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THE CHEMISTS' WAR

The Impact of World War I on the American Chemical Profession

David J. Rhees, The Bakken Library and Museum

World War I was one of those momentous and horrifying events in American history that permanently reoriented, even revolutionized, American society. Indeed, it is difficult for us today to imagine the profound shock experienced by Americans in general and chemists in particular upon the outbreak of the war with Germany - that most scientific of all nations - in August 1914. Variously known as the European War, the Kaiser's War, the Great War, the Great Crusade, and, of course, the Chemists' War, it was a major turning point in Western civilization, marking the actual, if not the chronological divide between the Victorian world of the 19th century and the modern world of the 20th - a divide, a fault line, that was simultaneously social, political, economic, cultural, and moral.

In the standard accounts of the history of American science, however, World War I is usually overshadowed by its even more destructive successor. Understandably, the development of radar, the synthetic rubber project, and the Manhattan Project have captured the lion's share of historians' attention. I certainly would not dispute the importance of the Second World War in giving rise to Big Science, characterized by large-scale team research, close relations with industry, and heavy reliance upon government (especially military) funding. Nevertheless, I would like to suggest that insufficient attention has been paid to the importance of the First World War in terms of its impact upon the scientific profession, particularly the chemical profession. After all, chemistry played an extremely important role in the production of high explosives, poison gas, optical glass, synthetic coal-tar dyes and pharmaceuticals, and other chemical products of direct or indirect military value.

Although historians of science and technology are more or less familiar with how chemistry changed the war, relatively little is known about how the war changed chemistry (or, more precisely, the chemical profession), and it is the latter which constitutes the subject of this paper. Even though the United States was involved in the Great War for only 18 months (from April 1917 to November 1918), I wish to argue that it affected the American chemical community in five important ways:

1. *Industrialization:* The war greatly accelerated the growth of the American chemical industry, thus enhancing the financial and ideological importance of industry to the chemical profession.

2. *Militarization:* The war resulted in the development of strong ties between the chemical profession and the military establishment.

3. *Politicization:* The war jolted chemists out of their ivory-tower, laissez-faire mentality and led them to engage in aggressive political lobbying for the first time.

4. *Nationalization:* The war stimulated a surge of patriotism in the chemical community which helped build morale and pride in the achievements of American chemistry, but which at times degenerated into strident nationalism and nativism.

5. *Popularization:* The war engendered a new self-consciousness among chemists and a new awareness of their public image which led to a vigorous campaign to popularize chemistry.

Before I proceed to discuss these five trends, a few qualifications are in order. First, this analysis can only suggest the broad lines of change and is intended to be suggestive rather than comprehensive. This is particularly true of my necessarily brief discussion of the role of chemistry in the war, which, of course, is fundamental to any understanding of the impact of the war on chemistry. Secondly, I do not wish to overemphasize the importance of the war, for nearly all of the five trends I have identified had their origins in the prewar era. My point is simply that the war dramatically and decisively accelerated the pace of these trends. And third, I do not wish to imply that other scientific disciplines played trivial roles in the war. The important work of American physicists on submarine detection devices and of psychologists on Army "intelligence" tests, to cite but two examples, are well known. Nonetheless, of all the sciences involved in World War I, chemistry played the dominant role and this was publicly recognized almost from the beginning of the conflict by the fact that it became known as a "chemical war" or "chemists' war."

Industrialization

What were the industrial contributions of chemistry during the war and how did the industrialization of chemistry affect the chemical profession? Very briefly, the war triggered a major boom in the American chemical industry and in the industrial demand for chemists even before Americans joined the conflict in April 1917. It did this in two principal ways. First, it increased demand for munitions and other chemicals needed in the war effort. The manufacture of TNT, for example, the most important explosive of the war, rose from 3.4 million pounds in 1913 to a rate of 16 million pounds per month in 1916. Similar growth was reported in chlorine, potash, and coal-tar dyes and pharmaceuticals. Secondly, the British Navy placed an embargo on trade with Germany, which had supplied many chemicals to America, thus opening a golden window of opportunity for domestic manufacturers. In the case of coal-tar dyes, for instance, the U.S. was importing about 90% from Germany when the war broke out. When the supply of German dyes was cut by the naval blockade, a "dye famine" resulted.

