CHAPTER XIII

CHEMICAL EDUCATION

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Chemistry has been an appropriate subject for study in the secondary schools since the development of the high-school movement. In the colleges it has had recognition since the beginning of the nineteenth century. Indeed one college, the College of New Jersey (Princeton), had made definite provision for instruction in chemistry to undergraduates as early as 1795.[1] The growth of this subject in high schools and colleges has closely paralleled the development of the science itself.

Chemistry in American Secondary Schools

The academy was the first American secondary school to provide instruction in chemistry. This type of school came into being during the last half of the eighteenth century and the purpose of its promoters was to develop an institution in which adolescent students might acquire a liberal and practical education. In the early days of the academy much emphasis was placed upon the importance of training in agriculture and mechanics. The work of Davy and others on the applications of chemistry to agriculture and the many references to the practical value of chemistry in the trades and industries helped in no small way to secure for this subject a place in the "practical" course of study of the academy. As early as 1830 it had come to occupy a position of some prominence in the course of study of this institution.[2] Although the method of instruction was, for the most part, through the study of textbooks, the importance of illustrating the work by use of apparatus for demonstrations was recognized. Evidence of this is seen in advertising materials which set forth the claims of some of these schools. In an ad-

[1] Maclean, John, "History of the College of New Jersey," **2**, pp. 8–9.

[2] Powers, S. R., "A History of the Teaching of Chemistry in the Secondary Schools of the United States Previous to 1850," University of Minnesota, *Research Publication*, **1920**, pp. 16–17.

vertisement of the Oxford Female Academy which appeared in the Raleigh (North Carolina) Register of March 23, 1827, it is stated:

> Since the commencement of the session we have received a chemical and philosophical apparatus and now each recitation in chemistry, philosophy, and astronomy is accompanied with a lecture and experiments illustrating the principles of these sciences.[1]

That chemistry occupied a larger place in secondary education of this period than available records show is indicated by the number of textbooks which had been prepared for use in secondary schools. As many as eight books, written or revised by Americans, were available for use in the Academy by 1833.[2]

The first public high school in the United States, the English Classical School, now the English High School, was founded in Boston in 1821, and the second was the High School for Girls, Boston, which was founded in 1826.[3] In the girls' school it was provided that the course of study "should include as much chemistry as would be useful in domestic economy."[4] Throughout the cities of Massachusetts instruction in this subject was given at an early date. In 1857 Massachusetts passed a law which required that:

> Every town may and every town containing 500 families * * * shall maintain a school kept by a master * * * who * * * shall give instruction in * * * geometry, natural philosophy, chemistry, botany and * * *.[5]

Inglis reports that in three Massachusetts towns the number of students enrolled in chemistry in 1860 was 50.7 per cent of the number enrolled in algebra, and that during this same year, of fifty-five towns of five hundred families or over, fifty-two included chemistry in their course of study.[6]

In the high schools of Ohio the sciences received early recognition. The first report of the state commissioner of education was published in 1854. This and subsequent reports show that instruction in chemistry was offered to a considerable number of students. In 1855–1856 the number of students engaged in the study of this subject was 55 per cent of the number engaged in the study of geometry.

Chemistry was recognized in most of the large cities throughout the country as an important subject for secondary education at least as early as the decade of 1860–1870. Even earlier than

[1] Coon, Charles L., "North Carolina Schools and Academies, 1790–1840. A Documentary History," pp. 156–57.

[2] Powers, S. R., "A History of the Teaching of Chemistry in the Secondary Schools of the United States Prior to 1850," pp. 19–20.

[3] Brown, E. E., in Edmonds' "History of Franklin High School of Philadelphia," p. 29.

[4] "Boston High School for Girls," *Am. J. Education*, **1**, 99 (1826).

[5] Mass. Bd. Education, 24th Ann. Rpt., **1861**, p. 91.

[6] Inglis, A., "Rise of High Schools in Massachusetts," Columbia University, Teachers College, **1911**, pp. 84 and 90.

this it had come to occupy a place of importance in the course of instruction in certain cities and in some of these rather liberal provision had been made for laboratory instruction. Williams says in his report on the "Teaching of Chemistry in Schools, 1876–1901:"

> One of the earliest, perhaps the first, to adopt the new idea (laboratory) was the Girls High and Normal School, of Boston, about 1865. It was followed by the Cambridge, Massachusetts, High School in 1866, and the English High of Boston in 1871.[1]

There is evidence that laboratory instruction in chemistry was given prior to this in some midwestern high schools. The Central High School of Philadelphia entered a new building in 1854 in which there was a room set apart for a laboratory for chemistry and natural philosophy.[2] However, this room was not equipped for individual laboratory work until some years later. Chemistry was included in the first program of studies constructed for high schools in Chicago.[3] The first high school building erected in St. Louis (1854)[4] contained a chemical laboratory equipped for student use.

