1905–1908) at the Zurich Polytechnicum, came to the Ecole as a professor of organic chemistry (1910–1914) [59].

The German chemist Otto N. Witt [60] (1853–1915) – who had an impressive career as a professor in Charlottenburg (Berlin) and synthesized, with the Alsatian chemist Horace Koechlin [61] (1839–1898), indophenol [62] – “was associated with Noelting and Grandmougin, at Mulhouse, in developing the chemistry of indazole derivatives” [63].

Amongst the organic chemists who worked in Mulhouse were as well Albert Baur [64] (who discovered and synthesized synthetic musk), W. Feuerstein [65], C. Marschalk [66], C. Gassmann [67].

Concerning industrial chemistry and related fields, one may note that Edouard Muller-Schultz [68] (1834–1925) created at Dornach, in 1873, a factory for production of chemicals for printing [69]. It was displaced to Lutterbach in 1881 when a new associate arrived. Another dyes enterprise was «Wacker et Schmitt» (Mulhouse, 1893) [69].

Of the chemists born in Mulhouse after the 1870–1871 war, another who obtained his training [70] at the Ecole was Georges Thésmar [71] (1887–1965), ultimately becoming president of the Société Chimique de France (1948).

4. Chemists in Mulhouse between WWI and WWII

After WWI, Mulhouse, as did all Alsace, went back to France. A former assistant of Noelting, Eugène Wild, became director of the l’Ecole from 1918 to 1926. His successor, Martin Battégay [72] (1883–1942), a former pupil of the Ecole and research coworker of Noelting [73], was director until 1941. A specialist in anthracene chemistry, Battégay synthesized nitroanthracenes [74] and anthraquinone derivatives, and worked on the diazotation of the anthramines, as well as on naphthalene chemistry and various aspects of dye chemistry.

In the third decade of the 20th century, Marcel Bader (a former professor of the Ecole) and Charles Sunder from Mulhouse reacted leuco-indigo with chlorosulfonic acid in the presence of pyridine and thus obtained the disulfuric ester of the leuco-indigo. Its so-

dium salt, “known as Indigosol O is water soluble, resistant to alkali and can be converted into indigo by treatment with acid in the presence of oxidizing agents”[75]. Indigosols [76] much simplified the dyeing process.

In 1930, as part of the evolution of the Ecole, «la Fondation de l'Ecole Supérieure de Chimie de Mulhouse», a private establishment, but recognised of public utility, was created. In 1934, a course on plastic materials, which was innovative for that time, was introduced in the teaching program of the Ecole.

Organic chemistry was taught by Georges Mignonac (1889–1993) and Jean Lichtenberger (*vide infra*). Mignonac was a former pupil of the Nobel laureate Paul Sabatier [77] and gave his name to the synthesis [78] of primary amines from aldehydes or ketones, in presence of NH_3 , H_2 and Ni catalyst. P. Mondain-Monval, a former pupil of Le Chatelier, taught physical chemistry, while A. Perret, G. Hugel and R. Flatt were in charge of analytical chemistry. Flatt's research dealt with uranium compounds [79] and with solvation [80]. In 1937, Léon Denivelle [81] (1905–1992) became the chief of a laboratory focused on rubber research.

A textile chemist specializing in artificial silk and a former collaborator of Noelting's, Emile Bronnert [82] (1868–1928) founded, in 1924, after developing a factory in Niedermorschwiller, the silk factory «Soieries de Strasbourg».

During WWII, the Ecole moved to Toulouse in 1939, then to Lyon in 1941. Martin Battégay, a victim of the anti-semitic laws adopted by the Vichy government, had to stop his activities as professor and director of the Ecole in 1941. The organic chemist Jean Lichtenberger [83] (1889–1984) became the new director of the Ecole. His work dealt with the study of aldehydes, with organofluorine derivatives etc.

From 1943 and until the return of the Ecole from Lyon, the Mulhouse buildings of the Ecole were occupied by a German institute of textile chemistry.

5. Chemists in Mulhouse after WWII

Mulhouse was liberated in November, 1944. In 1945, the Ecole went back to Mulhouse from Lyon and picked up again its teaching and research [84] activities [85]. In 1957, the Ecole was attached to the University of Strasbourg, then in 1972 to the Centre Universitaire du Haut-Rhin (CUHR). A decree from 1977 granted the Ecole the status of a public establishment, thus becoming a national advanced school.