In response to the embargo of German imports and the booming demand for munitions and other chemicals, many American companies rapidly expanded the manufacture of existing products and initiated production of new chemicals, notably dyes. Before the war, American dye companies simply assembled finished dyes from intermediates supplied by Germany. In 1917, however, DuPont began construction of a complete coal-tar dye plant at Deepwater, New Jersey. As one observer put it, the war "touched off the wildest explosion of chemical activity this country had ever seen" (1).

As chemical production boomed, the need for chemists boomed as well, especially as manufacturers diversified into "high tech" areas such as synthetic organic dyes, drugs, and plastics. From 1914 to 1920, DuPont increased its staff of chemists from 40 to about 300. The boom in chemical research spread throughout other industries as well: from 1916 to 1920 more than 200 industrial research laboratories were founded, and chemists played the dominant role in the new research organizations.

As more and more chemists with advanced degrees moved into industry, efforts to strengthen the relations between industry and the chemical profession were accelerated. Industrial fellowships modeled on those given by Pittsburgh's Mellon Institute of Industrial Research (founded in 1913) were established at half a dozen universities even during the disruptions of the war, and companies such as DuPont established their own fellowship programs as well. At the American Chemical Society, a committee on university-industry relations was established in 1916 which sponsored symposia on ways to improve the application of chemistry to industrial needs. The pages of the Society's *Journal of Industrial and Engineering Chemistry* were filled with exhortations for greater cooperation between pure and applied chemists, and in 1918 the ACS elected as its president William H. Nichols, president of the General Chemical Company. Although both of Nichols' predecessors were academics - Charles H. Herty of the University of North Carolina (1915-16) and Julius Stieglitz of the University of Chicago (1917) - they, too, were quite sympathetic to industry. Even chemists who had reputations for sneering at industrial chemistry, such as Ira Remsen of Johns Hopkins University, felt obliged during the war to make public declarations supporting the application of chemistry to industry.

The Great War stimulated chemical production, expanded the industrial demand for chemists, and strengthened the links between academic chemists and industry. It also served to legitimize industrial chemistry and to raise the status of the industrial chemist both professionally and publicly. The Chemists' War thus helped make chemistry's role in industrial progress the dominant theme of the professional ideology and public image of the chemical profession.

Militarization

When we speak of World War I as the Chemists' War, the image that usually comes to mind is the famous battle near the Belgian town of Ypres (sometimes referred to as the "Battle of Wipers"), where on 22 April 1915 the German army released a greenish-yellow cloud of chlorine gas on Allied troops. This was the first use of chemical warfare on the Western Front, and though the battle lasted only 15 minutes, it produced over 7,000 casualties and 5,000 deaths. At this point in time, of course, there were no American troops in Europe, it being another two years before the U.S. would enter the conflict. Indeed, it was not until the spring of 1917 that the U.S. began to organize its chemical warfare research program under the initial direction of the Bureau of Mines. That program, which was eventually folded into the Army's Chemical Warfare Service, established in June 1918, was a massive project. As historian of science Daniel Jones has argued, the U.S. gas research program was "the largest of the government sponsored research organizations of the war" (2). In spirit, if not in scale, it presaged the Manhattan Project of World War II.

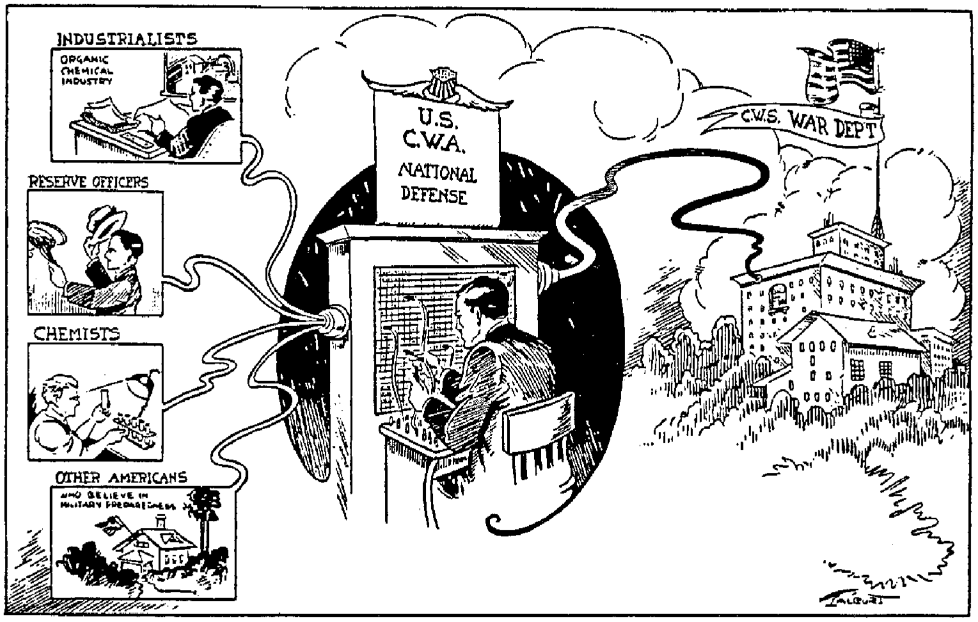
The gas research program was centered at the so-called "Experimental Station" located at American University in suburban Washington, DC. By the end of the war, 60 buildings had sprouted on the American University campus, and about 1,000 technical personnel (mostly chemists) were employed there. Many of these chemists were actually inducted into the Army after the Army took over the program from the Bureau of Mines. By the end of the war in November 1918, 5,400 chemists were serving in the Armed Forces, and one-third of all American chemists were serving, or had served, in some agency of the federal government.

