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Thesis

THE STATUS OF THE SUBJECT OF CHEMISTRY IN THE SECONDARY SCHOOLS OF CONNECTICUT

Submitted by

Edward Sholto Wolcott

(S.B., Connecticut State College, 1928)

In partial fulfillment of requirements for the degree

of Master of Education

1933

Thesis Readers: Jesse B. Davis, Professor of Education.
: Edward J. Eaton, Professor of Education.

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THE STATUS OF THE SUBJECT OF CHEMISTRY IN THE SECONDARY SCHOOLS OF CONNECTICUT

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I INTRODUCTION

With the desire of determining the present status of the subject of chemistry in the secondary schools of Connecticut, the writing of this thesis has been undertaken. In order to secure the original information for this report a questionnaire, together with a brief letter of introduction and return postage, was sent to the heads of chemistry departments in 91 secondary schools of which 84 were classed by the Connecticut State Board of Education as public high schools and 7 as endowed or incorporated academies approved as high schools. Sixty-five returns, or 71.4% of those sent out, were made. Sixty-four schools are included in this study as no chemistry is offered in the Commercial High School in New Haven, Connecticut, which was among those reporting.

The questionnaire was composed of 46 items covering a wide range of information including organization, equipment and common practices to be found in the chemistry department of the average secondary school. While every school in the state is not included in this report, the writer believes that the results to be found in the body of this paper represent the general status of the subject of chemistry in the secondary schools of Connecticut.

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Various syllabi, magazine articles, and bulletins relating to high school chemistry have been read, and worthwhile suggestions have been included in this report. It is hoped that whatever may be of value in this paper to any particular locality will be adopted in the interest of improving instruction in high school chemistry.

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II HISTORY OF HIGH SCHOOL CHEMISTRY

The origin and development of chemistry in the high school will be given first with respect to the early schools in this country, and later will be followed by an account of the beginnings of the subject in the secondary schools of Connecticut.

A high school chemistry course was first offered in the English Classical School, later called the English High School of Boston, in 1821.(1) It was introduced primarily because of the demand on the school for instruction in subjects of a more practical nature than those usually offered. However this chemistry as taught can hardly be compared with that to be found in the average course today - certainly not in content even though some of those archaic methods may have been handed on and still persist. There was practically no laboratory work. Most of the experiments performed were conducted by the instructor as lecture demonstrations. It was purely a book subject with pupils being required to absorb the printed page as such and reproduce its contents verbatim.

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(1) "The Teaching of High School Chemistry" - J. O. Frank
Chapter 2 - P. 6

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By the middle of the nineteenth century chemistry was increasing in importance and was finding a place in the curriculum of more and more high schools. This was taking place even in the face of many prejudices and handicaps, real and assumed. Chemicals and apparatus were expensive and difficult to procure, but chemistry continued to make great advancement especially in the new and more progressive schools. Still the "swallow-the-text" idea prevailed and was helped by higher institutions of learning in this respect. The Committee of Ten (1) sought to establish a uniform requirement for entrance to college and demanded specially trained teachers. This brought into the schools men and women who were inclined to teach from the college point of view. The requirements of the College Entrance Board have always had an important influence on the high school chemistry course. The secondary school that wished to enter its graduates in the leading colleges of the day was forced to meet the demands of this standardizing body. The period of college domination of the high school began about 1870 and has not yet disappeared.

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A few comments on the influence of the college over high school sciences are significant. Professor George H. Mead, of the University of Chicago, wrote that the "university influence upon the study of science has not been fortunate"[1], resulting in the isolation of science from the experience of the child, and in restricting the extent of the field of high school science. Professor R. A. Millikan, also of the University of Chicago, in discussing Professor Mead's paper, said, "This influence has been unfortunate because it has tended to force university methods and university material into a sphere of education to which they are wholly unsuited". President David S. Jordan, of Stanford University, wrote, "To demand thoroughness of secondary instruction and to enforce this demand in any practical way is the duty of the college, but the question of what the high schools shall teach is a question for those schools to decide for themselves"[2].

Under the influence of students returning from German universities after 1850 the importance of laboratory

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(2) Popular Science Monthly - July, 1908

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(1) School Review - April, 1908

(2) Popular Science Monthly - July, 1908

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While the period of college domination had a beneficial result on the teaching of chemistry in the beginning by setting up standards and requirements, it worked to the ultimate disadvantage of the high school until about 1910. Since then conditions have changed and we find new aims, methods and subject matter embodied in most of the high school chemistry courses of today. The trend has been toward practical chemistry and a number of text books, which were written with modern educational principles in mind, have appeared on the market.

The growth of chemistry in the secondary schools of Connecticut closely parallels the general development mentioned above. The first mention of chemistry as a separate subject in any school in Connecticut appeared in the curriculum of Emerson's Female Academy in Wethersfield, in 1826.(1) In 1833 the curriculum of the Ellington School included chemistry. The first permanent high school in the state was in Middletown in 1840(2) and chemistry is found in the list of subjects of instruc-

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(1) "The Rise of the Public High School in Connecticut" Silas Hertzler - Warwick & York - Baltimore - P. 11

(2) Ibid - P. 50

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(1) "The Rise of the Public High School in Connecticut" Silas Bertolet - Berwick & York - Baltimore - P. 11

(2) Ibid - P. 90

tion. Later we find chemistry being taught in the Hartford Public High School in 1848, in the New Britain High School in 1853, the Norwalk High School in 1855, the Waterbury High School in 1858, and the New Haven High School in 1863. Since then the high schools in Connecticut have grown in number until at the present time there are ninety-one recognized secondary schools in the state, practically every one offering instruction in one or more courses in chemistry.

There seems to be no uniformity as to the grade chemistry should be taught in these early schools - some offering the subject throughout the senior year, others during the middle class of a three year school, and others only during certain terms of middle or senior years. Two early text books used were "Johnston's" in the Middletown High School in 1850, and "Gray's" in the Hartford Public High School in 1851.(1)

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III Aims and Objectives

As one looks over the various syllabi for high school chemistry, it is evident that chemistry is supposed to acquaint the pupil with his environment. This is as it should be,but unfortunately is true in only a minority of the better organized courses. To many teachers chemistry is just another subject to be taught and to many pupils to be passed at examination time. It is certainly of little real value to merely expose boys and girls to many apparently uninteresting facts of chemistry. Discovery and invention within the last fifty years have brought tremendous changes in the daily life of the average person. And so in teaching chemistry it seems evident that we should teach pupils so that they may be better able to appreciate chemical principles with which they come in contact and properly apply these principles to their everyday life.

In 1920, Bulletin 26, Department of Interior, Bureau of Education, appeared entitled "Reorganization of Science in Secondary Schools". While probably in need of revision to meet changes in conditions since 1920, this bulletin nevertheless contains a great deal of valuable material relating to the aims and objectives of high

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school chemistry and should be familiar to every teacher. It might be well to include here a list of objectives for teaching chemistry, similar to those to be found in the above bulletin.

1. Instruction in minimum essentials which make up main body of a high school chemistry course.
2. Appreciation of the value of chemistry to daily life including health, industry and recreation.
3. Development of proper manipulative skills, habits of neatness, interests and attitudes.
4. Training in ability to apply scientific methods to problems of everyday life.
5. Exploration and guidance in reference to further work in chemistry or applied science.

In teaching chemistry it must be recognized that important emphasis should be placed on carrying out the above objectives. Many high school pupils who take chemistry have no intention of using it as a foundation for their life occupation. This is an important group and the one whose needs must receive careful consideration. The second group will probably use their high school course for further study in chemistry, medicine, pharmacy, etc. Regarding the former group habits which

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will be of direct value in life, and not habits limited to the application of chemistry alone, should be the chief objective. In chemistry the pupil should obtain a chemical viewpoint and recognize that substances can now be made according to prescription, in amounts needed and with desired properties. Examples of such achievements are the synthetic production of explosives and fertilizers, the artificial production of silks, dyes, and the utilization of many by-products. In addition the pupil should learn to reason from observations and be able to apply scientific laws to explain and modify factors in his environment.

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IV ORGANIZATION OF DEPARTMENT

A. Personnel

From sixty-four returns of a questionnaire sent to ninety secondary schools of the state of Connecticut, the writer has found wide divergencies in administration and organization of chemistry courses. A total of eighty-nine teachers were reported teaching chemistry in the sixty-four high schools to 5,420 pupils or 10.37% of the school enrollment. In 1914-15 there was reported in the public schools of the United States a total of 86,031 pupils taking chemistry or 7.38% of the school enrollment.(1) The accompanying table will indicate the great variety of subjects taught or duties which are filled by chemistry teachers. The range is from a school where four teachers give full time to chemistry to one where chemistry is offered every other year and the teacher is assigned four other subjects.

The average number of pupils per teacher was found to be 60.9 with a range from one school where four teachers give part time to 107 pupils to three schools where one teacher gives full time to 150 pupils in chemistry. With reference to organization of the department, forty-

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TABLE I. Subjects Taught or Duties Assumed by Chemistry Teachers as Reported by 70% of High Schools in Connecticut

Subject	Number of Teachers
Chemistry (alone)	52
Physics	30
General Science	26
Biology	23
Mathematics	13
American History	4
Mechanical Drawing	3
Physical Education & Hygiene	3
Physiology	2
Principal	1
Vice-principal	1
Anatomy	1
Astronomy	1
Economics	1
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three high schools report having one head for all sciences, sixteen no organization, three two heads (one for biological and one for physical sciences), one reports having a head for each branch of science, and one has subject committee organization.

B. Types of courses offered

That there are few differentiated chemistry courses in high schools of Connecticut is shown by the fact that 53, or 82.8% of those reporting, offer only one general course in chemistry. Six distinguish between courses in college preparatory and in general chemistry, four maintain classes in household chemistry, two in industrial, and one offers a course for nurses, and for normal school preparation. Even though few schools include more than one chemistry course in their programs of study, many of them make a special effort to adapt their courses to the needs of the particular locality.