Jean Lichtenberger kept his position of director until 1957. From 1957 to 1974, the Ecole was directed by Jean Meybeck [86] (1909–2008), a CNRS silver medallist (1956) who performed research in the field of dyes and polymers, and worked on the photo-degradation of oligopeptides. In 1947, he founded with Lichtenberger the Centre de Recherches Textiles de Mulhouse (CTRM; Mulhouse Centre for Textile Research).

The first president of the Université de Haute-Alsace [87], created in Mulhouse in 1975, was Jean-Baptiste Donnet [88], a leading specialist in the physico-chemistry of solid surfaces. He was a former student of Charles Sadron in Strasbourg and directed the Ecole from 1974 to 1977. He was also a president of the Société Française de Chimie (1989–1994).

Many other valuable chemists worked or studied at Mulhouse after the WWII - and we can cite here as an example, two members of the Académie des Sciences, a former professor (Michel Rohmer [91]) and a former pupil (Pierre Braunstein [89]) of the Ecole - but it would be difficult to list them all, and, what is more, this would considerably exceed the time-related limit (i.e. the 1st half of the 20th century) of the topic of this very short article.

6. Conclusions

Although its history was dramatically perturbed by the wars from the second half of the 19th century to the first half of the 20th century, the city of Mulhouse managed to preserve its rich chemical traditions which are, like those of Strasbourg [90], a part of Alsatian chemistry. This was due to the strong base of its chemistry in local industry and to the prestige of both those who conducted research and those who were educated in the Ecole de Chimie. It is understandable that a scientist of the eminence of Alfred Werner - who ultimately made such a fundamental contribution to contemporary understanding of metal ion behaviour - should have been nurtured by this environment.

Acknowledgement

We thank Professor Jean Michel Chézeau for his very helpful suggestions.

References

- [1] See, for example: (a) P. Karrer, *Helv. Chim. Acta* 3 (1920) 196; (b) P. Karrer, *Helv. Chim. Acta* 49 (1966) 7; (c) G. Schwarzenbach, *Helv. Chim. Acta* 50 (1967) 38; (d) L.H. Gade, *Chem. Unserer Zeit* 36 (2002) 168; (e) G.B. Kauffman, *J. Chem. Educ.* 53 (1976) 445.
- [2] G.B. Kauffman, Alfred Werner Founder of Coordination Chemistry, Springer-Verlag, Berlin, 1966.
- [3] (a) Société Industrielle de Mulhouse, *Histoire documentaire de l'industrie de Mulhouse et de ses environs au XIXe siècle (enquête centennale)*, Veuve Bader & Cie, Mulhouse, 1902; (b) G. Livet, R. Oberlé, *Histoire de Mulhouse des origines à nos jours*, Editions des Dernières Nouvelles d'Alsace - ISTRAL - Willy Fischer, Strasbourg, 1977, especially pp. 185–187, 424–429; (c) M. Hau, *L'industrialisation de l'Alsace (1803–1939)*, Association des Publications près les Universités de Strasbourg, Strasbourg, 1987, especially pp. 129–139, 366–370, 403–406; (d) S. Jonas, *Le Mulhouse industriel. Un siècle d'histoire urbaine 1740–1848*, vol. 1, L'Harmattan, 1994, especially pp. 32–37, 117–150, 167–176; (e) B. Vogler, M. Hau, *Histoire économique de l'Alsace*, La Nuée Bleue, 1997, pp. 94–96, 188–193; (f) P. Fluck, *Mulhouse, trésors d'usines*, Le Verger Éditeur, 2011.
- [4] (a) P. Mieg, *Bull. Soc. Ind. Mulhouse* 2–3 (1948) 21; (b) École Supérieure de Chimie de Mulhouse, *Recherches et travaux des professeurs et anciens élèves 1822–1972*; (c) See also: R. Fox, *Culture Technique* 18 (1988) 10.
- [5] (a) For the history of Mulhouse, see: E. Meininger, *Histoire de Mulhouse, Le Livre d'histoire/Lorisse*, Paris, 1999; (b) G. Livet, R. Oberlé, *Histoire de Mulhouse des origines à nos jours, Dernières Nouvelles d'Alsace - Istra - Willy Fischer*, Strasbourg, 1977.
- [6] L.-G. Werner, *Bull. Soc. Ind. Mulhouse* 2–3 (1948) 16.
- [7] (a) E. Meininger, *Histoire de Mulhouse, Le Livre d'histoire/Lorisse*, Paris, 1999, pp. 81–86; (b) S. Jonas, *Le Mulhouse industriel. Un siècle d'histoire urbaine 1740–1848*, vol. 1, L'Harmattan, 1994, p. 35.
- [8] R. Fox, *Brit. J. Hist. Phil. Sci.* 17 (1984) 128.
- [9] (a) M. Hau, *L'industrialisation de l'Alsace (1803–1939)*, Association des Publications près les Universités de Strasbourg, Strasbourg, 1987, p. 131; (b) Société Industrielle de Mulhouse, *Histoire documentaire de l'industrie de Mulhouse et de ses environs au XIXe siècle (enquête centennale)*, Veuve Bader & Cie, Mulhouse, 1902, p. 585, 587 and 589.
- [10] (a) M. Hau, *L'industrialisation de l'Alsace (1803–1939)*, Association des Publications près les Universités de Strasbourg, Strasbourg, 1987, p. 131–133; (b) J. Sakudo, *Les entreprises de la chimie en France de 1860 à 1932*, P.I.E. Peter Lang, Bruxelles, 2011, pp. 87–91; (c) C. Simon in *The Chemical Industry in Europe, 1850–1914: Industrial Growth, Pollution and Professionalization*, ed. E. Homburg, A. S. Travis and H. G. Schröter, Kluwer Academic Publishers, 1998, p. 18.
- [11] M. Hau, *L'industrialisation de l'Alsace (1803–1939)*, Association des Publications près les Universités de Strasbourg, Strasbourg, 1987, p. 135.
- [12] Société Industrielle de Mulhouse, *Histoire documentaire de l'industrie de Mulhouse et de ses environs au XIXe siècle (enquête centennale)*, Veuve Bader & Cie, Mulhouse, 1902, p. 583.
- [13] About the Alsatian chemical industry, see: (a) M. Hau, *L'industrialisation de l'Alsace 1803–1939*, thèse de doctorat d'Etat, Université de Paris X Nanterre, 1985, tome I, pp. 228–243, and tome II, pp. 630–637; (b) L. Denivelle, *Bull. Soc. Ind. Mulhouse* 801 (1986) 47; (c) C. Pointet, *Bull. Soc. Ind. Mulhouse* 1–2 (1950) 65; (d) See also: A. Penot, *Bull. Soc. Ind. Mulhouse* 44 (1874) 145.

