The Evolution of the Secondary Literature in Chemistry

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Abstract

Information scientists and librarians commonly define secondary publications as tools that facilitate identification of relevant primary publications. In this paper, the early history of secondary publications in general is considered briefly, commencing with the first abstracting journal, the *Journal des Sçavans* in 1665. The paper then concentrates on the evolution of the secondary literature in chemistry. Chemistry was one of the first branches of knowledge for which specialist secondary sources were published, the first such publication being Crell's *Chemisches Journal für die Freunde der Naturlehre* in 1778. The reasons for the need for secondary sources in chemistry are examined. Histories of several of the most important secondary sources in chemistry are given, including, in some cases, short biographies of their originators. The differences in editorial policy and criteria for inclusion of publications among the secondary sources are discussed. The organization of information is presented along with how classification schemes were developed to aid retrieval of data and references, since most chemical information requests are based on the need for information about chemical compounds. The evolution of index systems in the pre-computer era, which make use of chemical names and formulae to enable access to chemical information, is described. The ability of systems to deal with new types of substances as they have been discovered is also discussed. A list of major secondary sources in chemistry, both those still published and those that have ceased publication, is given at the end of this article.

Introduction

Information scientists and librarians commonly define secondary publications as tools that facilitate identification of relevant primary publications (Neufeld & Cornog, 1983). They usually provide bibliographic references and brief descriptions as well as subject terms and indexes that can be used to locate many types of primary information sources, such as journal articles, reports, patents, and conference papers. Nowadays, the most common product of such an exercise is a serial publication, either printed or electronic, that covers the literature produced in a specific period.

Every researcher is aware that finding papers on a specific subject can be problematic because of the vast number of journals and other primary sources available. *Chemical Abstracts* today covers approximately nine thousand journals from ninety-three countries in fifty languages, not to mention the patents, conference papers, and other primary sources covered, leading to the publication of about half a million abstracts per year. But when did the volume of literature generated through scholarly research become unmanageable, and how were secondary sources such as *Chemical Abstracts* conceived?

The object of this paper is to consider the origins of the major abstract publications and other secondary literature in chemistry, that is, the publications whose main aim is to organize and index the primary publications, the tools that chemists use or have used to identify primary references. This paper does not consider encyclopedias, monographs, reviews, or works that are purely data compilations and stops short of the computer era. Also excluded are modern publications specifically for current awareness. This paper concentrates on British, American, and German sources, which have traditionally dominated the secondary literature in chemistry.

The Need for Secondary Sources

In the seventeenth and eighteenth centuries the emerging format for learned publication was the journal article. In that period the number of journal titles grew from about thirty-five to about four hundred journal titles. By 1900 there were about 5,000 scientific journal titles being published and 136 abstract journals to cover the articles in these journals (Kaser, 1995). By 1950 there were about 30,000 primary scientific journals. Chemistry was one of the first branches of science to publish abstracts (Crosland, 1994). By the beginning of the twentieth century the pressure on the scientist to keep up to date with the literature was becoming severe and occupied an ever-increasing proportion of the day (Williams, 1977). Thus, abstract journals and other secondary publications came into being. They summarized the material in primary publications to indicate the content of the original papers and acted as a tool for tracing relevant references. From them the reader could judge whether it was worthwhile reading the original article.

Origins of Abstracts

The collection and organization of knowledge can be traced back five thousand years to clay tablets and papyrus scrolls (Skolnik, 1982). The invention of the printing press around 1450 heralded the beginning of the information age, enabling information to be published, stored, and disseminated as never before. Abstracts originated in the Middle Ages; the word abstract is derived from the Latin *abstractus*, meaning "to draw away." Monks would often write marginalia summarizing documents they were transcribing. Kings often required their generals and ambassadors to write summaries of their reports, and since the eleventh century, the Vatican has abstracted reports from its envoys.

On 5 January 1665 Denis de Sallo issued the first number of the first published abstract journal, *Journal de Sçavans*, which was published weekly (Cooper, 1982; Collison, 1971a, 1971b). The journal was part reviews and part abstracts, and each item occupied about half a page. The summaries or reviews covered books, decrees, or informative letters, with the primary publication's author, title, and place of publication. De Sallo can therefore be considered the inventor of the abstract journal, although he was only personally involved for the first thirteen issues. The journal continued until 1792.

Other early abstract publications include the *Nouvelles de la République des Lettres* (1684–1718) and *Histoire des Ouvrages des Savans* (1687–1706; 1708–1709), both published by French people living in exile. The first German abstract publication was *Monatsextracte*, which commenced in 1703. The famous *Aufrichte*, which abstracted about forty journals, was published between 1714 and 1717. The first abstract journals published in England were the *Universal Magazine of Knowledge and Pleasure* (1747–1815) and the *Monthly Review* (1749–1844).

Origins of Abstracts in Chemistry

Abstracts in Primary Journals

It became common for primary scientific journals to publish abstracts of work reported elsewhere in addition to original papers, often in separate sections titled "News from the Literature" or something similar. The *Philosophical Transactions of the Royal Society*, for example, published abstracts. The first such publication in chemistry was *Crell's Chemische Journal für die Freunde der Naturlehre* (1778–81). This was the first in a series of journals published by Lorenz Florenz Friedrich von Crell (1744–1816), a professor at Braunschweig and then Helmstadt and Göttingen. Subsequent publications were *Chemisches Annalen für die Naturlehre, Arzneygelahrtheit, Haushaltungskunst und Manufacturen* (1784–1803), *Beiträge zu den chemischen Annalen* (1785–99), and *Neueschemisches Archiv* (1784–91). These provided a forum for German chemists to exchange their views and aided dissemination of information. They became models for publications in Germany and elsewhere. A number of French chemistry journals published abstracts (Crosland, 1994), including *Bulletin de la Société Chimique de France* (from 1863), *Annales de Chimie* (from 1851), and *Comptes Rendus*, the last composed mainly of abstracts because of its inability to attract original work. The Deutsche Chemische Gesellschaft published abstracts in its *Berichte* from 1868 to 1896. (In 1896 it assumed responsibility for publishing *Chemisches Zentralblatt*.) In Britain abstracts were published in the *Journal of the Chemical Society*, beginning in 1871, and *Journal of the Society of Chemical Industry* beginning in 1882 (Whiffen, 1991). Another British journal to publish abstracts was *The Analyst*. A number of current primary journals still publish abstracts in this way.

