# CHEMISTRY IN THE OLD NORTHWEST[1, 2]

AARON J. IHDE, Departments of Chemistry and History of Science, University of Wisconsin, Madison, WI 53706

*Abstract.* Immediately after the War for Independence, Americans began to move westward in earnest. There were numerous factors pulling migrants westward, among them the fertile land which had a particular appeal for farmers. Ohio felt the impact first; settlement of Wisconsin was delayed until opening of the lead mines during the later Indian wars. Settlers in the Northwest Territory revealed a penchant for the exploitation of the territory's resources and the creation of educational institutions. Excellence of the soil led to significant agricultural expansion and, later, to growth of an innovative food industry. Mineral resources stimulated the growth of a metals industry and an energy industry based first on coal, then on petroleum. The extensive forests in the northern part of the territory supplied a forest products industry. Pioneer developments took place without benefit of science but after 1850 science took on increasing significance as the colleges and universities prepared individuals for a role in the innovative growth of agriculture, industry, and medicine. A critical question revolves around the disproportionate regional excellence in science (chemistry in particular) shown by universities and colleges of the region.

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Migrants into the territory created by the Ordinance of 1787 were attracted by readily available resources, including the excellent conditions for agriculture. Settlers in the Northwest Territory were characterized by an enthusiastic exploitation of the region's resources and the creation of educational institutions. The territory's soil had a significant attraction for the early settlers. Seaboard soils, never impressive for their fertility, were being rapidly depleted. The lands to the west, even when forested, as in Ohio, Michigan, and Wisconsin, were attractive and the rich prairies of Indiana and Illinois became veritable magnets for farmers. The cultivation of wheat developed rapidly since it provided a cash crop which could be moved to more densely settled regions on readily available waterways which were beginning to carry steamboat traffic. Wheat, in unmilled form, kept well when shipped to distant markets to the east and south. Maize did not become an important crop until much later, when animal husbandry took on greater significance.

Agricultural activities stimulated industries utilizing agriculturally derived raw materials, not only food-processing industries such as meat slaughtering, grain milling, cheese making, and canning, but derivative industries such as tanning and soapmaking. With the growth of slaughter houses around mid-century, in line with expansion of livestock production and improvement in preservation processes (canning, refrigeration), large slaughtering centers began to spread westward. Cincinnati became such a famed pork packing center that it was referred to as "Porkopolis." Chicago dominated meat packing later in the century, especially after development of the refrigerator car by Gustavus Swift in the seventies. The packers became economically powerful, not only by taking advantage of available livestock and processing it efficiently by disassembly line techniques, but by encouraging profitable disposal of inedible by-products—offal and bone into fertilizer, hides into

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leather, tallow and waste fat into soap and candles and, in the twentieth century, glandular extracts into pharmaceuticals (hormones).

Soap-boiling was originally a farm enterprise utilizing waste household fats and potash produced from wood ashes. In 1820, when James Gamble's family immigrated from Ireland, he was apprenticed to a local soapmaker in Cincinnati and in 1828 he started his own business. His product was soon peddled by William Proctor, an English immigrant who had learned candlemaking in London and operated a candle works in Cincinnati. The two men, who married sisters, joined their business activities in 1837, forming a company which steadily expanded by developing innovative practices in production and merchandising. They soon adopted the lime saponification process invented by de Milly in France. When they later adopted Tilghman's autoclave process, they were sued for patent infringement--the first lawsuit involving a patent of a chemical process. The suit, which ended in the Supreme Court, upheld the concept of a chemical process being patentable (Haynes 1954).

The extensive waterways in the territory, both rivers and lakes, figured prominently in economic expansion of the region. The development of the steamboat during the first half of the century coincided with growth of the territory and played a significant role in bringing immigrants and essential goods in, and carrying produce out. Later, in the second half of the century, growth of railroad lines stimulated further expansion of commercial activities (Klingaman and Vedder 1975).