- [14] For the history of this school, see: (a) Histoire de l'Ecole de Chimie de Mulhouse, publiée à l'occasion du 25e anniversaire d'enseignement de M. le Dr Emilio Noelting, Imprimerie alsacienne anct G. Fischbach, 1905; (b) J. Lichtenberger, Bull. Soc. Ind. Mulhouse 3 (1947) 21; (c) J. Meybeck, Bull. Soc. Ind. Mulhouse 752 (1973) 35; (d) P. Brandt, Bull. Soc. Ind. Mulhouse 752 (1973) 40; (e) J.-M. Chézeau, Bull. Soc. Ind. Mulhouse 828 (1993) 49; (f) J.-M. Chézeau, Bull. Soc. Ind. Mulhouse 836 (1997) 15; (g) J. Meybeck, J.-M. Dolle, Bull. Soc. Ind. Mulhouse 836 (1997) 23; (h) Bull. Soc. Ind. Mulhouse 836 (1997) 117.
- [15] (a) P. Leuilliot, Bull. Soc. Ind. Mulhouse (1954) 111; (b) R. Oberlé, Nouveau Dictionnaire de Biographie Alsacienne (NDBA), vol. 29, Fédération des Sociétés d'Histoire et d'Archéologie d'Alsace, 1997, p. 2962.
- [16] A. Penot, Ann. Sci. Ind. Midi France 1 (1832) 97.
- [17] Penot, Bull. Soc. Ind. Mulhouse 24 (1852) 246.
- [18] Penot, Bull. Soc. Ind. Mulhouse 15 (1841) 83.
- [19] (a) F. Ott, La Société Industrielle de Mulhouse 1826–1876: ses membres, son action, ses réseaux, Presses Universitaires de Strasbourg, Strasbourg, 1999; (b) F. Ott, La Société Industrielle de Mulhouse au temps de l'Empire Allemand 1871–1918, Société Industrielle de Mulhouse, Mulhouse, 2004; (c) Bull. Soc. Ind. Mulhouse 764 (1976); (d) S. Jonas, Le Mulhouse industriel. Un siècle d'histoire urbaine 1740–1848, vol. 1, L'Harmattan, 1994, pp. 117–150.
- [20] F. Ott, J.M. Chézeau, in: U. Fell (Ed.), Chimie et industrie en Europe: l'apport des sociétés savantes industrielles du XIXe siècle à nos jours, Edition des Archives contemporaines, Paris, 2001, pp. 109–126.
- [21] (a) T.L. Davis, J. Chem. Educ. 6 (9) (1929) 1403; (b) G. Emptoz, Bull. Soc. Ind. Mulhouse 833 (1994) 44; (c) G. Emptoz, in: The Chemical Industry in Europe, 1850–1914: Industrial Growth, Pollution and Professionalization, ed. E. Homburg, A. S. Travis and H. G. Schröter, Kluwer Academic Publishers, 1998, pp. 293–304; (d) G. Emptoz in Itinéraires de chimistes, L. Lestel (Ed.), EDP Sciences, 2007, pp. 489–493.
- [22] C. Elschenbroich, Organometallics, Wiley-VCH Verlag GmbH & Co., 2006, p. 4.
- [23] P. Schützenberger, C. R. Acad. Sci. 61 (1865) 485.
- [24] (a) P. Schützenberger, C.R. Acad. Sci. 69 (1869) 196; (b) A. Bernthsen, Ber. Dtsch. Chem. Ges. 13 (1880) 2277; (c) A. Bernthsen, M. Bazlen, Ber. Dtsch. Chem. Ges. 33 (1900) 126; (d) H. Bucherer, A. Schwalbe, Z. angew. Chem. 17 (1904) 1447.
- [25] (a) P. Schützenberger, Ann. Chim. Phys. 20 (1870) 351; (b) J.G. de Vries, R.M. Kellogg, J. Org. Chem. 45 (1980) 4126.
