AN HISTORICAL SURVEY OF CHEMISTRY AS A SUBJECT IN THE COLLEGES AND UNIVERSITIES OF THE UNITED STATES

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CHAPTER I

INTRODUCTION

The historic trends in the development of chemistry in the colleges and universities of the United States are exceedingly interesting and valuable as a means of interpretating conditions which manifest themselves today. A complete understanding of the conditions which exist at the present time in college chemistry teaching is practically impossible without a knowledge of the forces which affected developments in subject matter, aim, method of teaching, and training of teachers as they grew to the point at which they are now found.*

The last seventy-five years have seen great and rapid developments along scientific lines. This development has come so quickly the last fifty years that society has not as yet had time to adjust itself to changed conditions. Coyler Meriwether expresses this thought very well in his writings. He says:[1]

> Man was emancipated from his own past. Since then he has turned to science. Getting control of himself, he sought control of nature. He has done forever with raking and gloating in the charnel houses behind; he has set his

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* Like most introductions this has been written after the study has been made.

[1] Coyler Meriwether, Our Colonial Curriculum. Central Publishing Co., Washington, D. C., 1907, p. 286.

face to the morning light ahead. In doing so, he has seen more in one century than his fathers saw in twenty.

The nature of the study. The main objective of this study has been to trace the growth and development of chemistry as a subject in the colleges and universities of the United States. In this survey an attempt is made to present a clear picture of the growth of the chemistry curriculum from a disorganized mass of material and information of colonial times to the highly diversified courses of study offered at the present. Another desirable objective of this study has been that of bringing to light the various forces which have played an important role in molding the chemistry curricula as they have developed.

Previous studies. Much material has been written on this subject, but none has been found which treats of the topic from the point of view which this study takes. A great number of articles have been published, and many books have been written which deal with the history of chemical education. Then too, there have been many valuable books written on the general history of education in the United States. Government circulars of information have also been published which present pertinent facts regarding chemical education in this country.

The scope of the study. This study treats of the nature, aims, methods of instruction, subject matter, and extent of chemical education as it is found during the various periods of its development in this country. It also attempts to present the data in such a fashion that the relationships existing between various factors may be recognized. The broad scope of the subject has caused a limitation of the survey in certain phases. Consequently no attempt has been made to completely exhaust the subject in all its details.

As a result of this, only the very important and influential men who had a part in the history of this subject have been considered to any great extent. Biography material has been entirely omitted in this study. The phases which are covered include the content, aim, method of instruction, and extent of the chemistry curriculum as it developed in this country.

Method of procedure. Pertinent historical influences and their relationship to each other were chosen from various types of informational material. By contrasting different types of representative data with other meaningful information and by the use of numerous quotations, an attempt was made to portray the nature and content of the chemistry curricula of the various periods of its development in the American colleges and universities.

Presentation of data. The plan of this study has been to present a chronological history of chemistry as a separate subject in the colleges and universities of the United States from its beginnings to the present time. The data have been presented in such a fashion so as to fulfill this objective. Beginning with chemistry in its beginnings in colonial times, and down to the present, the chronological order has been utilized. A great portion of the data included in this study are presented in the form of statistical tables. The text of this study is divided into four natural divisions. The second chapter treats of the beginnings of chemical education in colonial times; the third chapter traces the development of chemistry up to the time when it gained a foothold as a separate subject in the colleges and universities; the fourth chapter attempts to show the development of the laboratory method of chemical instruction; the fifth chapter brings the study up to the present time by picturing the advances in chemical education since 1870.

CHAPTER II

THE BEGINNINGS OF CHEMICAL EDUCATION IN COLONIAL TIMES TO ABOUT 1750

If the period of time including the development of the United States from the first settlements to the present were set to the scale of one day, it might be said that practically all the great advancements in the science of chemistry and the development of this subject in educational institutions have taken place during the last four or five hours. This rapid development has been a natural outgrowth of reacting forces which had their origin back in early periods. In order to obtain a true picture of the scene through which chemistry passed as it developed from an unorganized group of facts and superstitions to the highly organized and predictive science of today, it is necessary to examine and look into the conditions regarding science which prevailed during the earliest days of this country. Therefore, this will be the purpose of this chapter along with that of showing the beginnings of chemical education in the United States.

Science in colonial times. Our ancestors brought over the Atlantic with them a belief in the explanations given by ancients of any natural phenomena that came before their eyes. The world of physical things was surrounded by mysticism and superstitions. Their attitude was that of unquestioning reliance upon the explanations of things about them in terms of baseless theories which clutched at the actions of the Almighty for their basis. Coyler Meriwether expresses the attitude of these pioneers quite well when he says:[1]

> The forests around them rang with the cry of bird and beast, but when they wanted to solve any puzzle that they noted in animal life they leaped back years to Pliny, "the greatest gull of antiquity." The best educated among them stared in the greatest amazement at everything unusual and clutched at baseless theories that few naked savages around them would have scarcely tolerated. The ministers acted as soothsayers and expounded the hidden meaning of monstrous births and even played showman to exhibit these gastly messages from the Almighty. The doctors were almost as crude and primitive as medicine men in Central Africa. They looked up to Paracelsus and wrought cures on the principle of like by like. A toad has warts, therefore, the application of them is good for small pox. If you suffer from jaundice, why color the milk you drink with saffron and you will be free from your trouble.

This attitude may also be exemplified by the teaching of Charles Morton, Abraham Pierson, Gravensande, and Rohault.[2] Charles Morton came over from England highly recommended to teach science at Harvard University, the center of education and learning in the new world at that time. He explained that birds went to the moon in the process of migration.[3] Pierson, a Harvard graduate in 1668, afterwards the president of Yale

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[1] Coyler Meriwether, Our Colonial Curriculum. Central Publishing Co., Washington, D. C., 1907, pp. 187-88.

[2] Ibid., pp. 188-94.

[3] Ibid., p. 189.

college, took many notes which he afterwards used as a teacher at Yale. The following taken from one of these notes serves well to illustrate the relationship of science and religion at that time.[4]

> First, the world is neither from eternity nor able to be of itself, but is a round body the most capacious of all figures sent forth perfect. Second, angels are a spirit, not made of one of the elements, but of rare medium, endowed with reason and will, and ministers of God, having always existed from the beginning, of least materiality but of many forms.

The afore-mentioned men all had the same general conception in which metaphysics and religion rule. This may seem queer until one fully realizes the extent of scientific knowledge present at that time.

__The foundations of modern chemistry.__ It is a general fact that it is not until the eighteenth century that the decline of alchemy and the birth of chemistry took place.[5] There are several reasons why science was thought of as it was in the early days, the most prominent one being that so little was known about it. The great possibilities of chemistry were not demonstrated to the world until the eighteenth century when the experimental researches of Black

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[4] Ibid., p. 192.

[5] Samuel Ralph Powers, "A History of the Teaching of Chemistry in the Secondary Schools of the United States Previous to 1850," __Research Publications of the University of Minnesota__, Current Problems No. 13, University of Minnesota, Minneapolis, 1920, p. 2.

(1728-1799), Cavendish (1731-1810), Priestly (1733-1804), and Lavoisier (1743-94) came forward to play an important role in establishing this new science.[6] It is probably true that when, in 1755, Joseph Black graduated from the University of Edinburgh with the degree of M. D., his thesis on Magnesia Alba, Quicklime, and other Alkaline Substances was the first accurate quantitative examination of a chemical action which we possess.[7]

The researches of Cavendish, Priestly and Lavoisier on water and the gases of the atmosphere are, in reality, the basis upon which the science of chemistry is built.[8] It is not surprising, then, that the earliest chemical contribution from the United States was "An Analysis of the Chalybeate Waters of Bristol in Pennsylvania," in 1768, by Dr. John de Normandie.[9] This was found in the pages of the Transactions of the American Philosophical Society dated September 10, 1768. In order to gain an insight into the nature of chemical analysis at that time, it might be well to examine some of the remarks made by the author regarding his work with water.

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[6] Loc. cit.

[7] Ibid., p. 3.

[8] Loc. cit.

[9] Edgar F. Smith, Chemistry in America. D. Appleton and Co., New York, 1914, p. 2.

He says:[10]

> . . . although it must be confessed that a chymical analysis is, in some measure, an uncertain test of the medical virtues of any compound; and that the qualities of its constituent parts, when separated, may not only differ from, but are sometimes opposite to, those of the mixture; yet, when we want the testimony of experience, a chymical analysis is the best means of investigating the truth.

In the analysis of the water he proceeds to describe his experiences:

> Experiment I. A small portion of white oak bark, infused in the waters, induced an immediate change from transparency to a dark purple colour, which it retained twenty-four hours, without depositing any sediment.
>
> II. Some of the same water, after being made hot, or exposed for a few hours to the open air, in a great measure lost its irony taste, and received no other colour than a common tincture from the white oak bark.
>
> III. One drop of strong oil of vitriol, in two ounces of the water, produced no sensible alteration; and the water after standing some time continues transparent, without depositing any okerish or other sediment to the sides or bottom.
>
> IV. Ol. tart. pr. deliq. dropt in some of the same water induced a change in the colour, rendering it somewhat yellow; and in time precipitated to the bottom of the cup a fine gold coloured oker.
>
> V. Sixteen ounces avoirdupois, carefully evaporated to a dryness in a China bowl in B. M. left one grain of yellowish brown powder of the taste of tart. tartariz.
>
> VI. Linen, moistened with the scum floating on the top of the spring, is tinged with a strong iron mold.
>
> VII. This water in weight is exactly the same as that of rain water.

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10 *Ibid.*, pp. 2-3.

If one wonders why the early colleges did not include more extensive work in the sciences, he must realize that as late as the eighteenth century chemistry was struggling in the manner described above to be organized as a science on a quantitative basis. It might be said, then, that before this time the science of chemistry hardly existed as such and was too infantile to be included in the curriculum of the very early colleges. Therefore, in an attempt to establish the time when chemistry was first introduced into the colleges and universities of this country, it would, of course, be futile to look to a period of time earlier than the science itself.

It is believed that the factors which contributed to the development of science teaching in general, also contributed to the introduction and development of the teaching of chemistry. Therefore, time will be taken at this point to examine the various forces which were important in molding the development of the sciences and their consequent introduction into the curriculum of the colleges and universities of this country.

<u>The conflict of science with religion and the classics.</u> The exact period of time in which science started to develop is, of course, not definitely known. It is probably true, however, that science had started to develop back in the days

of Roger Bacon.[11] During the Renaissance, science was opposed because it tended to conflict with religion. Also, the revival of the classics was at the time in its greatest glory and was near to the hearts of the educated persons of the time. As a result, the classics became strongly interwoven in the educational curriculum of the time and consequently became one of the strongest opponents of science and its introduction into the colleges.[12] In the early part of the seventeenth century, Dalton's studies led to the theory of atoms on which is based the fundamental principles of chemistry. Other investigations followed and it should be noted that these were for a long time carried on outside the walls of the colleges and universities. As a matter of fact, the sciences did not enter the curriculum of these institutions for a long period of time. The advocates of the classics worked to keep the sciences out of education and met with no great opposition until the close of the seventeenth century, when the growth of reason and the removal of the religious monopoly, the scientific movement, which had been so long in coming, began to advance in rapid strides.[13]

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[11] Frank Pierrepont Graves, A History of Education in Modern Times. The Macmillan Co., New York, 1913, p. 320.

[12] Loc. cit.

[13] Ibid., p. 321.

At about the time the scientific movement was in its beginnings, the colonial colleges were in the process of development. The standing of the sciences in their curricula can very readily be anticipated by considering the nature of the institutions. These colleges were patterned after the model of the British Universities, and therefore, it is found that the teachings were in a large part made up of the classics, with logic, geometry, and physics.[14] This is found to be true because the primary object in the institution of these colleges was the education of the ministers of the Gospel. The great effort of the instructors was to train young men to write and to speak. Subjects of theology, ethics, and metaphysics were much cultivated.[15] With the aim being of this nature, it is evident that the introduction and development of the sciences in their teachings would, by necessity, be a very slow process. The early colleges were by no means completely lacking in sympathy for the sciences, for many of these schools contained men who were vitally interested in science and astronomy as a result of the discoveries during and preceding this time.[16]

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[14] Ellwood P. Cubberley, Public Education in the United States. Houghton Mifflin Co., New York, 1934, p. 34.

[15] George P. Fisher, Life of Benjamin Silliman, vol. I. Charles Scribner and Co., New York, 1866, p. 88.

[16] Loc. cit.

The nature of the early colleges. As was mentioned previously, the earliest chemical contribution from this country was dated 1768, and the experimental researches of Black, Cavendish, Priestly, and Lavoisier did not come until the eighteenth century. Consequently, it would be useless for one to look to a period of time earlier than the eighteenth century for evidences of extensive science teaching in the curricula of the colleges. Graves says:[17] "In the colleges of the United States the courses show some evidence of science teaching in the eighteenth century and a little even in the seventeenth." Astronomy and "the nature of plants" are found in the list of studies advertised at Harvard in 1642, and by 1690 "natural philosophy" was offered by the same institution.

In his writings Cubberley shows the content of the Harvard College course in 1690 by quoting the following from the Harvard College papers:[18]

> The first year the Freshmen recite the classick authors learn't at school, viz., Tully, Vergil, Isocrates, Homer, with the Greek testament and Greek catecism, Dugard's or Farnaby's rhetoric and the latter part of the year Hebrew grammar and Psalter, Rasmus's and Burgersdicius's Logick.
>
> The second year the sophomores recite Burgersdicius's logick and a manuscript called the New Logick extracted

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17 Graves, op. cit., p. 346.

18 Ellwood P. Cubberley, Readings in Public Education in the United States. Houghton Mifflin Co., New York, 1934, pp. 36-37.

> from Legrande and Mr. (?) Copeland. Wollebius on Saturday, and in the latter part of the year Herebord's Meletemata, continuing still part of the year recitations in the forementioned Greek and Hebrew books and dispute on logical questions twice a week.
>
> The third year the junior Sophisters recite Herebord's Meletemata, Mr. Morton's Physicks, Dr. More's Ethick, a sistem of geography, and a sistem of metaphysicks. Wollebius divinity on Saturday, and a dispute twice a week on physical and metaphysical and ethical questions.
>
> The fourth year the senior sophisters recite Alsted's geometry, Gassendus's astronomy, goe over the arts, viz., grammar, logick and natural philosophy, Ames Medulla, and dispute once a week on philsophical and astronomical questions.

Cubberley continues to say: "A statement, signed by President Wadsworth of Harvard, and dated March 15, 1725, shows the same course of instruction in use, unchanged."

<u>The beginnings of chemistry instruction in natural philosophy courses.</u> In some colleges chemistry was introduced as a part of the course in natural philosophy or natural history and for this reason it is well to look into the general nature of these courses as they were taught in the early educational institutions. During the eighteenth century Yale, Princeton, Kings, Dartmouth, Union and Pennsylvania Colleges offered work in natural philosophy or natural history.[19] These courses usually included physics, chemistry, geology, astronomy, botany, and zoology. Chemistry when taught at all

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[19] Graves, <u>loc. cit.</u>

was an unimportant branch of physics which seems to have been a subordinate branch of mathematics. Because of the lack of scientific knowledge at that time physics consisted of practically nothing more than lectures on mechanics, hydrostatics, pneumatics, and optics, with possibly a few discussions on heat, sound and electricity.[20] This was taught by lectures with a few demonstrations by the teacher. These demonstrations were, in most cases, given over to entertainment and spectacular effects. The apparatus which as a general rule was scarce and seriously lacking in efficiency and was used not to exhibit a scientific principle as much as it was used to create a pleasing display of unusual phenomena. Mysticism and superstition surrounded chemistry at this time because it was thought of in terms of alchemy. It was also usually conceded to be an art rather than a science. Natural philosophy was usually taught without the aid of a text book because of the absence of available and adequate books. Probably an exception to this is Charles Morton's college text book which might serve well to bring out the general content of the early natural philosophy courses.[21] In this book he used poetry to impress the explanations. He tried to explain why the Indian monsoon changed its direction. These currents

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[20] Ibid., p. 347.

[21] Meriwether, op. cit., p. 190.

of air streaming in a northward direction strike against high mountains or large clouds and are thrown back and therefore during the rest of the year the winds blow in the opposite direction. He carries this explanation further by putting it into verse:[22]

"From breize, streams clouds the monsoons are North East
From the atlantick vapors South and west."

He explains that earthquakes come from the choking up of wind below fermenting, bursting out, causing "tremblings" and "strokes." He puts this also in verse:

"In subterraneous caverns winds do frolick
When mother earth is troubled with the colick."

The following is the table of contents of Morton's book,[23] taken from a manuscript copy of 1687.

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22 _Loc. cit._

23 _Ibid._, pp. 191-92.

17 Of perfectly mixed bodies and first of stone
18 Of metalls and mineralls
19 Of animate bodies in generall and speciall
20 Of the growing faculty
21 Of procreation
22 Of sensitive living bodies
23 Of seeing
24 Of hearing
25 Of smelling taste and touch
26 Of interior senses
27 Of sensative appetite
28 Of locomotion
29 Of secondary affections, awake and asleep
30 Of the species of animal brute and man
31 Of the world

As was mentioned previously, Abraham Pierson, a Harvard graduate in 1668, afterwards the first president of Yale college, was very industrious in taking notes. Along toward the middle of the little book in which his notes were bound is a part which he called Compendium Philosophiae Naturalis. This is composed of a series of 160 propositions, and virtually definitions of such terms as affinity, motion, porosity, air, water, savor, odor, color, species, and senses. Thus the nature of the course may be gathered by noting the material included.

The science authorities for Yale from her beginning down to the end of the colonial period include Pierson, Roheult, Gravesande, and Enfield. These men had practically identical conceptions of science. It was a science drenched in metaphysics and religious clouds; it was a science in which metaphysics and religion rule.[24] The first physical

[24] Ibid., p. 193.

theses at Harvard bring out the same idea regarding science.[25]

Forma est accidens.
The form is accidental.

Quicquid movetur ab alio movetur.
Whatever is moved is moved by something else.

Nihil agit in seipsum.
Nothing acts upon itself.

In uno corpore non sunt plures animae.
In one body are not many souls.

Phantasia producit reales effectus.
An appearance makes real effects.

<u>Science apparatus in the early colleges</u>. The natural philosophy or natural history courses were taught under the handicap of inadequate apparatus. In 1731, Harvard College had the longest list of apparatus for the study of science. the following is a list of the apparatus:[26]

<u>Mechanicks</u>

1. A strong ballance and stool for measuring the force of falling bodies,
2. The double cone and brass rules,
3. A sett of bodies for experiments of the falling and rolling of bodies; also a small ballance for experiment of the center of gravity, with a support for Ballance,
4. A Ballance with its weights, false scales and pedastal,
5. An instrument for estimating oblique powers in the axis in Peritrochio,
6. Apparatus for explaining the three kinds of Levers, with a sett of compound levers,
7. Apparatus for explaining the pulleys,

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[25] <u>Ibid</u>., p. 194.

[26] <u>Ibid</u>., p. 196-97.

8. Apparatus for the wedge,
9. A compound Engine,
10. Apparatus for experiments of centrifugal force, together with apparatus for experiments of light and electricity with solid glass cylinders,

Optics
1. A large concave mirror,
2. A small convex mirror,
3. A concave cylindrical mirror,
4. An instrument for showing that the lines of the angles of Incidence and refraction bear a constant proportion to each other,
5. Apparatus for experiments of light and colors,
6. A portable camera obscura,
7. A cylinder and picture,
8. A small telescope with a concave eye-glass,
9. A single concave, a double concave, and a miniscus glass, also multiplying glass,

Hydrostaticks
1. A large stool Ballance with a counterpoise to one scale, a pillar for supporting it, a large glass jarr, a Ballance for Wighing levity, with all the particulars expressed in Hyd. Plate 1,
2. A sett of Troy weights 64 oz., with Penny weights and Grains, A box with lock and Hinges for scales,
3. Apparatus for the grand Hydrostatical experiment,
4. Three legg'd syphon, with two syphons,
5. A glass with hydrostatical Images,
6. An hydrostatical Ballance,
7. A model of a sucking pump in glass, Hydrostatics Pl. 2, Fig. 2,
8. An areometer,

Pneumaticks
1. Two setts of Tubes for Torricellian experiments,
2. A frame for supporting them,
3. Apparatus for Mons. Auzout's experiment,
4. A large double air pump with its apparatus,
5. A Tube in a screw for experiment against suction,
6. Apparatus for lifting of weights by the spring of air, contained in a bladder,
7. A bottle for weighing the air, with a bent pipe for exhausting the bottle,
8. Capillary Tubes and Glass plains for the ascent of of fluids,
9. A pair of brass plains,

10. Apparatus for the Hemispheres,
11. A syringe for the compression of the air,
12. A portable Barometer,
13. A Thermometer,
14. Six vials in caps,
15. 48 ditto without caps,
16. A small bowl fountain,
17. A Diving Bell,

Miscellanies

1. 12 Lbs. of Quicksilver,
2. 12 Glass Tubes of different Bores,
3. A loadstone,
4. Solid Phosphones,
5. 12 Doz. of Granade Drops,
6. 6 Doz. of the Lacryme vitrol,
7. Cement and Ladles,
8. An hand vice,
9. Two spare double screws,
10. A duplicate of the Gunpowder Glass unfixed,
11. Tube for Rec. Pneu, P. 2, fig. 2,

The amount of chemistry taught in the early colleges may be inferred by an examination of the preceding discussions. Note should be taken of the fact that the nature and extent of chemistry teaching present at this time continued until the middle of the eighteenth century when the first professorships of chemistry were created. Before the middle of the eighteenth century there were no separate courses in chemistry, so naturally that which was taught was included in the natural philosophy or natural history courses.