What was the impact of the crash program in chemical warfare research and development? Initially, many chemists were concerned about the impact of military control on their research, worrying that bureaucratic red tape and a scientifically naive military brass would impede scientific progress. They objected strenuously to the Army's campaign to take control of the gas research program from the Bureau of Mines, and even the *New York Times* implored President Woodrow Wilson not to burden chemists with "the military harness, which they could not help finding uncongenial and embarrassing" (3). Indeed, Roger Adams of the University of Illinois found it quite irritating that he was required to participate in military drills every afternoon.

However, these kinds of problems were gradually worked out and the chemists' worst fears about military control proved unfounded. Their participation in the crash research program, with its patriotic sense of life-or-death urgency, soon brought them much closer to their military colleagues. The ACS, for example, quickly established a Committee to Cooperate with the Chemical Warfare Service, and the *Journal of Industrial and Engineering Chemistry* established a special section on "Contributions from the Chemical Warfare Service." During the demobilization period after the war, the ACS would lobby successfully to prevent the Chemical Warfare Service from being dismantled.

The gas research effort also had the effect of bringing academic and industrial chemists closer together. For instance, chemists such as Roger Adams, working at the Experimental Station at American University, received their first hands-on experience in problem-oriented team research and the technical challenges of large-scale manufacturing. This helped break down the "class barriers" between the pure and applied chemists, thus reinforcing the industrialization trend noted above. Roger Adams also observed that the gas research program resulted in the formation of a network of friendships between chemists from geographically diverse areas. This encouraged an unprecedented degree of unity and cooperation in the American chemical profession which continued into the postwar era, helping create a new sense of disciplinary identity and solidarity.

And finally, the war helped lay the basis for the mobilization of science during World War II. Roger Adams, for instance, went on to play a leading role in organizing the scientific community during the next war, as did James Bryant Conant, who supervised the production of mustard gas at the Edgewood Arsenal in Maryland. Conant, who became president of Harvard University in 1933, headed the National Defense Research Committee during the Second World War.



This illustration shows the network of groups who lobbied successfully against Senate ratification of the Geneva Protocol, an international treaty that called for a ban on chemical warfare. From *U.S. Chemical Warfare Association Bulletin*, **1925**, *No. 14 (13 May)*.

Just as the war opened a new era of cooperation between chemists and industry, it also established closer ties between the chemical profession and the military, gave national defense an important place in the professional ideology and public image of chemistry, enhanced the respect of academic chemists for industrial problems, helped unify the profession, and served as a dress rehearsal for World War II (4).

Politicization

And just as the war brought chemists closer to industry and to the military, it also brought them into a new relationship with politics and politicians. Before the war, the ACS had rarely involved itself in matters of national policy. Science, after all, was supposed to be above politics. The war, however, forced chemists to come down from the ivory tower and plunge into the hurly-burly world of lobbying and log-rolling.

Why did the chemists shed the traditional apolitical ideology of science? First of all, it was not because they were eager for federal funds, which is one of the principal reasons why scientists today become involved in national politics. (The ACS did briefly consider the notion of federal funding of research, and even formed a committee to investigate this subject in 1918, but enthusiasm for the idea seemed to evaporate with the return to normalcy.) Rather, chemists became involved in politics primarily because of their desire to promote and protect the American chemical industry. This desire, in turn, rested on two motives: their belief that establishing an independent American chemical industry was of vital importance to national welfare, and their awareness that industry provided jobs and research funds. Based on these motives, whose importance was greatly accentuated by the war, chemists became involved in a number of major legislative campaigns both during and after the war.