Early Secondary Chemistry Sources in Germany and France

Chemistry was one of the first subjects to have secondary publications. Berzelius was prompted by the increasing amount of journal literature to begin *Jahresberichte über die Forschritte der physichen Wissenschaften* in 1829, the first review journal that concentrated on chemistry, continuing for over twenty-five years. According to Crosland (1994), abstracts were first published in France in 1858 by the Société Chimique de France in the *Répertoire de Chimie Pure.* Crosland quotes Charles Adolphe Wurtz, the editor of *Répertoire*, "This journal is intended to put the public of our country in touch with the progress of pure chemistry in France and abroad. A publication of this kind does not yet exist in our scientific literature and seems to meet a real need. It will accept no original work but will offer to the reader a summary [of what has been published elsewhere]." There was also the *Répertoire de Chimie Appliquée*, edited by the French industrial chemist Charles Louis Barreswil, covering applied chemistry (Manzer, 1977). The *Répertoires* were cover-to-cover abstract journals, containing unnumbered abstracts organized into subject categories with annual author and subject indexes. They were replaced by the *Bulletin de la Société Chimique de France*, which in 1863 started to publish abstracts.

Funding and Sponsorship

Funding and sponsorship of secondary publications came from personal sponsors, learned and professional societies, industrial research institutes, government agencies, and commercial enterprises (Cooper, 1982). In the nineteenth century the Société Chimique de France, Deutsche Chemische Gesellschaft, Chemical Society, and Society of the Chemical Industry were important sponsors. A strong chemical, and later pharmaceutical, industry had created extraordinary demand for chemical information. Chemistry's industrial links have always ensured that funding is available for research into the organization and dissemination of chemical information. Between 1900 and 1945 there was exceptional growth in the chemical industry, an increase in the number of chemists and engineers, and a corresponding growth in the literature. Nevertheless, secondary sources were not guaranteed to be commercial successes (Whiffen, 1991).

The Language of Chemistry

According to Bowman (1974), most requests for chemical information focus on chemical compounds, with chemists commonly asking questions of the following types: What are the properties of this compound? How can I make this compound? What compounds have the following properties? What compounds similar to this one exist? It has been estimated that approximately 85 percent of index entries in the 1966 subject index to *Chemical Abstracts* are associated with compounds and materials (Tate, 1967; Whittingham, Wetsel, & Morgan, 1966). Information retrieval systems must be able to provide answers to these questions. The early producers of secondary information sources in chemistry recognized the central role of the chemical compound and developed systems accordingly.

Unlike some other scientists and technologists, chemists often consult older literature. Tate (1967) suggested that it was not uncommon for chemists to go back sixty years and find immediately useful information. This is borne out by the present author's experience of working in a chemistry library, where material up to a hundred years old can still be of use, particularly to organic chemists. The information required, as stated above, is usually concerned with chemical structures, hence the importance of understanding older chemical indexing and nomenclature systems even today.

The development of the language of chemistry is beyond the scope of this paper and is well documented (Crosland, 1962). Communication of chemical substance information depended initially on trivial names before systematic nomenclature schemes were devised. Use of trivial names and different systematic nomenclature systems can create problems. Chemical names vary between languages; for example, many early secondary sources were in German, a problem for non-German speakers. Other problems arise with complicated structures. Although the publishers of the secondary sources employ nomenclature experts who standardize chemical names, few practicing chemists have sufficient knowledge of the nomenclature schemes used by different sources to allow derivation of accurate names. This disjunct between designers and users has commonly led to the production of empirical formula indexes, although these do not solve the problem completely, as often many structures can be drawn from one empirical formula.

Computers solve many of these problems by enabling the two- or three-dimensional structure to be the means of communication. In the pre-computer era some secondary sources overcame these problems in part by use of innovative classification schemes for compounds, which could appear complex but, once mastered, ensured effective retrieval of information. Such schemes were used in the *Beilstein Handbuch der organischen Chemie* and *Gmelin Handbuch der anorganischen Chemie*.

Gmelin's *Handbuch der Anorganischen Chemie*

An early information source is the *Gmelin Handbuch der anorganischen Chemie,* founded by Leopold Gmelin (1788–1853). Some might consider the Gmelin and Beilstein handbooks to be tertiary sources of information, (defined by Mellon [1965] as aids to searching the secondary and primary sources, such as guides to the literature or publications that provide facts about chemists and their work, for example, directories and dictionaries; they are more often used by librarians than practicing chemists), but they are so frequently considered the main sources alongside *Chemical Abstracts* that they are discussed here.

Gmelin's Life

Leopold Gmelin came from a family closely involved with chemistry (Gillespie, 1970–1980). Gmelin graduated in 1804 and then worked in the family apothecary in Tübingen. During the period from 1700 to 1860 (Walden, 1954) about a dozen members of the Gmelin family were professors in the three university cities of Tübingen, Heidelberg, and Göttingen. Apparently three kinds of Gmelin professors were referred to: those who had passed away, those on the lecture platform, and those in the cradle. Walden reproduces a family tree of the chemistry professors, derived from the publication *Stammbaum der Familie Gmelin* published in Karlsruhe in 1877.