At various times, the timber which grew luxuriantly in the northern tier of states was a prime attraction but elsewhere it was considered a nuisance. Clearing of land for farming was backbreaking work and trees were generally hacked down and burned. Except for use in log cabins, out-buildings, and fences, and occasionally for charcoal and potash production, the trees were looked upon as an evil to be removed. Lack of trees on the prairies made those regions particularly attractive. In upper Michigan and Wisconsin, however, the excellence of the forests for lumber attracted a particularly exploitative class of entrepreneurs who, in the last part of the nineteenth century, moved in rapidly to remove the forests; then moved on to the virgin timber in the Pacific northwest.

In various places and at various times the forests served as a source of chemicals, particularly potash and tanbark. Early in the nineteenth century, alkalies for soapmaking and glassmaking were chronically in short supply. During much of the century small operators extracted potash from wood ashes for use locally for soapmaking or for sale in markets as distant as Europe. Such operations were never large in scale and seldom were they long lived. Nevertheless, substantial amounts of alkali were produced by such operations (Ihde and Conners 1955).

Tanbark was another forest resource which took on significance when leather production became important in the Northwest. When farmers turned away from wheat growing to concentrate on dairying and meat production, and as animal slaughtering grew in importance, first in Cincinnati and later in Milwaukee and Chicago, hides became available and a substantial tanning industry developed in those cities. Forests also supplied charcoal for the early metal extractive industries but charcoal declined in importance as a reducing agent when metallurgical operations increased in magnitude and coke became the reductant of choice. Ultimately, the timber lands, now largely second growth and to some extent the result of tree farming, provided pulpwood for the paper industry.

Minerals figured prominently in the economic development of the Old Northwest. Coalfields of the Allegheny Mountains extended into Ohio and provided a product suitable for metallurgical coke, a factor in the ultimate development of Cleveland and Youngstown as metallurgical centers. Coalfields were also present in southern Indiana and central and southern Illinois. These deposits, while dirty and frequently high in sulfur, were important not only as fuels but as industrial raw materials used in metallurgy, for illuminating gas production, and in the chemical industry. The northeast quartile of Ohio developed into an area of heavy industry, not only in proximity to the Lake Erie shore but alongside the bank of the Ohio River where the industry mirrored the development on the West Virginia side of the river. The Chicago-Gary complex also benefitted from easy access to coal from Indiana and Illinois.

The southern tier of states was favored with substantial deposits of petroleum and natural gas. The oil deposits of Ohio, exploited soon after the original development of the industry in western Pennsylvania, made Cleveland an important base in the development of the Standard Oil complex.

Geologically, a large part of the territory had been overlain by an inland sea extending from eastern New York to central Wisconsin. The inland sea was responsible for several strata of limestone underlying these states and for the rock salt deposits of New York, Ontario, Michigan and Ohio. These salt deposits figured prominently in a chemical industry directed toward the production of alkalis, chlorine and bromine, related salts, and metallic magnesium. The limestone deposits figured prominently, not only as a source of stone and quicklime for the building trades, but as a flux in the metallurgical industries.

Metal ores played a significant part in the industrial development of the region. Small deposits of iron ore were located in many parts of colonial America; those of Pennsylvania were particularly extensive. Deposits were worked according to traditional procedures on a local basis. Such ironworking practices extended into the Northwest Territory as settlement took place but were abandoned when the small deposits of rich ore became exhausted. Various temporary operations developed in Ohio, Michigan, and Wisconsin. They seldom developed beyond simple operations which took care of local needs, since competitive iron was available from Europe and a large iron industry developed rapidly in Pittsburgh after 1810. Pittsburgh was the major iron producing center by mid-nineteenth century; favorably located with respect to limestone and coking coal, although suffering from a shortage of nearby iron ores. Rich and extensive ore fields were discovered in northern Michigan and Wisconsin, and ultimately in Minnesota. The northwest ore made Pittsburgh the steel center of the nation after 1873 when the Edgar Thompson Steel Co. was incorporated there. The Carnegie Steel Co. was incorporated in 1892 and in 1901 and the U.S. Steel Corp. was created by merging the major works.