Perhaps the best example of the new political activism of the chemical profession was the campaign for tariffs to protect the infant American dye industry against the expected postwar resumption of German chemical imports. That campaign actually began soon after the guns of August began firing in 1914, when a committee of the New York Section of the American Chemical Society issued a report calling for a considerable increase in the tariff on synthetic dye imports. This report became the basis of a tariff bill introduced to the House of Representatives in December 1915. A number of ACS leaders went to Capitol Hill to lobby for this and a succession of other dye tariff bills which the Congress considered between 1914 and 1922. The Society issued a flurry of resolutions urging protection for the chemical industry and it waged an extensive campaign of popular education, hoping to bring public pressure to bear on Congress. In 1922 these efforts culminated in the passage of the Fordney-McCumber Tariff Act, which placed high duties on imports of German dyes and medicinals.

"David" in this cartoon is Francis P. Garvan, president of the Chemical Foundation, who helped to lead efforts to defend the American chemical industry against German competitors after World War I. The "hyphenated American" refers to German-Americans who were thought to be aiding the "enemy." From *U. S. Chemical Warfare Association Bulletin*, **1925**, *No. 21 (1 July)*.

Aiding the ACS and the chemical companies in the dye tariff battle was a little known but quite important organization named the Chemical Foundation. The Chemical Foundation was very much a "war baby," being founded in March 1919 to hold the German chemical patents sequestered by the U.S. Alien Property Custodian, Francis P. Garvan, during the war. Garvan became president of this quasi-public corporation, which licensed the German patents to U.S. chemical companies and used the proceeds to fund chemical research. The Foundation gave about three-quarters of a million dollars to the ACS, for instance, in support of its publications program. However, the Foundation also spent millions of dollars in lobbying for dye tariff legislation and for popular literature promoting chemistry and the chemical industry. Through its research, lobbying, and promotional efforts, the Chemical Foundation played a key role in the development of chemistry and the chemical industry during the postwar period.

The ACS and the Chemical Foundation collaborated on several other political campaigns after the war, most notably the campaign to establish a "chemo-medical institute." This proposal went through a number of changes during the 1920s and led to the founding of the National Institute of Health in 1930. The ACS, the Chemical Foundation, and a lobbying group called the U.S. Chemical Warfare Association also waged a successful battle to defeat Senate ratification of the Geneva Protocol in the mid-1920s, an international treaty that called for a ban on chemical weapons. (In 1973 the Society reversed its position and the Geneva Protocol was subsequently ratified.)

Perhaps the most telling indicator of the politicization of the chemical profession was the gradual transfer of ACS offices to Washington, DC. The move began somewhat by accident in 1912, when the Society's secretary, Charles L. Parsons, moved to Washington to take a position with the Bureau of Mines. In 1921 the offices of the *Journal of Industrial and Engineering Chemistry* (the predecessor of *Chemical & Engineering News*) were moved from New York to the nation's capital, though again, not specifically for political reasons but because the new editor, Harrison E. Howe, was then working for the National Research Council. With the Society's increasing involvement during the Depression in public policy issues such as Prohibition and the revision of food and drug laws, the ACS successfully applied to the Congress in 1937 for a federal charter, which helped strengthen the Society's stature as a national scientific advisory body. The culmination of this trend came in 1941 when the Society moved into its own headquarters building on 16th Street, just a few blocks from the White House (5). Although the war did not by itself bring about the politicization of the chemical profession, it certainly accelerated the process.

Organic chemist William A. Noyes (1857-1941), a lone voice of moderation during and after World War I.