C. Place of chemistry in science courses

In answer to the question "In what year is chemistry offered regularly?" 49 high schools, or 76.6% of those answering, report giving chemistry in the senior year and 15 schools, or 23.4% in the junior year. For administrative reasons we find both juniors and seniors taking

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C. Place of chemistry in science courses

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chemistry at the same time. Forty four high schools allow pupils above or below the regular grade to take chemistry, while 20 report they do not allow such a practice. In the small high school it is necessary to alternate chemistry and physics courses in successive years. In Connecticut 20 high schools alternate chemistry and physics while 44 offer chemistry and physics every year. Regarding the sequence of chemistry and physics in the schools where both subjects are taught every year, some writers claim that physics should precede chemistry due to the fact that physics has many more life contacts than has chemistry.(1) In addition it is claimed greater abstract thinking is required in chemistry than in physics making it advisable to teach chemistry after physics.

The writer is of the opinion that very good reasons could be advanced for teaching chemistry in the 11th grade and physics in the 12th grade. Of the two subjects it must be recognized that physics is the more technical, involves more difficult mathematical calculations, and so would be appreciated more by the older pupils. This sequence is commonly followed by secondary schools in the United States outside of New England.

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(1) Frank, J. O. "The Teaching of High School Chemistry" J. O. Frank & Sons, Oshkosh, Wis. 1932 - p.60

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The usual order of the courses covering the four years of high school work in the natural sciences in Connecticut appears to be as follows:

First year - General Science

Second " - Biology

Third " - Physics

Fourth " - Chemistry

As an indication of departure from tradition we find some educators advocating a program of science for each grade in the senior high school made up of topics from all the old divisions now taught as subjects.(1) Such a program could be worked out based on principles characteristic of the general science course of today.

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V. EQUIPMENT

A. Permanent

The classroom, often improperly called a lecture-room either because it is too frequently used as a lecture-room or because it has inherited the name from college practice, should be a room well lighted and large enough to insure proper ventilation for the greatest number of pupils it is to accommodate. In the United States not less than 125 cubic feet of space per pupil is recommended,(1) while in England it is suggested that 14 square feet of floor space per pupil be provided.(2) A demonstration table 8 to 12 feet long with gas and water cocks, sink and ample drawer and cupboard accommodation is necessary. Direct and alternating electricity will be found in the better equipped laboratories. It is very important that the demonstration table be completely stocked with all necessary reagents and equipment, and this material should remain here and not be a part of the general laboratory apparatus, missing when needed.

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(1) Frank, J. O. "The Teaching of High School Chemistry" J. O. Frank & Sons, Oshkosh, Wis. 1932 - p. 199
(2) Westaway, F. W. "Science Teaching" Blackie & Son Ltd. - London - p. 409

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(1) Frank, J. O. "The Teaching of High School Chemistry" J. O. Frank & Sons, Oshkosh, Wis. 1932 - p. 189
(2) Westaway, F. W. "Science Teaching" Blackie & Son Ltd. - London - p. 409

The demonstration table should be so situated that it is clearly visible to all pupils in the room. In a small room this may be accomplished by having the table on a low platform, or in a large room rising tiers of seats can be used. Four inch risers are sufficient and care should be taken not to have the back row of pupils too high above the ordinary floor level, causing them to breathe the poor and improper air found in the upper part of the room. There should be sufficient blackboard space behind the demonstration table, and a hood should be provided in the passageway between the classroom and adjoining preparation or store room. Facilities for visual instruction should be provided including shades that will darken the room satisfactorily. An estimated cost of equipment for a classroom is shown in the following:(1)

	Best quality	Medium quality
1 Demonstration table	$250.00	$136.00
36 Tablet arm chairs	234.00	127.00
2 Chairs, plain	5.20	4.30
1 Roller screen (8' x 8')	20.00	15.00
1 Projector, opaque and transparent projection	250.00	129.00
1 Cabinet for demonstration materials	175.00	127.00
1 Projector for 16 m.m. film	200.00	150.00
Totals	1134.20	688.30

(1) Frank, J. O. "The Teaching of High School Chemistry" p.211

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(1) Frank, J. O. "The Teaching of High School Chemistry" p.221

As to the question of conducting laboratory and recitation in the same room, there is an increasing tendency to use the room for the double purpose. Present economic conditions are having a great influence on doing away with much extravagance and needless waste of space and money in our schools. Thirty seven or 57.8% of schools in Connecticut report conducting laboratory and recitation in the same room. In line with conservation of space and making more efficient use of all parts of the school building there seems no good reason why the laboratory and classroom should not be used for a home room. Thirty one schools report using the classroom for a home room while 33 do not. Increased enrollment has caused a number of these schools, within recent years, to use these so called "special rooms" for home room purposes. If the classroom is separate from the laboratory, the seating capacity should be double or triple that of the laboratory so that two or three laboratory sections may be combined for special demonstrations.(1)

B. Laboratory

For the one science teacher schools a single laboratory, properly equipped is sufficient and will do away

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(1) Bulletin, 1927, No. 22 - Dept. of Interior, Bureau of Education, "Laboratory Layouts For The High School Sciences" - p. 3

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with the waste in laboratory space especially evident in the smaller schools. There are between 80 and 85 per cent of all high schools in the United States which have but one full time teacher for all sciences.[1] With the lengthened period of sixty minutes there should be no difficulty in scheduling laboratory work and one room used throughout the school day should be adequate for all but the very large high schools.

Opinion varies with respect to the location of the chemistry laboratory. The deciding factors are the efficiency of the ventilating system and the cost of plumbing and building materials. If good ventilation can be secured, the most satisfactory place in the average building for a chemical laboratory is on the ground floor, provided there is an adequate amount of light, because of extensive piping for water and gas, and to facilitate disposal of waste. Neither pupils nor teacher should have to face windows. Many of our modern two and one-half story buildings are constructed so that the ground floor is well lighted. If there is any doubt about the ventilating system, the laboratory should be on the top floor even at the expense of the added cost for plumbing.

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(1) Bulletin 1927, No. 22 - Dept. of Interior, Bureau of Education, "Laboratory Layouts for the High School Sciences" p. 2

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(1) Bulletin 1927, No. 22 - Dept. of Interior, Bureau of Education. "Laboratory Layouts for the High School Sciences" p. 2

Vents should be located at the top of the room, and the fume hood, with direct draft open like a chimney, is the most satisfactory and economical.

The size of the laboratory is determined by the number of pupils to be accommodated at any one time. Most authorities recommend at least 25 square feet of floor space per pupil.(1) If the laboratory work is well organized and administered there is no reason why one teacher cannot take care of from 24 to 30 pupils at one time. The survey of chemistry laboratories in Connecticut range from those accommodating 36 pupils to one fitted for 6 pupils with the greatest number reporting 24 as the maximum capacity.

TABLE II Size of Laboratory (as reported by High Schools in Connecticut)

Number of Pupils	Number of Schools	Number of Pupils	Number of Schools
36	3	20	9
35	1	18	1
34	1	16	10
32	2	15	1
30	3	14	1
28	3	12	3
26	1	10	1
25	2	8	3
24	18	6	1

Mode 24
Range 36-6

(1) Bulletin, 1927, No. 22 - Dept. of Interior, Bureau of Education, "Laboratory Layouts for the High School Sciences" - p. 8

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Thirty-eight or 59.4% of the high schools answering the questionnaire report having the laboratory seated for recitation, while twenty-six schools do not have such equipment. With the laboratory seated for recitation an increase from 25 to 35 per cent more floor space is required,[1] but this is offset by the fact that the one room serves the purpose of both laboratory and recitation room.

Forty-eight of the 64 high schools in Connecticut, included in this study, do not use the laboratory for a home room, while 16 do make such a practice, some due to the overcrowded conditions in their schools at the present time.

The type of laboratory table varies with different schools depending upon the size of classes and the number of pupils to be accommodated. This furniture can be obtained from factories which specialize in laboratory furniture or designed and built by some local contractor or cabinet specialist. Considering the hard usage to which such furniture must be subjected, a better and more permanent product will be obtained from the concern which employs laboratory experts. While not necessary, it will generally be found more economical over a period of years to purchase a good grade of hardware, plumbing fixtures,

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and such permanent equipment, thus keeping the cost of maintenance and upkeep as low as possible.

For the small high school the Lincoln type desk is often recommended. This type has certain advantages as well as certain disadvantages. Among the former are:

1. Economizes space, combining laboratory and classroom
2. Facilitates supervision of pupil experiments
3. Allows for economy of supplies and apparatus.

Among the latter are:

1. Plumbing is hidden making repair work difficult
2. Water faucets, being exposed, are a great temptation for pupils to twist and break them
3. All pupils cannot see demonstration work

In answer to the question on the type of laboratory the following results were obtained from the 64 high schools in Connecticut:

Long table with pupils on one side ----------	1
" " " " " two sides ----------	41
Square table for two pupils ----------	0
" " " four " ----------	17
The "Lincoln desk" type for individual work --	5

The cost of chemistry laboratory equipment will vary as much or more than any other topic which could be in-

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The cost of chemistry laboratory equipment will vary as much or more than any other topic which could be in-

vestigated. Some of our high schools can get along on a mere minimum of equipment and often give a better training in chemistry than will be found in some of the schools with equipment more elaborate than that possessed by many colleges. A great deal depends upon the ingenuity and resourcefulness of a teacher who decides to equip a laboratory even without sufficient funds. A recent study of 212 high schools in Michigan indicates that the average value of laboratory equipment was $31.75 per pupil taking chemistry and in 1928 Jensen and Glenn found the average value of chemical laboratory equipment to be $332.00.(1)

The following list is included for the purpose of showing an estimated cost of laboratory equipment:(2)

	Best Quality	Medium Quality
1 Apparatus Case	$100.00	$90.00
1 Key Cabinet (100 keys)	25,00	18.00
1 Wall Combustion Table	80.00	50.00
2 Cases of shelves, reagents	300.00	100.00
1 Exhibition Case	75.00	54.00
1 Quantitative analysis desk (12 students)	300.00	100.00
4 Students' Chemistry desks (32 students)	1,200.00	472.00
1 Balance shelf	60.00	29.50
4 Fume hoods	200.00	150.00
1 Book case	30.00	25.00
	$2,370.00	$1,088.50

(1) "The Teaching of High School Chemistry" J.O.Frank p.208-9
(2) Ibid p. 211

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Only a total of 29.7% of the high schools in Connecticut answering the questionnaire were able to give any approximate cost of equipment. Some of the higher estimates include both physics and chemistry costs. The average is not reliable because it is not based on a representative selection of high schools - the newer and more expensively equipped schools making most of the returns.