Gmelin was awarded his medical doctorate in 1812, but he was also trained as a chemist and had a keen interest in mineralogy and geology. Gmelin was appointed docent at Heidelberg in 1813, became extraordinary professor in 1814, and was appointed director of the Chemical Institute in 1817. Gmelin worked hard to improve the teaching of chemistry, but he also continued his research. He published papers on physiology, inorganic and organic chemistry, mineralogy, and the theory of chemistry.

The Handbuch

The first edition of Gmelin's *Handbuch* was published in three thin volumes between 1817 and 1819, as *Handbuch der theoretischen Chemie* (*Handbook of Pure Chemistry*). In this book Gmelin reviewed all chemistry, organic as well as inorganic (Skolnik, 1982). The book was conceived to assist Gmelin with his lectures, but it was commercially very successful. His aim was "to arrange systematically all the precisely determined facts concerning every element and compound, to state these facts succinctly and accurately, and also give the pertinent references to the literature" (Walden, 1954). He used the term "organic chemistry" for the first time in German textbooks; he spoke of "imponderable elements" (heat, light, and electricity), as well as "ponderable elements" (the forty-eight elements known at the time); and he coined some new terms, such as *ester* and *ketone*. Further editions followed quickly, and the organic part of the second edition was translated into French. By the time of the fourth edition, published between 1843 and 1852, the work had changed its name to *Handbuch der Chemie*. By 1870 there were ten volumes. The handbook was the most important book of chemistry for more than a generation, and it had a remarkable impact on the development of the science. In addition to his systematic organization of the information within the handbook, Gmelin devised his own arrangement of the fifty-one elements known at the time of the third edition, that is, his own periodic table (*Synergisms in Chemical Information*, 1992). The periodic table organized the known elements in a horseshoe arrangement and was ordered according to the affinities of the elements rather than the atomic number order adopted by Mendeleev and Meyer in 1869. The table was revised in the fourth edition and is now almost forgotten.

Gmelin was solely responsible for the first three editions of the handbook. He also edited the first four volumes of the five-volume fourth edition and the fifth of these volumes was prepared by Gmelin's associates, Karl List and Karl Kraut. They continued the publication on a part-time voluntary basis after his death (part way through the production of the fifth edition). A translation of the fourth edition by H. Watts was published by the Cavendish Society between 1848 and 1872, in nineteen volumes (Skolnik, 1982). The fifth edition was concerned only with inorganic chemistry. In all, five editions had been published in fifty years. The sixth commencing publication in 1872 and seventh editions were edited by Kraut, and the work became known as *Gmelin-Kraut* for that period. In 1921 publication was taken over by the Deutsche Chemische Gesellschaft.

Erich Pietsch served an important role in the progress of the *Handbuch* in the twentieth century (Oesper, 1949). Pietsch was still at the university in Berlin when he was appointed to the editorial staff of the handbook as a part-time assistant. In 1927 he was promoted to an assistant editorship and head of section. In 1935, the Deutsche Chemische Gesellschaft decided to enlarge the staff, and Pietsch was chosen to work out the plan for the expansion and to implement it. He became the head of the Gmelin Institute on 1 January 1936 and continued throughout World War II. After the war conditions were not favorable for production of the handbook, but the British and American governments gave their support as its importance was realized.

In 1946, the Gmelin Institute was placed under the Max Planck Society for the Advancement of Science, in conjunction with the Deutsche Chemische Gesellschaft. The eighth edition is the latest, and in it, Pietsch expanded the scope of the work. The text of the eighth edition was compiled without reference to earlier editions: Each topic is covered by reference to the original sources. By 1948 there were about sixty scientists on the editorial staff and a similar number of technical, presumably production, staff. Pietsch introduced information about ferrous metallurgy, partly because he perceived a gap in the literature, and he added the *Gmelin Patentsammlungen*, coverage that is particularly important for metallurgy. It was prepared in collaboration with the Reichspatentamt. The Max Planck Society decided against producing a ninth edition of the *Handbuch*. Instead, a *New Supplement* series was started in 1970. By the two-hundredth anniversary of his birth in 1988, there were 570 volumes (O'Sullivan, 1988), occupying fifty feet of shelf space, with about twenty volumes being added per year. Since the early 1980s the *Handbuch* has been produced in English. As with Beilstein's *Handbuch der organischen Chemie*, all data in Gmelin's *Handbuch* were critically evaluated.

Organization and Arrangement

As mentioned above, the first edition of the Gmelin handbook dealt with the forty-eight elements or "ponderable substances" known at the time. The meaningful ordering of these was one of Gmelin's major concerns (*Synergisms in Chemical Information,* 1992). First, he differentiated between inorganic and organic compounds. The ponderable inorganic compounds were then organized according to Gmelin's system, such that each volume deals with a different element. A classification scheme exists, with rules that determine in which volume compounds are located. Gmelin's system evolved into the present "principle of last position": Elements are assigned to one of seventy-one system numbers so that those that form anions are assigned lower numbers than those that form cations. The system numbers have no connection with atomic numbers. The information under each element is concerned with the element itself and all compounds that contain it along with other elements that have lower system numbers; for example, hydrogen chloride is discussed in volume 6 (chlorine), as H has System No. 1, and Cl, No. 6; $ZnCl_2$ is in volume 32 (zinc), and $ZnCrO_4$ is in volume 52 (chromium). Each section, or volume, can have supplements that update the work. Within each volume, the information is also arranged systematically: Analytical chemistry comes first, then atomic physics, ore preparation, chemical technology, electrochemistry, geochemistry, history, colloidal chemistry, coordination chemistry, corrosion and passivity, crystallography, economic deposits, metallurgy, mineralogy, physical properties, alloys, toxicity and hazards, and finally production statistics.