Iron deposits were recognized in the Lake Superior area at the time that Douglass Houghton, an 1829 graduate of Rensselaer Polytechnic Institute, began making geological surveys in Michigan after appointment as state geologist in 1837. Before drowning in Lake Superior cut short his career in 1845, Houghton had mapped the rock salt springs and wells which became the basis of the Michigan chemical industry and had located various copper and iron deposits in the Upper Peninsula. At the time of his death, Houghton was serving as the first professor of geology, mineralogy, and chemistry at the University of Michigan. Other mineral prospectors carried on from the foundations laid by him.

The Marquette Range, discovered by William A. Burt in 1844, was the first major iron ore discovery in the area. It lay close to Lake Superior near the present city of Marquette. The Menominee Range was recognized in 1848, but it was across the state where transportation to a lake port was impractical until the railroad made a connection to Marquette. A third major deposit, the Gogebic Range, lay at the western end of the Michigan peninsula and extended southwestward into Wisconsin. All of these ore bodies were composed of hard magnetite and siderite. They were mined underground by traditional methods introduced by Cornish miners who flocked to the copper and iron mines after mid-century. Transport from Lake Superior ports to Pittsburgh became practical by boat after 1855 when the U.S. government opened a lock and canal at Sault Sainte Marie, making it possible for ore boats to move from Lake Superior into Lake Huron by-passing the falls of the St. Mary's River. The "Soo' locks and canals, substantially enlarged in 1881, 1895–6, 1914–1919, and during World

War II made it possible to exploit the Great Lakes as a transportation system for carrying rich but heavy iron ore from its source to Pittsburgh and other lower lake metallurgical centers. U.S. Steel created a new steel center at Gary in 1906. This took advantage of coal and limestone deposits in Indiana and Illinois, while reducing transport distance for ore and producing the steel near an expanding population center.

The Michigan-Wisconsin ranges soon took a minor rank to the Minnesota iron ranges, all in the northeastern part of the state which had been a part of the Northwest Territory. The most northerly range, the Vermillion, opened in 1884 with ore being hauled to Duluth by rail and there transferred to ore boats. In 1890 the Mesabi Range was discovered. Made up of soft hematites and limonites lying close to the surface, the deposit was workable by open pit methods and soon became the major source of supply for the steel producing centers. Still another Minnesota range, the Cayuna, southwest of Duluth, began shipments in 1911.

The Lake Superior ore deposits figured prominently in the economic growth of the country. The fortuitous combination of rich iron ore resources, Great Lakes transportation to steelmaking centers on or near the southern shores, satisfactory sources of coking coal and limestone near the smelting centers, and a populous market in a growing nation figured in the rise of the country to world power. Unfortunately, the destructiveness of two world wars saw the end of these rich deposits. To be sure, lean ores known as taconites ultimately became exploitable as a consequence of scientific innovation but at striking cost in terms of damage to the environment.

Other metal ores figured prominently, if not as spectacularly, in the development of the region. In fact, the first mining boom was not associated with iron but with lead, needed for shot in the opening of the west. Early explorers recognized outcrops of galena (lead sulfide) within the present boundaries of Wisconsin, Illinois and Iowa. These were exploited on a small scale from the seventeenth century when traders taught the local Indians to smelt the ore. A lead mining boom took place in the area in the 1820's attracting immigrants from the South and East. Troubles with the Indians slowed early activity but conclusion of the Black Hawk War was followed by rapid development. The surface deposits were quickly exhausted and it became necessary to go underground. Timber for charcoal needed in smelting was soon exhausted and operations became marginal near mid-century. The miners turned to farming, or left for more attractive mining activities elsewhere.

Although zinc was associated with these lead deposits, it was not seriously exploited before 1860. After the Civil War a zinc boom occurred but this was of short duration. The lead and zinc deposits of the area took on marginal importance, with mines operating vigorously in times of high prices (as in wartime) then closing down until the next price escalation.