The table on the following page represents the status of the cost of laboratory equipment in 19 high schools in Connecticut.

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The table on the following page represents the status of the cost of laboratory equipment in 19 high schools in Connecticut.

TABLE III Cost of Laboratory Equipment in High Schools in Connecticut

Number of Schools	Cost	Number of Chem. Pupils
1	$ 200	30
1	250	40
1	400	28
1	500	32
1	500	21
1	1,000	43
1	1,000	75
1	1,000	75
1	1,200	31
1	1,400	14
1	1,900	107
1	2,000	16
1	4,000	51
1	4,000	116
1	4,000	151
1	5,000	48
1	5,000	50
1	6,000	107
1	10,000	86
19	$ 49,350	1,121

Average per school $2,597.37

Average per pupil $44.02

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Average per school $2,597.37

Average per pupil $44.02

C. Storage Space in Laboratory

Another very important part of the laboratory equipment is sufficient cabinet space for the storage of apparatus and supplies. European schools far surpass us in providing such facilities. Plenty of drawers and cupboards are necessary for keeping the laboratory well arranged and a good motto for the teacher and pupils to follow is "A place for everything and everything in its place." Too often do we find shelves extending up to the ceiling with the result that those above the reach of the average person are frequently not used at all or if they are, become what might be called "dead storage" space. Forty-two schools in Connecticut report having sufficient storage cabinets in the laboratory, while 22 indicate a shortage in this equipment.

A preparation-storage room should be the part of every well equipped chemistry department. The ideal place for this room would be adjacent to the classroom and should be provided with a passageway so that supplies and equipment may be passed directly to the main room. Here may be stored most of the apparatus and main stock of chemicals. It should be well lighted, provided with

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gas, running water and a sink, and capable of being darkened when so desired. The room makes an ideal place for preparing solutions and getting out reagents needed for experiments. Twenty-five schools report having a chemical preparation room, while 39 do not. It was also found that 45 or 70.3% of the high schools have sufficient storage room for their chemicals and supplies, while 19 or 29.7% do not have sufficient space.

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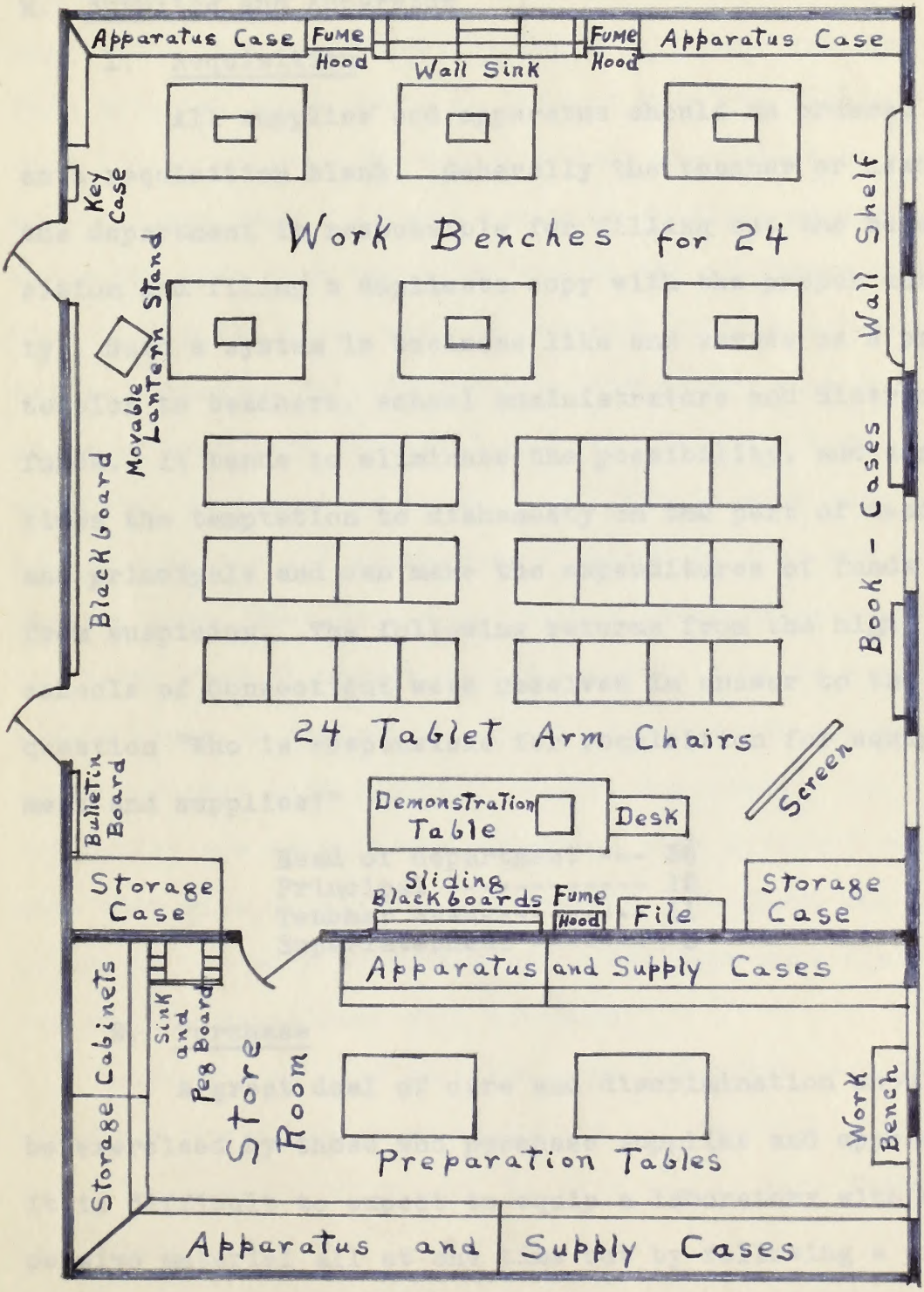
D. IDEAL LAYOUT FOR CHEMISTRY DEPARTMENT



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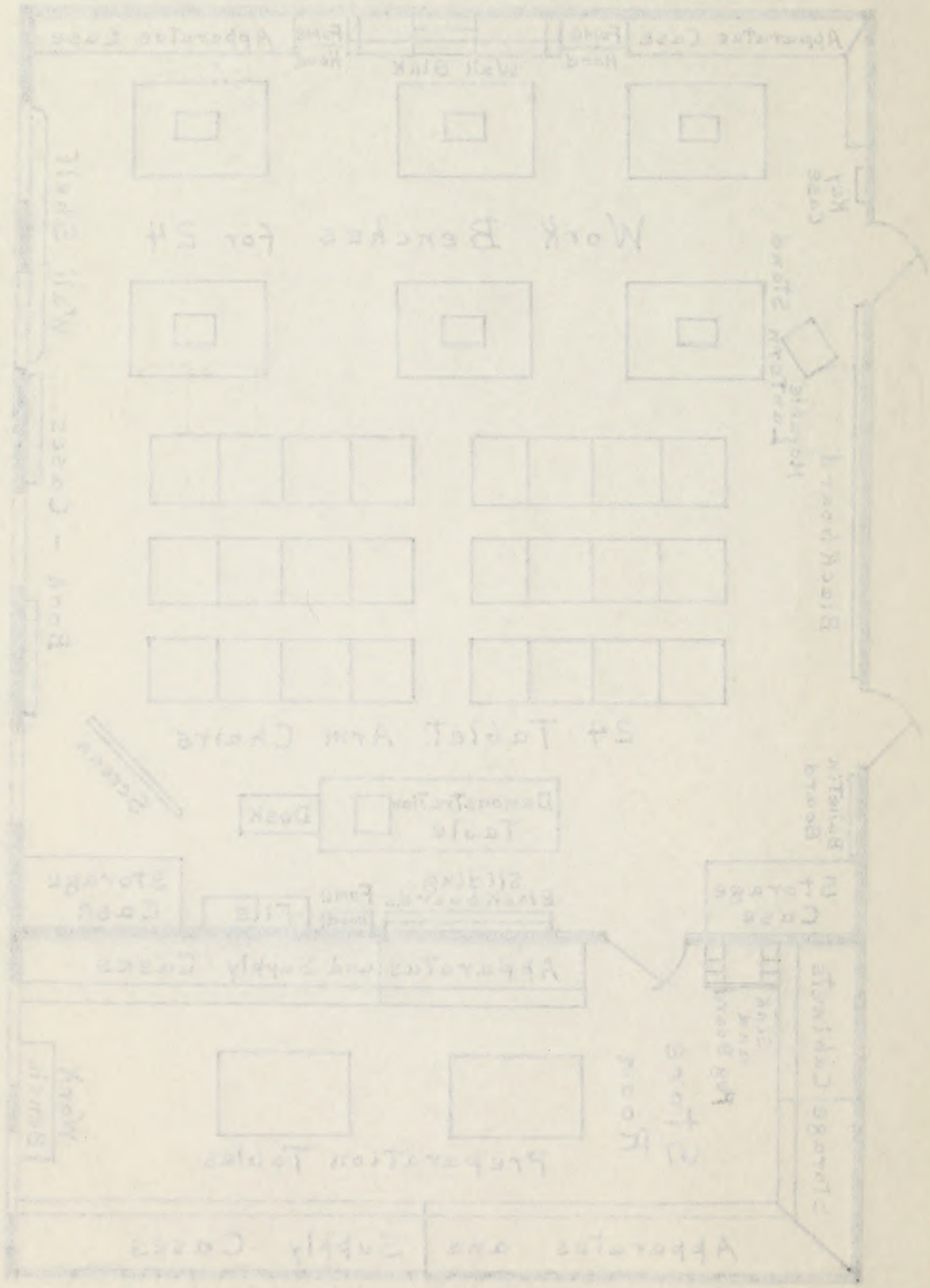

E. Supplies and Apparatus

1. Requisition

All supplies and apparatus should be ordered upon a requisition blank. Generally the teacher or head of the department is responsible for filling out the requisition and filing a duplicate copy with the proper authority. Such a system is business like and serves as a protection to teachers, school administrators and district funds. It tends to eliminate the possibility, and sometimes the temptation to dishonesty on the part of teachers and principals and can make the expenditures of funds free from suspicion. The following returns from the high schools of Connecticut were received in answer to the question "Who is responsible for requisition for equipment and supplies?"