Chemisches Zentralblatt

At the age of twenty-nine Gustav Theodor Fechner (1801–87) conceived and edited *Chemisches Zentralblatt*, another early work. In 1817 Fechner matriculated at the University of Liepzig, where he remained for the rest of his life. He took his M.D. there, though he never practiced medicine. He also did research in physics and electricity and was appointed professor of physics in 1834. Later his research moved to psychology, for which he is primarily remembered (Gillespie, 1970–1980).

The *Pharmaceutisches Zentralblatt* began life in 1830. Its name changed in 1850 to *Chemisches und Pharmaceutisches Zentralblatt.* Six years later the name was shortened to *Chemisches Zentralblatt*. Indeed, the *Chemisches Zentralblatt* remained the most important abstracting service for chemistry globally until the World War II, which interfered with the production (Schulz & Georgy, 1994). Publication ceased for a period during the war, and the postwar publication is described by Dyson (1951) as "but a shadow of the pre-war publication." After the war, production was split between the West and East Berlin offices, which proved logistically difficult. The East Berlin office was closed in 1969, and in the same year publication finally ended. The West Berlin office along with Bayer AG continued to publish *Chemischer Informationsdienst*, an independent reference journal, which still continues today as the organic reactions database *ChemInform RX*.

Chemisches Zentralblatt was published weekly, with abstracts grouped under nine main headings, which were subdivided by use of a classification scheme. Initially, the plan was to cover German literature only. However, in 1919, coverage was expanded with the inclusion of the abstracts section of *Angewandte Chemie*, patents from all major industrial nations, and from 1926, notices. But coverage of German material was always superior to that originating in other countries, and abstracts were in German. To enhance its utility, the *Chemisches Zentralblatt* published cumulative indexes.

Beilstein's *Handbuch der organischen Chemie*

Like Gmelin's *Handbuch*, Beilstein's *Handbuch der organischen Chemie* is not an abstracting service but a secondary source that contains evaluated information. Beilstein's objective was to include only compounds and facts that were known to be reliable in terms of current scientific knowledge, so that the user is provided with a "concentrate" of the original literature free from errors and trivial or unvalidated information. Despite the huge growth in the literature, this was the aim of the publishers until recently. This made Beilstein's *Handbuch* different from traditional abstracts, which made no attempt to check the accuracy of the information included.

During the 1970s and 1980s the *Handbuch* became increasingly out of date in its coverage of the literature and suffered losses in its subscription numbers as a result of this, the huge subscription cost, and the slowness of its inevitable transition to publication in English. In the 1990s it is experiencing a resurgence in interest because of the *Beilstein CrossFire* service, now widely used in industry and academia.

Beilstein's Life

Friedrich Konrad Beilstein (1838–1906) was born in St. Petersburg to German parents (Gillespie, 1970–1980). At age fifteen Beilstein was sent to Germany, where he studied in Heidelberg under Bunsen and Kekulé. After two years he moved to Munich and studied under Liebig (Witt, 1909). He returned to Heidelberg where he became interested in organic chemistry. He then moved to Göttingen to study under Wöhler. There he worked on the cyanogen group, which led to his dissertation on murexide, for which he was awarded a doctorate in 1858 at the age of nineteen. In 1860 he was appointed Wöhler's assistant (privatdozent) and, by 1865, professor of organic chemistry. In 1866 he was chosen to succeed Mendeleev as professor at the Imperial Technological Institute of St. Petersburg (Witt, 1909), where he remained for the rest of his life. From 1865 to 1871 he edited *Zeitschrift für Chemie* (founded by Kekulé) along with Fittig and Hübner. In 1881 he was elected to the St. Petersburg Academy of Sciences, which gave him an independent income and laboratory. During the period from 1856 to 1889 Beilstein published more than one hundred experimental contributions to German and French journals (Huntress, 1938), and more in Russian. Over the years Beilstein sacrificed opportunities for original experimental work in order to continue his efforts to produce the *Handbuch*. The last seventeen years of his life were devoted entirely to its production.

Production of the Handbuch der organischen Chemie

Despite his significant research, Beilstein is most remembered for his *Handbuch*. The historical studies of Liebig and Wöhler and also the structural theories of Kekulé, van't Hoff, and Le Bel (stereochemistry) influenced Beilstein's work and provided the stimulus for the reinterpretation and reclassification of the known facts of organic chemistry (Luckenbach, 1981). These factors presumably inspired Beilstein to produce the *Handbuch* as well as his need to keep comprehensive records of the literature for his own research work. The first edition was published in 1881–83 and contained approximately fifteen thousand organic compounds, divided into five sections. The work comprised two volumes (2,200 pages). Only twenty-three journals were covered, and the reference list was twenty-three pages long. The first edition resembled a traditional textbook, with sections on organic analysis and determination of physical constants in addition to data on organic compounds. The publication was a success, selling out within a few months (Richter, 1938). The publishers (Leopold Voss) wished to produce a reprint, but Beilstein insisted on updating the work to create a second edition with corrections to errors and inaccuracies, including those resulting from an incomplete knowledge or understanding of the science when the first edition was published. The second edition consisted of three volumes (4,080 pages, 1885–1889), and the third edition, eight volumes (approximately 11,000 pages, including a supplementary series, 1892–1899; supplement, 1901–1906). The third edition was the last to be produced by Beilstein himself. Although Beilstein requested the help of other chemists in identifying inaccuracies, the production of the *Handbuch* was almost exclusively his work.