It was thus that the early foundations for the teaching of chemistry were laid in the colleges of the United States. It is highly gratifying to know that the science of the period with which this chapter is concerned has developed to the extent which it has reached at the present time. At the close of this chapter, the period is reached in which is found the development of chemistry as a seperate subject in the colleges and universities of the United States. This period may be said to have had its beginnings during the middle of the eighteenth century.

CHAPTER III

CHEMISTRY GAINS A FOOTHOLD IN THE EARLY COLLEGES AS A SEPARATE SUBJECT, 1750-1850

As researches during the last half of the eighteenth century wrought revolutionary ideas concerning many established principles of chemistry, the great possibilities of this science began to be obvious to the world. During the last half of the eighteenth century a group of men in Europe was making discoveries which entirely altered the science of chemistry. This group included such men as Bergmann, Sheele, Black, Cavendish, Priestly, and Lavoisier.

The nature of the chemical science during the middle of the eighteenth century. In order to understand why these discoveries were so important in the development of the entire field, it must be remembered that up to this time chemists had believed fire, air, and water, to be simple substances which could not be divided or broken up into any other kind of matter. Nearly a century before this period, Newton had pointed out that when substances are mixed together some kinds attract each other very strongly and join together, making one compound substance. To illustrate this he said,[1] "If you put copper in nitric acid the copper will dissolve and disappear;

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1 Arabella B. Fisher (Buckley), A Short History of Natural Science. D. Appleton and Co., New York, 1881, pp. 225-29.

but if iron is added the copper will reappear because iron attracts the nitric acid more strongly than the copper does."

Chemists had until this time neglected this observation of Newton's. Bergmann worked on this and by a number of experiments made out a table of those substances which seemed to have the greatest affinity for each other. This he called a table of "elective affinities." From this time on much has been written on the subject of chemical affinity. At a little later period the text books are found to have whole chapters given over to this topic. This is found to be true in Henry's chemistry,[2] in which a chapter is given over to subjects such as cohesion, solutions, crystallization, chemical affinity, the phenomena of chemical action, the proportions in which bodies combine, atomic theory, elective affinity, causes which modify the action of chemical affinity, the establishment of the forces of affinity, complex affinity, and experimental illustrations of chemical affinity.

It is to be noted as characteristic of this period that chemistry became fully awake to her own proper task. This was to investigate the composition of substances and to find out the things from which they could be prepared.[3] An important

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[2] William Henry, Elements of Experimental Chemistry. Vol. 1, Robert Desilver, Philadelphia, 1823, pp. 36-72.

[3] Ernst Von Meyer, A History of Chemistry From Earliest Times to the Present Day. Macmillan and Co., New York, 1906, p. 163.

contribution of this period was the abolishing of certain prejudices, and the use of scientific principles in explaining chemical processes. It was during this time that a complete transformation of all ideas respecting combustion and calcination took place. This was a time of reorganization of chemical doctrine. It was truly a reform.[4]

The old "phlogiston theory" supported by Joseph Priestly found a forceful opponent in Lavoisier as he led the way for the new French School of Chemistry. This country early became the center for arguments between the advocates of the "phlogiston theory" and the anti-phlogiston people. It is interesting to note that it was during this time that chemistry was struggling to gain admittance into the colleges. Priestly's arrival here in America in 1794 was an important event in the history of chemical education. He declined election to the chair of chemistry in the Philadelphia Medical School.[5] Just what would have happened to the progress of chemical education in the United States if Priestly had accepted is not known. He probably would have taught the tottering theory of phlogiston and thus hindered the advance of the new chemistry of Lavoisier.

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[4] Ibid., pp. 165-67.

[5] Lyman C. Newell, "Chemical Education in America from the Earliest Days to 1820." Journal of Chemical Education, 9:682, April, 1932.

In writing of the period previous to the Revolutionary War, Merlwether says:[6]

> It was an age of discussion, not of investigation; it was an age of words, not of research into nature. Men harrassed their souls to know what the masters meant, they did not gather their forces and concentrate their efforts to learn the results of science.

Important chemical discoveries during the last of the eighteenth century. The preceding discussions serve well in picturing the conditions of chemistry during the period with which this chapter is concerned. This period includes the time from the middle of the eighteenth to the middle of the nineteenth century. As a means of showing the relationship between the growth of the science and its treatment as a subject in the colleges of this country as well as for future reference, it is well to make a brief summary of the important chemical discoveries influential in the development of the science during this time. This summary is compiled from Buckley's History of Natural Science.[7]

In 1756, Black extracted "fixed air" from limestone and examined it. In 1761, Bergmann discusses chemical affinity and tests and proves that "fixed" air is an acid. In 1766, Cavendish discovers hydrogen. In 1772, Rutherford

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[6] Coyler Meriwether, Our Colonial Curriculum. Central Publishing Co., Washington, D. C., 1907, p. 284.

[7] Buckley, op. cit., pp. 446-450.

describes nitrogen. In 1774, Priestly discovers oxygen. In 1775, Scheele discovers oxygen. In 1778, Lavoisier overthrows the theory of phlogiston. In 1779, he shows the composition of carbonic acid. In 1784, Cavendish explodes oxygen and hydrogen, forming water. In 1787, Lavoisier founds a new Chemical nomenclature. In 1789, Lavoisier's Elements of Chemistry is published. In 1880, Nicholson and Carlisle work with the decomposition of water. In 1880, Davy works on electrolysis and discovers sodium and potassium. In 1807, Darby treats on hydrochloric acid. In 1808, Dalton proposes his law of multiple proportions and atomic theory. In 1808, Gay-Lussac work on combination in multiple volumes. In 1818, Berzellius discusses the use of the blow-pipe. In 1822, Herschel works on use of the spectroscope to detect chemical elements. In 1830, Liebig analyzes organic substances. In 1832, Liebig discovers chloroform and chlorale. In 1834, Faraday works on electrolysis and chemical nature of electric current. In 1848, Wohler makes organic elements artifically. In 1861, metals in the atmosphere of the sun and stars discovered by spectrum analysis. Thus, is indicated that chemistry as a science was not merely progressing; it was moving by leaps and bounds.

The nature of the early colleges. During the time that the sciences were going through this revolution, the colleges justified their offerings on the basis of discipline and intellectual culture. This, of course, meant drill and mental discipline based on a study of the classics. By 1840 nearly all the northern colleges had a fixed and similiar curriculum.[8]

In discussing these early colleges Meriwether says:[9]

> Their Latin, their Greek, their Hebrew, their linguistic study generally, had given them a verbal razor for splitting the hairs of discussion. Logic, metaphysics, and theology had whetted their ardor still more keenly and had furnished them with great principles, which became bulwarks of safety to fall back upon. The little history they had supplied them with another form of argument, the most convincing to the average human mind, that of example. The shreds and patches of science that they got hardened them in their respect for authority. The formal rules and processes of mathematics that they memorized set them in crystals of unchangeable faith.
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> Thus they stood, with trained memory, fortified with great axioms, equipped with flexible and adaptive language, panoplied with hard dry logic. But all this arsenal, choked with the lore of the ancient world, needed the hand of activity, the power to do. The gymnasium lacked the athlete, and disputation met this want. All this outfit was mere lumber and rubbish unless it could be transformed into the energy of accomplishment. It was only a game, it is true, over a fantastic difference, but just as friendly trials of strength develop for future combats of importance so these mimic battles taught how to win.

Chemistry justifies its admittance into the colleges on various grounds. By considering the condition of the sciences along with that of the colleges during the aforesaid time, one must come to the conclusion that courses in chemistry

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[8] Ellwood P. Cubberly, Public Education in the United States. Houghton Mifflin Co., New York, 1934, p. 33.

[9] Meriwether, op. cit., p. 285.

secured a place in the curriculum of these colleges in competition with the other traditional subjects at a time when the support for all subjects was given in terms of formal discipline. Cubberley says that up to near the time of the out break of the Revolutionary War there had been but one real motive for maintaining school--the religious.[10] Consequently, in light of this fact, chemistry, while attempting to gain admittance to the colleges, had to justify its introduction into the curriculum and its value as a subject on various grounds. The knowledge value of a course was also an important objective for the different courses. This resulted in the early textbooks in chemistry becoming encyclopedias of information. As a matter of fact, when chemistry was first given a place in the curriculum as a separate subject, the greatest amount of chemical information known was included in one small text.[11]

__Early__ __medical__ __schools__. Probably too much credit cannot be given to the early medical schools for their fostering of the early courses in chemistry. It was through the medical schools that chemistry got its foothold in the colleges of this country. The beginnings of chemical education were, in

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[10] Cubberley, __op__. __cit__., p. 88.

[11] Guy Montrose, editor, "A Program for Teaching Science." __Thirty-First Yearbook of the National Society for the Study of Education__, PartI, Public School Publishing Company, Bloomington, Ill., 1932, pp. 24- 25.

of the subject of this period is to study each of these centers of influence individually.

New York. In spite of the fact that chemistry instruction began in the medical schools and that Philadelphia was the first to organize a medical school, the first professorship of chemistry seems to have been introduced in New York in 1767. There is evidence of some little instruction in medicine in New York before this time, but the first attempt to organize a medical school was in 1767 when Dr. James Smith was appointed professor of chemistry and materia medica.[15] The next year the school was placed under the direction of the College of the Providence of New York. This was broken up by the Revolution and was not reorganized until 1792. This reorganized institution was called Columbia College.[16]

In his review of the history of Columbia, President Barnard declared that during the first century of the college, the instruction in chemistry and physics was elementary, and that "natural history" was taught hardly more than in name.[17] But it is probably true that from the beginning and through

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15 Ibid., p. 76.

16 Loc. cit.

17 A History of Columbia University, The Macmillan Co., Agents. The Columbia University Press, New York, 1904, p. 205.

the first century of Columbia's existence, more attention was devoted to the natural sciences than was customary in the English and American Colleges during this period.[18]

The first chemistry teachers in Columbia doubtless taught the chemistry of Stahl's phlogistic notions, because it was not until 1774 that Priestly made his discovery of oxygen. This country was not slow in taking the new chemistry from Europe and teaching it. Dr. Samuel Mitchell early made clear the fact that he was adopting the anti-phlogistic chemistry of the French. It might be said that he taught this new chemistry sooner than any other professor in the United States.[19]

This early chemistry was taught wholly by means of lectures and demonstrations. Even though the demonstrations were spectacular and explosive, they were still an advance upon the mere didactic instruction of earlier times. There was no laboratory work by the individual students, but it seems that a chemical laboratory for the preparation of demonstrations existed from the first. From the beginning of Columbia to about 1850 the chemistry instruction was carried on in much the same manner by an unbroken line of practical chemists.[20]

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18 Loc. cit.

19 Ibid., pp. 328-29.

20 Ibid., p. 29.

Pennsylvania. The first medical school in the colonies was established in Philadelphia in 1765. This was sixteen years after the founding of the College of Philadelphia. However, there was no chair of chemistry till 1769. Before the school was opened the requirements were that chemistry should be taught, but there was no apparatus and no teacher qualified to give instruction. Dr. Benjamin Rush was appointed the first professor. He went abroad and brought home a set of chemical apparatus.[21]

At this particular time, chemistry consisted of little more than a knowledge of some acids, alkalies, salts and earths, of which the most important ingredients were unknown. The composition of such simple substances as air and water was not understood. Oxygen, hydrogen, and nitrogen were yet to be discovered.[22]

The College of Philadelphia medical school, like the College of the Providence of New York, was broken up by the Revolution. Little is known concerning the nature of the course in chemistry which Rush taught because for some time little is recorded besides the names of those who held the respective positions.

Ten years after this, the University of Philadelphia

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[21] Williams, _op. cit._, p. 77.

[22] _Loc. cit._

came into being. Now there were two instead of one, the University of Philadelphia and the College of Philadelphia, each having its professor of chemistry. Dr. James Hutchinson was professor of chemistry in the University of Philadelphia which position he retained when the College of Philadelphia was merged into the University.[23]

The exact value of chemistry to medicine was not fully recognized at this time. This may be brought out by examining a letter written by Benjamin Rush in 1768. In this he says:[24] "Something must be said in favor of the advantages of chemistry to medicine, and its usefulness to medical philosophy, as the people of our country in general are strangers to the nature and objects of the science." Rush laid an important foundation-stone of chemical education in America. He wrote a book, Syllabus of a Course of Lectures on Chemistry, in 1776. This is the first book of this kind written by an American teacher and published in this country. For many years this was the only available American text-book in chemistry.[25]

Upon the death of Hutchinson, Priestly was elected to

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23 Ibid., pp. 77-78.

24 Thomas Harrison Montgomery, A History of the University of Pennsylvania from its Foundations to A. D. 1770. George W. Jacobs and Co., Philadelphia, 1900, p. 487.

25 Newell, op. cit., p. 681.

the position, professorship of chemistry at the University of Pennsylvania, but refused. Dr. James Woodhouse was later elected. It has been said of his first year:[26]

> He went to work with zeal and delivered a course of lectures with great applause. As almost the whole of his time was devoted to the study of chemistry, he constantly added to the number, and varity, and brilliancy of his experiments. His enthusiasm was unbounded and his style sentimentally impressive.

James Woodhouse published The Young Chemists' Pocket Companion in 1797. This book was composed of over one-hundred varied experiments with pictures of apparatus. It compares very favorably with the laboratory manuals of today. It is likely that this is the first book of its kind written by an American and published in this country.[27]

Woodhouse's teaching consisted, besides recitations, of lectures and experiments before the class. Thompson in speaking of this period says,[28] "Chemistry at this time did not possess a single analysis which could be considered as even approaching to accuracy." It is probable that all experiments were explained in terms of the "phlogiston theory," founded by Stahl in 1702. Williams[29] says that Woodhouse was

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[26] Williams, op. cit., p. 78.

[27] Newell, op. cit., p. 685.

[28] Williams, loc. cit.

[29] Ibid., p. 79.

the last American professor to explain his experiments by phlogiston. There seems to be some disagreement on this subject for Smith says:[30]

> . . . It is interesting to note that the thought of the French School reached this country very early and there were here those who defended it.
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> Chief among these was James Woodhouse, who had founded the Chemical Society of Philadelphia in 1792. This was the first chemical society in the world. As far as can be learned, Woodhouse was its first president. This society lived about seventeen years. Its members favored Lavoisier's doctrine of combustion.

Philadelphia was the center of chemical study in America and Woodhouse became the teacher of teachers. Upon the death of Woodhouse, Dr. Coxe was appointed in his place. He was a very brilliant demonstrator. A report of the faculty in 1841 reads:[31]

> The chemical apparatus is, by the admission of all who have inspected it, unequaled in extent, variety and splendor. Individuals who have visited the schools of Germany, France and Great Britain agree in the statement that they have nowhere met with a laboratory so amply furnished with all that is calculated to illustrate the science of chemistry, as that of Dr. Hare.

A description of Hare's laboratory is very interesting. Smith[32] quotes it in the following manner:

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30 Edgar F. Smith, Chemistry in America. D. Appleton and Co., New York, 1914, p. 12.

31 Williams, op. cit., p. 79.

32 Edgar F. Smith, The Life of Robert Hare. J. B. Lippincott Co., Philadelphia, 1917, pp. 173-75.

The hearth, behind the table, is thirty-six feet deep. On the left, which is to the south, is a scullery supplied with river water by a communication with the pipes proceeding from the public water works, and furnished with a sink and a boiler. Over the scullery is a small room of about twelve feet square, used as a study. In front of the scullery and study are glass cases for apparatus. On the right of the hearth two other similar cases, one above the other, may be observed. Behind the lower one of these is the forge room, about twelve feet square; and north of the forge room, are two fire proof rooms communicating with each other, eleven feet square each; the one for a lathe, the other for a carpenter's bench, and a vice bench. The two last mentioned rooms, are surmounted by groined arches, in order to render them secure against fire; and the whole suit of rooms which I have described, together with the hearth, are supported by seven arches of masonry about twelve feet each in span. Over the forge room is a store room, and over the lathe and bench rooms, is one room of about twenty by twelve feet. In this room there is a fine lathe, and tools.

The space partially visible to the right, is divided by a floor into two apartments, lighted by four windows. The lower one is employed to hold galvanic apparatus, the upper one for shelves, and tables, for apparatus, and agents, not in daily use. In front of the floor just alluded to, is a gallery for visitors.

The canopy over the hearth is nearly covered with shelves for apparatus, which will bear exposure to air and dust, especially glass. In the center of the hearth is a stack of brick work for a blast furnace, the blast being produced by means of a very large bellows situated under one of the arches supporting the hearth. The bellows are wrought by means of the lever represented in the engraving, and a rod descending from it through a circular opening in the masonry.

There are two other stacks of brick work on the hearth against the wall. In one there is a coal grate which heats a flat sand bath, in the other there is a similar grate for heating two circular sand baths, or an alembic. In this stack there is likewise a powerful air furnace. In both of the stacks last mentioned, there are evaporating ovens.

The laboratory is heated not only by one or both of the grates already mentioned, but also by stoves in the arches beneath the hearth, one of these is included in a chamber of brick work. The chamber receives a supply of fresh air through a flue terminating in an aperture in the external wall of the building, and the air after being heated passes into the laboratory at fifteen apertures, distributed over a space of thirty feet. Twelve of these apertures are in front of the table, being four inches square, covered by punched sheet iron. In the hearth there is one large aperture of about twelve by eighteen, covered by a cast iron plate full of holes, the rest are under the table. By these means the hot air is, at its entrance, so much diluted with the air of the room, that an unusually equable temperature is produced, there being rarely more than two degrees of Fahrenheit difference between the temperature in the upper and in the lower part of the lecture room. There are some smaller windows to the south, besides those represented in the engraving. One of these is in the upper story, from which the rays enter at the square aperture in the ceiling over the table on the right. Besides these, are the windows represented in the engraving back of the hearth, and four others in the apartments to the north of the gallery. All the windows have shutters, so constructed as to be closed and opened with facility. Those which belong to the principal windows are hung with weights, so that they ascend as soon as loosened, and when the light is again to be admitted, are easily pulled down by cords and fastened. In addition to the accommodation already mentioned, there is a large irregular room under the floor of the lecture room on the eastern side. This is used as a place to stow a number of cumbrous and unsightly articles which are, nevertheless, of a nature to be very useful at times. Also for such purposes, and for containing fuel, there is a spacious cellar under the lecture room and laboratory.

It is interesting to note that Hare taught that acid properties never appear in the absence of water, and that this fluid or its elements are most entitled to be considered as the acidifying principle; but that probably it does not exist in acids as water, but is decomposed when added to them, the particles of hydrogen and oxygen by their different polarities taking opposite sides of those composing the base.[33]

After Benjamin Silliman found he was to teach chemistry in Yale he went to the University of Pennsylvania to study chemistry under Woodhouse. Silliman was one of the most influential men in shaping and developing the chemistry curriculum during his life. In speaking of his opportunities for professional improvement at the University of Pennsylvania, Silliman says:[34]

> The lectures on chemistry by Dr. James Woodhouse formed a part of the course of medical instruction in the Medical School of Philadelphia. These were given in a small building in South Fourth street, opposite to the State-House Yard. Above, over the laboratory, was the Anatomical Hall. Neither of these establishments was equal to the dignity and importance of the Medical School, and the accommodations in both were limited; the lecture-rooms were not capacious enough for more than one hundred or one hundred and twenty pupils, and there was a great deficiency of extra room for the work, which was limited to a few closets. The chemical lectures were important to me, who had as yet seen few chemical experiments. Those performed by Dr. Woodhouse were valuable, because every fact, with its proof, was an acquisition to me. The apparatus was humble, but it answered to exhibit some of the most important facts in the science; and our instructor delighted, although he did not excel, in the performance of experiments. He had no proper assistant, and the work was imperfectly done; but still it was a treasure to me. Our Professor had not the gift of a lucid mind, not of high reasoning powers, nor of a fluent diction; still, we could understand him, and soon began to interpret phenomena for myself and to anticipate the explanations. . .
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> . . . His lectures were quite free from any moral

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33 Ibid., p. 78.