Head of department ---	35
Principal ----------	12
Teacher ----------	11
Superintendent -------	6

2. Purchase

A great deal of care and discrimination should be exercised by those who purchase supplies and apparatus. It is difficult to expect to equip a laboratory with expensive material all at one time but by following a progressive program better and more permanent equipment can

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more easily be acquired year by year. Every chemistry department that has a thrifty buyer is indeed fortunate. Much material which could be ordered from the catalog with little effort upon anyone's part might just as well be purchased from the local hardware or Five and Ten Cent Store for less than the price set by the apparatus companies. Supplies which must be obtained from these companies can be purchased on a competitive bid system with the price of each item indicated and with the privilege of selecting or rejecting items. In order to make sure of having supplies and apparatus delivered on time and with greater care, they should be ordered early so as to avoid the heavy rush of orders that frequently come to supply houses early in September. In the purchase of equipment quality rather than quantity is more important. Too frequently are experiments attempted with inferior equipment that give unsatisfactory results. Teachers compelled to use such equipment are often kept busy explaining why the experiment will not work.

Generally we find that the superintendent is responsible for the purchase of equipment and supplies. The following results in respect to this matter were found in Connecticut:

Superintendent --	25 *	Principal ------	13
Teacher----------	14	Business Manager-	12

*Number of schools

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3. Care and Maintenance

For anything that costs as much relatively as science equipment, it is reasonable to expect that due care and protection be given such material. In Connecticut 58 schools report that the chemistry teacher or head of chemistry department is responsible for equipment and supplies, and 6 report this a responsibility of the principal. Here is a very good opportunity to enlist the cooperation of pupils in cleaning up the laboratory after an experiment, and seeing that everything is returned to its proper place. They should be taught to do as many things for themselves as possible. Certain pupils may be made assistants not for the main purpose of extracting labor from them but to give them what could be called exploratory experience which might be of very great value to them.

4. Inventory

A duty of every chemistry department should be that of conducting a regular inventory at least once a year. The importance of such a procedure is recognized in business and an inventory in the school in June would compare with the annual inventory conducted by business concerns in January. This should be part of the business

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side of school administration and serves to discourage waste and theft. It provides an excellent method for estimating replacements and future supplies that will be needed. In addition to this a "want book" should be kept in a convenient place in every laboratory. Into this book items are entered from time to time as they are found to be lacking or about to be needed. The practice of taking an inventory in chemistry is quite common in the high schools of the state - 44 take a regular inventory, 17 do not, and 3 report taking a partial inventory.

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5. List of Minimum Essentials (1)

Desk Apparatus (24 pupils)

24 Bunsen burners
24 blowpipes, brass, 8 inches
12 reagent bottles, No. 108, for ammonium hydroxide
12 reagent bottles, No. 106, for hydrochloric acid
12 reagent bottles, No. 104, for nitric acid
12 reagent bottles, No. 102, for sulphuric acid
24 burette clamps
24 crucible tongs
24 deflagration spoons, iron
24 files, triangular, 5 inches
24 gauze squares, iron, asbestos centers, 5 inches
24 mortars, with pestles, porcelain, 80 mm.
24 pneumatic troughs, galvanized iron
24 ringstands, 2 ring
24 sand baths, shallow, 4 inches
24 test-tube racks

Individual Apparatus (24 pupils)

24 beakers, 100 cc.
24 beakers, 250 cc.
24 beakers, 400 cc.
24 crucibles, porcelain, No. 0
24 dishes, evaporating, porcelain, 75 mm. No. 00A
24 flasks, 250 cc.
24 funnels, 75 mm.
72 glass plates, 10 by 10 cm.
24 graduates, cylindrical, 25 cc.
24 pipestem triangles, 2 inches
24 pinchcocks, screw compressor
24 rubber stoppers, 1 hole No. 1
24 rubber stoppers, 1 hole No. 5
24 rubber stoppers, 1 hole No. 4
72 bottles, wide-mouthed, 8 oz.
24 burettes, 50 cc.
24 rubber stoppers, 1 hole No. 8
24 rubber stoppers, 2 hole No. 4
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(1) "Laboratory Layouts for the High School Sciences" Bulletin, 1927, No. 22, Department of Interior, Bureau of Education, pp. 19-22

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24 rubber stoppers, 2 hole No. 4
24 rubber stoppers, 2 hole No. 8

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(1) "Laboratory Layouts for the High School Science" Bulletin, 1927, No. 22, Department of Interior, Bureau of Education, pp. 19-22

24 spatulas, horn, 150 mm
24 test tubes, ignition, 6 by $\frac{1}{4}$ inch
24 test tube brushes
24 test tube clamps
24 thermometers, -10^{0} to $110^{o}C$
8 thistle tubes

Apparatus and Stock for General Use

3 balances, trip scales
3 sets weights, iron, 10-500 g.
6 hand balances
6 sets weights, in blocks, 1 ctg.-20 g.
48 bottles, wide-mouth, glass stoppers, 4 oz.
12 calcium chloride tubes, 6 inches
12 condensers, Leibig, 15 inches
12 condenser clamps
12 condenser clamp holders
3 spls. copper wire, bare, No. 28, 4 oz.
3 pkg. corks, asst'd. 0-11
12 pkg. filter paper, 11 cm.
3 pkg. filter paper, 20 cm.
3 funnels, 125 mm.
12 funnels, separatory, with stopcock, 60 cc.
3 lbs. glass rods, 4-5 mm.
5 lbs. glass tubing, 5-7 mm
3 hydrometers
3 hydrometer jars, 2 by 15 inches
3 spl. iron wire, No. 28
12 vials litmus paper, blue
12 vials litmus paper, red
12 platinum loops, in glass handles
8 retorts, glass-stopper, 125 cc.
60 ft. rubber tubing 3/16 inch
30 ft. rubber tubing 1/4 inch
288 test tubes, soft, 4 by 1/2 inch
144 test tubes, soft, 6 by 3/4 inch

Chemicals

2 lbs. acid, acetic, glacial, C.P.
12 lbs. acid, hydrochloric, C.P.
14 lbs. acid, nitric, C.P.
1 lb. acid, oxalic, crystals, com'l
1 lb. acid, phosphoric, ortho, 85 per cent C.P.

24 spatulas, horn, 150 mm
24 test tubes, ignition, 6 by ¼ inch
24 test tube brushes
24 test tube clamps
24 thermometers, -10° to 110°C
8 thistle tubes

Apparatus and Stock for General Use

3 balances, trip scales
3 sets weights, iron, 10-500 g.
6 hand balances
6 sets weights, in blocks, 1 ctg.-20 g.
48 bottles, wide-mouth, glass stoppers, 4 oz.
12 calcium chloride tubes, 6 inches
12 condensers, Leibig, 15 inches
12 condenser clamps
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Chemicals

2 lbs. acid, acetic, glacial, C.P.
12 lbs. acid, hydrochloric, C.P.
14 lbs. acid, nitric, C.P.
1 lb. acid, oxalic, crystals, com'l
1 lb. acid, phosphoric, ortho, 85 per cent C.P.