- [26] (a) A. Haller, Bull. Soc. Chim. Fr. 21 (1917) I; (b) A.C. Déré, Bull. Soc. Ind. Mulhouse 833 (1994) 65; (c) A.-C. Déré, The Chemical Industry in Europe, 1850–1914: Industrial Growth, Pollution and Professionalization, ed. E. Homburg, A. S. Travis and H. G. Schröter, Kluwer Academic Publishers, 1998, pp. 305–320.
- [27] A. Rosenstiehl, Ber. Dtsch. Chem. Ges. 9 (1876) 946.
- [28] (a) D. Stehelin, L. Strauss, Nouveau Dictionnaire de Biographie Alsacienne, vol. 33, Fédération des Sociétés d'Histoire et d'Archéologie d'Alsace, 1999, pp. 3426–3428; (b) J.-C. Richez, Encyclopédie de l'Alsace, vol. 11, Editions Publitotal, Strasbourg, 1985, pp. 6723–6724; (c) J.-M. Chézeau, in Itinéraires de chimistes, L. Lestel (Ed.), EDP Sciences, 2007, pp. 483–487.
- [29] A. Scheurer-Kestner, Pouvoir calorifique des combustibles solides, liquides et gazeux, G. Masson, Paris, 1896.
- [30] (a) A. Rohmer in Nouveau Dictionnaire de Biographie Alsacienne, vol. 20, Fédération des Sociétés d'Histoire et d'Archéologie d'Alsace, 1993, pp. 1939–1940; (b) J.-C. Richez, Encyclopédie de l'Alsace, vol. 7, Editions Publitotal, Strasbourg, 1984, pp. 4456–4457.
- [31] L. Pasteur, C. R. Acad. Sci. 36 (1853) 19.
- [32] R. Oberlé, Nouveau Dictionnaire de Biographie Alsacienne, vol. 21, Fédération des Sociétés d'Histoire et d'Archéologie d'Alsace, 1993, p. 2051.
- [33] (a) J.-C. Richez, Encyclopédie de l'Alsace, vol. 8, Editions Publitotal, Strasbourg, 1984, pp. 4544–4545; (b) R. Oberlé in Nouveau Dictionnaire de Biographie Alsacienne, vol. 21, Fédération des Sociétés d'Histoire et d'Archéologie d'Alsace, 1993, p. 2055.
- [34] R. Oberlé, R. Schmitt, Nouveau Dictionnaire de Biographie Alsacienne, vol. 4, Fédération des Sociétés d'Histoire et d'Archéologie d'Alsace, 1984, p. 288.
- [35] R. Oberlé, Nouveau Dictionnaire de Biographie Alsacienne, vol. 8, Fédération des Sociétés d'Histoire et d'Archéologie d'Alsace, 1985, p. 677.
- [36] R. Oberlé, Nouveau Dictionnaire de Biographie Alsacienne, vol. 34, Fédération des Sociétés d'Histoire et d'Archéologie d'Alsace, 1999, p. 3573.
- [37] R. Oberlé, Nouveau Dictionnaire de Biographie Alsacienne, vol. 22, Fédération des Sociétés d'Histoire et d'Archéologie d'Alsace, 1994, p. 2064.
- [38] M. Mieg, Bull. Mus. Hist. Mulhouse (1891) 74–76.
- [39] R. Oberlé, Nouveau Dictionnaire de Biographie Alsacienne, vol. 36, Fédération des Sociétés d'Histoire et d'Archéologie d'Alsace, 2000, p. 3745.
- [40] (a) About Alfred Paraf see: The New York Times, May 1st 1885. Paraf was born on June 10th 1844 at Mulhouse. Birth certificate n° 509; (b) Paraf's works include: (1) a paper with Schützenberger on the dying matter from dyer's rocket (Reseda luteola); P. Schützenberger, A. Paraf, Bull. Soc. Chim. Paris, (1861) 18; (2) papers on the aniline black, e.g. A. Paraf, Polytechnisches Journal 178 (1865) 389; (3) patents on: the manufacture of ammonia (US67447 of August 6th 1867), on dyeing and printing textile fabrics and yarns (US60546 of December 18th 1866), on purification and separation of fats (US137564 of April 8th 1873) etc.