It is clear that the high school in St. Louis and probably some in other midwestern cities were equipped with laboratories at an earlier date than 1865. A survey, in 1867, by Henry Barnard, shows that of thirty large high schools distributed over the United States all gave instruction in algebra, geometry, and natural philosophy, and twenty-six gave instruction in chemistry.[5]

By 1860 the high school was an established educational institution. It should be recalled that the academy came into being as an institution which should furnish a more liberal and practical education than the Latin-grammar school, which was its predecessor. By 1860 it was evident that the academy could not survive and that an adequate system of popular secondary education could be developed only through state-controlled schools.

Throughout the period of their existence the high schools have given a place to the sciences. Stout has assembled high-school courses of study which were prepared between 1860 and 1900 and has computed from these, by five-year periods, the average amount of time allowed for instruction in each group of subjects. He has found that the amount of time allowed for

[1] Williams, R. P., "Teaching of Chemistry in Schools, 1876–1901," *J. Am. Chem. Soc.*, Supplement (Twenty-fifth Anniversary of the American Chemical Society), p. 128 (1902).

[2] "History of Central High School, Philadelphia," p. 142; and Hart, J. S., "Description of a Public School in Philadelphia," Barnard's *Am. J. Education*, **1**, 93 (1856).

[3] Wells, W. H., "Public High School in Chicago," Barnard's *Am. J. Education*, **3**, 531 (1857).

[4] Tice, J. H., "First Annual Report of the St. Louis Schools," Barnard's *Am. J. Education*, **1**, 353 (1856).

[5] Barnard's *Am. J. Education*, **19**, 463 (1869).

science was equal to or greater than that allowed for mathematics, and that Latin was the only subject or related group of subjects which was allowed more time.[1] All the courses examined for 1860–1865 showed an offering of physics (or natural philosophy). Eighty-five per cent offered chemistry. Throughout the period 1860–1900 physics was recognized by 100 per cent of the courses examined. Chemistry was included in from 60 to 90 per cent of the courses of each five-year period.

The extent to which chemistry was recognized as a subject of study in high schools in 1878 is revealed from the survey conducted during this year by the United States Bureau of Education.[2] Of one hundred and seventy-six public high schools, one hundred and fifty-four offered some instruction in chemistry. Of these, fifty-six made provision for some individual laboratory work and seventy-three illustrated the work with demonstrations which were prepared and presented by the teacher. The remainder of these schools, forty-seven in number, made no mention of laboratory work by the pupils or of demonstrations by the teacher. Of the one hundred and seventy-six public high schools included in the report, thirty-nine sent descriptions of their work which indicated that they had developed, with considerable care and thoroughness, the laboratory method of study and teaching.[3]

In the light of these reports it appears that chemistry has occupied nearly as large a place in the program of studies of the early high schools as it does today. Most of the "standard" schools have always provided a place for it. As already suggested, in the earlier period there were great variations in the kind of recognition which was given. In sixty-eight of the public high schools in the list of the Bureau of Education (1880), the course was given for but one-half year or less, and in many of these the total number of exercises, including recitations per week, was less than five. In laboratory equipment the variation was from none up to apparatus which, for chemistry and physics combined, had cost from three to four thousand dollars.

The past fifty years have not witnessed the extension of instruction in chemistry in a considerably larger proportion of the public schools. There were, however, two important developments during this period: (1) It has witnessed a standardization of content and methods; and (2), it has contributed a

[1] Stout, J. E., "The Development of High-School Curricula in the North Central States from 1860–1918," Supplementary Educational Monographs (University of Chicago), Vol. III, No. 3, **1921**, pp. 90–91.

[2] Bur. Education, *Circ. Information* **6**, pp. 170–74 (1880).

[3] *Ibid.*, pp. 20–22.

definition of objectives and the beginnings of a critical evaluation of these objectives by the application of scientific methods to education. These developments relate to instruction in college chemistry, as well as to high-school chemistry, and we shall return to them after taking an over-view of the history of chemistry in colleges.

Chemistry in American Colleges

The foundation of modern chemistry is in the work of Black, Cavendish, Lavoisier, Priestley, and others who worked during the latter part of the eighteenth and the early part of the nineteenth centuries. Before Priestley's death in 1804, Princeton, Columbia, and Harvard had made chemistry a required study for students who were candidates for the baccalaureate. However, it was many years before it was given a place of prominence in the curriculum. As late as 1875 the provision which had been made for chemistry in most of the colleges was quite meager. The progress since that time may be illustrated by reference to the offering for different years in representative institutions.