34 George P. Fisher, Life of Benjamin Silliman, Vol. 1. Scribner and Co., New York, 1866, pp. 100-103.

bearing, nor, as far as I remember, did he ever make use of any of the facts revealed by chemistry, to illustrate the character of the Creator as seen in his works. . . I should add respecting his lectures that they were brief. He generally occupied a fourth or a third of the hour in recapitulating the subject of the preceding lecture, and thus he advanced at the rate of about forty or forty-five minutes in a day.

At the commencement of my first course with him, in 1802, he had just returned from London, where he had been with Davy and other eminent men. He brought with him a galvanic battery of Cruickshand's construction,--the first that I had ever seen,--but as it contained only fifty pairs of plates, it produced little effect. Dr. Woodhouse attempted to exhibit the exciting effects of Davy's nitrous oxide, but failed for want of sufficient quantity of gas, and the tubes were too narrow for comfortable respiration. He did not advert to these facts, but was inclined to treat the supposed discovery as an illusion. I had afterwards, at New Haven, an opportunity to prove that there was no mistake, and that Davy had not overrated the exhilarating effects of the gas when respired conveniently and in proper quantities,--three or four quarts to a person of medium size, inhaled through a wide tube. An amusing occurrence happened one day in the laboratory. Hydrogen gas was the subject, and its relation to life. It was stated that an animal confined in it would die; and a living hen was, for the experiment, immersed in the hydrogen gas, with which a bell-glass was filled. The hen gasped, kinked, and lay still. "There, gentlemen," said the Professor, "you see she is dead;" but no sooner had the words passed his lips, than the hen with a struggle overturned the bell-glass, and with a loud scream flew across the room, flapping the heads of the studetns with her wings, while they were convulsed with laughter. The same thing might have occurred to any one who had incautiously omitted to state that this gas is not poisonous, like carbonic acid, but kills, like water, by suffocation.

From the foregoing the nature of the instruction of the period may be gathered. In speaking of the nature of the instruction and of chemistry in general, Silliman continues:

. . . The chemistry of that period--that of my attendance on the lectures of Dr. Woodhouse, more than half a century ago--had not attained the precision which it now has. The modern doctrine of definite proportions

> or equivalent proportions was then only beginning to be understood; the combining proportions of bodies were generally given in centesimal numbers, and thus the memory was burdened, and with little satisfaction. The modern analysis of organic bodies was then hardly begun. Galvanism had indeed awakened Europe, and progress had been made towards those interesting developments which have filled the world with astonishment; but their era was several years later. We may not, therefore, impute to a professor of that period the deficiencies which belonged to that stage of this science.

The preceding quotations serve to describe the nature of the chemistry course at the University of Pennsylvania as well as that of showing the type of training to which the first professor of chemistry at Yale was subjected.

Virginia. There seems to be some difference of opinion as to the nature of James Madison's professorship at William and Mary. Williams[35] says that the first professor of chemistry outside the medical school appears to have been Rt. Rev. James Madison. He goes on to say that chemistry seems to have been his only subject and after thirty years the records show the next teacher to be Dr. James McLean, professor of natural philosophy and chemistry. An opposing point of view is that of Lyman C. Newell[36] who states that even though records at William and Mary College are incomplete they indicate that chemistry was taught there as early as 1774 by Bishop James Madison who was professor of natural philosophy. The chemistry was a part of

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[35] Williams, op. cit., p. 81.

[36] Newell, op. cit., pp. 679-80.

this course in natural philosophy. Newell gives as evidence of this, certain notes taken by Madison's students which show that lectures on chemistry were a part of the course in natural philosophy.

The further developments of chemistry at William and Mary are of no further significance to this study.

Massachusetts. Thus far chemistry has been introduced as a separate subject in the colleges through the medical schools. Likewise, a medical school which included in its teaching staff a professor of chemistry and materia medica was opened in 1783 in Cambridge. Aaron Dexter was the first to hold this position. His record seems to be of importance in that through his influence Major William Erving in 1791 bequeathed one thousand pounds to endow a chair in Harvard called the Erving Professorship of Chemistry and Materia Medica. This was the first of its kind in America.[37] In 1809, Dr. John Gorham was appointed to fill the Erving professorship of chemistry and materia medica. His work exerted a great influence on the chemistry course of study when it was struggling for recognition as a separate subject in the educational institutions.[38]

Dr. John Webster was appointed professor of chemistry in both the medical school and the college in 1827. The nature

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[37] Ibid., p. 689.

[38] Ibid., p. 690.

of the course in chemistry in those days may be inferred from the description of one of his lecture courses in the college.[39]

> He gave the class two or three chemical lectures, which were brought to a sudden end by his show experiment called <u>The Volcano</u>--a large heap of sugar and potassium chlorate piled on a slab of soapstone. After he had lighted it with a drop of sulphuric acid, he saved himself by dodging out of the room and in a very few seconds all the members of the class found themselves obliged to jump out of the window.

The fact that chemistry was taught in this manner after nearly three-fourths of a century in the colleges shows that it was not greatly fostered. Williams said that in truth the teaching of chemistry in Harvard college had become extinct. Webster's successor, Josiah P. Cooke, wrought many revolutionary changes and he helped place chemistry on a par with the classical studies.[40] This particular phase will be taken up in Chapter IV.

<u>New Jersey</u>. Dr. John Maclean was appointed first professor of chemistry and natural history at the College of New Jersey-- now Princeton--in 1795. The records available indicate that he not only taught the chemistry of Lavoisier but defended it vigorously.[41] He was a physician and also practiced medicine. Before his appointment to the faculty of this

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39 Rufus Phillips Williams, "The Planting of Chemistry in America." <u>School Science</u>, 2:140, May, 1902.

40 <u>Loc. cit</u>.

41 Newell, <u>op. cit</u>., p. 680.

college he was invited to give several lectures on chemistry. He made such an impression that he was elected to teach. At first he was allowed to continue to practice medicine, but in 1797 it was ordered that chemistry and natural history be taught as branches of natural philosophy. From this time on Maclean gave his whole time to the college.[42]

New Hampshire. Lectures were given in chemistry in the department of medicine of Dartmouth in 1798. Lyman Spalding assembled the chemical apparatus and delivered the first course of lectures in chemistry at Dartmouth. There was no established chair of chemistry until 1820. In 1827 Benjamin Hale was appointed professor of chemistry and mineralogy, but lost it some time later over religious matters. One can get an insight into the conditions of science in this school at this time by reading his valedictory letter to the trustees on the loss of his professorship. In it he says:[43]

> It is a remarkable fact that there is not one member of your board whose pursuits in life lead him to any acquaintance with physical studies, and I presume the importance absolute and relative of such studies is viewed by you as it stood in American colleges from thirty to fifty years ago when you were undergraduates. And your college feels the effect of this deficiency. It has not taken a scientific periodical, so far as I know, for half a century. The few that have crept into your library you owe to the charity of a pamphlet society which, through

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42 Williams, op. cit., p. 143.

43 Ibid., p. 146.

> the influence of the late Professor Dana, among its other periodicals took one Quarterly Journal of Science, and at its decease bequeathed its collection to your library. Since its death, no report of the progress of science finds its way within your walls, save the Journal of Professor Silliman, taken by the two respectable societies among the students. . . A few years ago, no provision was made for chemical lectures to college classes, and members of the higher classes were in the habit of making a contract annually with my lectures.

Before Hale's time, seniors were allowed to attend lectures on chemistry and anatomy on payment of four dollars per year, and juniors two dollars. Later juniors and seniors attended fourteen or fifteen weeks of daily lectures which Hale delivered to the "medics." He also had five or six weeks of daily recitations with the junior class, and gave to the undergraduates a course of thirty lectures per year.[44]

Connecticut. The introduction of chemistry in Yale was much later than it was in the foregoing colleges because it came in Yale not as an adjunct to medicine. For this reason it did not gain a stronghold in Yale until the nineteenth century.

Because the introduction of chemistry in Yale presents an excellent typical picture of the development of this subject, a detailed study will be made of this institution. The situations and developments to be presented are typical of other institutions at that time, of course, to a limited extent.

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[44] Ibid., p. 147.

Benjamin Silliman, a graduate of Yale, was the first professor of chemistry in this college. He was appointed in 1802 and continued to execute the duties of this position until 1853. In writing of his work as a student at Yale, Silliman paints a very good picture of the conditions of science teaching in Yale at that time. He says:[45]

> In the first century of Yale College, a single room was appropriated to apparatus in physics. It was in the old college, second loft, northeast corner, now No. 56. It was papered on the walls; the floor was sanded, and the window-shutters were always kept closed except when visitors or students were introduced. There was an air of mystery about the room, and we entered it with awe, increasing to admiration after we had seen something of the apparatus and the experiments. There was an air-pump, an electrical machine of the cylinder form, a whirling table, a telescope of medium size, and some of smaller dimensions; a quadrant, a set of models for illustrating the mechanical powers, a condensing fountain with _jets d'eau_, a theodolite, and a magic lantern--the wonder of Freshmen. These were the principal instruments; they were of considerable value: they served to impart valuable information, and to enlarge the students' knowledge of the material world. We should not now undervalue the mental culture, and certainly the discipline, of the first century in Yale College. . .
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> During my novitiate, chemistry was scarcely ever named. I well remember when I received my earliest impressions in relation to chemistry. Professor Josiah Meigs--1794 to 1801--delivered lectures on natural philosophy from the pulpit of the College Chapel. He was a gentleman of great intelligence, and had read Chaptal, Lavoisier, and other chemical writers of the French school. From these, and perhaps other sources, he occasionally introduced chemical facts and principles in common with those of natural philosophy. I heard from him (Aet. 15 and 16) that water contains a great amount of heat which does not make the water any hotter to the touch or to the thermometer; that this heat comes out of the water when it

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45 Fisher, _op. cit._, pp. 88-90.

> freezes, and still the freezing water is not warmed by the escaping heat, except when the water has been cooled below the freezing-point before freezing; then, when it actually freezes, the temperature rises to 32°; and that all this heat must be reabsorbed by the ice when it melts, and then becomes latent, as if it were extinguished, but is again to escape when the ice melts anew. This appeared to me very surprising; and still more astonishing did it appear that boiling water cannot be made any hotter by urging the fire. My curiosity being awakened, I opened an encyclopedia, and there read that balloons were inflated by an inflammable gas obtained from water; and I looked with intense interest at the figures representing the apparatus, by means of which steam, made to pass through an ignited gun-barrel, came out inflammable gas at the other end of the tube. . .

This was Silliman's background for chemistry when he graduated from Yale. He had settled on the legal profession for a life work. President Dwight saw the great scientific possibilities in him and persuaded him to give up law and accept the newly created chair of chemistry and natural history. In order to prepare himself for this position, Silliman went to Philadelphia in 1803 to study under Woodhouse. The nature of his experiences there as been stated previously in connection with the discussion of education in chemistry in Pennsylvania. The next year he began lecturing to the students in Yale College. In speaking of his first lecture he says:[46]

> In a public room, hired for college purposes, in Mr. Tuttle's building on Chapel Street, nearly opposite to the South College, I met the Senior class, and read to them an introductory lecture on the history and progress, nature and objects, of chemistry. . . I continued to

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46 *Ibid.*, p. 121.

lecture, and I believe in the same room, until the Senior class retired in July, preparatory to their Commencement in September. . . On the 4th of April, 1804, I commenced a course of duty as a lecturer and professor, in which I was sustained during fifty-one years. . .

A member of the class of 1804 who heard Silliman's first lectures, pictures the nature of his teaching methods and the nature of the science which he taught. The member of this class of 1804 writes:[47]

. . . I do not recollect whether or not I went to his first lecture prepared to take notes of it. But I think I remember the introductory sentence of it, defining the science that was to be the subject of his course;--"Chemistry is the science that treats of the changes that are effected in material bodies or substances by light, heat, and mixture."

My impression now is, that he did not read his lectures; so that his instructions were not etymologically lectures or readings, but free, fluent talks, prepared for evidently with care, and delivered in a style, as some would say, rather ornate for a strictly scientific discourse. Severe and sensitive critics might go so far as to say that there was in his style of lecturing a slight affectation of the exquisite; while others would say "nay, but a very natural elegance."

In his demonstrative experiments he was always successful, and in all his manipulations there was uniformly a grace and nicety that was pleasant to those of us whose ideality had begun to be developed.

His elocution was distinct, sometimes rather too rapid for those of us who were slow of apprehension, but it seemed to go so fast because he feared there wouldn't be time enough for it all to get out--there was so much of it--before the clock would strike and shut the laggards in.

It was, I think, in 1829, that, at the request of the first association for a course of popular lectures in

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[47] Ibid., pp. 130-31.

Boston, I called upon Mr. Silliman to solicit from him a course of lectures in that city. As to his manner in that course, I could see in it but little change. It seemed almost identical with what it was when I first heard him. His style of rhetoric was perhaps rather more severe, but his experiments were equally graceful, and, of old, equally and always successful. What, under certain combinations and mixtures, he said would come to pass, always did come to pass. He was as a lecturer a true prophet, showing full knowledge of his subject, and because of that knowledge able to predict the phenomena that would result from stated conditions.

In speaking of his lectures, Silliman says of himself:[48]

As far as I could judge, the impression on my pupils of the institution and on the public was favorable. The experiments were prepared with great care, and a failure was a very rare occurrence. Although manuscripts fully written out lay before me, I soon began to speak without reading, and found my own feeling freer and easier, and the audience more interested. I always, however, prepared the matter of the lecture thoroughly, and therefore avoided embarrassment in the delivery. Even with my immature and limited acquirements I was encouraged to proceed by recollecting other remarks which I heard from Dr. Priestley. Being complimented upon his numerous discoveries, he replied to this effect:--"I subjected whatever came to hand to the action of fire or various chemical agents, and the result was often fortunate in presenting some new discovery. In teaching, I have always found that the best way to learn is to teach, then you will be sure to study you subject well, and I could always keep ahead of my pupils. Thus while I was teacher, I was still more a learner."

A better insight may be gained as to the nature of the early chemistry instruction by examining parts of a letter from Professor Day to Benjamin Silliman in 1804. In part it reads:[49]

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48 Ibid., pp. 127-29.

49 Ibid., pp. 117-18.

. . . I am much obliged to you for your plan of lectures, so far as you have already arranged them. As for myself, instead of having written my fifth lecture, I have not written my first, and probably shall not this long time. My present course of instruction occupies all the attention which my health will allow me to pay to the subject. My principal object at present is to collect and arrange the most important materials in a course of philosophy. I so contrive the business as to communicate the substance of these, in my recitations, to the Senior class, and at the same time preserve them for future use. I take the several branches nearly in the order in which they are arranged in Enfield's Philosophy. I consult the various authors on the subject, select what is particularly interesting from each, and if my own noodle suggests anything besides, I put all upon paper and throw it into a form somewhat like the skeleton of a lecture. This I carry to recitation, and, with such enlargements as occur on the occasion, retail it to the class. In addition to these recitations, I propose frequently problems in philosophy which require a mathematical solution. The answers which are handed in by the members of the class, I examine and correct. This, little as it may seem, is all that I am doing at present. As to what I intend to do hereafter, I can say very little. I intend to do what I can; but my health is such that I form no very distant and extensive projects. The course which I have begun I shall probably continue through next term. The summer will be partly or wholly occupied with experiments. After Commencement, it is possible I may begin to read lectures in the chapel. . .

Before Silliman was officially appointed to the chair of chemistry, the corporation of Yale College erected a building which was called the Lyceum. It was purposed to have a laboratory in one room of this building. A detailed description of this laboratory is given in Chapter IV. In 1804 the new laboratory received the class that was to graduate in September, 1805. In speaking of this, Silliman says:[50]

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[50] Ibid., pp. 125-27.

. . . The very limited apparatus was somewhat extanded and embellished by several chemical instruments which I found in a closet in the old philosophical chamber, and which, as I understood, had been brought out from London, in the time of President Stiles, by the late President Ebenezer Fitch. . . There were several very beautiful gas-flasks, with signoid tubes ground into them. There was also a Nooth's machine for impregnating water with carbonic acid gas, and a collection of glass tubes. I used also some of the glass bells from the philosophical apparatus; and, as my audience were novices, probably the appearance of the apparatus was respectable. I recollected, also, a remark which I heard Dr. Priestley make, namely, that with Florence flasks (cleaned by sand and ashes) and plenty of glass tubes, vials, bottles, and corks, a tapering iron rod to be heated and used as a corkborer, and a few live coals with which to bend the tubes, a good variety of apparatus might be fitted up. Some gunbarrels also, he said, would be of much service; and I had brought from Philadelphia an old blacksmith's furnace, which served for the heating of the iron tubes. . .

At that time there were very few chemical instruments of glass to be obtained in this country. I had picked up a few glass retorts in Philadelphia, and I made application to Mr. Mather, a manufacturer of glass in East Hartford, a few years later, to make some for me. On stating my wish, he said he had never seen a retort, but if I would send him one as a pattern, he did not doubt he could make them. I had a retort the neck or tube of which was broken off near the ball,--but as no portion was missing, and the two parts exactly fitted each other, I sent this retort and its neck in a box, never dreaming that there could be any blunder. In due time, however, my dozen of green glass retorts, of East Hartford manufacture, arrived, carefully boxed and all sound, except that they were all cracked off in the neck exactly where the pattern was fractured; and broken neck and ball lay in state like decapitated kings in their coffins. This more than Chinese imitation affords a curious illustration of the state of the manufacture of chemical glass at that time in this country, or rather in Connecticut; the same blunder would probably not have been made in Philadelphia or Boston.

Because he was expanding his laboratory to such a great extent, Silliman was asked by one of the members of the corporation if there was not danger that with these physical attractions in the chemistry courses Latin and Greek would be slighted by the students. He replied,[51] "Sir, let the literary gentlemen push and sustain their departments. It is my duty to give full effect to the sciences committed to my care."

In speaking of Silliman, Williams says:[52]

> Eminently a teacher and a popularizer rather than a discoverer, he was almost the father in this country of the three sciences in which he gave instruction. For many years the study of chemistry was the most popular one in the college. The first third of the year was devoted to chemistry, the second to mineralogy, the last to geology."

Silliman taught in Yale until he resigned in 1853.

The general nature of chemical education previous to 1850. The preceding portions of this chapter have indicated that while most institutions during this time included chemistry in their curriculum, only lectures were offered and the institutions allowed some experiments performed by the instructors only. The chemistry courses were meager in content and the methods were superfucial and rudimentary. The courses consisted mainly of a series of lectures with accompenying demonstrations. These lectures were usually written up beforehand and used over and over year after year. Laboratory study by students was almost wholly unknown. Partly responsible

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51 Ibid., p. 257.

52 Williams, op. cit., p. 145.

for these conditions was a scarcity of apparatus, a lack of teacheable text-books, and a lack of competent teachers. The apparatus that was used for lecture-demonstration purposes was crude and was in the main made for spectacular effects rather than to demonstrate scientific principles. Prior to 1820 there were approximately twenty-five text-books of American publication.[53]

During the latter part of the eighteenth century the practical and utilitarian seems to have dominated the chemistry instruction. The ideas of classification and philosophy and little experimentation were associated. The first half of the nineteenth century is characterized by the conflict of chemistry with the classics for a place in the curriculum.[54] Probably too much emphasis cannot be made of the fact that during the period with which this chapter is concerned the medical schools exerted the great influence which made for the rapid introduction of chemistry into the curriculum of the colleges.

Previous to 1850 there were approximately sixty colleges and universities which offered instruction in chemistry. The following table shows the institution and the date of the introduction of chemistry as a subject into its curriculum.

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[53] Newell, op. cit., p. 679.

[54] Bruce W. Merwin, "Developments of the Curriculum in College Chemistry." Journal of Chemical Education, 12:542, November, 1935.