- [41] A.S. Travis, Technology and culture 35 (1994) 70. especially p. 97.
- [42] (a) J.-P. Eberhart, Encyclopédie de l'Alsace, vol. 6, Editions Publitotal, Strasbourg, 1984, pp. 3216–3218; (b) M. Brini, Nouveau Dictionnaire de Biographie Alsacienne, vol. 12, 1988, p. 1044; (c) J. Wyart, The new crystallography in France, in: P.P. Ewald (ed.), Fifty Years of X-ray Diffraction, published for The International Union of Crystallography, A. Oosthoek's Uitgeversmij, Utrecht, 1962, pp. 446–455 (especially pp. 446–447 and 451); (d) O.B.M. Hardouin Duparc, J. Mater. Sci. 46 (2011) 4116; (e) J. Friedel, Graine de mandarin, Editions Odile Jacob, 1994, pp. 89–114.
- [43] G. Friedel, Etats mésomorphes de la matière, Annales de Physique 18 (1922) 273.
- [44] (a) D. Kritchevsky, J. Chem. Educ. 36 (1959) 196; (b) H. Newesely, Chromatographia 30 (9–10) (1990) 595; (c) L.S. Ettre, K.I. Sakodynskii, Chromatographia 35 (5–6) (1993) 329; (d) L.S. Ettre, Chromatographia 54 (5–6) (2001) 409.
- [45] (a) F. Reverdin, A. Pictet, Helv. Chim. Acta 6 (1923) 110; (b) N. Chézeau, J.-M. Chézeau, Bull. Soc. Ind. Mulhouse 833 (1994) 81; (c) J.-P. Fleury, Bull. Soc. Ind. Mulhouse 833 (1994) 91.
- [46] See for example: (a) E. Noelting, O. Kohn, Ber. Dtsch. Chem. Ges. 17 (1884) 370; (b) E. Noelting, A. Collin, Ber. Dtsch. Chem. Ges. 17 (1884) 268; (c) E. Noelting, E. Wild, Ber. Dtsch. Chem. Ges. 18 (1885) 1338; (d) E. Noelting, T. Baumann, Ber. Dtsch. Chem. Ges. 18 (1885) 1150; (e) E. Noelting, E. Weingärtner, Ber. Dtsch. Chem. Ges. 18 (1885) 1340; (f) E. Noelting, O. Kohn, Ber. Dtsch. Chem. Ges. 19 (1886) 146; (g) E. Noelting, T. Stricker, Ber. Dtsch. Chem. Ges. 19 (1886) 546; (h) E. Noelting, C. Geissmann, Ber. Dtsch. Chem. Ges. 19 (1886) 144; (i) E. Noelting, B. Pick, Ber. Dtsch. Chem. Ges. 21 (1888) 3158; (j) E. Noelting, B. Pick, Ber. Dtsch. Chem. Ges. 21 (1888) 3150; (k) E. Noelting, L. Stoecklin, Ber. Dtsch. Chem. Ges. 24 (1891) 564; (l) E. Noelting, E. Fourneaux, Ber. Dtsch. Chem. Ges. 30 (1897) 2930; (m) E. Noelting, K. Dziołowski, Ber. Dtsch. Chem. Ges. 39 (1905) 3516; (n) E. Noelting, V. Kadiera, Ber. Dtsch. Chem. Ges. 39 (1906) 2056; (o) E. Noelting, P. Gerlinger, Ber. Dtsch. Chem. Ges. 39 (1906) 2053; (p) E. Noelting, K. Dziołowski, Ber. Dtsch. Chem. Ges. 39 (1906) 2744; (q) E. Noelting, K. Philipp, Ber. Dtsch. Chem. Ges. 41 (1908) 579; (r) E. Noelting, A. Herzbaum, Ber. Dtsch. Chem. Ges. 44 (1911) 2585.
- [47] G.B. Kauffman, Alfred Werner. Founder of Coordination Chemistry, Springer-Verlag, Berlin, 1966.