At the College of New Jersey (Princeton) in 1871–1872 chemistry was a required subject only during the senior year and this constituted the sole offering. Professor Schanck gave lectures in (1) General Chemistry and (2) Applied and Organic Chemistry. He also gave lectures in (1) Zoölogy and (2) Anatomy of Physiology.[1]

There were but few changes in the titles of the courses offered in this college for several years. It was stated in 1881 that:

> Students in the academic department attend a required course in applied chemistry throughout the entire senior year. The aim is to give a full course of instruction in general chemistry occupying two hours in the class room each week and in this attempt is made to give quite fully the leading principles and facts of general chemistry, enforced by carefully prepared experimental illustrations. Free use is made of lantern projections, and recitations and written examinations are required. The additional parallel and elective course embracing the leading applications of chemistry in the arts of life, also illustrated fully, occupies one additional hour each week.
>
> Laboratory chemistry constitutes an elective study in the senior year. The class attend lectures with occasional recitations and also work in the laboratory. The course requires about four hours per week; three hours being generally devoted to laboratory work and one hour to lectures and recitations.[2]

There was an offering of a "general science course" in which chemistry was taken during the sophomore year. In 1880–1881 there were two professors of chemistry and one assistant at Princeton. In 1890–1891 general chemistry was required during the first semester of the sophomore year and an elective course in general chemistry was offered for the first semester of the

[1] Calendar of the College of New Jersey, 1871–72, p. 41.

[2] Princeton University Catalogue, 1882–84, p. 59.

junior year. A laboratory course consisting of qualitative analysis, organic compounds, and special examination of water, milk, etc., was elective during the senior year. In 1900–1901 general chemistry was a required subject in the second half of the sophomore year and an elective course, including organic chemistry, was offered during the senior year. The work had been differentiated to the extent of including eight additional elective courses. In 1905–1906 the work of the Department of Chemistry was given under "School of Science" and a course was offered for the training of chemical engineers. Nineteen distinct courses were listed, six being graduate courses. During this year there were five professors of chemistry and two assistants. In 1910, Princeton employed four professors, two instructors, and twelve assistants.

The following tabular statement shows the progress of the development of chemistry at Harvard University.

Courses in Chemistry Offered at Harvard in 1875–76, 1895–96, 1915–16, with Number of Students in Each

TITLE OF COURSE	NUMBER OF STUDENTS 1875–76	1895–96	1915–16
Elementary chemistry	251	268	221
Inorganic chemistry	..	..	129
Descriptive chemistry with laboratory practice	53	..	..
Advanced inorganic chemistry	..	..	88
Quantitative analysis	40	94	68
Mineralogy	2	..	..
Quantitative analysis	9	24	53
Organic chemistry	7	19	159
Advanced quantitative analysis	..	9	20
Gas analysis	..	11	20
Experimental chemistry	..	75	90
History of chemistry and chemical philosophy	..	9	..
Research courses (differentiated)	..	12	34
Physical chemistry	..	..	38
Experimental organic chemistry	..	..	55
Fire assaying	..	..	3
Metallurgical chemistry	..	..	3
Carbon compounds	..	..	55
Biological chemistry	..	..	36
Experimental biological chemistry	..	..	7
Industrial chemistry	..	..	56
Technical analysis	..	..	7
Photochemistry	..	..	19
Electrochemistry	..	..	17
Experimental electrochemistry	..	..	4
Chemical equilibrium	..	..	3
General reactions of organic chemistry	..	..	15
Structural organic chemistry	..	..	12
Total number of courses offered	6	9	25

In 1885 there were three professors of chemistry at Harvard; in 1895 there were four; and in 1915 there were nine professors, two instructors, and twenty-four assistants.

Elementary chemistry at Harvard in 1875–1876 was given to freshmen and consisted of one "exercise" each week for twenty-four weeks. During this year there was an appropriation of $800 for the chemistry laboratory and a special appropriation of $703.65 to fit up a laboratory of organic chemistry. In 1895–1896 research courses were offered in inorganic, organic, and physical chemistry, and twelve students enrolled in these courses. By 1900 the number of research students had increased to seventeen. The further gain in registration for research reflects the influence of German universities and constitutes one of the most significant developments of this period. In 1905 there were nineteen students enrolled in research courses, in 1915 thirty-four, and in 1920 thirty-seven.