TABLE I[55]

SHOWING THE DATE OF INTRODUCTION OF CHEMISTRY INTO THE CURRICULUM OF THE COLLEGES AND UNIVERSITIES PREVIOUS TO 1850

School	Place	Date
Kings College (Columbia Univ.)	New York, N. Y.	1767
University of Pa.	Philadelphia, Pa.	1769
College of William and Mary	Williamsburg, Va.	1774
Harvard College	Cambridge, Mass	1782
Washington College	Chestertown, Md.	1782
College of N. J. (Princeton)	Princeton, N. J.	1795
University of Georgia	Athens, Ga.	1800
Yale College	New Haven, Conn.	1802
Bowdoin College	Brunswick, Me.	1805
Dickinson College	Carlisle, Pa.	1811
Union College	Schenectady, N. Y.	1811
Brown University	Providence, R. I.	1811
Hamilton College	Clinton, N. J.	1812
University of N. C.	Chapel Hill, N. C.	1818
Western University of Pa.	Pittsburg, Pa.	1819
Dartmouth College	Hanover, N. H.	1820
Amherst College	Amherst, Mass.	1821
Trinity College	Hartford, Conn.	1823
Franklin College	New Athens, Ohio	1825
Hobart College	Geneva, N. Y.	1825
University of Va.	Charlottesville, Va.	1825
Centre College	Danville, Ky.	1826
St. Louis University	St. Louis, Mo.	1827

[55] These data were compiled from two different sources, namely:

Clarke, op. cit. pp. 200-12.

Samuel Ralph Powers, "A History of the Teaching of Chemistry in the Secondary Schools of the United States Previous to 1850." Research Publications of the University of Minnesota, Current Problems No. 13, University of Minnesota, Minneapolis, 1920.

TABLE I (Continued)

School	Place	Date
Tusculum College	Tusculum, Tenn.	1827
Indiana University	Bloomington, Ind.	1828
Hanover College	Hanover, Ind.	1829
Illinois College	Jacksonville, Ill.	1829
Georgetown College	Georgetown, Ky.	1830
Williams College	Williamtown, Mass.	1830
University of Ala.	University, Ala.	1831
Hiram College	Hiram, O.	1831
Wesleyan University	Middletown, Conn.	1831
Denison University	Granville, O.	1831
Randolph Macon College	Ashland, Va.	1832
Wabash College	Crawfordsville, Ind.	1833
Haverford College	Haverford, Penn.	1833
Norwich University	Northfield, Vt.	1834
Davidson College	Davidson College, N. C.	1837
Lafayette College	Easton, Pa.	1837
College of Charleston	Charleston, S. C.	1838
Emory and Henry College	Emory, Va.	1839
East Tenn. University	Knoxville, Tenn.	1839
University of the St. of Mo.	Columbia, Mo.	1840
Cumberland University	Lebanon, Tenn.	1842
Franklin College	Franklin, Ind.	1845
Wittenberg College	Springfield, O.	1846
Baylor University	Independence, Tex.	1846
Marietta College	Marietta, O.	1846
University at Lewisburg	Lewisburg, Pa.	1847
Beloit College	Beloit, Wis.	1847
Bethel College	McKenzie, Tenn.	1847
Iowa College	Grinnell, Iowa	1848
College of the City of N. Y.	New York, N. Y.	1849
Maryville College	Maryville, Tenn.	1849
Lawrence University	Appleton, Wis.	1849

<u>Efforts to popularize chemistry</u>. It is during the first half of the eighteenth century that great efforts were made to popularize chemistry as a subject. This was a movement, the main object of which was to popularize chemical instruction. Men traveled over the country giving showy demonstrations with startling experiments before institutes, lyceums, Sunday Schools, cattle shows, and other miscellaneous audiences. The spectacular and the sensational were present in all these lectures. Some of these lecturers were men of low attainments, others were very brilliant.[56]

In 1835 and for approximately twenty years, Benjamin Silliman gave lectures on chemistry in many large cities from Boston to St. Louis and New Orleans.[57] These proved to be very popular. The lectures reached thousands of people and the leading men and women of the day could always be found in his audiences. It is probable that he exercised a wider influence by these lectures than by his teachings at Yale for it is impossible to tell how many boys in his audiences received from him their first inspiration to take up chemistry. Silliman also used interesting experiments and these together with his

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[56] C. A. Browne, "The History of Chemical Education in America Between the Years 1820 and 1870." <u>Journal of Chemical Education</u>, 9:701, April, 1932.

[57] <u>Ibid</u>., p. 700.

splendid delivery and natural enthusiasm created a vast amount of interest in chemistry which was then being introduced into the colleges.[58] The following is quoted from Silliman's "Reminiscences":[59]

> After April 1, 1834, a new era opened upon me. Public courses of lectures by me were called for in many places, most of them out of Connecticut, and this call continued actively for twenty-three years,--from 1834 to 1857,--nor is it quite ended yet, at the close of twenty-five years. Those lectures were given while I was between fifty-five and eighty years of age. . . I was called out in the maturity of my powers, experience, and reputation; and while I enjoy the satisfactory assurance that I have popularized science, these efforts brought important assistance to my family at a period when my children were requiring aid in their settlement in life. I conceive that in no period of my life have my efforts been more useful, both to my country and my family; and as regards professional labors, there is no part of my career which I reflect upon with more satisfaction.

In writing of his lectures Silliman continues:[60]

> In the fifth lecture, I made a very liberal use of potassium and sodium, which are not only splendid subjects of experiment but are highly illustrative of chemical principles. Everything went beautifully. After the sixth lecture, at a large party at Deacon Walley's, great satisfaction was expressed to me regarding the lectures. The Mayor, Mr. Armstrong, said that he thought the subject very interesting and instructive, and was pleased that a moral and religious aspect was given to the science; and similar views were expressed by others. I communicated to-day, at the lecture, the discovery that cast-steel of the first quality is formed directly from the ore, and that malleable iron is manufactured from cast-iron without melting it again; specimens furnished to me by the manufacturers were also exhibited, and I was assured that the subject excited great interest, and gave much satisfaction. .

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58 Loc. cit.

59 Fisher, op. cit., p. 340.

60 Ibid., p. 371.

W. A. Richards was a representative of the better class of this type of public lecturers. However, he lectured at a later time than did Silliman. One of Richards' posters presents the idea which was outstanding in his lectures. This poster read:[61] "The Wonders of the Air with Many Dazzling Experiments." Among the experiments listed were the following: The Rekindled Light; Making Air; Lava from Air; Lava from Ice; A Missing Globe; Blue Light; Absorption from Air; Analysis of Air; Lake of Fire; Cannon Fired by an Icicle; Sun Flamer; the Meteoric Sphere; Phosphoric Glow or Mock Sun; Blowing Hot and Cold; A Flash of Lightening; Ice Volcanoes; Pillar of Salt; Sparks from Gold; Electric Flames; Sheet Lightening; House struck by Lightening and Set on Fire; The Safety Lamp; Grand Display of Geisler's Tubes; and many other of this same type.

The nature of these experiments may be gained from the following description of one of Richards' displays:[62]

> One of Richards' experiments which excited great wonder was converting a bottle of beer into a barrel full. A bottle of beer was uncorked and placed upon the bottom of a tall glass cylinder eight feet high. When the air was exhausted from the cylinder the beer, which was heavily charged, frothed out of the bottle, the foam filling the entire space.

The great popularizers developed a demonstration technique which was very attractive to the beginner and uninformed.

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[61] Browne, op. cit., p. 701.

[62] Loc. cit.

This influence was to be seen in the college teaching which later proceeded along the lines of demonstration and laboratory work.

Others of the group who gave popular lectures on scientific subjects were John Griscom, Hosiah Holbrook, Chester Dewey, Stephen Van Rensselaer, and Amos Eaton. These men fostered scientific societies which ere influential in popularizing chemical instruction to a very great extent. The following table gives the most important of these societies.

TABLE II[63]

SHOWING THE DATE OF THE FOUNDING OF THE EARLY SCIENTIFIC SOCIETIES

Name	Date
The Philosophical Society of Philadelphia	1744
The American Academy of Arts and Sciences, Boston	1780
The Conn. Academy of Arts and Sciences, New Haven	1799
The Linnean Society of Philadelphia	1804
The Columbian Chemical Society of Philadelphia	1811
The Literary and Philosophical Society of New York	1814
The Literary and Philosophical Society of Charleston	1814
The Academy of Natural Sciences of Philadelphia	1815
The Cabinet of Sciences of Philadelphia	1815
The Lyceum of Natural History of New York	1817

63 Powers, op. cit., p. 8.

Another force prominent in the encouagement of chemistry teaching in the colleges was the organization of scientific schools such as Yale Scientific School (1847), Lawrence Scientific School (about 1865), Gardiner Lyceum (1822), and Rensselaer Polytechnic Institute (1824). These institutions played an important part in the encouragement of laboratory instruction in the colleges.

CHAPTER IV

THE DEVELOPMENT OF THE CHEMISTRY LABORATORY AS A METHOD OF INSTRUCTION, 1850-1870

At the present time the systematized study of highly specialized courses in chemistry as well as the elementary and introductory courses could scarcely be carried out in the absence of the laboratory instruction methods which have developed the last thee-quarters of a century. The development of the laboratory is in a large part both the cause and the result of the rapid strides taken by chemistry during the last seventy-five years. Before this time there was no branch of physical or natural science, with the exception of anatomy, which the students could study in the laboratory.[1]

The effects of the mental discipline theory. It would have been impossible for the laboratory method to have been introduced into the colleges during the period in the history of education when the theory of formal mental discipline ruled, without its value being stated in terms of mental discipline. The idea of intellectual training and intellectual culture still reigned supreme as objectives of college training until a very late date. Indeed, the present colleges have not gotten

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[1] William H. Welch, "The Evolution of Modern Scientific Laboratories," Annual Report of the Board of Regents of the Smithsonian Institution, Government Printing Office, Washington, 1895, p. 493.

completely away from this thought.

As late as 1872, there was no provision for laboratory instruction in Williams College. Professor Ira Remsen said that when he went there in 1872, he suggested the installation of a few desks, etc., for this purpose to the President. He was rebuffed by the statement that he misunderstood entirely the purposes of Williams College if he intended to convert it into a manual training school.[2] This feeling, of course, did not exist without exception in all institutions. However, the foregoing incident does portray the general feeling which existed even at that late date. It also brings to light the handicap under which the laboratory method labored as it struggled for recognition as a valuable and essential method of chemical instruction. The beginnings of the laboratory movement had its origin at a much earlier time than the previously mentioned period.

The advocates for mental discipline and knowledge for knowledge's sake, and the people who proposed the accumulation of knowledges as a means to an end and not as an end in itself opposed each other continually as the laboratory method developed.

In speaking of the curriculum during the latter part of

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[2] C. A. Browne, "The History of Chemical Education in America Between the Years 1820 and 1870." Journal of Chemical Education, 9:713, April, 1932.

the nineteenth century, Rugg says:[3]

> The entire school curriculum was under the sway of a mythical faith in mental discipline. The current point of view was that learning, to be effective, must be hard and disagreeable. The faculties of the mind, the powers of logical analysis, critical judgment, were to be trained by observation, collection, and systematization of facts.

As a result of these conditions the introduction of chemistry into the colleges had to be justified in terms of mental discipline. This doctrine of faculties and formalism was so fixed that even some of the greatest scientists attempted to defend their subjects on that basis. It might be said that many advocates of the sciences made an effort to steal the disciplinary thunder of the classicists. Graves says that nearly every apologist for the natural sciences at some time or other has advocated these subjects from the standpoint of formal discipline.[4]

Herbert Spencer argues that the function of education is to prepare for complete living, but he then changes his whole point of view and attempts to steal the classicists smoke by justifying science teaching in terms of formal discipline. He admits that besides its use in making for a more

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3 Harold Rugg, "The School Curriculum, 1825-1890." Twenty-Sixth Yearbook for the Study of Education, Part I, Public School Publishing Company, Bloomington, Illinois, 1926, p. 24.

4 Frank Pierrepont Graves, A History of Education in Modern Times, Macmillan Co., New York, 1913, p. 336.

complete living, the gaining of each order of facts has also its use as a mental exercise. Both of these, he says, are useful in making for a more complete living. As evidence of his statements, he attempts to show that science, like language, trains the memory, and, in addition, exercises the understanding. He also says that science is superior to language in cultivating judgment and that by encouraging independence, perseverance, and sincerity, it gives a moral discipline. Because science generates a profound respect for, and an implicit faith in, those laws which govern scientific phenomenons, he argues that a great religious discipline is obtained.[5]

Combe[6] contends that "it is not so much the mere knowledge of the details of chemistry, of natural philosophy, or of any other science that I value, as the strengthening of the intellect, and the enlargement of the understanding, which follow these studies."

Youmans[7] says that "by far the most priceless of all things is mental power; while one of the highest offices of education must be strictly to economize and wisely expend it. Science made the basis of culture will accomplish this result."

Galloway claims that chemistry is superior to biology,

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[5] Ibid., p. 335.

[6] Ibid., p. 336.

[7] Loc. cit.

because it makes for active rather than passive observations, and to physics because it exercises habits of the mind which are the opposite of those developed by mathematics.[8]

<u>The justification of science teaching on the basis of its practical values</u>. Thus the sciences were rationalized as to their educational value at a time when the theory of formal discipline held sway. At the same time certain people were defending the sciences on other grounds. As sciences became more systematized many prominent men began to insist upon their inclusion into the curriculum on the basis of their subject matter value. Before this time Herbart and Froebel opposed the doctrine of mental discipline on the ground that it was unsound psychologically. Many writers maintained that the study of the classics did not provide a good preparation for life. An argument which is representative of this point of view is contained in Herbert Spencer's essay on "What Knowledge is of Most Worth." Quoted in part this essay reads as follows:[9]

> . . . As the Orinoco Indian puts on his paint before leaving his hut, not with any view to any direct benefit, but because he would be ashamed to be seen without it; so a boy's drilling in Latin and Greek is insisted upon, because of their intrinsic value, but that he may not be disgraced by being found ignorant of them. The comparative

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[8] <u>Ibid</u>., p. 337.

[9] <u>Ibid</u>., pp. 327-28.

> worths of different kinds of knowledge have been as yet scarcely even discussed--much less discussed in a methodic way with definite results. Before there can be a rational curriculum, we must decide which things it most concerns us to know. To this end a measure of value is the first requisite. How to live?--that is the essential question for us. . .

Spencer held that the function of education is to prepare for a complete living, and that the sciences held the knowledges which would satisfy this purpose. He suggested a substitution of the sciences for the traditional subjects. He says that the attitude of the universities toward science has been that of contemptious non-recognition.[10]

Thomas H. Huxley also recognized the need of a scientific education and the uselessness of classical training. His argument was as follows:[11]

> Suppose it were perfectly certain that the life and fortune of everyone of us would, one day or other, depend upon his winning or losing a game at chess. Don't you think that we should all consider it a duty to learn at least the names and moves of the pieces? Yet it is plain and very elementary truth that the life, the fortune, and the happiness of everyone of us, and, more or less, of those who are connected with us, do depend upon our knowing something of the rules of a game infinitely more difficult and complicated than chess. The chess-board is the world, the pieces are the phenomena of the universe, the rules of the game are what we call the laws of nature. What I mean by education is learning the rules of this mighty game.

This idea is further developed in a letter by Mr. William

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10 Ibid., p. 329.

11 Ibid., p. 330.

Maclure to Benjamin Silliman, Sr. Maclure says:[12]

> Your ideas concerning the utility that would result to mankind by a more strict attention to positive knowledge in our colleges, agree perfectly with my own, and I think that the means you propose would much tend to produce that desirable effect. . . In reflecting upon the absurdity of my own classical education, launched into the world as ignorant as a pig of anything useful, not having occasion to practice anything I had learned, except reading, writing, and counting, which any child could now acquire in six or eight months of a Lancasterian School,--I had been long in the habit of considering education one of the greatest abuses our species were guilty of, and, of course, one of the reforms the most beneficial to humanity, and likewise offering to ambition a fair field. Almost no improvement had been made in it for two hundred years; there was immense room for change to put it on a par with the other functions of civilization. . .

Some advocates of the sciences felt that a knowledge of nature was a necessity in man's life and that content rather than the method of study was important in education. This argument continued for a considerable length of time; in fact, it is not entirely lacking to-day.

In considering the following developments it is well to keep in mind the philosophic trends in education which ruled during the various periods concerned. With these in mind the causative factors in the development of the college chemistry laboratory will be more obvious and logical.

<u>Laboratory instruction in chemistry previous to the middle of the nineteenth century</u>. Of actual laboratory

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[12] George P. Fisher, <u>Life of Benjamin Silliman</u>, Vol. 2. Scribner and Co., New York, 1866, p. 41.

instruction before the middle of the nineteenth century, the students saw very little. They saw the experiments and demonstrations of the professor as he lectured but they were not permitted to handle the apparatus themselves. In this respect Benjamin Silliman, Sr., once said:[13]

> Many times I have said to those who as novices have offered aid to me that they might come and see what we were doing, and I should much prefer that they should do nothing; for then they would not hinder me and my trained assistants, nor derange nor break my apparatus.

This was a condition that could be found in any other college in this country at this particular time. The laboratories that did exist were crude and unsuited for efficient work and were for the use of the professor and his assistants only. In writing of this subject, C. A. Browne said:[14]

> Of experiments in general chemistry, of qualitative and quantitative analysis, of inorganic and organic preparations, or of experience in industrial operations the American College students of a hundred years ago obtained practically nothing except in those rare cases where they were so fortunate as to be selected as private pupils or assistants.

The laboratory at Yale during the first few years of the nineteenth century was probably typical of the college laboratories--where there were any--the country over. The nature of of this laboratory may be learned from Silliman's description of it. He says:[15]

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13 Ibid., Vol. 1, pp. 303-04.

14 Browne, loc. cit.

15 Fisher, op. cit., pp. 122-25.

An English architect, Mr. Bonner, had established himself in New Haven, and had acquired a deserved reputation for knowledge, talent, and taste in his profession. He was charged with the erection of the Lyceum; but, having no particular knowledge of a laboratory, he placed it almost underground. On my return from Philadelphia, in the spring of 1803, I found that a groined arch of boards had been constructed over the entire subterranean room. It rose from stone pillars of nearly half of the height of the room, erected in each of the four corners and on the middle of the opposite sides. The effect was, therefore, by the curves of the arches, to cut off the light, more or less, from all the windows,--one third, or half, and even two thirds in some of them. At once I saw that it would never answer, and I made my appeal to the Corporation at their next meeting. I invited them to visit the room, to which there was no practicable access except through a hole or scuttle in the roof of the arch. . . President Dwight, Rev. Dr. Ely, Hon. James Hillhouse, and his venerable father, then fourscore or more, and others,--members of the College Senate,--found themselves in a gloomy cavern, fifteen or sixteen feet below the surface of the ground, into which, especially as there was as yet no trench excavated around the outside of the building, little more light glimmered than just enough to make the darkness visible.

. . . I had no difficulty in persuading the gentlemen that the model arch of boards must be entirely knocked away, the stone pillars removed, and the space opened freely to the roof of the room, which should be finished dquare up to the ceiling, like any other large room. . . I suppose that Mr. Bonner, an able civil architect, as I have already said, had received only some vague impressions of chemistry,--perhaps a confused and terrific dream of alchemy, with its black arts, its explosions, and its weird-like mysteries. He appears, therefore, to have imagined, that the deeper down in mother earth the danger-our chemists could be buried, so much the better; and perhaps he thought that a strong arch would keep the detonations under, although, as an architect and engineer, he would of course know that the arch, when pressed from above, grows stronger until it is crushed; but, struck from below, its resistance is feeble, and it may more easily collapse with a crash.

I lost no time in having the model arch removed, and the room finished as if there had been no arch. I caused also a wide trench to be excavated outside, all around the room, and the earth-banks to be sustained by the masonry of stone walls whitened, so that a cheerful light was thus reflected into a large and lofty room, whose windows were now free to the external radiance of the atmosphere and the solar beams from the west.

. . . When I stood on the floor of the room, my head was still six feet below the surface of the ground, and of course the room was very damp: all articles of iron were rapidly rusted, and all preparations that attracted water became moist or even deliquesced.

. . . The room was now paved with flag-stones; a false floor of boards was constructed, rising from the lowest level as high as the ground-sill of the outer door, and thus affording an elevation--an inclined plane--sufficient to prevent the vision of the rear from being obstructed by the front row of hearers. A gallery was erected on the side of the room opposite to the windows, access being made from the front of the tower or steeple through the intervening cellar, over a paved walk. Tables were established on the floor of the laboratory, in a line with the large hydropneumatic cistern or gas-tub, and a marble cistern for a mercurial bath. The small collection of apparatus which I had got together was duly arranged, and things began to look like work. Arrangements were made for furnaces, and for the introduction of water from a neighboring well. The tables were covered with green cloth; the stone floor was sprinkled with white beach-sand; the walls and ceiling were white-washed; the backs and writing tables of the benches, and the front and end of the gallery, were painted of a light lead color; and the glass of the windows being washed clean, the laboratory now made a very decent and rather inviting appearance, like the offices, store-rooms, and kitchens that are seen almost underground in cities.