- [48] J. Tambor, Ber. Dtsch. Chem. Ges. 45 (1912) 1683.
- [49] (a) S. von Kostanecki, Ber. Dtsch. Chem. Ges. 20 (1887) 3137; (b) S. von Kostanecki, Ber. Dtsch. Chem. Ges. 20 (1887) 3146; (c) S. von Kostanecki, Ber. Dtsch. Chem. Ges. 20 (1887) 3133; (d) S. von Kostanecki, B. Feinstein, Ber. Dtsch. Chem. Ges. 21 (1888) 3119; (e) S. von Kostanecki, Ber. Dtsch. Chem. Ges. 21 (1888) 3109; (f) S. von Kostanecki, Ber. Dtsch. Chem. Ges. 22 (1889) 1347; (g) S. von Kostanecki, Ber. Dtsch. Chem. Ges. 22 (1889) 3163; (h) S. von Kostanecki, Ber. Dtsch. Chem. Ges. 22 (1889) 1342.
- [50] S. von Kostanecki, A. Różycki, Ber. Dtsch. Chem. Ges. 34 (1901) 102.
- [51] H. Dahn, T. Reichstein, Helv. Chim. Acta 35 (1952) 1.
- [52] (a) H. Rupe, G. Heberlein, Ber. Dtsch. Chem. Ges. 28 (1895) 1717; (b) H. Rupe, Ber. Dtsch. Chem. Ges. 29 (1896) 829; (c) H. Rupe, G. Heberlein, Ber. Dtsch. Chem. Ges. 29 (1896) 622; (d) H. Rupe, J. Všečeka, Ber. Dtsch. Chem. Ges. 30 (1897) 1101.
- [53] H. Rupe, Ber. Dtsch. Chem. Ges. 30 (1897) 2444.
- [54] H. Rupe, H. Labhardt, Ber. Dtsch. Chem. Ges. 33 (1900) 233.
- [55] H.S. Mosher, T.T. Tidwell, J. Chem. Educ. 67 (1) (1990) 9.
- [56] H. Goldstein, Helv. Chim. Acta 15 (1932) 315.
- [57] (a) F. Kehrmann, Ber. Dtsch. Chem. Ges. 41 (1908) 4357; (b) F. Kehrmann, A. Stépanoff, Ber. Dtsch. Chem. Ges. 41 (1908) 4133; (c) F. Kehrmann, O. Dengler, Ber. Dtsch. Chem. Ges. 41 (1908) 3440; (d) F. Kehrmann, Ber. Dtsch. Chem. Ges. 41 (1908) 2340; (e) F. Kehrmann, J. Riera y Puntí, Ber. Dtsch. Chem. Ges. 44 (1911) 2618.
- [58] J.M. Chézeau, L'Actualité Chimique 370 (2013) 36.
- [59] (a) E. Grandmougin, Ber. Dtsch. Chem. Ges. 44 (1911) 3756; (b) E. Grandmougin, Ber. Dtsch. Chem. Ges. 47 (1914) 384; (c) E. Grandmougin, K. Smirous, Ber. Dtsch. Chem. Ges. 46 (1913) 3425; (d) E. Grandmougin, P. Seyder, Ber. Dtsch. Chem. Ges. 47 (1914) 2365; (e) E. Grandmougin, S. Favre-Ambrumyan, Ber. Dtsch. Chem. Ges. 47 (1914) 2127.
- [60] (a) A. Binz, Z. angew. Chem. 28 (1915) 193; (b) Ber. Dtsch. Chem. Ges. 49 (1916) 1751.
- [61] R. Oberlé, Nouveau Dictionnaire de Biographie Alsacienne, vol. 21, 1993, p. 2057.
- [62] (a) A. Pabst, Bull. Soc. Chim. Fr. 38 (1882) 160; (b) G.F.B., Am. J. Sci. [3], 24 (1882) 467.
- [63] T.E. Thorpe, Nature 95 (2372) (1915) 179.
- [64] (a) A. Baur-Thurgau, Ber. Dtsch. Chem. Ges. 31 (1898) 1344; (b) A. Baur, Ber. Dtsch. Chem. Ges. 24 (1891) 2832; (c) A. Baur-Thurgau, A. Bischler, Ber. Dtsch. Chem. Ges. 32 (1899) 3647.
- [65] (a) W. Feuerstein, Ber. Dtsch. Chem. Ges. 34 (1901) 1804; (b) W. Feuerstein, M. Dutoit, Ber. Dtsch. Chem. Ges. 34 (1901) 2637; (c) W. Feuerstein, M. Heimann, Ber. Dtsch. Chem. Ges. 34 (1901) 1468; (d) W. Feuerstein, A. Musculus, Ber. Dtsch. Chem. Ges. 34 (1901) 409;