Copper, present in substantial quantity in the Keweenaw Peninsula of upper Michigan, was scattered glacially through the Mississippi Valley, some of it in the form of native copper. Early explorers were surprised to find the local Indians, a Paleolithic people, using copper artifacts. These objects were made not by smelting copper ores but by manipulating pieces of native copper. The Keweenaw deposits attracted Houghton's attention and federal mining permits were issued as early as 1844. On the northern tip of Keweenaw, the Cliff Mine was rich in native copper and the nearby Minnesota Mine yielded a 420-ton mass of copper metal at a depth of 150 feet. Removal of the latter was a problem which occupied 20 miners more than a year since the block had to be laboriously cut into small pieces. The Isle Royale lode, consisting mainly of copper sulfide ores near the present site of Houghton, required conventional techniques of underground mining which attracted Cornish miners in significant numbers in 1852.

The Calumet Conglomerate attracted major capitalization from the East in 1864 with the incorporation of the Calumet Mining Co. and the Hecla Mining Co. but the minerals proved difficult to work and profits slow in coming. The two companies merged in 1871. One independent company, the Tamarack, had mined ore 2270 feet underground when it was taken over by Calumet and Hecla who followed the ore down more than a mile. These mines saw the introduction of numerous innovations in mining technology such as air compressors for operation of rock drills, and the use of dynamite to break up rock masses.

The ore of the area was not inexhaustable, however, and in time operations became marginal since they involved costly underground operations in competition with open pit mining in the western states and in foreign countries. Processing innovations such as flotation made the mining of low quality ore profitable in time of good prices. Recently, promising ore deposits have been located in Florence and Barron counties in upper Wisconsin.

The above account summarizes the principal resources of the Old Northwest and the nature of the activities toward exploitation of these resources. Excellent as the resources were, they were not inexhaustable. Neverthless, they were generally treated as if they were.

## CREATION OF EDUCATIONAL INSTITUTIONS

The settlers of the Northwest Territory showed a surprising enthusiasm for higher education. This is reflected in more than thirty colleges and universities founded by 1851 (Hoover, 1946). Many of these schools were denominational colleges, created for education of young men for the ministry. The large variety of denominations reflects the diversity of religious groups populating the region.

The settlers of the eastern part of the Territory created Ohio University in 1804, the year after the region was granted statehood. Settlers in Ohio continued creating colleges during the next century—to the point that the state was frequently nicknamed the "Mother of Colleges". Most religious denominations were represented besides the early public institutions. Ohio University at Athens was funded out of proceeds derived from two townships granted by Congress to the Ohio Company. Miami University at Oxford was similarly created from a township granted by Congress in the Symmes Purchase. Academic creations were not limited to the state or to religious denominations because municipalities also created local schools; most of which ultimately became part of the state system of higher education.

Although none of the states of the Northwest Territory matched Ohio in the creation of educational institutions, all of them created a substantial number of colleges and universities before the end of the nineteenth century. A surprising number of these schools achieved a high level of distinction. While the original objective of many of the colleges was religious, they quickly broadened into various areas of learning and frequently lost their denominational status. Starting from lowly foundations, these schools gradually acquired distinguished faculties and gained academic recognition among the nation's institutions of higher learning. This was true not only for state supported institutions but the private colleges and universities as well.

Table 1 lists colleges and universities founded in the 5 states arising out of the Northwest Territory. The table does not include all institutions of higher learning but is restricted to those institutions whose chemistry program reached sufficient distinction to be given approval by the American Chemical Society's Committee on Professional Training. While it may be argued that this criterion overlooks schools which were once strong in chemistry but are strong no longer, a concerted effort to uncover such cases has been unsuccessful and the criteria for inclusion appear sound. The larger schools introduced graduate programs at the beginning of the twentieth century and became outstanding graduate schools at the national level. Table 2 indicates the rank of universities located in the Old Northwest according to quality of graduate education in chemical studies. There have been, since 1925, four major rankings of this sort (the Hughes Study of 1928, the Keniston Study of 1959, the Cartter Assessment of 1966, and the Roose-Anderson Rating of 1970). These four studies of graduate programs set as their principal objective the evaluation of quality of graduate education in various