18 lbs. acid, sulphuric, C.P.
1 gal. alcohol, ethyl, denatured
5 lbs. alum potassium
1 lb. aluminum, metal turnings
4 oz. arsenic, metal. cryst.
1 lb. arsenic trioxide, powder
1 lb. ammonium nitrate, pure
5 lbs. ammonium sulphate, com'l
1 lb. ammonium sulphide, light
2 lbs. ammonium carbonate, U.S.P.
2 lbs. ammonium chloride, pure, gran.
12 lbs. ammonium hydroxide, com'l
1 lb. antimony, metal, lump
1 lb. barium chloride, C.P.
1 lb. barium nitrate, powd. com'l
1 lb. barium sulphate, C.P.
4 oz. bismuth chloride, C.P.
1 oz. bismuth nitrate, C.P.
5 lbs. borax, cryst., pure
2 cans bleaching powder (12 oz. can)
4 oz. cadmium sulphate, C.P., cryst
2 lbs. carbon bisulphide, pure
2 lbs. calcium chloride, anhyd. lumps
2 lbs. calcium chloride, dry, granular
2 lbs. calcium fluoride (fluospar) powd.
5 lbs. charcoal, wood, lump
2 lbs. charcoal, animal, powd.
1 lb. chloroform, U.S.P.
4 oz. chromic chloride, C.P., green cryst.
4 oz. cobalt chloride, C.P.
1 oz. cobalt nitrate, C.P.
1 lb. copper chloride, C.P.
2 lbs. copper, metal foil, No. 36
2 lbs. copper, metal, turnings
5 lbs. copper sulphate, cryst., com'l
4 oz. copper oxide, powd. black, C.P.
1 lb. ether, U.S.P.
2 lbs. ferric chloride, U.S.P.
5 lbs. ferrous sulphate, cryst.
5 lbs. ferrous sulphide, gran.
1 lb. glycerine, C.P.
5 lbs. gypsum, lump
2 lbs. hydrogen peroxide
2 oz. iodine, resub. cryst.
5 lbs. iron filings, clean
2 lbs. lead acetate, cryst., com'l
2 lbs. lead nitrate, cryst., com'l

18 lbs. acid, sulphuric, C.P.
1 gal. alcohol, ethyl, denatured
5 lbs. alum potassium
1 lb. aluminum, metal turnings
4 oz. arsenic, metal. cryst.
1 lb. arsenic trioxide, powder
1 lb. ammonium nitrate, pure
5 lbs. ammonium sulphate, com'l
1 lb. ammonium sulphide, light
2 lbs. ammonium carbonate, U.S.P.
2 lbs. ammonium chloride, pure, gran.
12 lbs. ammonium hydroxide, com'l
1 lb. antimony, metal, lump
1 lb. barium chloride, C.P.
1 lb. barium nitrate, powd. com'l
1 lb. barium sulphate, C.P.
4 oz. bismuth chloride, C.P.
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2 cans bleaching powder (12 oz. can)
4 oz. cadmium sulphate, C.P., cryst
2 lbs. carbon bisulphide, pure
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2 lbs. calcium chloride, dry, granular
2 lbs. calcium fluoride (fluospar) powd.
5 lbs. charcoal, wood, lump
2 lbs. charcoal, animal, powd.
1 lb. chloroform, U.S.P.
4 oz. chromic chloride, C.P., green cryst.
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2 lbs. ferric chloride, U.S.P.
5 lbs. ferrous sulphate, cryst.
5 lbs. ferrous sulphide, gran.
1 lb. glycerine, C.P.
5 lbs. gypsum, lump
2 lbs. hydrogen peroxide
2 oz. iodine, resub. cryst.
5 lbs. iron filings, clean
2 lbs. lead acetate, cryst., com'l
2 lbs. lead nitrate, cryst., com'l

5 lbs. lime (quicklime)
2 lbs. litharge, lead oxide, mono., yellow, pure
4 oz. magnesium, ribbon
2 lbs. magnesium sulphate, C.P.
5 lbs. manganese dioxide, gran.
5 lbs. marble chips
8 oz. mercury, metal
4 oz. mercuric chloride, U.S.P.
4 oz. mercurous nitrate, C.P.
4 oz. mercuric nitrate, C.P.
8 oz. mercuric oxide, red, U.S.P.
4 oz. nickel nitrate (ous) C.P.
2 lbs. paraffin
4 oz. phenophthalein, U.S.P.
8 oz. phosphorus, red
1 lb. phosphorus, yellow, sticks
5 lbs. plaster of Paris
1 lb. potassium bromide, U.S.P.
5 lbs. potassium chlorate, cryst., pure
2 lbs. potassium chromate, cryst.
2 lbs. potassium chloride, pure
1 lb. potassium cyanide, pure
1 lb. potassium dichromate, cryst.
1 lb. potassium ferricyanide, cryst.
1 lb. potassium ferrocyanide, cryst.
2 lbs. potassium hydroxide, tech., gran.
4 oz. potassium iodide, U.S.P.
2 lbs. potassium nitrate, pure, gran.
2 lbs. potassium sulphate, C.P.
1 oz. silver, foil
2 oz. silver nitrate, pure, cryst.
2 lbs. soda, common baking (sodium bicarbonate)
4 oz. sodium, metal
2 lbs. sodium acetate, cryst., com'l
5 lbs. sodium chloride, fine, pure
2 lbs. sodium carbonate, cryst, com'l
2 lbs. sodium hydroxide, sticks, U.S.P.
5 lbs. sodium nitrate, pure
1 lb. sodium peroxide, C.P.
2 lbs. sodium sulphate, cryst.
8 oz. stannic chloride, C.P., cryst.
1 lb. stannous chloride, pure
1 lb. strontium nitrate, pure
2 lbs. sugar, cane
2 lbs. sugar, glucose (dextrose) lump
5 lbs. sulphur, roll
1 lb. tartar emetic, pure

5 lbs. lime (quicklime)
2 lbs. litharge, lead oxide, mono., yellow, pure
4 oz. magnesium, ribbon
2 lbs. magnesium sulphate, C.P.
5 lbs. manganese dioxide, gran.
5 lbs. marble chips
8 oz. mercury, metal
4 oz. mercuric chloride, U.S.P.
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2 lbs. sodium sulphate, cryst.
8 oz. stannic chloride, C.P., cryst.
1 lb. stannous chloride, pure
1 lb. strontium nitrate, pure
2 lbs. sugar, cane
2 lbs. sugar, glucose (dextrose) lump
5 lbs. sulphur, roll
1 lb. tartar emetic, pure

1 lb. tin, metal, mossy
2 lbs. zinc, metal, mossy
2 lbs. zinc sulphate, pure cryst.
2 lbs. zinc powder
2 lbs. zinc strips

Reserve Stock

24 beakers, 100 cc.
24 beakers, 250 cc.
24 beakers, 400 cc.
36 bottles, glass stopper, 4 oz.
12 burettes, 50 cc.
12 cobalt glass plates, 50 by 50 mm.
24 crucibles, porcelain, No. 0
3 cylinders, glass, 2 by 12 in.
24 dishes, evaporating, 75 mm.
24 flasks, 250 cc.
24 flasks, Erlenmeyer, 125 cc.
6 funnels, 75 mm.
3 graduates, cylindrical, 25 cc.
6 doz. test tubes, hard, 6 by 3/4 in.
24 thistle tubes

Additional Desirable Apparatus

1 barometer, mercurial
1 chart, periodic law
1 electrolysis apparatus

1 lb. tin, metal, mossy
2 lbs. zinc, metal, mossy
2 lbs. zinc sulphate, pure cryst.
2 lbs. zinc powder
2 lbs. zinc strips

Reserve Stock

24 beakers, 100 cc.
24 beakers, 250 cc.
24 beakers, 400 cc.
36 bottles, glass stopper, 4 oz.
12 burettes, 50 cc.
12 cobalt glass plates, 50 by 50 mm.
24 crucibles, porcelain, No. 0
3 cylinders, glass, 2 by 12 in.
24 dishes, evaporating, 75 mm.
24 flasks, 250 cc.
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1 barometer, mercurial
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VI INSTRUCTION

A. Classwork

The main objective in teaching chemistry is to give to pupils a fundamental knowledge of the principles, laws, and generalizations of the science, and make it possible for them to use methods of science in solving the problems with which they will come in contact in later life. Since most of the factual knowledge, which pupils acquire from the study of high school chemistry, is soon forgotten, it is desirable that considerable attention be directed to actual applications to be found in their environment.

While the lecture system which dates from medieval times and which was used for instructing students mature in mentality and experience, should not be used in the high school chemistry course to any great extent, there is a place for this method with the teacher who knows when and how to use it to advantage. It is useful in presenting a better view of a certain subject as a whole, organizing and establishing principles, making the assignment interesting, and for similar purposes.

The class discussion should not be a period for merely asking and answering questions. A record of whether or not the pupils have prepared their lessons can best be

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The class discussion should not be a period for merely asking and answering questions. A record of whether or not the pupils have prepared their lessons can best be

obtained from written answers to one or a few short questions at the beginning of the period. The teacher should have control over the discussion but not dominate it. The procedure should be guided by the teacher and questions for discussion should be to the point. When possible a few thought questions or exercises and problems at the end of the chapters in the text should be assigned with each lesson. Those pupils whose papers and responses in class indicate they are not doing well should be studied carefully. It is the sign of a poor teacher to give assignments, hear recitations, and mete out praise or rebuke only. The good teacher will, through inspiration, guidance, and assistance, help each pupil to find his proper place; will know when to teach, when to criticise, when to give praise, and when to leave the pupil alone so that the individual's methods may function in his own learning.

B. Lecture-Demonstration Method

Every high school chemistry teacher should realize the importance of a well planned and executed demonstration. It is a very good method for clearing up a point under discussion or for teaching a new principle. At the beginning of the course pupils are very much lacking in the necessary skills and techniques for performing individual

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laboratory work. Therefore the first experiments can best be given as demonstrations, the pupils repeating the more important ones later. The directions given in the manual can never be quite as satisfactory as an observation of the various processes performed correctly. Demonstration exercises might include the manipulation of glass tubing, the adjusting of glassware, the application of heat to apparatus, etc.--all of which can be taught best by preliminary demonstration.

The demonstration method is almost a necessity in performing dangerous experiments, those too difficult for pupils, or those which may be too long for the assigned chemistry period. Every high school manual usually contains a few experiments which have an element of danger for the pupil. For example, in the preparation of chlorine or carbon monoxide, the usual laboratory does not have ducts capable of taking away all such gases as would be formed if a large group were preparing the same experiment. Certain experiments are too difficult for pupils. An example would be in the preparation of nitrous oxide. The ammonium nitrate must be heated to just the right temperature and yet avoid an explosion. The cost of some kinds of apparatus is so great that the purchase of duplicate material is almost prohibitive. The apparatus needed in

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electrolysis experiments would be an example of this.

Studies indicate that at least the first of such experiments which are intended to explain new principles should be demonstrated.(1) Finding the equivalent weight of a metal by reaction with an acid and the measurement of hydrogen evolved, can be demonstrated with advantage as to procedure and calculations involved. After observing such an experiment the pupil should be much better prepared to perform similar experiments.