- (e) W. Feuerstein, Ber. Dtsch. Chem. Ges. 34 (1901) 415;
(f) W. Feuerstein, A. Lipp, Ber. Dtsch. Chem. Ges. 35 (1902) 3252;
(g) W. Feuerstein, K. Brass, Ber. Dtsch. Chem. Ges. 37 (1904) 821;
(h) W. Feuerstein, K. Brass, Ber. Dtsch. Chem. Ges. 37 (1904) 827.
- [66] (a) C. Marschalk, Ber. Dtsch. Chem. Ges. 45 (1912) 582;
(b) C. Marschalk, Ber. Dtsch. Chem. Ges. 45 (1912) 1481.
- [67] (a) C. Gassmann, Ber. Dtsch. Chem. Ges. 29 (1896) 1243;
(b) C. Gassmann, Ber. Dtsch. Chem. Ges. 29 (1896) 1521.
- [68] Revue générale des matières colorantes et des industries qui s'y rattachent 342 (1925) 177.
- [69] M. Hau, L'industrialisation de l'Alsace (1803-1939), Association des Publications près les Universités de Strasbourg, Strasbourg, 1987, p. 136.
- [70] E. Noelting, G. Thesmar, Ber. Dtsch. Chem. Ges. 35 (1902) 628.
- [71] E. Langlinay, in: Itinéraires de chimistes, L. Lestel (Ed.), EDP Sciences, 2007, pp. 507–511.
- [72] (a) J. Lichtenberger, Bull. Soc. Ind. Mulhouse n° spécial 1 (1962) 11;
(b) R. Oberlé, Nouveau Dictionnaire de Biographie Alsacienne, vol. 2, 1983, pp. 123–127.
- [73] E. Noelting, M. Battegay, Ber. Dtsch. Chem. Ges. 39 (1906) 79.
- [74] M. Battegay, P. Boehler, C. R. Acad. Sci. 203 (1936) 333.
- [75] W. Christ, J. Soc. Dyers Colour. 54 (1938) 95.
- [76] (a) F. Brunello, The art of dyeing in the history of mankind, Neri Pozza Editore, Vicenza, 1973, p. 306;
(b) A.K.R. Choudhury, Textile preparation and dyeing, Science Publisher, 2006.
- [77] (a) Chimie Strasbourg, edited by the Association amicale des anciens élèves de l'Ecole Nationale Supérieure de Chimie de Strasbourg, vol. 6, 1969, pp. 11–12.;
(b) P. Bieber, Chimie Strasbourg, edited by the Association amicale des anciens élèves de Ecole des Hautes Etudes des Industries Chimiques de Strasbourg, vol. 59, 1990, pp. 3–4.
- [78] (a) G. Mignonac, C.R. Acad. Sci. 172 (1921) 223;
(b) See also: G.N. Schrauzer, R.J. Windgassen, Nature 214 (5087) (1967) 492.
- [79] (a) R. Flatt, Helv. Chim. Acta 20 (1937) 894;
(b) R. Flatt, W. Hess, Helv. Chim. Acta 21 (1938) 525;
(c) R. Flatt, W. Hess, Helv. Chim. Acta 21 (1938) 1506.
- [80] R. Flatt, A. Jordan, Helv. Chim. Acta 16 (1933) 37.
- [81] N. Stoskopf, Nouveau Dictionnaire de Biographie Alsacienne, vol. 44, 2004, 4557.
- [82] (a) J. Textile Instit. Proc. 19 (11) (1928) P291;
(b) Nouveau Dictionnaire de Biographie Alsacienne, vol. 5, 1984, p. 371.