Nationalization

Every war generates its own domestic pathologies, and during World War I the forces of nationalism and nativism ran particularly strong. Though one might have hoped that scientists would have resisted such prejudices, chemists proved as susceptible to these forces as any other group. To be sure, there were positive aspects to this trend, for the war enhanced the chemical profession's sense of national identity, encouraged pride in American contributions to chemistry, and inspired efforts to make American chemistry stronger and independent of Germany. It also gave impetus to the study of the history of American chemistry, prompting a search for American patron saints to replace the foreign, especially German, "fathers" of chemical science. Hence the publication of such books as *Chemistry in America* (1919) and *Priestley in America* (1920) by the University of Pennsylvania's Edgar Fahs Smith (ACS president, 1895, 1921-22), and the founding of the American Chemical Society's Division of the History of Chemistry under Smith's and Charles A. Browne's guidance in 1921. Smith's underlying aim was stated in a letter he sent to Charles Herty in 1923 (6):

> Be assured, my dear boy, that there is a growing regard for our science in the hearts of many, many people, and we want to put the stamp of Americanism on it so that it can't be effaced.

But nationalism had an uglier aspect as well, degenerating at times into a virulent "100% Americanism," anti-Germanism, and anti-Communism. The Chemists' Club in New York, for example, banned the use of the German language and purged its membership of suspected alien sympathizers. In 1918 the ACS revoked the honorary memberships of three prominent German chemists, Emil Fischer, Wilhelm Ostwald, and Walther Nernst. (Cooler heads prevailed after the war, and their memberships were restored in 1926-27) (7). In 1921 the ACS Council also expelled from the Society a chemist named Charles Bramson of Joliet, Illinois, who had distributed propaganda of the United Communist Party (8).

There was, however, at least one voice for peace and reason during this unfortunate phase of the war - that of the organic chemist William A. Noyes. Noyes (1857-1941) edited the *Journal of the American Chemical Society* from 1902 to 1917 and was one of the founders of *Chemical Abstracts*. He built up the chemistry program at the University of Illinois into one of the leading departments in the country, and he served as president of the ACS in 1920. A deeply religious man, a Congregationalist who was raised on an Iowa farm, Noyes had many friends in Germany and was deeply distressed over the bitterness that divided the scientific community during the war. Although he was not a "dyed-in-the-wool pacifist," according to his son, the chemist W. A. Noyes, Jr., he opposed the war and worked diligently to promote international peace, disarmament, and good will, publishing a number of pamphlets on these subjects. The son wrote of his father that "he did what he could after World War I to minimize nationalism and hatred among scientists" (9).

In 1922, for example, Noyes sent a lengthy letter to the editor of the *Journal of Industrial and Engineering Chemistry* which deplored the rise of nationalistic and capitalistic tendencies after the war, particularly the excessively punitive war reparations which the Allies were imposing on Germany. He even went so far as to argue that "'America First' has become so exactly like 'Deutschland über Alles' that it is hard to distinguish the spirit of the two slogans." This provocative statement earned him a strong rebuke from the well-known food chemist Harvey W. Wiley in a subsequent issue (10). Neither the chemical profession nor the country at large were in a mood to listen to Noyes's call for tolerance.

Popularization

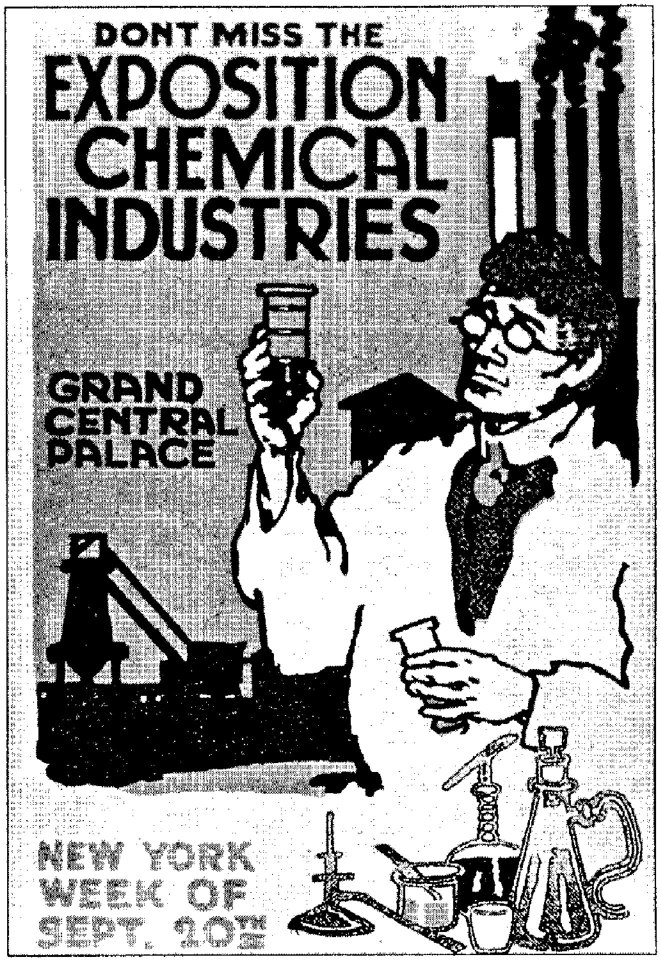
The war changed not only the relations of chemistry with industry, the military, and the Congress, but also with the media and the public in general. Before the war, it is safe to say, the average citizen was scarcely aware that this country possessed a chemical industry until the dye famine demonstrated its deficiencies. Insofar as the chemist had a public image at all, he (rarely she) was generally confused with the druggist, or with that distant ancestor, the alchemist. The chemist was perceived either as an insignificant pill-pusher or a disreputable crank.