The reports of Professor Chandler to the president of Columbia University show some of the difficulties with which he was forced to cope and reveal a situation which is quite in contrast with the one which prevails in this university today. In 1881 he wrote:

> I have the honor to report that in the academic department of the college I have met the sophomores once a week and have gone over the non-metallic elements. The holidays and monthly examinations reduce the number of exercises to such a degree that it is not possible to go over a great deal of ground. I think it would be a great improvement to double, if possible, the number of exercises, and allow the sophomores to come to me twice a week. I should then be able to give them a fair initiation into the field of chemistry.
>
> The seniors, or rather an elective section of them numbering twenty-nine, have attended three times a week with the second section of the School of Mines. The first term was devoted to inorganic chemistry, the second term to organic chemistry.[1]

In 1884 Professor Chandler reported:

> There has been one graduate student attending instruction in chemistry but for several reasons he has not been able to accomplish a great deal. Under a rule of the Board of Trustees he is not permitted to enter the analytical laboratories of the school—the only laboratory in which he can work under the present rules is the organic laboratory.[2]

Somewhat more attention was given to the study of chemistry in some of the midwestern universities than in the universities of the East. This may have been due in part to a greater willingness to break with the tradition which emphasized so strongly the importance of the classics. Furthermore, the agricultural states fostered the development of agricultural and mechanical colleges in connection with their state universities and chemistry was an essential subject in these institutions. As early as 1880–1881 chemistry had been differentiated into thirteen courses at the University of Michigan. The title of one of these was

[1] Annual Report of the President of Columbia University to the Board of Trustees, **1881**, p. 113.

[2] *Ibid.*, **1884**, p. 70.

"Original Investigations." This suggests that the major purpose of the course was the promotion of research.

The past fifty years have witnessed an enormous expansion of college work in chemistry. As we have seen, chemistry was assigned a place in the college course of study long before the opening of this period but it was a very inconspicuous one. Princeton has been recognized as the first American college (1795) to give lectures in chemistry to liberal arts students, but in 1871 the entire offering was given by one man who divided his time with other subjects. In 1800 the trustees of Columbia College determined that the study of the "chemical branch of physics" should precede the conferring of the degree of bachelor of arts, but in 1884 they had only one graduate student in chemistry and were poorly equipped to care for him. The rapid growth since 1875 may be measured by the increase in the number of differentiated chemistry courses; by the increase in the number of professors on the college faculty; and by the increased attention to graduate study and research.

An important accompaniment to the progress of chemistry has been the development of its application to mechanical and industrial pursuits. Chemistry is part of the training for all fields of industrial engineering. It is considered an essential study for the preparation of pharmacists, physicians, dentists, nurses, agriculturists, and research workers in all fields of science. The phenomenal growth of chemistry in colleges is unparalleled by any other subject.

Objectives of Instruction in Chemistry in Colleges

Two practical objectives guided the growth of chemistry as a subject of instruction in colleges. One of these was to teach chemistry as related to the manufacturing industries and the other its relation to agriculture. The possibility of extensive application of chemistry to industry was recognized as early as 1815, when it was said that chemistry was

> an important aid to the study of mineralogy, pharmacy, electricity, cooking, metallurgy and in various manufacturing industries, especially glass, leather, soap, paint, glue, starch, etc. In fact it would be an easy task to continue almost indefinitely the list of arts whose processes, if they admit of explanation at all, must be explained upon the principles of chemical philosophy.[1]

However, at as late a date as 1870 when the value of manufactured chemical products in France was 250 million dollars, the total value of American chemical products, including fertilizers, was but $25,217,000.[2] The total value of the products from chemical

[1] An unsigned essay on "The Classification, Mutual Relations and Various Uses of Physical Sciences," *Analectic Magazine*, **6**, 145 (1861).

[2] Bolles, Albert S., "Industrial History of the United States," **1879**, p. 489.

industry in 1923 was nearly six billion dollars. During the same year chemical industry employed 384,493 wage earners, paid $501,205,000 as wages, and used 2,739,519 horsepower.[1] The individuals who have developed this great industry for the most part have had their training in the technical schools. The development of industrial chemistry has been a leading objective of education in chemistry, and the present status of chemistry in industry is abundant evidence of successful accomplishment.

The importance of chemistry to agriculture was also recognized at an early date. In 1811, the Philadelphia Society for Promoting Agriculture recognized the possible application of chemistry to the maintenance of soil fertility. In its "Memoirs" were articles on the use of lime, gypsum, leached ashes, and salt as material for fertilizing, and it was lamented that there was not more exact knowledge of these substances.[2] Notwithstanding the frequent reference to the importance of applying chemistry to agriculture, the large developments have come during comparatively recent years. There are, in fact, many indications that this field is due for rather rapid advancement in the immediate future.