TABLE 1

*Colleges and Universities founded before 1900 (now approved by American Chemical Society Committee on Professional Training).**

| Ohio | Indiana | Illinois | Michigan | Wisconsin |
|---|---|---|---|---|
| Ohio U, 1804[a] | — | — | — | — |
| Miami U, 1809 | — | — | — | — |
| U of Cincinnati, 1819 | Indiana U, 1820[a] | — | U of Michigan, 1817[a] | — |
| Kenyon, 1824 | — | — | — | — |
| Case Western Reserve, 1826[c] | — | — | — | — |
| Oberlin, 1833 | Wabash, 1832 | — | Kalamazoo, 1833 | — |
| Marietta, 1835 | — | — | — | — |
| Muskingum, 1837 | DePauw, 1837 | Knox, 1837 | Albion, 1835 | — |
| Ohio Wesleyan, 1842 | Notre Dame, 1842 | — | — | — |
| Baldwin-Wallace, 1845 | — | — | — | Beloit, 1846 |
| Wittenberg, 1845 | — | — | — | Carroll, 1846 |
| Mount Union, 1846 | Earlham, 1847 | — | — | Lawrence, 1847 |
| U of Akron, 1850 | — | — | — | U of Wis. Madison, 1849[a] |
| Capital, 1850 | — | Northwestern U, 1851 | — | Ripon, 1851 |
| Dayton, 1850 | — | Monmouth, 1853 | — | — |
| Hiram, 1850 | Evansville, 1854 | Ill. State U. Normal, 1857 | — | — |
| Antioch, 1852 | Butler U, 1855 | Wake Forest, 1857 | Mich. St. U, 1855[b] | — |
| — | Valpariso, 1859 | Wheaton, 1860 | — | — |
| Wooster, 1866 | Ind. State U, Terre Haute, 1865[d] | U. of Illinois, 1867[a, b] | Hope, 1866 | Marquette, 1864 |
| Ohio St. U, 1870[b] | Purdue, 1869[b] | Loyola, 1870 | Wayne St. U, 1868 | UW-Oshkosh, 1871[b] |
| U of Toledo, 1872 | — | Southern Ill U, 1874[d] | Calvin, 1876 | — |
| — | — | — | U of Detroit, 1877 | — |
| Cleveland State U, 1881 | — | — | — | UW-Milwaukee, 1880[d] |
| Central State U, 1883 | — | — | Mich. Tech. U, 1885 | — |
| John Carroll, 1886 | — | — | Alma, 1886 | — |
| — | — | U of Chicago, 1891 | — | — |
| — | — | Ill. Inst. Tech., 1892 | Central Mich. U, 1892 | — |
| — | — | Northern Ill. U, 1895[d] | — | UW-Stevens Point, 1894[d] |
| — | — | Bradley, 1897 | — | UW-Superior, 1896[d] |
| — | — | DePaul, 1898 | Northern Mich. U, 1899 | — |

*Amer. Chem. Soc. 1969.
[a]Original university of the state.
[b]Land grant college under Morrill Act of 1862.
[c]Case Inst. of Technology (founded 1880) and Western Reserve U. (founded 1826) merged in 1966.
[d]Founded as normal schools or teachers colleges, later raised to university status.

learned disciplines. While such rankings should never be accepted as absolutes, they can be taken as having comparative merit. The 1925 rating, published in 1928, was fairly limited. Subsequent rankings included larger numbers of schools and disciplines, and perhaps reflect greater reliability, particularly the two most recent studies under the auspices of the American Council on Education. A significant number of Old Northwest universities apparently have taken a prominent place in graduate education in chemical areas in the United States, a ranking perhaps surprisingly high, considering that only 5 of the 50 states of the Union are represented.

## CHEMISTRY IN THE COLLEGES

Chemistry instruction in the early colleges followed the pattern of such instruction in established institutions in the east. Scientific disciplines were usually taught by theologians. Since members of the ministry were frequently the best educated members of the community, they appeared eminently qualified to offer instruction in all fields of learning, including science. This pattern characterized instruction in science in the denominational colleges well into and sometimes through the nineteenth century.