In an address before the Eastern Association of Physics teachers, Chas. W. Eliot said:[16]

When I was a student in the Harvard College, there was not a single laboratory open to the students on any subject, either chemistry, physics, or biology. The only

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16 Charles W. Eliot, "Laboratory Teaching." School Science, 6:703, November, 1906.

> trace of such instruction open to students was in the department of botany and that was only for a few weeks with a single teacher. . . I was the first student who ever had the chance to work in the laboratory in Harvard College, and that was entirely due to the personal friendship of Professor J. P. Cook, who fitted up a laboratory in the basement of University Hall, entirely at his own expense. This was the situation of the colleges in this country--for Harvard was by no means peculiar in this respect--only sixty years ago.

During the first quarter of the nineteenth century it is found that although facilities for practical work by the students were still wanting in all the colleges, the apparatus used for illustrations had grown in quantity and variety. A chemistry laboratory was in existence at Princeton, one was fitted up at Williams in 1812, and one at Harvard shortly after this date. Also others were to be found. However, these laboratories as was previously mentioned were for the exclusive use of the demonstrators.

<u>The founding of Gardiner Lyceum and Rensselaer Polytechnic Institute</u>. In the first quarter of the nineteenth century two schools were established for the purpose of giving instruction in the application of science. This type was very influential in the instigation of the laboratory movement. The first of these schools to be organized was Gardiner Lyceum in Gardiner, Maine, in 1822. The second was the Rensselaer Polytechnic Institute organized in 1825. An idea as to the educational objective of this type of school may be gathered from the inaugural address of Benjamin Hale when he opened the Gardiner

Lyceum. In part this address reads:[17]

> It is not sufficient for them, as for the general scholar, to be taught the general laws of chemistry, they must be instructed particularly in the chemistry of agriculture and arts. It is not sufficient for them to be able to repeat and demonstrate a few of the general laws of mechanics, they must be taught the application of the laws. They must be made acquainted with machines.

The principal object of the Rensselaer Institute was to establish a school of high grade for teachers of science and the application of science to everyday life. A written statement of the purpose of the school appears in a letter of Mr. Van Rensselaer dated November 5, 1824. He wrote:[18]

> I have established a school at the north end of Troy in Rensselaer County (New York) for the purpose of instructing persons, who may choose to apply themselves, in the application of science to the common purposes of life. My principal object is to qualify teachers for the instructing the sons and daughters of farmers and mechanics, by lectures or otherwise, in the application of experimental chemistry, philosophy and natural history, to agriculture, domestic economy, and the arts and manufactures.

The nature and extent of the course of study as well as the methods of instruction, may be learned from the minutes of the first meeting of the Board of Trustees of the Rensselaer

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[17] Palmer C. Ricketts, editor, Centennial Celebration of Rensselaer Polytechnic Institute. Published by the Board of Trustees, Troy, New York, 1925, p. 61.

[18] Samuel Ralph Powers, "A History of the Teaching of Chemistry in the Secondary Schools of the United States Previous to 1850." Research Publications of the University of Minnesota, Current Problems No. 13, University of Minnesota, Minneapolis, 1920, p. 34.

School. In part the minutes read:[19]

> Resolved, that persons attending the course of instruction at the Rensselaer School be distributed, viz: in the three classes, a Day Class, an Afternoon Class, and an Evening Class. . . The exercises of the Day Class, for six hours in each day, except Sunday, shall consist of experiments in chemistry performed by the students themselves, and in giving explanations, or the rationale of the experiments; the Afternoon Class shall consist of those who may have previously attended one or more courses of lectures on chemistry at some public institution. They will hear no afternoon lectures; but their exercises will consist on a course of experiments in chemistry performed by themselves, as above the rationale, conducted under the superintendence of the senior professor. . . The Evening Class will attend lectures, on three evenings of each week, for ten weeks. This course of lectures will embrase chemistry, experimental philosophy, and the outlines of mineralogy, botany, and zoology. . .

The founder of Rensselaer had stated in the letter quoted previously that the purpose was to give instruction in the <u>application of science to the common purposes of life</u>. A unique method of instruction was found in Rensselaer. This method was probably never used by any colleges before this time. The Board of Trustees of the Rensselaer School ruled that:[20]

> The course of exercises for the Spring Term shall be, nearly as circumstances will admit as follows: Each student shall, during the first six weeks, give ten lectures on experimental philosophy; ten lectures on chemical powers and on substances not metallic; and ten lectures on metalloids, metals, soils, and meneral waters. For the remainder of the term each student shall be exercised in the application of the sciences before enumerated to the analysis of particular selected specimens of soils, manures, animal and vegetable substances, ores, and mineral

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19 *Ibid.*, p. 35.

20 *Loc. cit.*

> waters; and shall devote four hours each day unless excused by one of the faculty, to the examination of operations of the agriculturists on the school farm, together with the progress of cultivated grains, grasses, fruit trees, and other plants, to practical land surveying and general mensuration, to calculations upon the application of water power and steam which is made to the verious machines in the vicinity of the school and an examination of the laws of hydrostatics and hydrodynamics which are exemplified by the locks, canals, aqueducts, and natural waterfalls surrounding the institution.

The objective of this method of instruction was, to instruct by putting the pupil in the place of teachers. It was argued that teachers improve themselves more by teaching than they do their students, and that advantage should be taken of this fact in imparting instructions. The influence of these two schools on laboratory instruction in the colleges may be anticipated by studying the preceding discourses.

<u>The Yale Scientific School</u>. Previous to 1842, there had been provided no means for laboratory instruction, with the exception of Rensselear, either at Yale or any other college in the United States. Professor Silliman, Sr., had been in the habit of taking into his laboratory a very limited number of persons who were fitting themselves to become teachers in the departments of science under his care. This number rarely exceeded two or three persons at one time. There were no recitation; the art of manipulations, the management of chemical processes, and the preparation of classroom experiments, were the chief subjects of attention.[21]

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21 Fisher, op. cit., Vol. 2, p. 274.

In 1842 Mr. Silliman, Jr., being then professional assistant to his father, arranged to teach a few students in chemical analysis and mineralogy. For this purpose a small analytical laboratory was fixed up in the Old College Laboratory.[22] Thus the credit for establishing the first regular college laboratory courses in chemical analysis belongs to Benjamin Silliman,Jr. These laboratory courses were entirely optional, and the students were not regular members of the college. As evidence of this it is found that their names did not appear upon the regular college catalogue.[23] The gradual development of the new branch of scientific instruction finally led to the design of giving it a recognized place in the University studies.

Silliman's small laboratory resolved itself into the Yale Analytical Laboratory which opened its doors to students in 1847. There was no source of income for this laboratory, consequently the work was carried on for several years at the personal expense of the two professors who not only got no salaries but furnished the laboratories, library, apparatus, and collections. They even paid a rent to the college for the use of the old presidential house, where the laboratory was located. Later the new school was fortunate in getting help from Joseph E. Sheffield. The institution was then later

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[22] Loc. cit.

[23] Ibid., p. 275.

named the Sheffield Scientific School of Yale College.[24]

The foregoing will bring out a notion of the feeling which existed at that time towards laboratory instruction. For a long time college presidents were loath to provide funds for the construction of proper laboratories for students. This warfare went on between the scientist and the classicist during the greater part of the nineteenth century. "The scientific goats were not allowed to mingle with the academic sheep. . ."[25]

The Lawrence Scientific School. In the same year that the Yale Scientific School was founded, the Lawrence Scientific School was endowed. This school was later affiliated with Harvard. Professor Eben N. Horsford was the first director. He had just returned from his laboratory training at Germany under Liebig. This is the start of Liebig's influence upon American chemistry teachers.

This school's new building was entirely given over to chemistry. It contained a laboratory not to be surpassed in Europe even at that time for convenience and instruction.[26] In this laboratory the student was mainly thrown on his own

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[24] Browne, op. cit., pp. 716-17.

[25] William H. Crawford, The American College. Henry Holt and Co., 1915, p. 62.

[26] Rufus Phillips Williams, "The Planting of Chemistry in America." School Science, 2:140, May, 1902.

resources. The laboratory work is described by one of the students as follows:[27]

> There were about a dozen students in the laboratory, of whom half were beginners. We were given Will's Qualitative Analysis, and were set at work upon the "hundred bottles." After we had finished them, we began to make quantitative analyses, but we soon met a difficulty, which at that time prevailed generally in the United States; it was the lack of any systematic, organized course of study for the chemical profession. We were simply turned into the laboratory. There was no regular graded course of study, consisting of two, three or four years, including not only chemistry, theoretical, analytical and industrial, but other studies necessary to the young chemist. As a matter of fact, there were no lectures on chemistry at all for the students of the scientific school. We were expected to provide ourselves with text books and study them by ourselves at home.

German influence on early laboratory instruction in this country. Many college professors in the United States finished their education in Germany; consequently it is natural that they should adopt German methods and techniques. Truly the German influence in the early laboratories of this country was highly significant. However, to-day it is not necessary to go to Germany to find the ultimate in laboratories, for this country contains some of the finest in the world. The students of Liebig who exerted the greatest influence upon the development of chemical education in America are: Eben N. Horsford (1818-93), Frederick A. Genth (1820-93), C. M. Wetherhill (1825-71), J. A. Porter (1822-66), Wolcott Gibbs

27 *Ibid.*, p. 141.

(1822-1908), J. Lawrence Smith (1818-83).[28]

Privately owned laboratories. The early scientific schools were by no means the only institutions influential in popularizing the laboratory method. At approximately the same time as the influence of the Yale Scientific School and the Lawrence Scientific School was felt, privately owned laboratories offered an opening for students who wished to take laboratory work. This type of institution played an important role in teaching men that branch of chemistry which was sadly neglected by the colleges. There were a number of such laboratories but two of them in particular deserve mention. These were the private laboratories of Dr. James Curtis Booth of Philadelphia, and Dr. Charles Thomas Jackson of Boston.[29] Both of these laboratories were opened in 1836. This type of instruction made the teachers conscious of the necessity for laboratory instruction. The young chemists who worked under these men had ample opportunity to familiarize themselves with analytical procedures and industrial processes. The natural result, of course, was their insistence, later as teachers, upon laboratory teaching.

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[28] Browne, op. cit., p. 719.

[29] Ibid., p. 713.

The early laboratory instruction at the medical school in connection with Harvard. The first laboratory instruction at the medical school in connection with Harvard was in 1846 when the medical school was transferred to a new building. In the basement of this building a chemical laboratory was built. It was fitted for one hundred and thirty-eight students. It seems that each student had his own place and his own apparatus for practical work in analysis and other chemical processes.[30] This plan so widely used and adopted at the present time, was then a great innovation, but even here the laboratory was not much used for several years. Dr. John W. Webster was then professor of chemistry at both the medical school and the college. Two or three lectures was the extent of the chemical instruction in the college at that time. In truth "chemical teaching in Harvard College had become extinct." It was left for Webster's successor, Josiah Cooke, to inaugurate a change for the better.[31]

In 1850 Josiah Cooke was appointed in the place made vacant by Webster. At that time the college had no apparatus, but Cooke furnished what he used from his own private laboratory. There was a small lecture room but no laboratory, because previously all that was required in the chemistry course was a

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[30] Williams, op. cit., pp. 139-40.

[31] Ibid., p. 140.

few lectures. It is true, as has been mentioned previously, that science teaching was not favored by the college authorities.

Cooke soon started a small laboratory in a small room beneath his lecture hall and later invited a few students to experiment with him. By 1853 Cooke had equipped the medical school in Boston, to the extent that a few pupils could take qualitative analysis. It is interesting to note that in 1857, laboratory work was made a requirement for the students who studied chemistry. From this start the chemical department of Harvard rose from practically nothing to one of the largest in the University. Cooke saw the laboratory of this institution rise from a mere cellar corner to a whole building completely filled with laboratories and lecture rooms.[32]

The Morrill Act. Because of the need for extensive laboratory technique training, the Morrill Act in 1862 proved to be a great force in the popularization of laboratory instruction. This act appropriated lands to promote and advance education in agriculture, mechanic arts, and natural science.[33] A result of this act was the founding of the present landgrant

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32 Ibid., pp. 142-43.

33 Guy Montrose Whipple, editor, "A Program for Teaching Science." Thirty-First Yearbook of the National Society for the Study of Education, Part I, Public School Publishing Co., Bloomington, Ill., 1932, p. 308.

colleges which have as their aim that of developing practical sciences. The very nature of these colleges disagreed with the advocates of the classical training. As early as 1875, the Kansas State Agricultural College claimed:[34]

> K. S. A. C. furnishes a mental training having less bosh and possessing more real value to the boys and girls who will have to make a living by working than can be obtained elsewhere; it affords a mental discipline equal to that of any other institution, and it gives a manual training which cannot be found elsewhere

As may be noted these schools did not deny the existence of disciplinary values in education, but they did suggest that the practical and useful were more important. Another force which encouraged the development of chemistry instruction was the introduction of the elective system in the colleges. This afforded the students an opportunity for the election of courses in science and a release from the study of the classics.[35]

It was in this manner that the laboratory method of teaching slowly gained a foot-hold in the colleges. Although certain institutions used and advocated the laboratory method early in the century, a general acceptance of this method did not come about until about 1870. From this time on the development of laboratory instruction has advanced at a rapid rate. However, this does not mean that the question of laboratory instruction is settled even to-day. The question as to the relative value of the lecture demonstration method as compared with that of

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34 Bruce W. Merwin, "Developments of the Curriculum in College Chemistry." Journal of Chemical Education, 12:542, Nov., 1935.

35 Whipple, loc. cit.

individual laboratory work is a problem of discussion at the present time.

The period from 1870 to 1900 was characterized by the general acceptance of the laboratory as a valid and essential mode of study. Then this laboratory method began to develop extensively about this time it resulted in a formalization of laboratory exercises and in a standardization of equipment. This formalization was a result of the influence of faculty psychology and an unquestioning belief in the transfer of training.[36]

This study of the evolution of the chemistry laboratory as a method of instruction has indicated: that the doctrine of mental discipline has played an important role in shaping the curriculum of the American Colleges from the time of the beginnings of laboratory instruction to the beginning of the twentieth century; that students saw very little laboratory instruction before the middle of the nineteenth century; that before the middle of the nineteenth century, students saw experiments performed by the instructor but were never allowed to handle the apparatus themselves; that the beginning of the laboratory method can be traced to the founding of the Rensselaer Institute in 1825 and the Gardiner Lyceum in 1822; that the private laboratories such as those of Dr. Charles Thomas

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[36] Ibid., p. 282.

Jackson and Dr. James Curtis Booth exerted the next great influence in stimulating laboratory instruction when the opened in 1846; that the first regular laboratory courses in college chemistry were offered at the Yale Scientific School in 1852; that the first laboratory instruction at the medical school in connection with Harvard was in 1846; that in 1857 laboratory work in Harvard was required of all students who studied chemistry; that it was not until about 1870 that laboratory instruction in chemistry became generally accepted.

CHAPTER V

THE RECENT EXPANSION OF THE CHEMISTRY CURRICULUM, 1870 TO THE PRESENT TIME

To recapitulate briefly, chemistry seems to have been offered as a separate branch of instruction in the American colleges and universities since the founding of the first professorship of chemistry at Kings College in 1767. The University of Pennsylvania was the next to offer chemistry as a separate subject when James Rush was the professor of chemistry in 1769. In William and Mary College, chemistry was introduced in 1774. Harvard included it in its curriculum in 1783, and Princeton in 1795. During the following fifty years it became a regular course of study in most of the large colleges and universities of this country.

The chemistry of these early colleges was usually taught in connection with the medical schools and was generally considered a part of the medical training. The chemistry courses were usually made up of a few lectures with an occasional demonstration, the main purpose of which was to produce spectacular effects. Very few laboratories were in existence and those were for the exclusive use of the instructors.

The beginning of the laboratory method can be traced back to the first quarter of the nineteenth century when the Rensselaer Institute and the Gardiner Lyceum were founded.

Under the influence of the scientific schools and private laboratories, the laboratory method was introduced in a general way into the colleges about the middle of the nineteenth century. About twenty-five years later it had gained a general recognition and acceptance among the colleges. The advancement of chemical education in the United States has taken rapid strides since 1875. It is from this date to the present time that is of primary concern to this chapter.

During the past half-century the offerings of the various college departments of chemistry have changed greatly. This change has resulted in the present discussion as to what new courses should be added to the curriculum. Great amounts of scientific research have been carried on inside the colleges. Many great chemical research accomplishments must be credited to college research laboratories. This, of course, was not true in the early colleges, for at that time practically all investigations were carried on outside of the colleges.

In an attempt to describe the conditions of chemical instruction at about 1880, a brief study of the methods used and the extent of the instruction in chemistry in six of the more important and typical colleges of this country follows.

Dartmouth. At this institution the regular course in chemistry occupied four hours a week during eleven weeks, the last term of the junior year. Lectures and experiments before the class made up the main part of the course. Miller's text book was used. In the middle term of the senior year there was an optional course of four hours a week in laboratory practice.

The agricultural college in connection with Dartmouth had a general course of study extending through only three years. In the second year, Barker's chemistry was studied for two terms and Douglas and Prescott's Qualitative Analysis for the third term. During the first term of the senior year, quantitative analysis was optional.[1]

Harvard. At Harvard, a course of twenty popular elementary lectures was delivered once a week by Professor Cooke to the freshmen. This course was required of all freshmen. The whole class was required to pass an examination at the end of these lectures. After the freshman year various elective courses could be taken.[2]

Clarke summarizes the content of these elective courses in the following manner:[3]

> After the freshman year the following elective courses are offered:

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1 Frank Wigglesworth Clarke, "A Report on the Teaching of Chemistry and Physics in the United States." Bureau of Education Circular of Information No. 6, Washington, D.C. 1880, p. 38.

2 Ibid., pp. 46-47.

3 Ibid., pp. 47-48.

(1) Descriptive chemistry, with laboratory work. Three times a week. Assistant Professor Jackson. The course as a whole consists of two lectures, one recitation, and four hours of laboratory work a week. The laboratory work is laid out for each exercise at the preceding lecture, and involves numerous experiments in practical chemistry. This course is intended for general education and is taken by more than half of every class. The average of number of students annually in attendance upon it is reported as one hundred.

(2) Determinative mineralogy and lithology, with study in the mineral cabinet. Three times a week. Professor Cooke and Mr. Melville. The mineralogy, including descriptive crystallography and blowpiping, is taught first by lectures on models and specimens, and later by practical exercises in determining minerals. Over two hundred drawers of specimens are selected for this purpose and assigned to the students. Their acquirements are tested by calling on them to point out on the specimens the characteristics by which the latter have been determined. The examination refers solely to their ability to identify species. About thirty students take this work.

(3) Qualitative analysis and chemical philosophy, with laboratory work. Three times a week. Assistant Professor Hill. Qualitative analysis is taught in much the usual way. Three hours a week means a minimum of nine hours' work in the laboratory. Most students work much more. About forty students take this work.

(4) Quantitative analysis. Three times a week, or a minimum of nine hours in the laboratory. Professor Cooke and Mr. Hodges. In this course, as in the last, some preliminary instruction is given by lectures. About twenty students attend.

(5) The carbon compounds. Three times a week. Assistant Professor Hill. This is an advanced course of lectures on theoretical organic chemistry, accompanied by work in the laboratory. The latter is chiefly in the preparation of organic products, although, as soon as the students show themselves competent, they are started on research.

(6) Advanced course in experimental chemistry. Three times a week. Professor Cooke. This is a continuation of earlier work, and here also students, as soon as they have acquired sufficient skill, are set at research. The instruction is all special and in the laboratory.

(7) Crystallography and the physics of crystals, with work in the mineral cabinet. Professor Cooke. Instruction is given by lectures, Miller's system being taught.

For graduate students there is a course in advanced organic chemistry, three times a week, under Assistant Professor Hill. In the laboratories advanced students are also directed by the professors in whatever special studies or investigations they may desire to undertake.

But little use is made of text books, their day having gone by. Indeed, there are no formal recitations except in courses 1 and 3, and in these they are directed rather to emphasize the lectures or to correct inaccuracies than to enforce the learning of lessons.