A third objective has been the promotion of research. As already indicated, there was but little research in chemistry in American universities of fifty years ago. The instruction in the School of Arts of Columbia College was not planned to promote research in 1875, nor for several years later. It was said in 1878 that in the School of Mines,

> this course of study is designed to train analysts and technologists, rather than purely scientific investigators. A considerable amount of original research work has, however, been done by the graduates of the course and a small pamphlet catalog of their publications has been prepared.[3]

At Princeton in 1878 "Postgraduate courses are offered" but there was little or nothing in the nature of research.[4] At Yale, during this same year, instruction in chemistry in the undergraduate academic department was given by one professor in the first third of the junior year, but there was no laboratory practice. Postgraduate courses in theoretical and analytical chemistry, agricultural chemistry, and metallurgy and assaying were given in the department of philosophy and the arts. In the Sheffield Scientific School "a good deal of original research

[1] "World Almanac and Book of Facts for 1925," p. 330.

[2] "Memoirs of the Philadelphia Society for Promoting Agriculture, Containing Communications on Various Subjects in Husbandry and Rural Affairs," 1811. Reviewed in *American Review*, **2**, 78–101.

[3] Bur. Education, *Circ. Information* **6**, pp. 65–68 (1880).

[4] *Ibid.*, pp. 75–76.

work is done by teachers and advanced students and a very large number of scientific memoirs have been published from the school."[1]

At Harvard, "In the laboratories advanced students are directed by the professors in whatever special studies or investigations they may desire to undertake."[2]

These references are sufficient to illustrate the meager recognition which was given to research in chemistry fifty years ago. Its importance was recognized, however, and effort was directed towards its stimulation. A measure of the success with which this objective has been accomplished may be had in terms of the enormous accumulations of reports of research; in terms of the influence which the results from research have had on present conditions of living; and in terms of the number of individuals now employed as research workers.

The materialistic contribution of chemical education has been most evident, but its cultural value has been none the less significant. The development of this science came at a time when the culture of the people was greatly influenced by superstition and mysticism. The development of chemistry and other sciences was accompanied by an accumulation of factual information about many phenomena which, for all time, had been looked upon as beyond human comprehension. The research scientists discover and rationalize the causes which lie back of effects. The educational outcome from instruction which shows relation of cause and effect, relative to phenomena which had been looked upon as mysterious, leads to the belief that all phenomena are results from definite causes and that all unexplained events may be rationalized if the facts relative to them are discovered. This aspect of the scientific method has, more than any other, influenced the thinking of educated individuals who are not specialists in science. The development of science and the frustration of superstition have paralleled since the middle of the eighteenth century. A general dissemination of this attribute of the "scientific attitude of mind" has been an achievement of the past fifty years. But much remains to be done.

It will be seen that the major accomplishments of college education in chemistry have been: (1) the development of industrial and agricultural applications; (2) the development of research; and (3) the general diffusion of the method and attitude of mind of the scientist.

[1] Bur. Education. *Circ. Information* **6**, pp. 57–59 (1880).

[2] *Ibid.*, p. 48.

Objectives of Instruction in Chemistry in Secondary Schools

It has already been shown that the past half-century has not witnessed any considerable extension of instruction in chemistry in high schools. The percentage of the four-year high schools of the United States offering this subject has remained fairly constant since 1876. This period has, however, witnessed the standardization of content and, in considerable measure, the method of instruction. This has resulted: (1) from the work of influential committees; (2) from Smith and Hall's textbook;[1] (3) from the influence of texts written by college teachers and used in high schools; and (4) from the transplanting by teachers of the content and method which they had learned in college to the high school. It will be profitable to make some examination of each of these standardizing agencies and, if possible, to suggest some evaluation of the objectives which they have set for accomplishment in secondary schools.

Fifty years ago the course in high-school chemistry was poorly defined, and there was wide divergence in practices relating to methods of teaching. The recognition of the subject as one suitable for a college entrance unit has, more than anything else, effected a standardization of content and of method.