The war helped change that image practically overnight due to the publicity generated by the use of high explosives, the dye famine, and chemical warfare. As one chemist rejoiced in April 1915, the public had "discovered" chemistry (11):

> Hundreds of newspapers and periodicals are devoting editorial space to the discussion of the chemists and chemical engineers and their relations to the coal-tar industries.

Along with public attention came public misunderstanding. Neither the press nor the public knew much about chemistry, resulting in both uninformed criticisms and wildly unrealistic expectations. To correct these misunderstandings, and to advance some of the political goals mentioned above, leading chemists in the ACS, together with the Chemical Foundation and some of the larger chemical companies, organized a massive crusade to popularize chemistry. Of the many educational activities launched during this campaign, only four can be briefly mentioned here: the National Exposition of Chemical Industries, the ACS News Service, the Chemical Foundation's mass distribution of popular literature, and the ACS Prize Essay Contests.

The first National Exposition of Chemical Industries was held in 1915 in New York City's Grand Central Palace. Though the "Chemical Show," as it was called, was essentially a trade exhibition, it was opened to the general public during



Stamp issued for the first National Exposition of Chemical Industries in 1915. (Courtesty of the Woodruff Library, Emory University)

the war years as a way to win public appreciation for the industrial achievements of chemistry and to show how chemistry was helping win the war. Attendance had reached a high of 128,000 in 1922 when the Exposition's organizers decided to exclude the general public. During the crucial war years, however, the Chemical Show played an important role in making chemistry and chemical industry visible to a wider audience (12).

The American Chemical Society News Service proved to be a more lasting player in the chemical publicity business. Formally established in January 1919, the origins of the News Service date back to the Society's Press and Publicity Committee, appointed in April 1916. It was the first permanent publicity service for the newspapers founded by an American scientific society, and to this day it has been busily engaged in issuing news bulletins about ACS meetings, new discoveries published in ACS journals, and ACS positions on political issues.

Only a few months after the News Service was born, the

Chemical Foundation began operations, as noted above, and in its quest to build public support for dye tariff legislation it began distributing massive quantities of popular literature on chemistry. Francis Garvan chose as the centerpiece for this campaign a book independently authored by Edwin E. Slosson titled *Creative Chemistry*, published in 1919. The Chemical Foundation distributed over 73,000 free copies of Slosson's book to Congressmen, editors, industrialists, women's clubs, and other groups during the final stages of the tariff campaign in 1921. By 1937, when most of its patents had expired and its source of income ran out, the Foundation had published or disseminated a total of eleven million pieces of educational literature.

One of the most successful popular educational projects of the interwar period was a joint endeavor of the Chemical Foundation and the ACS - the Prize Essay Contests. Funded by the Foundation and personal contributions from Francis P. Garvan and his wife, Mabel Brady Garvan, these contests offered cash prizes and scholarships to high school and college students for the best essays on the relations of chemistry to industry, national defense, agriculture, the home, medicine, etc. From 1923 to 1931 more than five million students participated in the contests, which were administered and judged by volunteer ACS members. Although the ACS Prize Essay Contests did lure a few students into pursuing chemical careers, the primary objective was not recruitment but improving the public's opinion of chemistry.

The war thus instilled a missionary mentality in the chemical community which resulted in an ambitious popular crusade. This crusade, in turn, was generally quite successful in enhancing the public image of chemists and the chemical industry and in winning support for dye tariffs, the Chemical Warfare Service, and other public policy issues related to chemistry.