- [83] (a) J. Meybeck, Ass. Amicale Anciens Elèves Ecol. Nat. Sup. Chim. Mulhouse. Annuaire 1984–1985, pp. 98–102;
(b) R. Oberlé, Nouveau Dictionnaire de Biographie Alsacienne, vol. 24, 1994, pp. 2359.
- [84] About the research at the Ecole, see: (a) Bull. Soc. Ind. Mulhouse 758 (1975) 61–104;
(b) Bull. Soc. Ind. Mulhouse 792 (1984) 111–120;
(c) Bull. Soc. Ind. Mulhouse 836 (1997) 75–174;
(d) École Supérieure de Chimie de Mulhouse, Recherches et travaux des professeurs et anciens élèves 1822–1972.
- [85] (a) J.-B. Donnet, Bull. Soc. Ind. Mulhouse 836 (1997) 45;
(b) J.-P. Fleury, R. Wey, J.-M. Chézeau, Bull. Soc. Ind. Mulhouse 836 (1997) 47;
(c) J. Streith, Haute-Alsace et enseignement supérieur: le modèle universitaire mulhousien, Presses universitaires de Strasbourg, Strasbourg, 2009, pp. 162–181.
- [86] R. Oberlé, Nouveau Dictionnaire de Biographie Alsacienne, vol. 26, 1995, p.2628.
- [87] (a) Bull. Soc. Ind. Mulhouse 792 (1984) 31–35;
(b) N. Stoskopf, Université de Haute-Alsace, la longue histoire d'une jeune université, La Nuée bleue, Strasbourg, 2005.
- [88] (a) R. Oberlé, Nouveau Dictionnaire de Biographie Alsacienne, vol. 8, Fédération des Sociétés d'Histoire et d'Archéologie d'Alsace, 1985, pp. 684–685;
(b) P. Delhaes, in: Itinéraires de chimistes, L. Lestel (Ed.), EDP Sciences, 2007, pp. 153–158;
(c) J.-B. Donnet, G. Derai, Bull. Soc. Ind. Mulhouse 792 (1984) 131.
- [89] (a) J.-P. Kintz, Nouveau Dictionnaire de Biographie Alsacienne, vol. 48, Fédération des Sociétés d'Histoire et d'Archéologie d'Alsace, 2007, p. 5070;
(b) An. Real Soc. Esp. Quím. 95 (1999) 22;
(c) See also: <http://dx.doi.org/10.1002/anie.201000183>.
- [90] (a) On Strasbourg and Alsace chemists, see: A.-M. Stadler, J. Harrowfield, Chem. Soc. Rev. 40 (2011) 2061;
(b) P. Federlin, Les Sciences en Alsace 1538–1988, Oberlin, Strasbourg, 1989;
(c) A. Chrétien, Rev. Chim. Ind. 48 (1939) 4;
(d) A. Kastler, Saisons d'Alsace 27 (1968) 343;
(e) L. Zilliox, Rayonnement du CNRS 52 (2009) 15;
(f) La chimie en Alsace, hors-série En Alsace, 2008, pp. 8–25;
(g) A.-M. Stadler, J. Harrowfield, Les personnalités de la chimie en Alsace in Alsace: alchimie d'une terre de savoirs, Carré Blanc, 2011, pp. 89–105;
(h) A.-M. Stadler, J. Ramirez, Le Quinze, May 2012, p. 7.
- [91] (a) J.-P. Lingelser, Nouveau Dictionnaire de Biographie Alsacienne, Fédération des Sociétés d'Histoire et d'Archéologie d'Alsace, vol. 47, 2006, p. 4890;
(b) M. Rohmer Pure Appl. Chem. 75 (2003) 375.