An analysis of the entrance requirements of forty-four colleges in 1879 showed that only three (Iowa State University, California State University, and Boston University) recognized chemistry.[2] This issue was brought to a focus by the action of Harvard College in 1888 when, for the first time, it included chemistry among the subjects that might be offered for admission. Professor Cooke issued this same year his "Laboratory Practice," which defined chemistry as the true educational equivalent of the other and older preparatory school subjects. This book was the first in this country which attempted to standardize the laboratory work in high-school chemistry, and the results from its use were in

> marked contrast to the miscellaneous experimentation with chemical substances, and the dabbling in qualitative analysis which had hitherto been in use and had afforded so little support to the classroom work on the principles of science.[3]

It was at this time that the advocates of a number of newer studies were clamoring for recognition as college-entrance sub-

[1] Smith, Alexander, and Hall, Edwin H., "The Teaching of Chemistry and Physics in the Secondary School," **1902**, Longmans, Green & Co., N. Y.

[2] Nightingale, A. F., "A Hand Book of Requirements for Admission to the Colleges of the United States," **1879**, pp. 10–25.

[3] Smith, Alexander, and Hall, Edwin H., "The Teaching of Chemistry and Physics in the Secondary School," **1902**, p. 19, Longmans, Green & Co., N. Y.

jects and that the more progressive of the college administrators were recognizing the need for a more liberal course of high-school instruction than was afforded by the study of the classical languages and mathematics. An effort to promote these two progressive movements found expression in the work of the Committee of Ten of the National Educational Association.

The report of the Committee of Ten has probably had the most far-reaching effects on secondary education of any document that has ever been printed. In his letter of transmittal to Hoke Smith, Secretary of the Interior, W. T. Harris, commissioner of education, said:

It has been agreed on all hands that the most defective part of the education in this country is that of the secondary schools. There is a wide divergence in the course of study, and the difference of opinion regarding what constitutes a secondary education works injury not only to the elementary schools by setting up an uncertain standard of admission but also through a want of proper requirements for graduation prevents in thousands of cases the continuance of the course of education of youths in colleges and universities. The recommendations of this report will draw the attention of great numbers of teachers to the question of educational values and this will lead to a better understanding of what the pupil should study to gain the most from his work in school. In this respect I consider this the most important education document ever published in this country.[1]

The committee was appointed in July, 1892, with President Charles W. Eliot of Harvard University as chairman. The members met at Columiba University on November 9 and decided to organize conferences on nine subjects or groups of subjects. One of the groups included physics, astronomy, and chemistry. Ten members were appointed to each of the conferences and each conference was requested to submit its report to the chairman of the main committee by April 1, 1893. The complete reports were submitted to the Department of the Interior for publication in December, 1893.

The conference on physics, chemistry, and astronomy met on December 28, 1892, at the University of Chicago. Prof. Ira Remsen of Johns Hopkins University was elected chairman. The recommendations of the conference affecting chemistry were:

(1) That the study of chemistry should precede the study of physics and that physics be pursued the last year of the high-school course.
(2) That at least 200 hours be given to the study of chemistry in the high school.
(3) That both physics and chemistry be required for admission to college.
(4) That there should be no difference in the treatment of chemistry for those going to college or scientific school and for those going to neither.
(5) That chemistry be taught by a combination of laboratory, textbook and thorough didactic instruction carried on conjointly, and that at least one-half of the time devoted to this subject be given to laboratory work.

[1] Bur. Education, Report of the Committee on Secondary School Subjects, 1893, p. ii.

(6) That careful notebook record of the laboratory work be kept by the student at the time of the experiment.

(7) That the laboratory record form part of the test for admission to college and that the examination for admission be both experimental and either oral or written.

(8) In the opinion of the conference admission to college should be by certificate from approved schools.

(9) In the opinion of the conference it is better to study the subject as well as possible during the whole year than to study two or more superficially during the same time.

(10) It should not be the aim of the student to make a so-called rediscovery of the laws.[1]

A committee of two was appointed to make out, subject to the approval of the conference, a list of fifty experiments in physics and one hundred experiments in chemistry. The report of this subcommittee is appended to the report of the conference. At this meeting it was

Resolved, That in the opinion of this joint conference at least one quarter of the time of the high-school course should be devoted to nature studies and that this amount of work should be required for admission to college.

One member of the conference opposed placing chemistry before physics in the course of study but with this exception the ten members were in complete agreement.

The report of the Committee of Ten urged the recognition of a wider range of subjects for college entrance. The high school was "the people's college" and must offer a rich and varied course of study. The classical languages and mathematics had been recognized by the colleges as the studies most acceptable for college entrance and students who had pursued other subjects, particularly the natural sciences, were frequently embarrassed when they applied for entrance.