The laboratory facilities, &c., are as follows: First, a qualitative laboratory, with one hundred desks; then a quantitative laboratory, with twenty-four desks, an organic laboratory, with twelve desks, and a mineralogical laboratory capable of accommodating about twenty-four students. There is a room of constant temperature for gas analysis, with a furnace room, a balance room and library, a larger and a smaller lecture room, and three private laboratories. The apparatus is ample, and the mineral cabinet is abundantly sufficient for all purposes of teaching. Every opportunity is afforded for research.

The foregoing does not include the courses in The Lawrence Scientific School and the Bussey Institution. These institutions are connected with Harvard.

Yale. In the undergraduate academical department, instruction in chemistry was given in the first third of the junior year, by recitations, lectures, illustrative exercises with problems, and examinations. There was no laboratory practice.

The extent of chemical education in Sheffield Scientific School, which is affiliated with Yale, is brought out in a description of the chemistry curriculum in that institution. Clarke describes it as follows:[5]

> Instruction is given by three professors and two assistants. There are several three years' courses of study, all of which are the same in the first year. The "course in chemistry" is as follows:
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> Freshman year.--First term: German, English, analytical geometry, physics, elementary drawing, chemistry (recitations and laboratory practice). Second term: Language, physics, and chemistry (as above), spherical trigonometry, elements of mechanics, botany, physical geography, political economy, drawing.
>
> Junior year.--First term: Theoretical and organic chemistry, lectures, qualitative analysis, blowpipe analysis, German, French. Second term: Quantitative analysis, mineralogy, blowpipe analysis and determination of species, French, German.
>
> Senior year.--First term: Voumetric and organic analysis, geology, zoology, French. Second term: Mineral analysis and assaying, agricultural chemistry, recitations and lectures (optional), geology, metallurgy (optional), mineralogy (optional), French.
>
> Blowpipe analysis is taught in all the regular courses. In the engineering courses this study is taken by the seniors. Other courses have it in the junior year. Students in the courses of "natural history" and "biology" have instruction in qualitative analysis during the first junior term. In the latter course toxicology and physiological chemistry are taught through the second junior term. Juniors in the agricultural course take the chemistry assigned for the same time to the chemical students, as specified above. In the senior year they have agricultural chemistry. Young men wishing to become mining engineers can pursue the reguler course in civil or mechanical engineering, and afterwards can spend a fourth year studying metallurgical chemistry, mineralogy, &c.
>
> The laboratories are well provided with all necessary facilities. A fee of $5 is charged to members of the

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[5] Ibid., p. 58.

freshman class for chemicals, &c., and the same fee is required from all who take the practical exercises in blowpipe analysis and determinative mineralogy. The special student of chemistry, over and above tuition fees, pays $70 per annum for chemicals and the use of apparatus. He also supplies himself at his own expense with gas, flasks, crucibles, &c., the cost of which should not exceed $10 a term.

Columbia. In the School of Arts, the sophomore class attended one exercise a week in chemistry throughout the year. The course consisted mainly of lectures and included the general principles of chemistry, a short account of the common elements, and the chief compounds and their uses. In addition, a brief outline of vegetable and animal chemistry was presented.

General chemistry was also taught during the senior year, three times a week, as an elective. Fownes's text book was used along with lectures to make up the course. The principles and details of both inorganic and organic chemistry were the topics discussed in these courses. The lectures were illustrated by chemical specimens. No laboratory work was required.[6]

The School of Mines which is in connection with Columbia had a course of study which in all probability was typical of the colleges the country over at about 1880. Clarke describes it as follows:[7]

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[6] Ibid., p. 67.

[7] Ibid., p. 66-67.

. . . General inorganic chemistry, stoichiometry, qualitative analysis, quantitative analysis, and blowpiping are required studies in all the courses. Assaying is taught to students in mining, metallurgy, and chemistry. In the geological and chemical courses, organic chemistry is studied. The chemical students have also a large amount of work in applied chemistry. Quantitative blowpipe analysis is an optional study in all of the courses.

In general chemistry the first year students attend three exercises a week throughout the year. This course is preliminary to practical instruction in the laboratory. The students are drilled upon the lectures, with free use of the best text books, and take notes which must be submitted to the professor. At the end of the year there is a rigid examination. The second class also attend three times a week during the year, and receive instruction in theoretical chemistry adapted to the needs of special scientific students.

For analytical chemistry there are three laboratories, one for qualitative analysis, one for quantitative analysis, and a third for assaying. Each of these is thoroughly equipped and is in the special charge of an instructor with an assistant. Every student is provided with a convenient table containing drawers and cupboards, and is supplied with a complete outfit of apparatus and reagents. The laboratories are open daily, except Saturdays, Sundays, holidays, and vacations, from 10 A.M. to 4 P.M.

During the second year, qualitative analysis is taught by lectures, blackboard exercises, and constant laboratory practice. The spectroscope is freely used. When the student shows, by written and experimental examination, that he is sufficiently familiar with qualitative work, he is allowed to enter the quantitative laboratory. In the third and fourth years, quantitative analysis is taught, the laboratory exercises being accompanied still by lectures and blackboard work. The laboratory course is graded after the usual manner, the student beginning with comparatively simple substances of known composition and passing on by degrees to the analysis of more complex bodies, such as coals, pig iron, various ores, slags, mattes, and so on. Both volumetric and gravimetric methods are employed. In the fourth year the student is admitted to the assay laboratory, where he is furnished with a suitable table and a set of assaying apparatus. Here he has access to crucible and muffle furnaces and to volumetric apparatus for the assay of alloys of gold and silver. The general principles and special methods of assaying are described in the lecture room and at the same time the ores of the various metals and their appropriate fluxes are exhibited and described. The student is then supplied with different ores and is required to assay each ore in duplicate under the supervision of the instructor.

Stoichiometry is taught, by lectures and blackboard exercises, as a part of the course in general chemistry, through the first and second years; and its practical applications are developed in lectures upon quantitative analysis and assaying.

In applied chemistry, the instruction extends through the third and fourth years and consists of lectures illustrated by experiments, diagrams, and specimens. The cabinet of industrial chemistry is very large and complete, containing several thousand specimens of materials and products.

Princeton. At this institution in the classical course throughout the senior year, chemistry was required. Applied and organic chemistry were held as electives for the same year. In the school of science, the freshmen were prescribed to take blowpipe analysis. Throughout the second year, general inorganic chemistry, with qualitative analysis during the second and third terms were required. The juniors had quantitative analysis and the seniors took up volumetric work, assaying, applied chemistry and organic chemistry.[8]

University of Pennsylvania. The nature and extent of the chemistry department of this institution is well described

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[8] Ibid., p. 75-76.

in the following:[9]

In the department of arts the sophomores have chemistry three times a week and hear during the year a course of lectures covering in a general way the whole field of the science, inorganic and organic.

In the Towne Scientific School there are provided six courses of study, which diverge at the beginning of the third year. The freshmen have a course of fully illustrated experimental lectures upon inorganic chemistry twice a week throughout the year. In the sophomore class one term is devoted to recitations upon theoretical chemistry, a second to the outlines of organic chemistry, and the third to laboratory exercises in chemical manipulation. The text book for recitation work is Greene's translation of Wurtz's Elements of Chemistry, and there are three exercises weekly. At the beginning of the junior year the class divides into six sections. All begin the study of analytical chemistry at this point, but devote very different amounts of time to the work. In the two engineering courses qualitative analysis, metallurgy, determinative mineralogy, and blowpiping are studied. Students in the course preparatory to medical studies have qualitative analysis, organic chemistry, and determinative mineralogy through the junior year; and in the senior class they take up quantitative work, toxicology, and physiological chemistry. For the "chemical section" the whole course of study from the beginning is as follows, the same amount of chemistry in the junior and senior years being taken also by the section in geology and mining:

Freshman year.--History, English composition, French, algebra, geometry, trigonometry, drawing, German, chemistry.

Sophomore year.--English, German, French, spherical trigonometry, descriptive geometry, differential calculus, drawing, physics, chemistry, geology.

Junior year.--Physics, logic, geology, English, organic chemistry, chemical manipulations, qualitative and blowpipe analysis, chemical preparations, introduction to quantitative analysis, descriptive mineralogy,

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9 Ibid., p. 80-82.

metallurgy, assaying.

Senior year.--History, English literature, international law, Thompson's Social Science and National Economy, compositions, declamations, quantitative analysis (gravimetric and volumetric), gas analysis (including the construction of eudiometers), organic analysis, water analysis, detection of impurities in food and drink, quantitative blowpiping, chemical preparations, metallurgy, determination of minerals by their physical properties, practice in agricultural chemistry.

A post graduate course of study has been arranged, but as yet no regular classes have been organized. Individual post graduate students have however been in attendance for several years past, working upon gas analysis, mineral analysis, organic research, and other special subjects.

The laboratories are exceptionally fine and fully equipped for all fields of chemical instruction. There is also a chemical museum. Since 1872 about twenty-five original investigations have been published by Professors Genth, Konig, Sadtler, and Smith in various scientific journals.

Chemistry and natural philosophy have been taught in a limited way in this university for nearly a hundred and twenty years. The present system of teaching these sciences was established in 1872. A scientific society has been organized among the students, and meetings are held every week for essays and discussions.

As may be noticed, the character of the work done in chemistry in the various institutions was by no means the same. However, a common characteristic of these institutions is that of prescribed and required work in chemistry. In these colleges a great portion of the chemistry courses offered was required. The variations existing among the colleges at that time was entirely natural and logical. A common aim and purpose was hard to obtain because institutions of higher learning grew up more or less independently of each other. Each grew up with a different object in view. Because they were the last stage in the educational scheme, the colleges have had no standardizing agent such as did the high schools. These secondary institutions had such things as college entrance requirements to fulfill, therefore, they grew up somewhat after the fashion of each other. This is not true in the case of college development. As a result, the colleges were found to have developed various types of curricula and courses which were as different as life itself.

In 1880 there were over three hundred colleges and universities in this country. This number does not include the medical schools, scientific schools, institutions for instruction of women, and normal schools which existed at that time. Frank Wigglesworth Clarke[10] made a comprehensive survey of chemistry and physics teaching in the United States in 1880. It is from this study that the following table is compiled. An examination of this table will indicate in detail the nature and extent of chemical education in the various colleges in 1880.

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10 *Ibid.*, pp. 200-12.

TABLE III*

SHOWING THE NATURE AND EXTENT OF CHEMICAL EDUCATION IN THE COLLEGES AND UNIVERSITIES OF THE UNITED STATES IN 1880

Name of Institution	No. of Teachers	Studies Began	Course of Study	Value of Apparatus	Text book	Instruction Began
1	2	3	4	5	6	7
Southern Univ., Ala.	1	Sr.	I.7		42	
Howard Col., Ala.	1	Jr.	I.7		19 or 20	
Spring Hill College, Ala.	1	6th yr.				
Univ. of Ala., Ala	1		E.6	$ 7,500	64-65-4 16-21-27	1831
Cane Hill Col., Ark.		Jr.	I			
Judson Univ., Ark.	1	Sr. prep.	9	500	30-31	1875

* This table, as previously indicated, was compiled from the Bureau of Education Circular of Information No. 6. It is interesting to note that this particular publication is out of print and rather scarce. The author obtained a copy from the duplicate collection of the United States Department of Education

The numbers and letters found in the various columns refer to a key which is to be found immediately following the above table. Sufficient directions will be given in that place for an intelligent reading of the table.

TABLE III (Continued)

1	2	3	4	5	6	7
St. John's Col. of Ark., Ark.	1					
Missionary Col. of St. Augustine, Cal.	1	Scient.	8	100	31	1867
Pierce Christian Col., Cal.	1	Fresh.	L		31	
Univ. of Cal., Cal.	4	Fresh.	B.2,3,4	20,000	12-27-42-50 53-64-65-	1869
St. Ignatius Col., Cal.	2		E.6	50,000	18-28-47	
St. Mary's Col., Cal.	1	2nd class Jr.	I.9		31	
Santa Clara Col., Cal.	1					
Pacific Meth. Col, Cal.	1	Jr.	9	500	26-36-	1871
Cal. Col., Cal.	1					
Wash. Col., Cal.		Soph.	L			
Hesperian Col., Cal.	1	Soph.	9	500	34	1865
Colo. Col., Colo.	1	Soph.	I.6,13,14		12	
Trinity Col., Conn.	1	Sen.	I.9	45,000	1-22	1823
Wesleyan Univ., Conn.	2	Jr.	C.6		12-37-43-53 64-65-74-77	1831
Yale Col., Conn.	1	Soph.	L.9		4	1802
Delaware Col.,Del.	1	Jr.	E.6,20		12-27-52-72 58-62-64-	
Univ. of Ga.,Ga.	2		E.6,20	25,000	14	1800
Atlanta Univ., Ga.	1	2nd yr. normal	M.9	550	31-36	1872
Gainesville Col., Ga.		Jr.	I		36	
Mercer Univ., Ga.	1	Sr.	L		27	

TABLE III (Continued)

1	2	3	4	5	6	7
Pio Nono Col., Ga.	1	Fresh.	E.9	600	12-31	1874
Emory Col., Ga.	1	Sr.	L		13	
Abingdon Col., Ill.	1		M		36	
Hedding Col., Ill.	1	Fresh.	M		36	
Ill. Wesleyan Univ., Ill.	1	Sr. prep.	E.9		33-36	1850
St. Viateur's Col., Ill.	1	6th year				
Blackburn Univ., Ill.	1	Jr.	K			
Carthage Col, Ill.	1	Middle Jr.	G.9	700	4	1872
St. Ignatius Col., Ill.	2		C.6	5,300	4-53-64-67	1873
Univ. of Chicago, Ill.	1		E.C.6	750	4-40-53	1861
Rock River Univ., Ill.	1		L			
Eureka Col., Ill.	1	Soph.	K.9	2,000	4-31	1855
Northwestern Univ., Ill.	2	Col.	F.6	3,000	26-46-53	
Ewing Col., Ill.	1	Fresh.	M			
Knox Col., Ill.	1	Jr.	K		4	
Lombard Univ., Ill.	2	Jr.	7	6,000	4-18	
Ill. Col., Ill.	1	Soph.	9	4,000	4	1829
Swedish Am. Ansgari Col. Ill.	1	Jr.				
Lake Forest Univ., Ill.	1	Sr.	B.6	2,000	2-53-64	1878
McKendree Col., Ill.	1	Jr.	M.9			
Lincoln Univ., Ill.	1			1,000		1866
Monmouth Col., Ill.	1	Jr.	M.9		36	
Northwestern Col., Ill.	1	Jr.	K.8	450	4-36	1862
Augustana Col., Ill.	1	Jr.	9	500	18-4	1875
St. Joseph's Eccl. Col, Ill.		5th year			31	
Shurtleff Col., Ill.	1	Jr.	K.9		36	

TABLE III (Continued)

1	2	3	4	5	6	7
Westfield Col., Ill.	1	Jr.	M.9		36-4	[illegible]
Wheaton Col., Ill.	1	Sr.	M			[illegible]
Bedford Col., Ind.	1	Soph.	9	100	36	1872
Indiana Univ., Ind.	2	Soph.	D.6,13	5,000	25-38-41-53 64-68-69	1828
Wabash Col., Ind.	1	Jr.	I.6	3,000	7-27-36-53 64	1833
Fort Wayne Col., Ind.	1	2nd yr.	H			
Franklin Col., Ind.	1	Jr.	O.9	750	18	1845
Ind. Asbury Univ., Ind.	1	Fresh.	7	2,000		1837
Hanover Col., Ind.	1	Jr.	8		13	1829
Hartsville Univ., Ind.	1	Sr.	9	800	4	1852
Butler Univ., Ind.	2	Jr.	I.6	1,000	27-50-64	1860
Smithson Col., Ind.	1	Jr.	K			
Union Christian Col., Ind.	1	Sr.	O.9	900	36	1856
Moores Hill Col., Ind.	1	Soph.	K.7	400	5-12	1857
Univ. of Notre Dame du Lac, Ind.	1	Sr.	E.7		4-36	
Earlham Col., Ind.	1	Fresh.	I.7	500	27-53-69	1861
Ridgeville Col., Ind.	1		9	200	31	
St. Meinrads' Col., Ind.						
Algona Col., Ind.	1	Jr.	K		31	
Amity Col., Iowa	1		K.9	293	36	
Griswold Col., Iowa	1	Jr.	I.9	1,000		1859
Norwegian Luther Col., Iowa						
Univ. of Des Moines, Iowa	1	Jr.				1869
Parsons Col., Iowa	1	Sr.		400		

TABLE III (Continued)

1	2	3	4	5	6	7
Upper Iowa Univ., Iowa	1	Soph.	K.9	400	36	1857
Iowa Col., Iowa	1	Fresh.	E.6	2,000	13	1848
Humboldt Col., Iowa	1	Prep.		200		1875
Simpson Centenary Col., Iowa	2	Jr.	M.9		18	
Iowa State Univ., Iowa	2	Fresh.	6	6,000	16-17	1868
Iowa Wesleyan Univ., Iowa	1	Town schs.	6	2,500	8-18	1854
Cornell Col., Iowa	1		I.6	1,300	4-47-65	1858
Oskaloosa Col., Iowa	2	Jr.	7	160	36-58	
Penn. Col., Iowa	1	Fresh.	I.7		13-18-52-53 59	
Central Univ. of Iowa, Iowa	1	Jr.	M			
Tobor Col., Iowa	1	Jr.	I.7	500	13-50	1870
Western Col., Iowa	1	Sr.	M		26	
St. Benedict's Col., Ks.		5th yr.				
Baker Univ., Ks.	1	Soph.	9		27-31	1860
Highland Univ., Ks.	1	Jr.	K	1,800		
Univ. of Ks., Ks.	1	Soph.	E.6,17	1,500	4-24	1866
Lane Univ., Ks.	1	Jr.	K			
Ottawa Univ., Ks.		Jr.	L			
Washburn Col., Ks.		Soph.	M		39	
St. Joseph's Col., Ky.		6th yr.				
Berea Col., Ky.	1	Soph.	M	300	4	1856
Warren Col., Ky.	1	Jr.	L			
Cecilian Col., Ky.					18	
Centre Col., Ky.	1	Jr.	6	3,000	4-46-53-65 68-75	1826

TABLE III (Continued)

1	2	3	4	5	6	7
Eminence Col., Ky.	1		9		34	
Ky. Military Inst., Ky.	1	Jr.	7	650	4-46	1850
Georgetown Col., Ky.	1	Jr.	L.9	3,000	26	1830
Ky. Wesleyan Col., Ky.	1	Soph.	I.8	500	13-21	1866
Murray Male & Female Inst., Ky.		Sr.	L			
Concord Col., Ky.	1	1st yr.		150	35	1868
Central Univ., Ky.	1	Jr.	E.6	3,000	14-53-64	1874
Bethel Col., Ky.	1	Sr.	L.9			
St. Mary's Col., Ky.	1	4th yr.				
La. State Univ., La.			E.6,19		27	
Centenary Col. of La., La.	1	Jr.	I.9,20		85	
Leland Univ., La.	1	2nd yr.	N			
Straight Univ., La.						
Jefferson Col. (St. Mary's), La.	1	3rd Classical	G.7	10,000	20	1864
Bowdoin Col., Me.	2	Soph.	F.7			1805
Bates Col., Me.	1		L		12	
Colby Univ., Me.	1	Soph.	I.7	7,000	12-35-56	
St. John's Col., Md.	1	Sr.	I.9	3,000	14	
John's Hopkins Univ., Md.	4	1st yr.	A.1		43-54-62	1876
Loyola Col., Md.	1		10	350		1852
Wash. Col., Md.	1	Sr.	9	900	36	1782
Rockhill Col., Md.		Fresh.			4-27	
Frederick Col., Md.	1	Fresh.	9	500	36	
Western Md. Col., Md.	1	Soph.	I.9	500	14-26	1869
Amherst Col., Mass.	2	Soph.	E.6,15,16	10,000	15-55-62	1821

TABLE III (Continued)