Here it might be well to include a few remarks about performing the demonstration. It is desirable to have everything on hand that will be needed for the exercise. Nothing is more embarrassing to a teacher than to find that he lacks some important part for the experiment after it has been started. High school pupils are critical and notice such points. This, of course, will not increase their respect for the ability of the teacher. One should make sure that the experiment will work and that the desired results will be obtained. Whether or not the whole procedure ought to be gone through beforehand may depend upon the ability and experience of the teacher. But even though it may take considerable time and energy on the part

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of the teacher, as a general rule it is rather dangerous to attempt any experiment without a preliminary trial. "Keeping demonstrations up to the highest standards that the school permits, demands heroic effort and often self-sacrifice on the part of the busy teacher."(1)

In order to avoid disciplinary troubles and provide a fair opportunity to learn the teacher should make sure that the demonstration will be visible to all. It would be foolish not to have pupils adjust themselves to see what was to happen even at the expense of a little formalism in the classroom. The attention of the students should be maintained and this can be effected by making the demonstration short. If a long pause in the course of the experiment is necessary, there should be some appropriate questions or pertinent discussion on the work. Another thought which would seem hardly necessary to mention is that of having the apparatus clean and neat. Such habits should be acquired and if the teacher does not set a good example, it is almost impossible to expect pupils to develop them.

In conducting the demonstration the teacher should

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remember that details which appear perfectly obvious to him may not be recognized by the inexperienced observer. Apparatus and materials should be explained to the class. Attention should be called to certain parts of the experiment which may be more or less obscure and yet important. For example, in the fountain experiments for solubility of such gases as hydrogen chloride and ammonia, if the pupils' attention is drawn too much by the fountain phenomenon and liquid color change and they do not observe any evidence of a partial vaccuum being formed, then they should be guided as to what to see. This does not mean that they should be told what to see and think but should form tentative conclusions from their observations. The teacher should be clever at manipulation of apparatus and, like any performer, should be skillful in the demonstration. Discussion should be guided along the right path, for all too often the high school mind is apt to wander off to something entirely irrelevant to the topic at hand. The student should have a written record of the exercise which should result from the observation and discussion. This does not mean that all laboratory work should be given as demonstrations. The demonstration method should not be used to the exclusion

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of all individual work for there are certain values, such as skills and techniques, to be acquired from individual work which can be secured in no other way. The following list may sum up the value of the demonstration method:

(1) Greater saving of time
(2) Greater variety of material can be presented
(3) Allow more time for drill and review
(4) Better presentation
(5) Saving in expense

C. Standard of Attainment

"Measurement is essential in the education process."(1) A good teacher should be able to measure quickly and accurately what his class is learning. This should be done with proper frequency and with the purpose of keeping the learning process up to the maximum efficiency. There is as much danger in giving too many tests as there is in giving too few. A pupil should always receive some report on every test that he may take. Too frequently test after test is given only to find its way into the waste basket.

A very good way to insure daily preparation is by means of the short written quiz at the beginning of the period. This may be corrected immediately in class or if not should be corrected outside and discussed at the next meeting of the class. In Connecticut 21 high schools

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report the use of the daily quiz and of the remaining 43 schools about one half indicate that short written quizzes are given frequently though not daily. Among the tests used to enforce preparation may be mentioned the short answer test, the true-false test, and the five or ten minute written quiz. In answer to the question "How frequently do you give written tests?" the following replies were obtained:

TABLE IV Frequency of Written Tests in High Schools of Connecticut

Frequency	No. of Schools
Every week	20
Every 2 weeks	18
Every 3 weeks	2
Every 4 weeks	14
Every 5 weeks	1
Every 6 weeks	3
No answer	6
Total	64

Within recent years there has been much work done on devising and standardizing new type tests. Reference to the work done along this line in the field of chemistry may be found in "Measurement in Secondary Education", Symonds, P. M., Macmillan Co., New York, pp. 139-147.

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In Connecticut the writer found that 37 or 57.8% of the high schools reporting, use the objective type test more frequently than the essay type. Sixteen make greater use of the traditional essay type test, while eleven high schools report using both types about equally.

The various forms of objective type tests for measuring the instruction and achievement of pupils include true-false, multiple choice, completion, matching, etc.

Some of the advantages claimed for these newer tests are:

(1) They test the pupil on a wider range of material in a shorter time.

(2) They are easier and quicker to grade.

(3) They are more reliable by being more nearly objective.

(4) They are graded so as to eliminate guessing as far as possible.

Following is an outline of some types of tests with example and discussion of each kind:

1. Formal (requiring discussion)

   Ex. Discuss the use of catalytic agents in oxidation experiments.

   This test measures the ability of students to remember and reitterate facts and apply principles.

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Following is an outline of some types of tests with example and discussion of each kind:

I. Formal (requiring discussion)

Ex. Discuss the use of catalytic agents in oxidation experiments.

This test measures the ability of students to remember and reiterate facts and apply principles.

2. True and false

Ex. Ammonium nitrate is sometimes called "muriate of ammonia". (True) (False)

Factual memory characterizes this type.

3. Completion

Ex. Solutions which conduct electricity contain _____.

This test is similar to No. 2.

4. Multiple choice

Ex. Aluminum chloride is a (1) neutral salt, (2) acid salt, (3) basic salt, (4) complex salt.

This test tends to develop accurate discrimination.

D. Assignment

Every assignment should be definite and given in such a way as to be perfectly clear to the pupil. Nothing is more discouraging to a pupil or destructive to his interest and ambition than to be given indefinite assignments so that he feels neither he nor his teacher knows what is expected.

Just when during the period the assignment should be made is not as important as the necessity for explaining how it should be done. The teacher should not only definitely outline the advance work, showing the relative importance of the various parts of the lesson, but should

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interest the pupils so that there will be an active desire on their part to prepare the work for the next day. Six high schools in Connecticut use the long assignment where the advance work is outlined for periods of from one to five weeks; ten give the assignments at the end of the period; eleven vary it from time to time as the occasion demands; while thirty-seven or 57.8% of the schools reporting give the assignment before class work begins.

E. Organization of Chemistry Course

In order to care for the individual differences to be found in a group of pupils taking high school chemistry, it seems to the writer that the course should be organized into various levels of difficulty, and differently sized units of work. Those pupils of lowest ability would be required to complete satisfactorily the minimum course which would consist of fundamentals and local essentials, and so on up till those of highest ability would take in addition to the minimum course what might be called near and related essentials. It is impossible to expect all pupils within a group to come up to a fixed and arbitrary standard. Rather should we expect each

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pupil to perform to the best of his ability.

The unit plan of teaching consists of dividing the course into a few large blocks and each block into smaller units. Such units should be as closely related as possible so as to avoid the isolated and unorganized impressions likely to be formed in the mind of the pupil. In Connecticut 23 high schools organized their chemistry courses according to this plan. One school reports using the project method similar to the contract plan, and 40 high schools or 62.5% of those included in this study base their courses upon chapters in the text book. The unit plan, however, is becoming more widely adopted and in time will probably be the accepted method of organization.

F. Text-Book

The value of a good text-book lies in the fact that it is a source of knowledge arranged systematically. But any book has its limitations and the best of them must be supplemented in many ways in order that a chemistry course may meet the needs of pupils in various localities. The chemistry teacher who teaches his course merely by transferring the contents of a text-book into the heads of his pupils is performing little more than a mechanical process and the product will tend to be stereotyped.

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In order that pupils may obtain a comprehensive and correlated view of chemistry an approved text-book should be used. A good text goes far towards making a course a success. The teacher or committee of teachers and school officials ought to give a great amount of thought and study to the selection of the text. The use of a score card[1] for the evaluation of high school chemistry texts will aid in this work. Every pupil should be equipped with the one accepted text and should have at his disposal several different texts and references to the subject of chemistry. Out of a list of about 150 high school chemistry texts available, more than 60 of which have been published during the last twenty years, it is estimated from publishers' reports that six are used at the present time in about 90% of the schools of the United States.[2]

The chemistry text-books of the late nineteenth century were much alike. A very formal and systematic treatment of the elements and their compounds was customary. This was due chiefly to the fact that most of the texts were written by college professors who merely

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adapted their own texts for high school purposes with little consideration for the differences between high school and college students. In recent years there has been a decided change, some of the newer books being not only models of logical and psychological development but make chemistry a really live subject.

An analysis of four widely used text-books shows that over 50% of their pages deal with descriptive material. This, many believe, is too much. Parts of ever increasing chemical information find places in the text-books, with a result that they contain more material than can well be covered in a year's time. In order that pupils may use chemistry later on in their lives, they need to be well acquainted with the fundamentals of the subject. To accomplish this it seems better to cover a selected amount of material rather intensively than spend the same time on a comprehensive requirement and give the pupils only a smattering of chemistry. The field is too broad for a detailed study by high school pupils in one year.

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TABLE V CHEMISTRY TEXT BOOKS USED IN HIGH SCHOOLS OF CONNECTICUT *

Name	Number of schools using text
Black and Conant, "Practical Chemistry" 522 pp. 1927 Macmillan Co.	20
Bradbury, "A First Book in Chemistry" 664 pp. 1928 D. Appleton & Co.	1
Brownlee, Fuller, Hancock, Sohon & Whitsit "First Principles of Chemistry" 777 pp. 1931 Allyn & Bacon, N.Y.	19
Brownlee, Fuller, Hancock, & Whitsit "Chemistry of Common Things" 605 pp. 1914 Allyn & Bacon, N.Y.	1
Bruce, "High School Chemistry" 550 pp. 1928 World Book Co.	2
Dinsmore, "Chemistry for Secondary Schools" 574 pp. 1925 F. M. Ambrose Co., N.Y.	1
Dull, "Modern Chemistry" 776 pp. 1931 Henry Holt & Co.	4
Emery, Davis, Boynton and Downey "Chemistry in Everyday Life" 719 pp. 1928 Lyons and Carnahan	1
Fletcher, Smith & Harrow " Beginning Chemistry" 454 pp. 1929 American Book Co.	6
Gordon, N. E., "Introductory Chemistry" 620 pp. 1930 World Book Co.	2
Gray, Sandifur, & Hanna 650 pp. 1929 Houghton Mifflin Co. "Fundamentals of Chemistry"	2

* Some high schools report using more than one text-book.