Poster for the ACS Prize Essay Contest, circa 1924. (Courtesy of the American Heritage Center, University of Wyoming)

Summary

In this paper I have attempted to suggest a few of the ways in which the Chemists' War deeply affected the chemical profession in the United States. Industrialization, militarization, politicization, nationalization, and popularization - these five trends were decisively accelerated by World War I and introduced a new era in the social and cultural history of American chemistry. By the end of the war, the chemical community was transformed: industry and the military took their place as the profession's most powerful patrons; the ACS took its place in Washington as one of a growing number of professional interest groups; nationalism both energized the profession and caused some severe lapses in judgment; and thousands of chemists were converted into evangelists who enthusiastically spread the chemical gospel to the masses.

No study of the impact of the Chemists' War would be complete, however, without pausing to reflect on its terrible human toll - its "frightfulness," to use the contemporary term for describing the war's horrors. I would not consider myself a true student of Theodor Benfey, whom we honor in this symposium, if I failed to remind myself and my audience that World War I was a global war, an industrial war, a total war, and it was a cruel and brutal affair. While as historians we may find the occasional silver lining even in this depressing conflict, we should not forget that it caused the deaths of nine million people, not a few chemists among them.

The Chemists' War is one of the many burdens of history that we must bear as a nation and as members of the community of scholars and scientists. Although the cause may have been a just one, and though life-saving drugs and other beneficial spin-offs may have resulted, we cannot avoid the fact that chemistry, too, added to the death and destruction. It is well to periodically remind ourselves that we carry such burdens, for only by facing them is there hope that we may someday transcend history and break out of the seemingly endless cycle of war and devastation. By remembering the Chemists' War in all its frightfulness, perhaps we will learn to listen more carefully in the future to those who call, as William A. Noyes called, for peace, reason, and tolerance.

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Acknowledgment: The principal documentation and citations for this paper may be found in the author's 1987 University of Pennsylvania doctoral dissertation, "The Chemists' Crusade: The Rise of an Industrial Science in Modern America, 1907-1922." Only direct quotations and new material are referenced below.

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THE HISTORICAL DEVELOPMENT OF THE VAN ARKEL BOND-TYPE TRIANGLE

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As the biographical sketch by James Bohning in this issue of the *Bulletin* reveals, one of the key events in Ted Benfey's career was his association with Larry Strong at Earlham College and their mutual involvement in the development of the Chemical Bond Approach (CBA) course in the late 1950s and early 1960s (1). CBA was undoubtedly the most innovative of the many attempts at curriculum reform in chemistry which appeared during this period in the United States and elsewhere, and was constructed, as its name implied, around the development of self-consistent models of the chemical bond, starting from a fundamental knowledge of the laws of electrostatics (2). By the end of Chapter 13, the CBA textbook, *Chemical Systems*, had led students through a presentation of the three basic models used to describe the bonding in covalent, metallic, and ionic materials, and had paused for a reflective overview of what had been accomplished up to that point. The finale of this bonding retrospective was a brief discussion of the possibility of intermediate bond-types using the simple triangular diagram shown in figure 1 (3):

> Covalent, metallic, and ionic bonds prove to be a useful way of regarding the structures of many substances. These three types of bonds symbolize three different arrangements of atoms to give structures characteristic of particular substances. The underlying principles for the three types of bonds, however, are based on electrostatics in each type. Each substance represents a system of low energy consistent with the limitations imposed by the Pauli exclusion principle and geometrical relations of the electrons and nuclei which are more fundamental units of structure than are atoms.
>
> With the same underlying principles common to all structures, it is not surprising that not all substances can be neatly classified into one of three possible types. The situation can be symbolized by a trigonal diagram [see figure]. The vertices of the triangle represent bond types characteristic of the three extreme bond types. Along each edge of the triangle are represented bond types characteristic of the many substances which do not have extreme bond types.

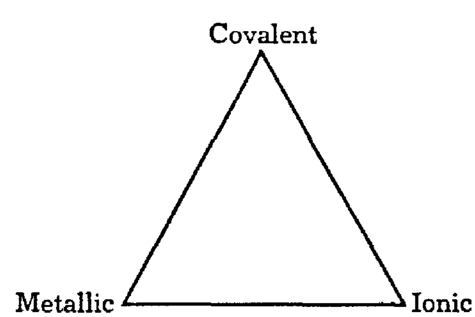

Figure 1. The CBA Bond-Type Triangle