1	2	3	4	5	6	7
Boston Univ., Col. of Liberal Arts, Mass.	1		I.7			1873
Harvard Col., Mass.	9	Fresh.	A.1		42-9-56	1782
Tufts Col., Mass.	1	Jr.	E.6	3,500	33-46-50-58 65	1855
Smith Col., Mass.	1	Soph.	C.6	8,000	12-51-67	
Wellesley Col., Mass.	1	Soph.	E.6	7,500	57	
Williams Col., Mass.	1	Jr.	M.9	5,000	13	1830
College of the Holy Cross, Mass.	1	6th yr.	L			
Adrian Col., Mass.	1	Prep.	I.7	1,750	4-32-46-12 25	1859
Albion Col., Mich.	1	Jr.	K			
Univ. of Mich., Mich.	5	Optional	A.I,3		64-67-68-69	
Battle Creek Col., Mich.	1	Last yr.	9	2,000	4-36	1873
Grand Traverse Col., Mich.						
Hillsdale Col., Mich.	1	Soph	I.9		4	
Hope Col., Mich.	1	Jr.	K.		26	
Kalamazoo Col., Mich.	1	Soph.	9	500	4	
Olivet Col., Mich.	1	Jr.	K			
Univ. of Minn., Minn.	1	Fresh.	C.6,17	5,000	4-46-61-63 78	1868
Carleton Col., Minn.	2	Fresh.	7	4,000	5-12-36-51	1871
St. John's Col., Minn.	1		I.9	1,000	4	1877
Miss. Col., Miss.	1	3rd yr.				
Shaw Univ., Miss.	1	Fresh.	9 or 11		31	1878
Univ. of Miss., Miss.	2	Jr.	E.6	15,500	68-75-78-80 81-8-12-14	

TABLE III (Continued)

1	2	3	4	5	6	7
Alcorn Univ., Miss.		Jr.		500	36	1872
Univ. of the State of Mo., Mo.	1		6,15,19	5,000	27-53-64-68-73	1840
Central Col., Mo.	1	Jr.	9,20	2,750	14-83	1870
Louis Col., Mo.	1	Prep.	I		31-36	
Pritchett Sch. Inst., Mo.	1	Grammar School	7	1,000	18-25-31-52-67	1866
Lincoln Col., Mo.	1	Jr.	9 or 11		36	
LaGrange Col., Mo.	1	Jr.	9	1,200		
William Jewell Col., Mo.	1	Jr.	E.7	3,000	34	
Baptist Col., Mo.	1	Jr.	9 or 11		36	1869
St. Louis Univ., Mo.	1		E.9	5,000	20	1827
Wash. Univ., Mo.	1	Soph.	C.6,14	4,500	27-52-53-64	1857
Drury Col., Mo.	1	Soph.	K.7		4	
Central Wesleyan Col. Mo.	1	Sr.	M		31	
Doane Col., Neb.	1	Jr.	O.8	30	4-13	1876
Univ. of Neb., Neb.	2	Prep.	H.7	2,500	4-10-52	1871
Dartmouth Col., N.H.	2	Jr.	L.7	7,500	22	1820
Rutgers Col., N.J.	6	Fresh.	E.6	6,500	4-27-53-64-68	
Col. of N.J., N.J.	3	Sr.	I.7		3-14-22-27	
Seton Hall Col., N.J.	1	Soph.	L		204	
St. Bonaventure's Col., N.Y.	1	4th yr.			25	
St. Stephen's Col., N.Y.						1860
Wells Col., N.Y.	1	Jr.	I.7	3,000	4-46-53	1868
Brooklyn Collegiate & Polytechnic Inst., N.Y.	1	1st Col.	D.6,14	6,700	4-42-53-64-68	1854

TABLE III (Continued)

1	2	3	4	5	6	7
Canisius Col., N.Y.	1	5th Classical	I.9	4,000	13	1876
St. Joseph's Col., N.Y.		Jr.	E			
St. Lawrence Univ.,N.Y.	1	Jr.	9	1,600	4	1872
Hamilton Col.,N.Y.	1	Sr.	I.7,20		12-52	1812
St. John's Col.,N.Y.	1	Jr.			22	
Hobert Col., N.Y.	1			10,000		1825
Madison Univ., N.Y.	1	Soph.	K.9	3,000	4-27	
Cornell Univ., N.Y.	6	Soph.	C.2,4	19,000	7-24-33-42-50-64-68-81	1868
Ingham Univ., N.Y.	1	Jr.	9	1,000		1835
Col. of the City of N.Y., N.Y.	2	Sub. Fresh.	9,13	15,000	6-68	1849
Columbia Col., N.Y.	2	Soph.	E.9		14-27	1802
Col. of St. Francis Xavier, N.Y.	1	Jr.	9		4	
Univ. of the City of N.Y., N.Y.	2	Soph.	F.6		11	
Vassar Col., N.Y.	1	Soph.	I.7	7,500		
Univ. of Rochester	1	Jr.	7	3,000	27-35-51-53-75	1851
Union Col., N.Y.	1	Soph.	6	25,000	27-43-49-67	1811
Syracuse Univ., N.Y.	1	Fresh.	0.8		4-14	1872
Univ. of N.C., N.C.	1	2nd yr.	E.6	2,500	14-21-27-53-80-64	1818
Davidson Col., N.C.	1	Jr.	E.7	3,000	4-53	1837
Rutherford Col., N.C.	1		9			1854
N.C. Col., N.C.	1	Jr.	9	8000	36	1856

TABLE III (Continued)

1	2	3	4	5	6	7
Trinity Col., N.C.	1	Jr.	I.6		34	
Wake Forest Col., N.C.-	1				32-85	
Weaverville Col., N.C.	1	Sr.	L		36-47-76	
Ohio Univ., O.	1	Jr.	K.9	1,800	4-36	
German Wallace Col., O.	1	Jr.	K.8		36	1864
Baldwin Univ., O.	1	Jr.	K		36	
St. Xavier Col., O.	1	Next to highest	B.9	2,600	36	
Univ. of Cinn., O.	1	Fresh.	A.1	8,000	27-37-43-53-62-64	1874
Farmers' Col., O.	1	Soph.	I.9,20		36	
Ohio State Univ., O.	2	Prep.	E.6,14	30,000	25, etc.	1873
Ohio Wesleyan Univ., O.	2	Soph.	I.6,15,16	2,000	21-27	1866
Kenyon Col., O.	1	Jr.	M.9	5,000	27	
Denison Univ., O.	1	Jr.	M.8	1,200	4	1831
Hiram Col., O.	1	Jr.	M.9	300	36	1850
Western Reserve Col., O.	1	Jr.	H.7	7,500	13-52	
Mt. Union Col., O.					34	
Franklin Col., O.	1		9	2,000		1825
Muskingum Col., O.	2	Jr.	M			
Oberlon Col., O.	1	Jr.	G.7,13	8,000	13-50-67	1878
McCorkle Col., O.	1	Jr.	9	600	36	1859
Scio Col., O.					31-47	
Miami Valley Col., O.	1	Jr.	K.9,20			
Wittenburg Col., O.	1	Jr.	7	1,000	4-52	1846
Heidelberg Col., O.	1	Jr.	9	800	36	

TABLE III (Continued)

1	2	3	4	5	6	7
Urbana Univ., O.	1	Jr.	K.8	600	13	1854
Otterbein Univ., O.	1	Soph.	L.9	4,000	27	1856
Willoughby Col., O.	1	Jr.	K.9		36	
Wilmington Col., O.	1	Fresh.	9	175	27	
Univ. of Wooster, O.	1	Sr.	K.7			
Xenia Col., O.	1	Jr.	M.9		36	
Wilberforce Univ., O.		Jr.	K.			
Antioch Col. O.	1	Middle prep.	K.8	1,900	14	1853
Pacific Univ., Ore.	1	3rd yr.	O.8	600	11	1862
McMinnville Col., Ore.	1	Soph.	9	2,000	31	1861
Christian Col., Ore.	1	Soph.	9	100	11	1869
Muhlenberg Col., Pa.	1	Jr.	I.9			
Lebanon Valley Col., Pa.	1	Sr.	M		36	
Dickinson Col., Pa.	1	Soph.	E.6	6,000	14-27-53-60-64	1811
Pa. Military Academy, Pa.	1	Soph.	7	5,000	4-46-54-58	1863
Layfayette Col., Pa.	3	Fresh.	A.2	12,000	21-27-53-62-64	1837
Ursinus Col., Pa.	1	Soph.	9	500		1869
Pa. Col., Pa.	1	Jr.	H.7			
Thiel Col., Pa.		Jr.				
Haverford Col., Pa.	1	Fresh.	B.6	4,500	13-52	1833
Franklin & Marshall Col., Pa.	1	Jr.	9	1,000	36	
Univ. at Lewisburg, Pa.	2	Soph.	O.9	1,500	12-36	1847
Allegheny Col., Pa.	1	Fresh.	I			
Mercersburg Col., Pa.	1	Soph.	K.7	500	4-25	
Palatinate Col., Pa.	1					

TABLE III (Continued)

1	2	3	4	5	6	7
Newcastle Col., Pa.	1	Jr.	7		27-47	
Westminster Col., Pa.	1	Jr.	H.7	1,200	27	1852
Lincoln Univ., Pa.	1	Jr.	I			
La Salle Col., Pa.	1	Fresh.	A.7	2,000	4-12-50	
Univ. of Pa.	4	Rresh.	A.1	40,000	53-54-62-64	1769
Western Univ. of Pa., Pa.	1	Prep.	H.7		27-53-64-67-68	1819
Lehigh Univ., Pa.	2	Fresh.	B.2,3	20,000	14-41-42-54-64-67-68-69-70-72	1866
Swarthmore Col., Pa.	2		B.6		42-58-68	
Augustinian Col. of St. Thomas of Villanova, Pa.	1		E			1855
Wash. & Jefferson Col., Pa.	1	Jr.	H.7		27-52	
Waynesburg Col., Pa.	1		9	500	36	1851
Brown Univ., R.I.	2	Fresh.	A.6		2-33-44-45-46-61	1811
Col. of Charleston, S.C.	1	Sr.		900	27	1838
Univ. of S.C.	1	Jr.	I.8		12-42	
Erskine Col., S.C.	1	Sr.	L.	*	32	
Furman Univ., S.C.	1	Jr.	7		4-23	
Newberry Col., S.C.	1	Jr.	9	100	36	1858
Wofford Col., S.C.	1	Jr.	9	600	4	1855
East Tenn. Wesleyan Univ., Tenn.		Jr.	L		36	
Beechgrove Col., Tenn.	1	Jr.	L		4	1869

TABLE III (Continued)

1	2	3	4	5	6	7
King Col.,Tenn.	1	Jr.	L		36	
Southwestern Presby. Univ., Tenn.	1	Soph.		2,000	12	1850
Hiwassee Col., Tenn.	1	Fresh.	11		34	1849
Southwestern Baptist Univ., Tenn.	1	2nd yr.			27	1877
East Tenn. Univ., Tenn.	2	Fresh.	A.46	2,000	27-53-64-81	1839
Cumberland Univ., Tenn.	1	Jr.	6	1,500	4-39-53-64-68	1842
Bethel Col., Tenn.	1	Sr.	1.11		4-36	1847
Manchester Col., Tenn.	1	Fresh.	11		20-31	1866
Maryville Col., Tenn.		Jr.	9	2,100	13	1849
Christian Bros. Col., Tenn.	2	Soph.	9	1,500	14	1874
Mosheim Inst., Tenn.	1		11		36	1870
Mossy Creek Col., Tenn.	1	Jr.	L		34	
Central Tenn. Col., Tenn.	1	Soph.	9	350	31	1874
Fisk Univ., Tenn.	1		7	2,000	13	1874
Vanderbilt Univ., Tenn.	3	Jr.	E.6	30,000	27-52-53-64-70 71-78-80-82	1875
Univ. of the South, Tenn.	1		E.7		14,53	
Tusculum Col., Tenn.	1	Sr.	L	150	4	1827
Texas Military Inst., Tex.	1	Next to highest	9	300	36	
Southwestern Univ., Tex.	1	Prep.	8		27	
Baylor Univ., Tex.	1	Academic	9	700	36	1846

TABLE III (Continued)

1	2	3	4	5	6	7
Salado Col., Tex.	1	Jr.	I			
Trinity Univ., Tex.	1	Soph.	I			
Waco Univ., Tex.	1	Soph.	L		3	
Univ. of Vt. and state Agricultural Col., Vt.	1	Fresh.	4.6	6,000	4-13-53-64	1830
Middlebury Col., Vt.	1	Jr.	K		12	
Norwich Univ., Vt.	1	Soph.	9		36	1837
Randolph Macon Col., Va.	1	3rd yr.	I.9	800	27-36	1832
Emory & Henry Col., Va.	1	Common Schs.	9	4,000	4-13-36	1839
Hamdon Sidney Col., Va.	1	Jr.	G.9,20		27-36-85	
Wash. & Lee Univ., Va.	1		E		27-36	
Richmond Col., Va.	1		9		14	
Roanoke Col., Va.	1	Jr.	L		36	
Univ. of Va., Va.	2	Ungraded	1	26,000	14-53-64-80	1825
Bethany Col., W.Va.	1		L.6	5,000	4-46-64-68	
W. Va. Col., W. Va.	1	Prep.		100	4-12	1869
W. Va. Univ., W. Va.	1	Fresh.	H.7		12	
Lawrence Univ., Wis.	1	Sr.	L.9	600		1849
Beloit Col., Wis.	1	Soph.	I.7	1,000	27-42	1847
Galesville Univ., Wis.	1	Jr.	K.9		34	
Univ. of Wis., Wis.	2	Jr.	E.6	5,000	33-53-64	1868
Milton Col., Wis.	1	Soph.	9	1,000	12	1855
St. John's Col., Wis.						
Racine Col., Wis.	1	Grammar Sch.	A.6	10,000	7-12-53-65-66-67	1852
Ripon Col., Wis.	1	Soph.	I.7	2,000	12-52	1865
Northwestern Univ., Wis.		Soph.				

TABLE III (Continued)

1	2	3	4	5	6	7
Georgetown Col., D.C.	1	Soph.	E.7	4,500	27-75	1834
Columbian Univ., D.C.	1	Jr.				
Howard Univ., D. C.	1	2nd yr. Prep.	K.9	1,500	27-31-52-75	1870
National Deaf-Mute Col. D.C.	1	Soph.	E.7	1,000	52	1864
Univ. of Deseret, Utah	2	Optional	6,14	3,000	31-47	1869

Key to Table III. In the preceding table most of the figures speak for themselves without special explanation or comment. Some of them, however, are abbreviations for which a key must be furnished.

Columns 1, 2, 3, 5, and 7 are self explanatory.

Column 4. This column indicates the course of study. The length of each course in point of time is represented by a letter, and the character of the course, by a numeral. The letters used have the following meaning:

A. Four years.
B. Three and a half years.
C. Three years.
D. Two and a half years.
E. Two years.
F. One and two-thirds years.
G. One and a half years.
H. One and one-third years.
I. One year
J. Three-fourths of a year.
K. Two-thirds of a year.
L. One-half year--from sixteen to twenty weeks. (Under this heading are put the usual medical school courses of five months.
M. One-third year.
N. Less than one-third year.
O. Length of course unstated, but not over a year.

The numerals have the following meaning:

1. Full course of general and analytical chemistry including higher organic chemistry and original research.
2. Same as number 1, but with less organic chemistry, little research, and special attention to applied chemistry.
3. Same as number 1, but with special reference to mining and metallurgy.
4. Same as number 1, but with special reference to agriculture.

5. Full course in general and analytical chemistry, followed by special instruction in medical or physiological chemistry.
6. Course in general chemistry, with qualitative and quantitative analysis.
7. Course in general chemistry, with qualitative analysis.
8. Course in general chemistry, with experiments by the teacher, but no regular laboratory work for pupils.
9. Course in general chemistry, with elementary laboratory work.
10. Elementary oral instruction, with experiments by the teacher.
11. Elementary text book work, without experiments.
12. Elementary oral instruction, without experiments.
13. Supplementary course in blowpipe analysis.
14. Supplementary course in assaying.
15. Supplementary course in toxicology.
16. Supplementary course in urine analysis.
17. Supplementary course in medical chemistry, with laboratory work.
18. Supplementary course in medical chemistry, without laboratory work.
19. Supplementary course in agricultural chemistry, with laboratory work.
20. Supplementary course in agricultural chemistry, without laboratory work.

Column 5. This column shows the text books used. Each number refers to an individual text book. The following text books are indicated by the various numbers.

I. Chemical Physics

1. Pynchon, T. R. Introduction to Chemical Physics.

II. General Chemistry

2. Appleton, J. H. The Young Chemist. A New Book of Chemical experiments for the Use of Beginners in Chemistry.
3. Baker, Chemistry.
4. Barker, G. F. College Chemistry.
5. Bloxam, C. L. Laboratory Teaching; or, Progressive Exercises in Practical Chemistry.

6. Brande, W. T., and Taylor, A. S. Chemistry.
7. Caldwell, B. C., and Breneman, A. A. Manual of Introductory Chemical Practice.
8. Church, A. H. Laboratory Guide.
9. Cooke, J. P., Jr. The New Chemistry.
10. Cooley, LeRoy C. Elements of Chemistry.
11. Draper, H. Text Book on Chemistry.
12. Eliot, C. W., and Storer, F. H. Manual of Inorganic Chemistry.
13. Eliot, C. W., and Storer, F. H. Manual of Inorganic Chemistry; abridged by W. R. Nichols.
14. Fownes, G. Manual of Elementary Chemistry, Theoretical and Practical; edited by R. Bridges.
15. Harris, E. P. Lecture Notes.
16. Hinrichs, G. Elements of Chemistry and Mineralogy.
17. Hinrichs, G. Principles of Chemistry.
18. Hooker, W. First Book in Chemistry.
19. Johnston, H. Elements of Chemistry.
20. Johnston, H. Manual of Chemistry: on Basis of E. Turner's Elements.
21. Jones, F. The Owens College Junior Course of Practical Chemistry, with Preface by Professor Roscoe.
22. Miller, W. A. Introduction to the Study of Inorganic Chemistry.
23. Mott, H. A., Jr. Chemist's Manual.
24. Naquet, A. Principles de Chimie.
25. Norton, S. S. Elements of Chemistry.
26. Porter, H. A. First Book of Chemistry and Allied Sciences.
27. Roscoe, H. W. Lessons in Elementary Chemistry, Inorganic and Organic.
28. Roscoe, H. E. Primer of Chemistry.
29. Silliman, B., Jr. First Principles of Chemistry.
30. Smith, G. Aids to the Study of Practical Chemistry.
31. Steele, J. D. Fourteen Weeks in Chemistry.
32. Stockhardt, J. A. The Principles of Chemistry.
33. Thorpe, T. E. Inorganic Chemistry. 2 vols.
34. Wells, D. A. Principles of Chemistry.
35. Wilson, G. Chemistry; revised and enlarged by Stevenson Macadam.
36. Youmans, E. L. Classbook of Chemistry.

III. Organic Chemistry

37. Armstrong, H. W. Introduction to the Study of Organic Chemistry.
38. Schorlemmer, C. Manual of the Chemistry of the Carbon Compounds.

39. Watts, W. M. Elements of Organic Chemistry.
40. Wheeler, C. G. Outlines of Modern Chemistry, Organic.
41. Wohler, F. Outlines of Organic Chemistry; edited by R. Fittig; translated by Ira Remsen.
42. Cooke, H. P., Jr. First Principles of Chemical Philosophy.
43. Remsen, I. Principles of Theoretical Chemistry.
44. Thorpe, T. E. Chemical Problems, with a Preface by Professor Roscoe.

V. Qualitative Analysis

45. Appleton, J. H. A Book of Reactions, for the Use of Students in the Chemical Laboratory of Brown Univ.
46. Appleton, J. H. A Short Course in Qualitative Chemical Analysis.
47. Bowman, J. E. Introduction to Practical Chemistry, Including Analysis.
48. Brown, J. C. Analytical Tables for Students of Practical Chemistry.
49. Clowes, F. Elementary Treatise on Practical Chemistry and Qualitative Inorganic Analysis.
50. Crafts, J. M. A Short Course in Qualitative Analysis, with the new notation.
51. Douglas, S. H., and Prescott, A. B. Qualitative Chemical Analysis.
52. Eliot, C. W., and Storer, F. H. Compendious Manual of Qualitative Chemical Analysis; revised by W. R. Nichols.
53. Fresenius, C. R. Manual of Qualitative Analysis; translated into the new system and newly edited by S. W. Johnson.
54. Galloway, R. Manual of Qualitative Analysis.
55. Harris, E. P. Manual of Qualitative Analysis.
56. Hill, H. B. Lecture Notes on Qualitative Analysis.
57. Spencer, W. H. Elements of Qualitative Chemical Analysis.
58. Thorpe, T. E., and Muir, M. M. P. Qualitative Chemical Analysis.
59. Wiley, H. W. Tables for Qualitative Analysis.
60. Will, H. Tables for Qualitative Chemical Analysis; translated by Prof. C. F. Himes.