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Hessler, John C.,"The First Year of Chemistry" 580 pp. 1931 Benj. H. Sanborn & Co.	1
Holmes & Mattern, "Elements of Chemistry" 519 pp. 1927 Macmillan Co.	1
McPherson, Henderson, & Fowler "Chemistry for Today" 588 pp. 1930 Ginn & Co.	12
Newell, "Practical Chemistry" 543 pp. 1922 D. C. Heath & Co.	3

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VII LABORATORY WORK

A. Objectives

The fundamental principle of the laboratory work is illustration, its purpose is to make real what is studied in the classroom and to enable the pupil to find out by experiment facts necessary to the solution of his problem. One could read about sodium for many hours without obtaing important impressions that come easily in a few minutes of seeing the element in action. Good laboratory work does not necessarily depend on expensive laboratories and equipment. A good deal of experimental work in chemistry can be carried on with very simple yet fairly accurate and serviceable apparatus together with a moderate supply of materials. Complicated apparatus will often lead pupils astray of the important points of experiments.

From a study of various syllabi, available laboratory manuals, and the general objectives of high school chemistry, the following list of objectives for laboratory instruction seem significant.

1. To fix firmly in the mind of the pupil some of the important facts and principles of chemistry.
2. To develop certain skills and abilities which he can use in future work.

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1. To fix firmly in the mind of the pupil some of the important facts and principles of chemistry.
2. To develop certain skills and abilities which he can use in future work.

3. To develop certain ideals such as accuracy, neatness, promptness, etc.
4. To increase the pupil's interest for the subject through vividness.
5. To develop initiative and resourcefulness on the part of the pupil.
6. To give the pupil practice in the application of the scientific methods of procedure.

Wherever possible, pupils should perform experiments individually, rather than in partnership or in groups in order to develop independent habits of thought and action. Too frequently do we find one pupil doing all the work while others look on and are merely "entertained". From the results of the questionnaire 27 schools report conducting laboratory work individually, 28 allow two to work together, 1 has three working in a group, 5 have four in the group, while 3 schools conduct all laboratory work by demonstration entirely.

B. Size of Laboratory Section

While it has often been thought that a single teacher can care for no more than 20 pupils in a laboratory section, there seems to be no valid reason why sections could not be as large as 30 or 40 provided the laboratory

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8. <u>Size of Laboratory Section</u>

While it has often been thought that a single teacher can care for no more than 30 pupils in a laboratory section, there seems to be no valid reason why sections could not be as large as 30 or 40 provided the laboratory

routine is well organized and followed. The general trend within recent years has been to increase the size of sections. The following table indicates the range found in high schools in Connecticut - 25 pupils being most common:

TABLE VI Size of Laboratory Sections in High Schools of Connecticut

Size of section	Number of schools
0 - 9	4
10 - 19	19
20 - 29	29
30 - 39	11
40 - 49	1
Mode 25	Total 64

The amount of time devoted to laboratory work varies greatly as do the number of experiments performed during the year. In answer to the question "How many times a week do you have laboratory work?" 30 high schools report - once; 27 - twice; 2 - three times; and 5 vary the amount of work according to present conditions. The range in the number of experiments performed during the year is from one school with 20 teacher demonstrations to 2 schools with 80 experiments - the average being approximately 45 separate experiments.

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TABLE VII Number of Experiments Performed During Year

Number of Experiments	Number of Schools
20 - 29	1
30 - 39	13
40 - 49	27
50 - 59	12
60 - 69	4
70 - 79	5
80 - 89	2
Mode 45	Total 64

The length of period also varies considerably with some schools devoting a single 40 minute period per week to laboratory work, while one has a two hour laboratory period each week. A suggested procedure would be to adopt the lengthened period of from 50 to 60 minutes each. This would not only eliminate the difficulty often encountered in scheduling double laboratory periods but would make for a closer correlation between recitation and experiment. In this way the period could be used for either purpose and the chemistry course would require no more time than any other course in the curriculum.

Studies, in general, indicate that it is better practice to take the laboratory work on a given topic just before it is studied in the text-book. Habits of observation tend to be missed if ideas have already been formed from discussion in the text. To be of greatest value laboratory work must,as far as possible, be closely

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coordinated with the work of the class-room. As previously mentioned the lengthened period would make this possible to a considerable extent. At the present time 33 high schools in Connecticut report that laboratory work follows class discussion on the topic, 24 have one accompany the other, while 7 try to have experimental work precede discussion in class.

C. Recording Experiments

The question as to the value of the laboratory notebook has been and is a matter of much discussion. It should be recognized that the experiment is to help the pupil gain a clearer understanding of chemical facts and not for the purpose of making a model notebook. Too frequently the undue emphasis placed on "writing up" the experiment has destroyed the pupil's interest in the work. The rigid and stereotyped form of notebook destroys any originality on the part of the pupil and it is a question whether the advantages of the uniform records are justified. Provided the important facts and results, together with a clear description of the work and answers to all specific questions are included, the notebook should be accepted as the pupil's own work and he should be encouraged to improve his own methods.

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In order that the pupil may make accurate observations, all notebooks should be prepared in the laboratory as the work is done, and the length of the experiment should be adjusted so that this is possible. If records are made at a later time, the value of independent work will tend to be destroyed for the pupil will be apt to use his manual more on the "cook book" plan in order to recall what happened or one may do the work and others copy it. In Connecticut the high schools are about equally divided on the practice of writing up experiments, 24 report that the work is done during the laboratory period, 24 that it is done outside the period, and 16 state that part is done during the period and part outside. Many of this last group would prefer to have the records made during the laboratory period if time were available.

Even though laboratory work is relatively expensive to provide, the writer believes that there is a legitimate place for it in meeting the objectives of a chemistry course. But unless it is so planned and conducted as to be of contributive value to the rest of the course, it will be largely a waste of time and money.

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VIII ENRICHED TEACHING OF CHEMISTRY

A. Special Reports

In order to encourage pupils along the line of some special interest they should be expected to investigate topics and make reports to the class. Often a pupil's interest may thus be aroused and developed and he certainly will profit from the experience of finding answers to his questions from various sources of information. That many high schools in Connecticut make use of this valuable training is indicated by the report that 41 or 64.1% of those answering the questionnaire do require such work, 2 schools give extra credit for it, and 21 do not require special reports from pupils.

B. Industrial Excursions

If trips to local chemical industries can be arranged, they can be employed to good advantage. If the pupil can see chemistry at work in industry, it will make him realize the practical and definite relation his subject has to real, worth-while activities. In advance of any visit the processes involved in the plant should be discussed so that every pupil will have a better understanding and knowledge as to what should be observed. Every excursion should follow a well organized plan and

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a report should be expected from all pupils to impress upon them the importance of such work. Unless advised in advance, the tendency for many high school pupils is to regard such trips as pure amusement. Of course pupils should realize that they are guests while at the plant and are expected to act accordingly.

Many schools are so located that it is difficult for them to conduct industrial excursions. Especially is this true of many of the rural communities. However, there are many high schools in Connecticut which do not avail themselves of the opportunities for such instruction even though they be right at hand. There are 27 or 42.2% of the high schools in the state which do conduct industrial excursions. The following types of places are reported by this group:

Electroplating, Telephone, Photography, Fountain Pen, Bakelite, Coke, Gas, Water, Tooth Paste, Soap, Tannery, Ice Cream, Silver, Rubber, Hatting, Refrigeration, Paper Mill, Artificial Ice, Laundry, Bleachery and Dye Works, Airplane, Iron Foundry, Research Laboratories.

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C. Sample Display Material

The display cabinet should be a part of every chemistry department. This need not be an expensive piece of equipment nor contain costly material. Much supplementary or enrichment material can usually be obtained from industrial concerns at no cost, or if there is a charge it is a very small one. In writing for such things better results will be obtained if the school letterhead is used and if the teacher signs the letter. An acknowledgment upon receipt of the material is only courteous to the sender. Carelessness or abuse of materials has caused certain companies to limit or even discontinue the sending of such articles to schools.

While these materials are produced primarily for advertising purposes, very seldom do we find unfair advertising or propaganda. There is considerable teaching value in these articles and many are more helpful than corresponding descriptions in textbooks. The objection is sometimes raised that such material often presents biased facts and opinions. In answer it might be said that much that is read by our pupils in newspapers, magazines, and books is open to just as much criticism. At least in the classroom the teacher is in a position to caution pupils to form their own conclusions based on evi-

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D. Visual Aid

Undoubtedly there is a great future for visual aid apparatus in the field of education and in the teaching of chemistry in particular. European schools far surpass those in this country with the use and application of these teaching devices. While certain forms of visual aid have been in use for many years, it is only within the last five years that they have become fairly widely adopted in our up-to-date high schools. Improved apparatus available at lower costs and an increased interest in the value of teaching by such methods have helped a great deal to bring this about.

Thirty-four or 53.1% of the high schools in Connecticut report that they use visual aid apparatus in teaching chemistry and 21 of the 34 schools use moving picture equipment. There is a wide variety of films available. Some may be had free except for transportation expenses and others may be rented for a moderate charge up to one dollar and a half per reel. It is advisable to apply for films considerably in advance as the demand exceeds the supply at the present time. While all these

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films are valuable for teaching purposes, some are better than others. It has been estimated that those relating to the field of chemistry can be improved from 100% to 200%.[1]

In addition to the moving picture importance should also be placed on the value of glass slides, film slides, charts, diagrams, tables and scrap files. Some very good equipment can be collected or made by the resourceful teacher and very often valuable assistance in this work can be obtained from the pupils. As mentioned elsewhere good results do not depend necessarily on elaborate and expensive equipment.