In 1895 Prof. William Corey Jones, of the University of California, read a paper before the Department of Secondary Education of the National Education Association on the subject, "What Action Ought to Be Taken by Universities and Secondary Schools to Promote the Introduction of the Programs Recommended by the Committee of Ten?" Discussion of this paper led to the appointment at this session of the Committee on College Entrance Requirements. The final report of this committee was issued in 1899.

The report of the chairman to the meeting of the association in 1896 made special mention of the sciences. He said:

The sciences as they are beginning to be taught in our best schools add to the wealth of mind as well as the stock of facts and the colleges must recognize them as full equivalents for other work which they have hitherto demanded to the exclusion of science.

[1] Bur. Education. Report of the Committee on Secondary School Subjects, **1893**, pp. 116–21.

In their preliminary report of this year[1] the committee presented an analysis of the entrance requirements of fifty-six of the "most important institutions." This analysis shows that twenty-four of the fifty-six institutions required or recognized chemistry as a college entrance subject. Three institutions required physics or chemistry; four required physics and chemistry; and thirteen required physics and chemistry and "some other good natural science subject."[2] In their summation of the requirements in natural science, the committee noted that "the average requirement is very low, incoherent, and illogical."

In its "Plan of Work for 1896–1897" it was recommended that the committee should invite the active coöperation of specialists in the various subjects and that special attention should be given to what constitutes a year's work in each subject.[3] This recommendation prevailed. Alexander Smith, then of the University of Chicago, was made chairman of the Committee on Chemistry. The divisions of his committee report were: (1) value and place of chemistry; (2) outline of a one-year course; (3) methods of teaching, with recommendations for laboratory, classroom, and library work; (4) subject matter; and (5) equipment.[4] This committee incorporated many of the recommendations of the Committee of Ten, including the statement that at least 200 hours be allowed for the one-year course and that about one-half the time, in two-hour periods, should be spent in the laboratory. They took exception to the recommendation relating to sequence by placing chemistry in the fourth year of the high school and physics in the third.

Professor Smith's treatise on "The Teaching of Chemistry and Physics in the Secondary School"[5] appeared in 1902, three years following the issuance of the Report of the Committee on College Entrance Requirements. It met a real need in that it furnished a practical guide for the accomplishment of the committee's recommendations. Professor Smith's book gave a definition of the place of chemistry in the high-school curriculum, and it contained chapters on Instruction in the Laboratory; Instruction in the Classroom; Some Constituents of the Course; The Laboratory, Equipment, and Illustrative Material; and The Teacher, His Preparation and Development.

[1] "Preliminary Report of the Committee on College Entrance Requirements," *School Review*, **4**, 341–460 (June, 1896).

[2] *Ibid.*, p. 453.

[3] National Education Association, Report of Committee on College Entrance Requirements p. 9 (July, 1899).

[4] *Ibid.*, pp. 165–71.

[5] Smith, Alexander, and Hall, Edwin H., "Teaching of Chemistry and Physics in the Secondary School," **1902**, Longmans, Green & Co., N. Y.

No factors affecting education in high-school chemistry have been so potent as those associated with the standardization of the course for college entrance. The past fifty years have witnessed progress from almost no recognition to complete recognition by practically all colleges and universities.

The content and methods of high-school chemistry have been determined in large measure by the textbooks available. Through these, college professors of chemistry have until quite recently enjoyed almost complete domination. This domination has been wholesome and necessary through the formative period of secondary education. Those equipped in training and scholarship to write books were for the most part in college positions, although there have always been some notable exceptions. During the past decade some of the most popular books have come from the pen of high-school teachers, but thus far none have broken with the tradition established by the college authors.

The Outlook for Chemical Education

The past fifty years have witnessed the establishment of practices and the extension of instruction until today chemistry is, in some manner, affecting the lives of thousands of students. It is now time to make some evaluation and some refinement of these practices.

The past quarter-century has seen notable contributions to the methods of educational investigation and study, and these have come in large part as a result of transfer of the method of work evolved by scientific workers in the fields of the biological and physical sciences to this field. Educational workers, like chemists, are no longer content with philosophy or theory which has no factual foundation. Acceptance of educational theory and philosophy is now conditioned upon factual support. Opinionated committee recommendations are no longer adequate. The future of chemical education is, in large measure, dependent upon the application of the scientific method to the study of its problems.

It has already been shown that the reports of the Committee of Ten (1893) and the Committee on College Entrance Requirements (1899) have greatly influenced present practices. Their recommendations relating to content and method have been accepted because they came from experts who were presumably most competent to advise concerning these matters. The future will see the scientific method used in testing and evaluating the practices which have evolved from the deliberations of these committees. In fact, this testing and evaluating is now in progress.