Prior to publication of the third edition Beilstein transferred responsibility for publication to the Deutsche Chemische Gesellschaft. Beilstein was concerned about maintenance of the quality of the *Handbuch* and in 1895 he authorized the publishers to approach Professor Paul Jacobson of Heidelberg to continue publication of the work, beginning with a supplement to the third edition. Jacobson, aware of the magnitude of the task, proposed that the *Handbuch* should be merged with the abstracts prepared for *Berichte* and the *Jahresbericht*, under the auspices of the Deutsche Chemische Gesellschaft. Although not entirely happy with this arrangement, Beilstein did agree to pass over his rights as author, and the directors of the society voted to continue the *Handbuch*. Jacobson became the editor to the supplement of the third edition, and Beilstein was satisfied that his *Handbuch* was in safe hands.

There was no formula index to the first three editions, but in 1884 M. M. Richter published his *Lexikon der Kohlenstoff-Verbindungen*, which served as an index to the third edition of the *Handbuch*. The index arranged substances in molecular formula order. Physical properties were also given, with references to the original literature and to the appropriate pages of Beilstein. The third edition of Richter, in four volumes, covered the literature up to 1909 and was superseded by the index to the fourth edition of Beilstein. In the Richter index formulae are divided into groups according to the number of carbon atoms present. Compounds are then subdivided based on the number of additional elements present. Formulae in each group are arranged in the order C,H,O,N,Cl,Br,I,F,S,P followed by others in normal alphabetical order. (See Mellon [1965] for a fuller account.) This order differs from the Hill system frequently adopted today, which lists C, then H, then all other elements in alphabetical order.

The fourth edition of the *Handbuch* commenced publication in 1918, with P. Jacobson and B. Prager as joint editors-in-chief. This edition covered the literature to the end of 1909. The task of scanning the primary literature had been partly removed because the staff was also working on *Chemisches Zentralblatt* (Richter, 1938). The staff checked the accuracy of the information for the abstracts against the original literature. This arrangement was successful for around twenty years, but an increasing number of editorial staff and their greater turnover, combined with the increase in the amount of primary literature, led to problems. With the second supplement of the fourth edition the Beilstein editorial staff reverted to consulting the original literature for about forty of the most important journals, referring to *Chemisches Zentralblatt* for the remainder. Compilation involved documenting the data in a strict order for each compound on a "slip": occurrence, formation, preparation, physical properties, chemical and biological behavior, analytical data, and salts. Each slip contained information from one paper only. The slips were assigned a system number according to the Beilstein classification scheme, which determined the position in the final handbook. In 1933 F. Richter took over responsibility from Beilstein. The fourth edition differs from the first three in scope and in the classification of the compounds. All compounds that had been synthesized, analyzed, and characterized were included and in addition any natural products that had been investigated. In total, thirty-one volumes were produced, twenty-seven covering the main classes of organic compounds, volumes 28 and 29 being the indexes (name and formula) and volumes 30 and 31 differing from the others in that they cover longer periods (vol. 30 to 1935 and vol. 31 to 1920) and that they cover natural products that had not been classified elsewhere or were poorly defined and therefore difficult to classify. Some classes of compounds were not dealt with adequately by Beilstein, for example, alkaloids. The fourth edition covered about 140,000 compounds. After this edition it was decided not to produce new editions but to bring out supplements. Table 1 gives the periods covered by the original work and supplements to Beilstein.

Table 1. The Supplements of the Beilstein Handbook

Series	Abbreviation	Period covered
Original work (Hauptwerk)	H	Up to 1910
Supplementary series I	EI	1910–19
Supplementary series II	EII	1920–29
Supplementary series III	EIII	1930–39
Supplementary series III/IV (Vols. 17–27 of supplements III and IV were combined as EIII/IV)	EIII/IV	1930–59
Supplementary series IV	EIV	1950–59
Supplementary series V	EV	1960–79

The work was produced in German up to the end of the fourth supplement; the fifth is in English. A cumulative set of name and formula indexes for the Hauptwerk and the first two supplements was published in 1955 and 1957.

Evolution of the Classification Scheme

There is a huge diversity of organic compounds, and this was also the case in Beilstein's time. Any classification scheme of organic compounds, therefore, needs to be able to accommodate all types of compounds and to be future-proof. The original scheme arose from existing knowledge of homologous series, parent nuclei, and functional groups, which have been known since about 1840, as well as differences between alicyclic and heterocyclic compounds discovered in the 1860s (Richter, 1938). It became clear to Beilstein that classification of the vast number of new compounds was becoming increasingly difficult according to the original scheme, mainly because of the increase in the number of heterocyclic compounds discovered in the 1880s. So the scheme was revised by Beilstein's staff before publication of the fourth edition.

The new scheme is a freely extendable method of classification, as new compounds can be incorporated on the basis of their structural features. There is a hierarchy that determines which structural feature has priority when compounds are allocated to system numbers and volumes. The scheme remains the same today, now dealing with over seven million compounds. The scheme is unique to the *Handbuch* and was the first such classification of organic compounds. As did Gmelin, Beilstein allocated system numbers to compounds. Specific volumes always covered the same range of system numbers. For example, 4-aminophenol has system number 1841 and is found in volume 13 and its supplements, which cover amines containing OH groups. The index to the Hauptwerk and the first two supplements gives the page numbers, and through the system number, its exact location can be identified in later supplements. The main divisions of the Beilstein classification are as follows: alicyclic compounds, volumes 1–4, and system numbers 1–449; isocyclic compounds, volumes 5–16, and system numbers 450–2358; heterocyclic compounds, volumes 17–27, and system numbers 2359–4720. As an example, volume 24 covers heterocyclic compounds containing two nitrogen atoms, which also contain an oxo group; their system numbers fall in the range 3555–3633. Many chemical literature guides give further details of the present classification scheme: See, for example, Skolnik (1982) and booklets produced by the Beilstein Institute.