E. Chemistry Library

"A part of the requisite equipment of every chemistry department is a well chosen set of reference books, available and in constant use."[2] The library can be made to enrich a chemistry course to a considerable extent. In addition to various textbooks on chemistry and related sciences there should be a collection of books on various subjects related to chemistry, also periodicals, phamphlets and current publications. These may be

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(1) "The Teaching of High School Chemistry" - Frank, J.O. p 176
(2) "Reorganization of Science in Secondary Schools" Dept. of Int., Bulletin, 1920, No. 26, p 40

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used either as a source for reference material or for reading-for-enjoyment purposes. Too little attention has been given in most of our schools to the matter of providing reading material and encouraging the use of it.

In some high schools the chemistry library is located in the department, while in others it is found in the school library. There are certain advantages for having the library right at hand in the department but wherever it may be it should be readily accessible to all pupils. Books in an inside private office or in a room that is locked up except during the time classes are in session will not be used as extensively as they should. Fifty high schools or 78.1% of those included in this study have chemistry libraries ranging in size from a very few books to those with several hundred - the average having approximately 50 copies. It was also found that the chemistry libraries of some schools consisted of a few volumes belonging to individual teachers while others have generous amounts of money appropriated each year for new books and subscriptions. There should be some way for providing more nearly equal opportunities for the pupils of all schools.

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F. Chemistry Club

The Chemistry or Science Club can be made an attractive part of an enriched program of chemistry teaching. The extra-curricular activities have become recognized as having an important place in the secondary school. To be of the greatest value the club must be formed to carry out a worthwhile constructive program, be of interest to all members and not merely used for the purpose of "teaching" chemistry in place of the class-room. Membership should be limited to those who have a real interest in chemistry and have qualifications for deriving something worthwhile from the association.

In Connecticut 35.9% of the high schools reported having a club - either Chemistry, Science, Photography, Edison, or some other special branch of science. Generally the clubs hold meetings every two weeks. Often meetings are held early in the evening and yet many schools find them more satisfactory if they are held either during school time or immediately after school closes. It must be remembered that all programs should be "educational" - not necessarily "instructional".

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In Connecticut 38.9% of the high schools reported having a club - either Chemistry, Science, Photography, Radion, or some other special branch of science. Generally the clubs hold meetings every two weeks. Often meetings are held early in the evening and yet many schools find them more satisfactory if they are held either during school time or immediately after school closes. It must be remembered that all programs should be "educational" - not necessarily "instructional".

IX SUMMARY

Three periods in the development of the teaching of chemistry in the secondary schools of Connecticut can be recognized. The first period (about 1820-1870) was concerned with the science largely for the sake of information. From about 1870 to 1910 might be considered a period of college domination for the trend was to plan the work of the high school according to the demands of pure science. Since 1910 there has been a decided attempt to organize the work in chemistry so as to bring out applications of science to the environment and every-day life of the pupil.

In 1914-15 in the public schools of the United States about 7.38%[1] of the school enrollment took chemistry and by 1930 this had increased to nearly 10 per cent.[2] It was found in this study that in 1931-32 about 10.37% of the pupils enrolled in the secondary schools of Connecticut were taking chemistry. There was a wide variation in the duties assumed or subjects taught by chemistry teachers

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(1) Inglis, Alexander, "Principles of Secondary Education" Houghton Mifflin Company, Boston, 1918 - p. 510

(2) Frank, J. O. "The Teaching of High School Chemistry" J. O. Frank & Sons, Oshkosh, Wis. - p. 11

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In 1914-15 in the public schools of the United States about 7.38% (1) of the school enrollment took chemistry and by 1930 this had increased to nearly 10 per cent. (2) It was found in this study that in 1931-32 about 10.87% of the pupils enrolled in the secondary schools of Connecticut were taking chemistry. There was a wide variation in the duties assumed or subjects taught by chemistry teachers

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(1) Inglis, Alexander, "Principles of Secondary Education" Houghton Mifflin Company, Boston, 1918 - p. 310

(2) Frank, J. O. "The Teaching of High School Chemistry" J. O. Frank & Sons, Oshkosh, Wis. - p. 11

in Connecticut. Of the 89 teachers included in this study, 52 were teaching chemistry as the only subject. Physics, general science, biology, and mathematics were the subjects most frequently taught by those teachers who did not devote full time to chemistry. Contrary to practice followed by secondary schools in the United States outside of New England, we find chemistry being taught after physics in over 76% of the high schools answering the questionnaire.

Nearly 83% of these secondary schools offer only one general course in chemistry. Eleven schools give courses in college, household, or industrial chemistry in addition to the general course.

In order to bring about more efficient use of the school plant there is an increasing tendency to combine laboratory and recitation work in the same room. Thirty-seven high schools, or 57.8% of those included in this report,have the laboratory and recitation room combined. Likewise it was found that 16 of the schools are now using these so called "special rooms" for home room purposes. It is now generally conceded that with sufficient equipment and proper supervision a laboratory section need be no smaller than the recitation section.

in Connecticut. Of the 39 teachers included in this study, 32 were teaching chemistry as the only subject. Physics, general science, biology, and mathematics were the subjects most frequently taught by those teachers who did not devote full time to chemistry. Contrary to practice followed by secondary schools in the United States outside of New England, we find chemistry being taught after physics in over 75% of the high schools answering the questionnaire.

Nearly 85% of these secondary schools offer only one general course in chemistry. Eleven schools give courses in college, household, or industrial chemistry in addition to the general course.

In order to bring about more efficient use of the school plant there is an increasing tendency to combine laboratory and recitation work in the same room. Thirty-seven high schools, or 57.8% of those included in this report, have the laboratory and recitation room combined. Likewise it was found that 16 of the schools are now using these so called "special rooms" for home room purposes. It is now generally conceded that with sufficient equipment and proper supervision a laboratory section need be no smaller than the recitation section.

The number of pupils which can be accommodated in the laboratories of those schools answering the questionnaire ranges from 36 to 6, with the greatest number reporting 24 as the maximun capacity. Forty-one of the 64 secondary schools use the long laboratory table with pupils on two sides. The average cost of laboratory equipment was found to be $44.02 per pupil, as compared with $31.75 per pupil in 212 high schools in Michigan in 1928.(1)

Sufficient storage space for equipment and supplies is reported by 42 of the 64 high schools in Connecticut. Strict business-like procedures in the purchase and care of equipment should be followed. The head of the department was found to be the one responsible for supplies and apparatus in 35 schools - the principal in 12, the teacher in 11, and the superintendent in 6 schools. A regular inventory is taken by 44 of the secondary schools.

The teacher should adapt his methods of instruction to meet the needs of his particular group. The lecture-demonstration method is used extensively in foreign schools and is becoming recognized as a very important and efficient procedure in the teaching of chemistry in our secondary schools. It was found that the objective

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(1) Frank, J. O. "The Teaching of High School Chemistry" J. O. Frank & Sons, Oshkosh, Wis. pp. 208-9

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type test is used more frequently than the essay type in the high schools of Connecticut. Thirty-seven schools make greater use of the new type tests, 16 the traditional essay type test, while 11 high schools report using both types about equally.

At the present time 62.5% of the schools base their course upon chapters in the text book but the unit plan of teaching is increasing in importance. The text books in use today are decided improvements over the early texts which were written by college professors mostly, and were not particularly well adapted for high school use. In Connecticut 16 different chemistry text books were found to be in use. "Practical Chemistry" by Black and Conant; "First Principles of Chemistry" by Brownlee, Fuller, Hancock, Sohon, and Whitsit; "Chemistry for Today" by McPherson, Henderson, and Fowler, are the three texts most frequently used.

The purpose of laboratory work is to furnish concrete evidence of what is studied in the class room. Wherever possible, pupils should perform experiments individually. When this is inconvenient, the partnership plan is found satisfactory if properly supervised. From the results of the questionnaire it was found that 27 high schools conduct laboratory work individually, while 28 allow two

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pupils to work together. In Connecticut the general trend within recent years has been to increase the size of laboratory sections.

The average number of experiments performed during the year in the high schools of Connecticut was found to be 45. The lengthened period of approximately 60 minutes is recommended by the writer for it not only eliminates the difficulty often met with in scheduling double laboratory periods but makes possible a closer correlation between recitation and experimental work. Thirty-three high schools in Connecticut report that laboratory work follows class discussion, 24 conduct both together, and 7 try to have experimental work precede discussion in class.

Twenty-four secondary schools report that experiments are written up during the laboratory period, 24 that it is done outside the period, and 16 state that part is done during the period and part outside. It is recommended by the writer that records of experiments be made in the laboratory as the work is done, and many schools report they would carry out this practice if sufficient time were available. Definite objectives for the laboratory work should be set up and attained, otherwise it becomes an expensive procedure and an opportunity for

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some pupils to regard the work as little more than amusement.

Under the heading "Enriched Teaching of Chemistry" the topics developed include Special Reports, Industrial Excursions, Sample Display Material, Visual Aid, Chemistry Library and Chemistry Club. Forty-one of the 64 high schools require special reports and 2 schools report giving extra credit for such work. There were 27 or 42.2% of the schools in this study which do conduct excursions to a wide variety of industrial places. Thirty-four high schools use visual aid apparatus in teaching chemistry and 21 of these use moving picture equipment. Libraries, ranging in size from a very few books to those with several hundred copies, were found in 50 of the high schools and only 23, or 35.9% of the schools in Connecticut included in this study, reported having a club - either for chemistry or for some other branch of science.

It is the energetic and resourceful chemistry teacher who makes the most of these opportunities in order to encourage pupils in the study of chemistry and to show the many applications of the science to the world in which they live.

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