The Committee on College Entrance Requirements outlined a high-school course of study which was similar but presumably simpler than the freshman college course. A recent study reports a quantitative analysis of the content of instruction in the high school and in the first-year college course.[1] This analysis shows that there is almost no part of the high-school course which is not repeated in the college course.

Facts relative to some of the committees' recommendations of methods have recently been reported. One study reports an evaluation of different methods of laboratory procedure and shows that, for the accomplishment of certain objectives, the teacher-demonstration method is equally or possibly more effective than the individual method of laboratory work.[2]

A measure of the relative values of different methods for recording laboratory notes has been reported. The study reports the results of experimental teaching in which three methods of recording were used. These methods were evaluated by administering tests of achievements to the students after the experiment.[3] Another study compares the achievement of high-school students in three high schools with that of freshmen students in three colleges on tests prepared from the first division of the "Syllabus for College Freshmen" prepared by the Committee on Chemical Education of the AMERICAN CHEMICAL SOCIETY.[4] This study shows that the differences in achievement on these tests by students in good high schools and in good colleges is relatively small. Another report gives an analysis of the errors which pupils make after instruction.[5] The author of this study contends that it reveals the points at which more intensive instruction must compensate deficiencies in learning ability. A significant trend is illustrated by a report of an analysis of the needs for instruction in chemistry of certain vocational groups and an outline of a course of study to meet this need.[6]

[1] Koos, L. V., "Overlapping of High School and College Chemistry." The Junior College, Ch. XXXIII, **1925.**

[2] Carpenter, W. W., "Certain Phases of the Administration of High-School Chemistry," Columbia University, Teachers College, *Contributions to Education* **191** (1926).

[3] Stubbs, M. F., "An Experimental Study of Methods for Recording Laboratory Notes in High-School Chemistry," *J. Chem. Education*, **3**, 296–300 (1926).

[4] Mabee, Fred C., "A Test of Achievement in College Chemistry and Results Obtained by Its Use with Both High-School and College Classes," *J. Chem. Education*, **3**, 70–76 (1926).

[5] Bennet, J. C., "A Study of Pupil Errors in Chemistry," *J. Chem. Education*, **2**, 760–69 (1925).

[6] Beery, Pauline, "A Practical Course in Household Chemistry," *J. Educational Research*, **5**, 125–34.

These reports are sufficient to illustrate present trends in chemical education. Their significance lies in the fact that they illustrate some of the ways in which the methods of science are applied to educational problems. In education, as in so-called pure science, the development of hypotheses and theories and the formulation of more intelligent philosophy follow upon the accumulation of factual material, such as is reported in these studies. An important problem, and one about which but little is definitely known, is what should constitute the course in chemistry for students who are not preparing for specialization? The history of the development of the high-school and college-freshman courses shows that their present content has been selected in an effort to train technical chemists and research workers. The technician is a creator of chemical products and the investigator is a revealer of truth. The major objective of a liberal education in chemistry is to teach an interpretation and appreciation of the truths of chemistry and, in some measure, to train in intelligent usage of chemical products. There is need for a factual statement of what chemical truths are of most importance to a program of liberal education and for a statement of what is needed most in the way of training for intelligent consumption. A course which is designed for students who are not preparing for specialization should embody this content. Up to this time it has been assumed that the same chemistry course was sufficient for all. It is now time to question whether the course which is best for vocational training is also best for liberal training.

Closely related to the problem of developing a course for liberal training in chemistry is the problem of providing a proper differentiation of courses to meet the needs of various vocational groups. There is an evident feeling of doubt that the present course in chemistry for dentists, for example, is for them either vocational or cultural in the best sense. The vocational values of chemistry for dentists (or for medical students, nurses, or civil engineers) have not been carefully defined. Attention to this problem will surely effect an economy of time to students and financial economy in colleges.

Some other important problems for immediate study are:

What should constitute the training in chemistry for college preparation, and how should the college preparatory course be correlated with the college course?

What are the values which should come from laboratory work in training for a liberal education?

Is there support for the present emphasis on laboratory notebook work?

Is chemistry an appropriate subject for study in small high schools in which laboratory equipment is necessarily meager?

How much and what kind of laboratory equipment is necessary for successful high-school work?

What are the fundamental concepts and generalization of chemistry? Of what use are these fundamentals?

How may the method and content of chemistry be modified so as to raise effectively the standards of accomplishment in useful learning?

How can the high-school and liberal arts college course be taught so as to accomplish more effectively training in the methods of the scientists?

The important developments of the immediate future will come from application of the scientific method of study to these and similar problems.