British Chemical Abstracts and *Analytical Abstracts*

British Chemical Abstracts had its origins in 1849, when the Chemical Society began to publish abstracts (Whiffen, 1991). The Society of Chemical Industry followed with its abstracts in 1882. Eventually it was decided that the overlap in coverage justified a merger, which occurred in 1926, leading to publication of *British Chemical Abstracts*. This merger resulted in formation of a bureau that produced *Abstracts A (Pure Chemistry)* and *Abstracts B (Applied Chemistry)*. In 1937, the *A* abstracts were split into three sections: *Ai Pure chemistry (General, Physical and Inorganic)*, *Aii Pure Chemistry (Organic),* and *Aiii Pure Chemistry (Biochemistry)*. In 1938 the publication was renamed *British Chemical and Physiological Abstracts* after the Physiological Society joined the bureau, which was renamed the Bureau for Chemical and Physiological Abstracts. Later the Society for Experimental Biology joined in production of the publication. The *B* section was divided as follows: *Bi General and Inorganic Chemistry*, *Bii Industrial Organic Chemistry, Biii Agriculture, Foods, Sanitation* (from 1938). The Society for Analytical Chemistry had published abstracts in its primary journal, *The Analyst*, but it was decided to publish these as part of *British Chemical Abstracts* and a new section *C Analytical Chemistry* was introduced in 1944.

World War II caused problems with production because of the lack of published scientific work, a paper shortage, and the lack of access to many European journals. In 1945 the bureau was renamed the Bureau of Abstracts and the journal was renamed *British Abstracts*. The abstracts were never financially viable and were discontinued in 1953, with debts to the tune of around £90,000, which were paid by the chemical industry, the societies involved with its production, and the British government. The *Journal of Applied Chemistry* assumed responsibility for abstracting the applied literature.

One positive outcome from these events was the birth of *Analytical Abstracts*, which began in 1954. Having decided to stop publishing abstracts in *The Analyst*, the Society for Analytical Chemistry still wanted to communicate abstracts to analytical chemists. *Analytical Abstracts* is still published today and is profitable. Differences in material covered (for example, standards) and the ability to search for compounds in specific roles in the electronic version, such as analyte or matrix, complement the coverage of *Chemical Abstracts* for the analytical chemist.

Chemical Abstracts

The major abstracting service in chemistry that dominates today is *Chemical Abstracts* (*CA*), which began in 1907. By then there were more than sixty abstract journals in pure science (Manzer, 1977; Skolnik, 1982). *CA* was born partly out of American chemists' dissatisfaction with the coverage of American chemical literature by European abstracting journals (Baker, Horiszny, & Metanomski, 1980). This dissatisfaction came despite the trend for abstracting journals to broaden their coverage to include literature from countries other than their country of origin. Faculty members at MIT tried to remedy this by producing *Review of American Chemical Research* in 1895, the forerunner to *CA*. *CA* was sponsored by the American Chemical Society, its first editor being W. A. Noyes, Sr. The first issue of *CA* contained 11,847 abstracts (Wolman, 1988), taken from 396 journals (Donnell, 1995). The number of journals covered increased to a thousand by 1922 and two thousand in 1932; today the number is around nine thousand, along with patents from twenty-seven patent offices.

Subject Coverage

CA's mission was to abstract the complete world's literature of chemistry, at first glance a straightforward objective, but in fact one that led to problems with the definitions of three words, *complete*, *abstract*, and *chemistry*. E. J. Crane (1889–1966), editor of *CA* from 1915 to 1958, indicated that publications suitable for inclusion were "studies of new chemical reactions, new information on known reactions, chemical, physical and biological properties of elements or compounds, apparatus of particular interest to the chemist or chemical engineer and procedures that in themselves may not involve chemistry but are essential to an industry that is generally considered chemical." *CA* covered applied and industrial chemistry as well as pure chemistry from the outset. This was encouraged by an early worker on the publication, W. Russell Stemen. He was also aware of the importance of patents as an information source, although patent summaries were brief until 1945.

In the first volume there were twenty-four issues of *CA*. Each issue was divided into thirty sections. The biggest sections were organic chemistry and biological chemistry. The patents section covered U.S., British, French, and German patents at the outset. Early decisions about the classification scheme laid the foundations of the systems in use today. Present users of printed *CA* know that the section headings have necessarily evolved and expanded to reflect changes in the importance of research areas and the appearance of new subjects. However, it was not until 1962 that a major overhaul of the classification took place, when the number of sections was increased to seventy-three. By 1980 there were eighty sections.

The Abstracts

The first issue of volume 2 contained an informative section titled "Organization, Directions for Assistant Editors and Abstractors and List of Journals," which provides insight into the selection procedures, editorial policy, and coverage of *CA* at the time. The duties of an assistant editor are indicated to have been:

> (1) The selection of the abstractors for his division. (2) To select the journals which contain material important for the division and to see that no such journals are overlooked. (3) To keep an oversight of the character of the abstracts and make sure that they give an adequate report of the articles abstracted, in good English and with the necessary brevity. (4) To advise the editor with regard to defects in *CA* and to indicate directions in which the journal may be improved. (5) To make sure that abstracts are prepared for all journals and articles assigned to his care. (6) To examine the proof for his division.

Each section had its own assistant editor. On editorial policy, in 1917, the "guidelines for abstractors" instructed abstractors not to make any personal judgments of the content of the papers being abstracted; this was the responsibility of the reader of the information. This is in contrast to the policy used in the production of Beilstein and Gmelin.