Exceptions are found in certain colleges where physicians were called upon to offer instruction in the sciences. Such

TABLE 2
*Rank of NW Territory Universities in ratings of graduate education.*

*Chemistry*

| University | 1969 | 1964 | 1957 | 1925 |
|---|---|---|---|---|
| Illinois | 6 | 6 | 3 | 8 |
| Chicago | 8* | 9* | 4 | 4 |
| Wisconsin | 8* | 7* | 5 | 13 |
| Northwestern | 14 | 14* | 12* | — |
| Purdue | 15* | 16* | — | — |
| Ohio State | 17* | 16* | 16 | 14* |
| Michigan | 20* | 19 | 14 | 12 |
| Indiana | 20* | 20* | — | — |
| Michigan State | 24* | — | — | — |
| Case Western Reserve | 30* | — | — | — |
| Notre Dame | 35* | — | — | — |
| Total ranked | 38 | 28 | 16 | 15 |

*Biochemistry*

| University | 1969 | 1964 |
|---|---|---|
| Wisconsin | 5 | 4* |
| Illinois | 16* | 10 |
| Chicago | 16* | 17* |
| Case Western Reserve | 19* | 12* |
| Michigan | 23* | 15* |
| Purdue | 26* | — |
| Michigan State | 28* | — |
| Indiana | 30* | — |
| Total ranked | 32 | 26 |

*Chemical Engineering*

| University | 1969 | 1964 |
|---|---|---|
| Wisconsin | 1 | 1* |
| Illinois | 6* | 8 |
| Michigan | 8 | 6* |
| Northwestern | 11* | 10* |
| Purdue | 17 | — |
| Total ranked | 17 | 15 |

*Tied with at least one other school.

medically trained science teachers were commonplace in the chemistry departments of the state universities from the beginning and they also began to appear in the denominational colleges as the century came to a close.

Exceptions to the D.D. and M.D. science teachers appeared around mid-century in the form of graduates of Benjamin Silliman's science program at Yale and that of Amos Eaton at Rensselaer Polytechnic Institute. Graduates of these schools tended to follow the methods of scientific instruction deriving from these two masters. This pattern accelerated after mid-century with the founding of the Lawrence Scientific School at Harvard and the Sheffield Scientific School at Yale. The founding of the scientific schools reflected a new phenomenon characterizing American higher education—the appearance of German-trained Ph.D.'s (Ihde 1964).

The German pattern of graduate education in the universities had a profound effect on American higher education after 1850. While a few German immigrants were taking a prominent place in American science after 1850, the German universities attracted a steady flow of American boys who sought a German scientific education and returned to their homeland to follow educational and industrial careers. The inflow of German-trained chemists was noticeable in the Old Northwest after 1850, particularly after 1875.

Beloit College was almost unique in America for the steady utilization of German Ph.D.'s from Göttingen after 1854 (Siegfried and Ihde 1953). Chemistry was taught at Beloit by a succession of four Göttingen Ph.D.'s from that date until 1920. Other schools in the Old Northwest also began to utilize German Ph.D.'s, or more frequently, American youth who had capped their education by a year or two in Germany. A few examples are: Frank Jewett, who studied at Göttingen before becoming professor of chemistry at Oberlin in 1880; Harvey W. Wiley, who spent several months in Germany before becoming the first chemistry professor at Purdue; William A. Noyes of Illinois who worked with Baeyer in Munich in 1888–89; Lewis Kahlenberg of Wisconsin who took his Ph.D. in Leipzig in 1895 (Ihde and Schuette 1952); and Henry A. Weber of Ohio State who studied with Liebig from 1866 to 1868 (McPherson 1931).

By 1900 many colleges and universities in the Old Northwest had at least one German trained Ph.D. on their chemistry staff. Such professors were frequently research oriented and carried on a modest research program. They were joined by American Ph.D.'s who had taken their degree at Harvard, Columbia, Pennsylvania or Johns Hopkins where they received their training under such German-trained Ph.D.'s as T. W. Richards, C. F. Chandler, E. F. Smith, and Ira Remsen. Consequently, it is no surprise that the larger universities were undertaking graduate instruction in chemistry by the turn of the century and that some of these institutions ultimately rose to a high level of distinction.