VI. Quantitative Analysis

61. Appleton, J. H. An Introduction to Quantitative Analysis.

62. Classen, A. Elementary Quantitative Analysis; translated, with additions, by E. F. Smith.
63. Crookes, W. Select Methods of Chemical Analysis.
64. Fresenius, C. R. System of Instruction in Quantitative Chemical Analysis; translated, with additions, by S. W. Johnson.
65. Thorpe, T. E. Quantitative Chemical Analysis.

VII. Blowpipe Analysis and Assaying

66. Bodemann, T., and Kerl, B. Treatise on the Assaying of Lead, Silver, Copper, Gold, and Mercury; translated by W. A. Goodyear.
67. Brush, G. J. Manual of Determinative Mineralogy, with introduction on Blowpipe Analysis.
68. Elderhorst. Manual of Qualitative Blowpipe Analysis and Determinative Mineralogy; edited by H. B. Nason and C. F. Chandler.
69. Plattner, C. F. Manual of Qualitative and Quantitative Analysis with the Blowpipe; revised and enlarged by T. Richter.
70. Ricketts, P. Dep. Notes on Assaying and Assay Schemes
71. Sutton, I. A systematic Handbook of Volumetric Analysis.
72. Otto I. J. On Detection of Poisons by Medico-Chemical Analysis.
73. Taylor, A. S. On Poisons in Relation to Medical Jurisprudence and Medicine.
74. Neubauer and Vogel. Guide to the Qualitative and Quantitative Analysis.

VIII. Medical and Physiological Chemistry

75. Attfield, J. Chemistry: General, Medical, and Pharmaceutical.
76. Bowman, J. E. Practical Handbook of Medical Chemistry; edited by C. L. Bloxam.
77. Gautier, E. J. A. Chimie Appliquee a la Physiologie, a la pathelogie, et a l'hygiene.
78. Odling, W. Course of Practical Chemistry, arranged for medical students.
79. Ralfe, C. H. Outlines of Physiological Chemistry including the Qualitative and Quantitative Analysis of Tissues, Fluids, and Excretory Products.
80. Wagner, R. Handbook of Chemical Technology; translated, and edited, with extensive additions, by William Crookes

IX. Agricultural Chemistry

81. Caldwell, G. C. *Agricultural Qualitative and Quantitative Chemical Analysis.*
82. Church, *Agricultural Analysis.*
83. Johnson S. W. *How Crops Feed.*
84. Johnson S. W. *How Crops Grow.*
85. Johnston, J. F. W. *Agricultural Chemistry.*
86. Wolff, E. *Anleitung Zur Chemischen Untersuchungen Landwirthschaftlichwichtiger Stoffe.*

The nature of chemical instruction after 1880. The period including the development of chemistry in the colleges and universities after 1880 was characterized by the further development of the laboratory. During this age there was an expression of the growing scientific spirit, and there was also the tendency to stress the study of laws and theories. The aim of these studies was that of disciplining the mind. The transition from the theoretical to the utilitarian was in process, and by the end of the nineteenth century the changes in subject matter and content indicate that this transition was practically complete.

When the disciplinary aim was given up, required work gave way to optional. In 1880 a great portion of the work in chemistry that was offered was prescribed and required, but as aims and methods changed, the transition from required to optional became practically complete by the end of the first decade in the twentieth century.[11]

Granting that Kansas is typical of the states as far as the development of college chemistry is concerned, one may use the amount of chemistry required in this state during the years 1880 to 1910 to typify the requirements over the United States. The following table shows that in nine Kansas colleges

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[11] Bruce W. Merwin, "Developments of the Curriculum in College Chemistry." Journal of Chemical Education, 12:542, November, 1935.

existing in 1880, seven required some work in chemistry. The chemistry that was required included nine courses which was seventy per cent of the total work listed in this field. This condition may be contrasted with the condition in 1910. At that time of twenty-three colleges, only six required work in chemistry. These six colleges again required nine courses, but now this included only seven per cent of the total offerings in this field.[12]

TABLE IV[13]

SHOWING THE AMOUNT OF CHEMISTRY REQUIRED IN KANSAS COLLEGES, 1880-1910

	1880	1890	1900	1910
Total Number of Colleges	9	18	22	23
Number of Colleges Requiring Work in Chemistry	7	16	14	6
Number of Courses in Chemistry Required	9	21	21	9
Percentages of Courses in Chemistry Required	70	68	30	7

Read table thus: In 1880 there were 9 colleges in Kansas. Of these nine, seven required nine courses in chemistry. This included seventy per cent of the total number of hours offered by these departments.

[12] *Loc. cit.*

[13] *Loc. cit.*

Table V shows the rapid growth of the offerings of the chemistry departments in the Kansas colleges from 1870 to 1930. The maximum of fourteen hours in 1870 was offered by Baker University. Six hundred and sixty-five hours was the total number of semester hours offered by the twenty-three colleges in 1910. In 1925, twenty colleges offered a total of one thousand and nine hours of chemistry. The following table indicates a rapid development in chemistry offerings during the last half century.

TABLE V[14]

SHOWING THE MAXIMUM AND MINIMUM NUMBER OF SEMESTER HOURS OFFERED IN THE CHEMISTRY DEPARTMENTS OF CERTAIN KANSAS COLLEGES

	1870	1910	1920	1925	1930
No. of Colleges	7	23	20	20	17
Maximum No. of Semester Hours	14	94	106	119	83
Median No. of Semester Hours	3	24	33	40	42
Total Number of Semester Hours	41	665	879	1009	

Read table thus: In 1870 there were seven colleges in Kansas whose chemistry departments' offerings included a maximum of 14 semester hours, a median of three semester hours, and a total of forty-one semester hours.

14 <u>Loc. cit.</u>

An interesting comparison may be made between the percentage of time given to the department of chemistry and other departments during the periods from 1870 to 1925. It may be noticed that table VI makes this comparison in terms of the percentage of the total hours offered by various departments in certain Kansas Colleges. Of course, the percentage of time allotted to the department of chemistry during the various periods varied a great extent. However, it is important to note that in each decade it ranked high. As may be seen from the table, in 1870, chemistry ranked fourth in the percentage of total semester hours offered. At this time chemistry was exceeded by Latin, Greek, and mathematics. This same relation did not exist in 1925, for at this time only one department listed more work than did the chemistry department.

TABLE VI (after Merwin)[15]

SHOWING THE DISTRIBUTION BY PERCENTAGES OF THE TOTAL SEMESTER HOURS OFFERED BY 33 DEPARTMENT IN CERTAIN KANSAS COLLEGES, 1870-1925

	1870	1890	1910	1925
Chemistry	5	4.4	7.8	6.7
Physics	5	5.2	3.8	4.1
Astronomy	2	1.8	.9	1
Geology	4	2.4	2.6	1.9

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15 *Ibid.*, p. 543.

TABLE VI (Continued)

	1870	1890	1910	1925
Agriculture		.3	1.7	2.2
Mathematics	14	11.1	7.2	5.4
Bacteriology			.8	1.4
Biology		.1	.7	1.1
Physiology	1	1.3	1.6	1.1
Botany	3	2	2.2	2.4
Zoology	3	2.7	3.7	2.6
Entomology	.1	.2	.5	.8
English Literature	2	6.1	5.9	5
English Composition	3	3.7	2.7	1.8
Journalism			.3	1.7
Public speaking	.3	1.2	2.2	2.4
History	3	3.4	5.4	4.9
Political Science	2	1.7	1.2	2.5
Economics	.4	1.4	2.2	3.1
Business Administration			.3	2
Sociology		.6	1.4	2.3
Manual Training and Engineering	1	1	3.9	3
Home Economics		.3	1.7	5.5
Education	4	2.1	5.3	7
Philosophy	4	4.5	3.2	1.7
Psychology	1	1.8	1.9	1.7
Art		.3	2.3	2
French	2	4.8	4.9	4.9
German	2	7.4	7.3	3.4
Spanish		.6	.8	4.2
Latin	15	11.5	6.6	4.8
Greek	15	11.9	6.8	2.9
Religious Education	1	2.1	3.8	3.5
Miscellaneous	3	2		

Read table thus: In 1870, five per cent of the total offerings of various Kansas colleges was chemistry. In 1890 this was four and four-tenths per cent. In 1910 it was seven and eight-tenths per cent, etc.

Certain major trends in the development of college chemistry may be traced by an examination of the following table which shows the percentage of individual chemistry courses offered by certain Kansas colleges during the period from 1870 to 1930. This table indicates that since 1910 or perhaps a little earlier, there has been a strong transition to the useful and practical. This is indicated by the large percentage of the colleges offering such courses as agricultural chemistry, physiological chemistry, household chemistry, and industrial chemistry.

TABLE VII[16]

SHOWING THE PERCENTAGE DISTRIBUTION OF COURSES OFFERED IN CHEMISTRY BY CERTAIN KANSAS COLLEGES, 1870-1930

Number of Colleges Year	6 1870	18 1890	23 1910	20 1920	17 1930
General Chemistry	83	83	70	75	94
Inorganic Chemistry	17	17	43	60	65
Qualitative	0	11	74	85	94
Organic Chemistry	0	17	74	100	100
Quatittative	0	17	52	85	100
Advanced Quantitative	0	6	9	20	71
Physical Chemistry	0	6	17	45	82
History of Chemistry	0	6	22	20	41
Industrial Chemistry	0	0	13	35	35
Glass Blowing	0	0	5	0	6
Teachers' Course	0	6	0	0	29
Philosophy of Chemistry	0	0	0	0	0
Water Analysis	0	0	0	0	24
Assaying	0	6	17	20	24

16 *Loc. cit.*

TABLE VII (Continued)

Number of Colleges	6	18	23	20	17
Year	1870	1890	1910	1920	1930
Agriculture Chemistry	0	6	13	25	29
Physiological Chemistry	0	6	22	20	24
Household Chemistry	0	11	22	45	29
Experimental Chemistry	0	0	0	5	6
Photography	0	6	9	5	0
Fuel Analysis	0	0	0	0	41
Food Analysis	0	0	0	0	53
Oil Analysis	0	0	0	0	24
Metallurgy	0	0	0	0	35
Advanced Organic	0	0	0	0	71
Organic Preparations	0	0	0	0	65
Organic Problems	0	0	0	0	29
Advanced Physical Chemistry	0	0	0	0	24
Survey of Chemistry	0	0	0	0	6
Chemistry of Rare Elements	0	0	0	0	12
Chemistry of Cement	0	0	0	0	6
Sanitary Chemistry	0	0	0	0	12
Inorganic Preparations	0	0	0	0	18
Chemistry of Explosives	0	0	0	0	6
Chemistry Problems	0	0	0	0	12

Read table thus: In 1870, General Chemistry comprised eighty-three per cent of the total offerings in chemistry; in 1890, this was still eight-three per cent; in 1910, it was seventy per cent; in 1920, this was seventy-five per cent; in 1930, this was ninety-four per cent.

Since the beginning of the twentieth century there have been several factors that have operated in modifying instruction in chemistry. Important trends in educational psychology, which have discredited the theories of general transfer and discipline, were responsible in a large part for the changed offerings of the colleges and universities. The beginning of modern educational research started a movement which required that the educational institutions justify their curricula on the basis of valid scientific investigation and proof.[17] The rise of modern educational research probably has had more to do with determining curriculum content than any other influence of this period.

Until about twenty-five years ago opinion was the only means for determining the content of courses. At the present time science has been directed against science in the attempt to determine the most efficient methods of teaching, the content of courses, and the validity of certain aims and objectives. Before 1910 the students were being urged and required to take courses for various reasons, for the practical, for strictly disciplinarian, and for the broadly cultural.[18] Later, as many experiments of the transfer of training invalidated many of the former objectives of the chemistry course, college teachers began to wonder if they had not gone too far in recommending chemistry to everyone for the various reasons given previously. As a result, the recommendation of chemistry to everyone began to fall off. A period of critical study of

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17 Guy Montrose Whipple, editor, "A Program of Teaching Science." Thirty-first Yearbook of the National Society for the Study of Education, Part I, Public School Publishing Company, Bloomington, Illinois., 1932. p. 109.

18 Ibid., p. 308.

the aims, methods, and content of chemistry teaching followed. It is very probable that no other part of the school curriculum has been subjected to such critical scientific study as has the sciences. The reasons for this condition are several in number. As has been mentioned previously, the science teachers have been asking themselves what is wrong. Then too, the sciences lend themselves more readily to scientific study of methods and subject matter than do other subjects.[19]

The reasons for the extensive chemistry curriculum in the colleges and universities to-day can be best understood if at the same time it is recognized that there are three types of functions in college education. These three types of functions are cultural, teacher training, and highly specialized or technical.[20] As a result of the attempt to fulfill these three functions, all types of courses were developed. These ranged from the most diversified to the very highly specialized and technical courses. Thus it is that the colleges and universities have extended their curricula to the extent that it is found to-day.

In an article on the extent of chemical education, Victor H. Noll paints a picture of the conditions which exist

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[19] *Ibid.*, pp. 308-09.

[20] *Ibid.*, p. 310.

to-day in chemistry instruction.[21] He said that in 1928 there were approximately eight-hundred degree granting institutions in this country, exclusive of separate junior colleges and teacher training institutions. In these eight-hundred institutions were enrolled eight-hundred thousand pupils and sixty-thousand instructors were employed.

Noll said that of the eight-hundred thousand students no one knows how many are taking chemistry; neither do they know how many of the sixty-thousand professors are occupied with chemistry. However this number can be approximated. By getting the per cent of students taking chemistry in various states, Noll approximates an average for the whole country. This average he finds to be around twenty per cent. Thus twenty per cent of the eight-hundred thousand or one-hundred sixty-thousand students in the United States take chemistry.[22]

The present decade has witnessed a growth of enrollment in engineering curriculum. This may for illustrative purposes be compared with the growth of enrollment in the various other engineering curricula. It may be noticed from Table VIII that during the period from 1925 to 1931, the enrollment in chemical engineering has practically doubled it

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21 Victor H. Noll, "The Extent of Chemical Education." Journal of Chemical Education, 12:475-81, Oct., 1935.

22 Ibid., p. 479.

self. The data in the following table are based on 145 engineering schools and colleges in all parts of the United States.

TABLE VIII[23]

SHOWING THE TOTAL ENROLIMENT IN VARIOUS ENGINEERING COURSES, 1925-1931

Year	Elec.	Civil	Mech.	Chem.	Arch.	Mining and Metallurgical
1925-26	18,161	12,502	10,642	4,897	2,529	2,070
1927-28	20,210	14,073	11,273	5,987	3,256	2,143
1930-31	19,992	14,534	15,684	9,667	2,940	2,944

Read table thus: During 1925-26, there were 18,161 electrical engineering students, 12,502 civil engineering students, 10,642 mechanical engineering students, 4,897 chemical engineering students, 2,529 archetical engineering students, and 2,070 mining and metallurgical engineering students.

Another phase of chemical education which holds a very important place in the colleges and universities of to-day is graduate work or graduate research. Table IX indicates that there is a constant and uninterrupted growth in graduate enrollment from 1924 to 1932 inclusive. It is worthy of note that the total enrollment in graduate courses in 1932 was almost twice that for 1924. The only decline is found in 1933.

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23 *Loc. cit.*

It is no doubt true that this decline was due in the most part to the economic situation during that year.

TABLE IX[24]

SHOWING THE NUMBER OF STUDENTS ENGAGED IN GRADUATE RESEARCH IN CHEMISTRY BY YEARS, 1924-1933

Year	No. of Students	Year	No. of Students
1925	1763	1930	2795
1926	1882	1931	3261
1927	1934	1932	3348
1928	2081	1933	3023
1929	2498	1934	3126

Read table thus: In 1925 there were 1,763 graduate students, in 1926 there were 1882, etc.

The fields of graduate research in chemistry may be classified in the order of the largest numbers of pupils working in them. This classification would place organic first, general and physical second, chemical engineering third, physiological fourth, analytical fifth, inorganic sixth, agricultural seventh, and colloid eighth.[25]

The latest figures available for the total number of graduate research students in all colleges and universities

[24] *Loc. cit.*

[25] *Loc. cit.*

are for the year 1930. At this time there were 47,255 persons engaged in research work.[26] According to the figures presented previously there were 2795 research students in chemistry in 1930. This represents 5.9 per cent of the total number of graduate students.

Noll in a very rough approximation suggested that there are about 2500 teachers of chemistry, 3000 teachers of biological sciences, and 1300 teachers of physics in the American colleges and universities. From these figures, Noll estimates the percentage of college and university instructors in certain sciences. He suggested that of the total number of professors in the colleges and universities of this country about three and four-tenths per cent are biology instructors, and eight-tenths per cent are chemistry instructors, and one and five-tenths per cent are physics instructors.[27]

Summary. The major objectives of this study are:

(1) To present a chronological history of chemistry as a subject in the colleges and universities of the United States from its beginnings to the present time.

(2) To find historical reasons for the presence of many conditions in college chemistry teaching of to-day.

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26 Loc. cit.

27 Loc. cit.

This survey is limited in scope to the extent that only the aims, nature, methods of instruction, subject matter content, and extent of chemical education are studied.

The chronological order has been utilized in presenting the data of this study. Tables presenting pertinent facts have been used to illustrate certain movements which have proven important, or which will in time be recognized as important.

In summing up the results of this study it may be said that:

(1) Science in colonial times hardly existed.

(2) It was not until the eighteenth century that the researches of Priestly, Black, Lavoisier, and Cavendish demonstrated the possibilities of chemistry to the world; and thus laid the foundation for modern chemistry.

(3) There are some evidences of college science teaching in the eighteenth century and a little even in the seventeenth.

(4) Astronomy and the nature of plants are found in the course of study at Harvard in 1642.

(5) By 1690, "natural philosophy" was offered by Harvard.

(6) The only chemistry taught in the early colleges was taught as an unimportant branch of natural philosophy of natural history.

(7) The early natural philosophy courses usually con-

sisted of lectures with a few spectacular demonstrations by the teacher.

(8) It was in the early medical schools that chemistry was first introduced as a seperate subject of instruction.

(9) Before 1765, there was not a school of medicine in this country.

(10) In 1765, the first medical school was established in Philadelphia.

(11) The first professorship of chemistry was introduced in New York in 1767.

(12) In 1769, a chair of chemistry was established in the medical school of the College of Philadelphia.

(13) In 1791, Major William Erving bequeathed one thousand pounds to endow a chair in Harvard called the Erving Professorship of Chemistry.

(14) During the eighteenth century, the chemistry courses usually consisted of two or three lectures with a few demonstrations.

(15) There was no laboratory work done by students before the middle of the nineteenth century.

(16) The Rensselaer Institute and the Gardiner Lyceum, were the first institutions to encourage student laboratory work.

(17) The influence of the scientific schools on the introduction of laboratory work into the colleges was present

about 1845.

(18) The first laboratory instruction in chemistry, with the exception of Rensselear, was offered to students at Yale in 1842.

(19) It was not until about 1870 that the laboratory method of instruction had a general acceptance by the colleges.

(20) The theory of mental discipline held sway during the last half of the nineteenth century.

(21) During this time, the justification for the teaching of chemistry was based on its value as a disciplinary subject.

(22) About 1880, a great portion of the chemistry courses offered were required.

(23) In 1880, most of chemistry courses were not to be taken until the junior or senior years.

(24) Great advancements in all phases of college chemistry teaching have been made the last fifty years.

Conclusions.

(1) The expansion of the chemistry curriculum is merely one phase in the growth of the science of chemistry.

(2) The chemical science is growing by leaps and bounds; and this development is centered in the colleges and universities of this country as well as the institutions of other countries. Therefore, it is to be expected that as

long as the science of chemistry grows so rapidly, the curriculum in chemistry must needs develop and expand at a similar rate. The chemistry curricula have been expanding rapidly since 1870. This is indicated by:

a. The addition of numerous and varied courses to the curriculum. (Table VII, p. 121.)

b. The growth in total number of semester hours offered in chemistry departments. (Table VI, p. 119.)

c. The great amount of chemical research which is carried on in college laboratories.

(3) The transition from required to optional work in chemistry was practically complete by 1910. This is shown by:

a. The changed aims and methods of instruction. (p. 116.)

b. The amount of chemistry required in 1880 as compared with that required in 1910. (Table IV, p. 117.)

(4) The future chemistry curriculum will expand along three lines; first by the introduction of technical courses for those who wish to become research chemists, second, by the addition of courses designed to prepare people for allied fields, such as medicine and engineering, and third, by the introduction of courses of a general nature for those who wish a knowledge of this subject for the purposes of avocational interests. This is indicated by:

a. The recent addition of courses in technical chemistry. (Table VII, p. 121.)

b. The growth of the number of chemical engineering students. (Table VIII, p. 126.)

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