In 1907 about 50 percent of the abstracts were of articles originally published in German. By 1937 this had been reduced to 15 percent, with 40 percent in English, 5 percent in Japanese, 7 percent in Russian, and 27 percent in other languages. Now about 80 percent are in English, with only 2 percent in German, demonstrating the shift from German to English as the principal language for publication about chemistry. By 1959 papers were being received in fifty different languages (Heumann & Bernays, 1959), which gave rise to problems with translation of the subject matter and with transliteration of authors' names from Chinese, Cyrillic, and other alphabets.

Indexes

The first volume of *CA* had author and subject indexes, which occupied 363 pages. The number of pages taken up by the indexes increased with time as would be expected. The subject index covered both chemical names and general subjects. In 1907 the original subject index to volume 1 contained 7,850 index headings (Zaye, Metanomski, & Beach, 1985), and about 19,000 subject index entries, equivalent to 0.6 percent of the number of entries in 1983. Of the 7,850 headings 75 percent had only one reference associated with the index term, the maximum number being around 140. From the outset the overall aim was to index abstracts by subject rather than word; index headings were controlled, with cross references guiding the user to the correct heading. The headings have been revised as the need has arisen; some headings are the same today as they were in 1907. The development of indexing policy was initiated by Austin M. Patterson, the *CA* editor from 1909 to 1913, but as in many other areas, the key player was E. J. Crane, who laid the foundations of today's indexing system. Chemical nomenclature experts ensured consistency among the chemical names used, and naming conventions evolved in the same way as general subject headings. The decennial indexes required complete re-editing of the annual indexes. Bernier and Crane (1948) state that "chemistry is a growing science, and the indexer of an abstract journal must frequently deal with nomenclature in its early stages when lack of standardization and even lack of full knowledge make for indefiniteness. It is on this account that the collective indexing presents so many tough problems." In 1972 the subject index was divided into the general subject index and the chemical substance index, with general topics indexed in the former, specific compounds in the latter. The chemical substance indexing scheme involves inversion of names so that related compounds are grouped under the same heading.

Formula indexes were first published in 1920. They are organized according to the Hill system (Hill, 1900, 1907), which lists elements in a compound in the order carbon, then hydrogen, followed by all other elements in alphabetical order. For example, 2-nitropyridine would have the formula $C_5H_5N_2O_2$. These indexes were not intended to be used independently of the subject indexes; they provide names of commonly referenced compounds, and for these "common" compounds, the references themselves are to be found in the subject index. The subject index includes modifying phrases (not included in the formula indexes) to aid in determining the usefulness of references. The formula index leads directly to abstract numbers for "uncommon" compounds, which would usually have only one or a few abstracts associated with them in a decennial index period. There was a somewhat arbitrary cutoff of greater than fifty references differentiating between "common" and "uncommon" compounds.

Patent indexes started in 1912. A further index is the Index of Ring Systems, which first appeared as a separate publication with the 1957–66 Collective Index (it was formerly part of the introduction to the subject index).

The Production Process

In 1907 there were 129 volunteers involved in the production of *CA*, who received no remuneration (Baker, Horiszny, & Metanomski, 1980). In 1929 minimal pay was offered. By 1938 there were over four hundred abstractors in the United States and elsewhere (Scott, 1938); by 1954, over a thousand; and by 1961, more than three thousand. The Columbus-based staff coordinated this activity, final responsibility resting with E. J. Crane. The Columbus editors were also responsible for assigning each abstract to the appropriate section and cross-referencing. Scott (1938) states that while she was employed at *CA*, there were twenty-five full-time workers, and their responsibilities also included editing manuscripts from the abstractors, other aspects of quality control, and indexing.

After 1966 the policy of employing volunteers was gradually phased out, so that only 8.6 percent of abstracts were compiled externally, the number of abstractors falling from 3,292 in 1966 to about 1,000 in 1979. This decrease was mainly caused by difficulties of administering such a large number of dispersed personnel and also the arrival of computers in the 1960s, enabling automation of some production procedures that could then be carried out in house.

An account of the compilation of the indexes is given by Bernier and Crane (1948). The indexers, all chemists, worked from pages of typeset abstracts. Words to be included were underlined or noted in the margin. An index card was made, with the index modification and the volume and column reference. Cards were checked to eliminate inconsistencies. Over the years the depth of indexing increased; For example, the number of index entries increased from 2.9 per abstract in 1936 to 4.2 in 1946.

Scott (1938) perceives that certain personal qualities are needed for the type of work at *CA*:

> Accuracy should perhaps rank the highest and with that conscientiousness, patience, a meticulous attentiveness to detail, . . . power of concentration, good judgement, an interest in words as words, a love of puzzles . . . The analytical rather than the creative type is probably best suited for the work . . . Work of this type is not for the overly energetic or restless person.

Patents

Use of patents as an information source has always been overshadowed by other forms of publication (Schofield, 1996), but patents cannot be ignored when a literature search is conducted; the figure of about 80 percent of information in patents never appearing elsewhere is frequently quoted. Publications that specialize in producing summaries of patents have existed for the last two centuries. One example is the *London Journal of Arts and Sciences and Repertory of Patent Inventions*, which was compiled by W. Newton and concentrated on civil and mechanical engineering inventions. Some examples of publications in chemistry and chemical engineering are Kirk and Othmer (1947–56); *Fortschritte der Teerfarbenfabrikation und verwandter Industriezweige*, covering 1877 to 1942 and, although concentrating on German patents, also covers others in the later years and deals with dyes and related subjects; *Fortschritte der Heilstoffchemie, erste Abteilung: Das deutsche Patentschriftwesen*, published from 1926 to 1939, covering German patents on medicinals, cosmetics, and other aspects of organic chemistry; *Fortschritte in der anorganisch-chemischen Industrie*, describing German patents from 1877 to 1932; *Zusammenstellung der Patente auf dem Gebiete* *der organischen Chemie*, which discusses organic chemistry patents from 1877 to 1905; *Chemical Patents Index,* which includes all U.S. chemical patents granted from 1915 to 1924. National patent offices also publish abstracts and alerting services, such as the U.K.'s *Official Gazette (Patents)* and the U.S.'s *Official Gazette of the United States Patent and Trademark Office*. All organize their patents according to classification schemes and are indexed. The importance of patents to the chemical industry was recognized by most of the producers of secondary sources described, and their coverage has been mentioned. There was considerable variation in the comprehensiveness of subject and country coverage. Derwent Information is now a major producer of patent information retrieval tools, first with their *Patents Abstract Publications,* which began in 1951, and now with the *World Patents Index* database.