### CHEMISTRY IN AGRICULTURE

Because of its strong agricultural base, chemistry in the Northwest institutions showed a strong orientation toward that field. This was reflected in rapid creation of agricultural colleges following passage of the Morrill Act of 1862 and the establishment of agricultural experiment stations even before passage of the Hatch Act in 1887. While early agricultural chemistry on the experimental farms was directed toward practical problems such as quality of fertilizers and feeds, the agricultural stations quickly took on greater significance when they turned their attention to basic research on plants and animals. Rather than recounting general trends in agricultural research, a few specific developments are emphasized in the paragraphs which follow.

When Harvey Wiley became professor of chemistry at Purdue he was also named State Chemist. Because of his strong interest in sugars and syrups he quickly recognized the widespread adulteration of such foods. He left Purdue in 1883 to become Chief of the Division of Chemistry in the U.S. Department of Agriculture and extended his studies to purity of foods in general and revealed the widespread extent of adulteration. This aroused his deep concern for protective legislation to insure pure foods and drugs for the American public. Wiley's work, even while at Purdue, was important for its emphasis on improvement of analytical procedures and shortly after going to Washington he founded the Association of Official Agricultural Chemists which took leadership in developing reliable analytical procedures for agricultural materials.

Somewhat in the same mold was the early work of Stephen M. Babcock who joined the Wisconsin agricultural experiment station in 1888. Within two years, he perfected a simple, rapid, and reliable test for butterfat in milk, thereby laying the foundations for reform in the marketing of milk (Ihde 1971). Babcock was also skeptical about traditional ideas regarding the nutritive value of animal feeds and encouraged his younger colleague, E. B. Hart, to undertake a study of comparative values of cattle rations scientifically compounded from the parts of specific cereal crops. The famous single grain experiments at Wisconsin laid important foundations toward the recognition of trace nutrients in foods.

E. V. McCollum and Harry Steenbock, younger associates of Hart in the single grain experiments, went on to make important contributions in the development of the newer knowledge of nutrition. McCollum introduced the use of white rats as test animals for studying the biological value of foodstuffs and thereby recognized, independently but concurrently with others, the importance of trace nutrients in foods. McCollum (1964) recognized the presence of vitamin A in butterfat and vitamin B in the aqueous fraction of milk. Although McCollum left Wisconsin in 1917 to continue his career at Johns Hopkins, his pioneering studies were extended at Wisconsin by Hart, Steenbock, Elvehjem, and their students (McCollum 1957).

Steenbock made an important breakthrough in the early twenties when he recognized the conversion of naturally occurring sterols in foods into vitamin D by irradiation with ultraviolet light. Hart made important contributions to the understanding of vitamin and mineral metabolism and his former student, Conrad A. Elvehjem, made broad contributions toward understanding mineral metabolism, the vitamin B complex, and recognized nicotinic acid as the antipellagra factor. Related studies of animal nutrition took place in other midwest agricultural stations and these studies, although carried out by agricultural chemists, had important consequences for human nutrition (Ihde and Becker 1971).

### CHEMISTRY IN INDUSTRY

The chemical industry showed unique developments in the region of the Old Northwest with Ohio taking on particular significance as the center for the industry. Substantial chemical industries also developed in Michigan and in the industrial complex surrounding Chicago and extending into northwest Indiana. As in the case of agricultural chemistry, it is impossible in a short paper to do full justice to the history of chemical industry in the region of the Old Northwest, so attention will again be focused on a few substantial and unique developments (Haynes 1949).

Ohio took on importance in the rapidly developing petroleum industry. Substantial amounts of Ohio crude oil, however, were high in sulfur and the unpleasant odor and sulfurous fumes associated with kerosene produced from such crude oil put Ohio petroleum products at a commercial disadvantage compared to those coming from Pennsylvania and later from midcontinent wells. A German immigrant, Herman Frasch, developed procedures for desulfurizing oil by treatment with copper oxide. While his process was first applied commercially to crude oils in Ontario, his invention quickly attracted the attention of John D. Rockefeller who hired him as a consultant and obtained rights to the Frasch process. This made possible the large scale exploitation of high-sulfur crudes from Ohio deposits.