Conclusion

The need for secondary sources in chemistry arose in a way similar to that in other disciplines, that is, when the primary literature of the subject started to become unmanageable. For chemistry this was perceived earlier than for most other subjects. The most important type of secondary source is the abstract journal, devoted exclusively to publication of abstracts, themselves having origins considerably before such journals.

A major difference between chemistry and other disciplines is the importance of chemical structures as the universal means of communication, necessitating multiple access routes to information. This is usually achieved through formulae or chemical names, often in combination with a substance classification scheme, which has led to the evolution of especially sophisticated information retrieval systems in chemistry.

Why did secondary sources develop to a greater extent in some counties than others? Many secondary sources were conceived during the nineteenth century, when the primary literature was growing because of the flourishing chemical industry and research activity in universities and research organizations. The Gmelin and Beilstein handbooks commenced during a particularly productive period for research in Germany. In the aftermath of the Napoleonic wars, the Prussians were keen to develop a counter to French culture. One result of this nationalistic response was a reform of science in German universities, giving a great stimulus to research. In Great Britain, science was less organized, and science education somewhat weaker at that time. *CA* was developed during a period of growth in the chemical industry in the United States.

Important Secondary Sources in Chemistry

Some significant works not specifically mentioned in the text are also included.

❖ = original title
➢ = publication related to that above, name changed

- ❖ *Crell's Chemische Journal für die Freunde der Naturlehre,* 1778–1781
- ❖ *Chemisches Annalen für die Naturlehre, Arzneygelahrtheit, Haushaltungskunst und Manufacturen,* 1784–1803
- ❖ *Neues Chemisches Archiv*, 1784–1791
- ❖ *Beiträge zu den Chemischen Annalen*, 1785–1799
- ❖ *Gmelin's Handbuch der Anorganische Chemie,* 1817–date
- ❖ *Pharmaceutisches Zentralblatt*, 1830–1849
  - ➢ *Chemisches und Pharmaceutisches Zentralblatt,* 1850–1856
  - ➢ *Chemisches Zentralblatt*, 1856–1896
  - ➢ *Chemisches Zentralblatt*, 1897–1969
  - ➢ *Chemischer Informationsdients* (*ChemInform*), 1970–date
- ❖ *Répertoire de Chimie Pure*, 1858–1863
- ❖ *Répertoire de Chimie Appliquée*, 1858–1864
- ❖ *Beilstein's Handbuch der Organischen Chemie,* 1881–date
- ❖ *Review of American Chemical Research*, 1895–1906
  - ➢ *Chemical Abstracts*, 1907–date
- ❖ *Houben-Weyl: Methoden der organischen Chemie,* 1909–date
- ❖ *British Chemical Abstracts*, 1926–1937
  - ➢ *British Chemical and Physiological Abstracts,* 1938–1944
  - ➢ *British Abstracts*, 1945–1953
  - ➢ *Analytical Abstracts*, 1954–date
- ❖ *Nippon Kagaku Soran*, 1927–1957
- ❖ *Theilheimer's Synthetic Methods for Organic Chemistry*, 1946–date
- ❖ *Bulletin Signalétique*, 1940–date
- ❖ *Referativnyi Zhurnal Khimiya*, 1952–date
- ❖ *Index Chemicus*, 1960–date
  - ➢ *Current Abstracts of Chemistry*, 1970–date

So why did some secondary sources survive while others did not? To some extent it was survival of the fittest, but in addition wars and cultural developments had an effect. The flexibility of the classification schemes employed in the handbooks of Gmelin and Beilstein have contributed to their survival. These schemes revolve around functional groups, ring systems, and the chemical elements, that is, the true language of chemistry. The majority of these structural features were known before the publications originated, and so the classification schemes have needed little amendment as new structures can be slotted into the existing schemes. In addition the financial support of these publications by the German government clearly helped.

A common factor among some of the publications that failed to survive was the inadequacy of the coverage of the international literature. After World War II and during the rise of *CA*, scientific research in the United States boomed, whereas Europe was still recovering from the war. It was dangerous for the producers of secondary sources to give scant coverage to U.S. publications. The decline in *Chemisches Zentralblatt* and *British Chemical Abstracts* can be attributed in part to this factor. *CA*'s breadth of coverage, both in terms of subject and country of origin of publications, has reduced the impact of most other surviving abstract services, even in their country of origin. The importance of international coverage is confirmed by the success of *Science Abstracts*, a British publication that has survived where *British Chemical Abstracts* failed, since the former paid more attention than the latter to the American literature from its inception.

Another factor in survival is specialization. For example, *Analytical Abstracts* survives because it covers sources of particular interest to analytical chemists, such as standards, not included in *CA*.

It seems clear, however, that individuals like Beilstein, Gmelin, and Crane, who laid the foundations of today's information retrieval systems in chemistry, will continue to have an influence on the organization and evolution of secondary information sources in chemistry while chemistry as a subject continues to develop and evolve.

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