Herbert H. Dow became interested in the salt deposits of the region while studying with Charles F. Mabery at Case Institute of Technology. Mabery, the first professor of chemistry at Case, not only developed the chemistry department but gave attention to local industrial problems, particularly those of the petroleum industry. During his student years at Case, Dow recognized the presence of bromine in brine from certain salt wells and developed a process by which bromine might be released by electrolysis and aerated from the solution. Soon after graduation he organized the Canton Chemical Company for production of bromides (Whitehead 1968). Although this business venture was unprofitable, Dow utilized his experience by organzing a new firm at Midland, Michigan in 1890 where he slowly mastered the problems of producing alkalis, bromides, and bleaching powder by the electrolysis of brines. Dow's company was successful in marketing bromides in the face of German competition and gradually expanded into production of a broad range of inorganic halogen salts and halogenated organic chemicals. The Dow Chemical Company later became important for the electrolytic extraction of magnesium from brine and later from sea water, and played on important role in the commercialization of that metal.

Still another Ohio youth, Charles Martin Hall, had an important role in the commercialization of aluminum. While a student at Oberlin College, Hall learned from Professor Jewett of Wöhler's isolation of aluminum in 1825. Jewett pointed out that while aluminum was abundant in the earth's crust, it was prohibitively expensive to extract from its minerals. Following graduation, Hall undertook the preparation of aluminum by electrolysis. Recognizing that aqueous solutions of aluminum compounds fail to electrolyze satisfactorily, Hall discovered that aluminum oxide can be dissolved in melted cryolite ($Na_3AlCl$). By utilizing carbon electrodes he was able to release molten aluminum from the solution (Carr 1952). Hall encountered numerous difficulties before the process was successfully commercialized, particularly since Paul Hérault discovered the same process in France at approximately the same time. Patent conflicts were ultimately resolved by joint agreements and developmental research led to successful commercial production; first at Pittsburgh, then on a more substantial scale at Niagara Falls where cheaper electricity was available.

The development of the internal combustion engine and its use in the automobile led to rapid transformation of the petroleum industry after the turn of the century. Gasoline became the most valuable fraction of crude oil while demand for kerosene fell off as a result of expansion of lighting with coal gas and also with electricity. Petroleum refineries found it difficult to keep up with demand for gasoline while kerosene stocks accumulated and remained unsold. Under these circumstances, interest developed in increasing the yield of gasoline, hopefully at the expense of the kerosene fraction. William M. Burton, a chemist with the Standard Oil Company of Indiana, attacked the problem about 1909. He undertook the cracking of the large hydrocarbon molecules of the kerosene and fuel oil fractions by passing the oil through an appropriate furnace under high pressure. Under these conditions many of the larger molecules were split into fragments in the gasoline range. Burton took out his first patent on the process in 1912. This research was followed by a sequence of improvements by Standard Oil and other midwestern research groups as well.

Another attack on the gasoline problem, begun around 1920, was aimed toward improvement of the combustion characteristics of gasoline. The leader in this research was Charles Kettering of the Dayton Engineering Laboratories. Kettering was joined by Thomas Midgley, Jr. who sought gasoline additives which would improve the burning characteristics of the fuel in internal combustion engines (Boyd 1957). In 1922 Midgley discovered the antiknock characteristics of tetraethyllead. Production of ethyl gasoline soon followed, the lead compound being added as an antiknock agent. Since the antiknock agent improved the burning qualities of the gasoline, it became possible to utilize engines with higher compression ratios; thus obtaining improved engine performance.

The above examples of chemical innovation in agriculture and industry represent applications of scientific knowledge which have had important technological and social impacts. It is difficult to avoid the conclusion that the comparative success of life in the Old Northwest was attributable in some degree to the chemical activities in the region. The abundent natural resources, such as fertile soil, timber, and abundant minerals, would have made the region a reasonably successful one in which to live in any case. Through the application of chemical knowledge to agriculture and to technology the natural endowments were markedly enhanced. Certainly the vigorous growth of scientific education in the schools in the Old Northwest played an important role in the economic development of the region by providing a pool of talented scientists and engineers qualified to bring about successful application of scientific knowledge. The settlers of the region were unconsciously being farsighted in supporting the growth of high quality education, rather than being content to exploit only the valuable resources that brought them into the area.

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