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LABORATORY LAYOUTS FOR THE HIGH-SCHOOL SCIENCES

By

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LETTER OF TRANSMITTAL

DEPARTMENT OF THE INTERIOR,
BUREAU OF EDUCATION,
Washington, D. C., August 13, 1927.

SIR: Demand is frequently made upon this bureau for practical information relating to equipment and supplies for teaching science in small high schools. Knowing that Mr. A. C. Monahan, formerly a specialist in the Bureau of Education, has recently given special attention to this subject, I asked him to prepare a manuscript containing facts for which the need is often expressed. He has complied with my request, and his production is submitted herewith. Mr. Monahan sets forth the results of recent experience in the development of modern laboratories in furniture, equipment, apparatus, and supplies. The lists presented are modest and contain much less than is usually supplied in large city high schools, but they are sufficiently inclusive to cover the requirements of all the States which have fixed definite standards of laboratories and equipment for accrediting science courses.

I recommend that this manuscript be published as a bulletin of the Bureau of Education.

Respectfully submitted.

JNO. J. TIGERT
Commissioner.

The SECRETARY OF THE INTERIOR.

Laboratory Layouts for the High-School Sciences[1]

Laboratories for science courses have been for several decades necessary parts of every high school teaching these sciences. Developments in the types of laboratories and in their equipment have been constant. Subjects and courses and methods have varied much in different parts of the country. Now, however, there seems to be a more nearly uniform idea of what is necessary than ever before. This bulletin is a brief survey of the necessary equipment to teach the high-school sciences according to generally accepted standards.

Reviewing briefly the subjects taught as high-school sciences, it is found that in the past three decades, for instance, the list includes astronomy, physics, chemistry, physical geography, zoology, botany, biology, geology, general science, physiology, hygiene and sanitation, household economics, and agriculture.

In 1895, of all students enrolled in all high-school subjects, approximately 65 per cent were enrolled in science subjects, not including those in physiology, hygiene and sanitation, household science, and agriculture. This figure must be interpreted in terms of the aggregate enrollment. High-school students are ordinarily enrolled in four or five subjects; the aggregate enrollment therefore is more than 400 and less than 500 per cent of the actual number of different pupils enrolled.

The students enrolled in science subjects in 1922 constituted approximately 53 per cent of the students in all high-school subjects. However, the decrease has been in the "book" subjects and not in the "laboratory" subjects. Physical geography, astronomy, and geology have almost disappeared from the curriculum. Zoology and botany are giving place to biology, and physiology to hygiene and sanitation. The sciences of agriculture and household economy have come into the curriculum, and general science is fast becoming the first-year subject.

In fact, it seems safe to say that four subjects now dominate, and that the majority of high schools with four years of sciences are now giving general science in the first year, biology in the second, and

[1] In the preparation of this bulletin the author has had the cooperation and active assistance of well-known science instructors, Dr. Neil Gordon, University of Maryland, and editor Chemical Education Prof. Earl R. Glenn, head science department, Lincoln School, Teachers College, Columbia University, N. Y.; Louis T. Mattern, McKinley High School, Washington, D. C., and chairman of laboratory committee of the American Chemical Society; Francis M. Crowley, Director Bureau of Education of the National Catholic Welfare Conference; C. G. Campbell, of Kewanee, Wis.; S. L. Redman, of Chicago Ill.; and others.

physics and chemistry in either order in the third and fourth. Hygiene and sanitation, agriculture and domestic science often replace the general science or biology, but perhaps more often parallel them as special subjects for those interested in them both as pure sciences and for practical purposes.

For the purpose of this bulletin, laboratory and equipment for these four universal subjects are included. The scientific laboratory work in agriculture, domestic science, and hygiene and sanitation will in practically all cases be carried out in the chemistry, physics, or biology laboratory. Practical work requires vocational rooms and equipment. Their equipment is not included in this publication.

Number of Laboratories Needed

Very few high schools need more than a single laboratory for each of the four principal high-school science subjects: Chemistry, physics, biology, and general science. In all but very large schools the general science classes may well use the other laboratories, particularly the biology laboratory. Smaller schools often use a single laboratory for physics and chemistry, and another laboratory for biology and general science. In the smaller schools where there are but three or four classes in all sciences altogether, a single laboratory for all will suffice, provided it is equipped with special furniture for student desks, and with sufficient cabinet and storage room, and apparatus, equipment, and supplies.

Waste in Laboratory Space

Studies made in many high schools show that few laboratories are used to their capacity. Dr. P. C. Parker made a recent study in eight cosmopolitan high schools in New York City. His results are given in a bulletin published by Teachers College, Columbia University, Housing of High-School Programs. Doctor Parker found in the eight high schools chemistry laboratories with a total capacity of 4,350 students, but with a total enrollment of 1,787 students or 41 per cent of the capacity. Physics laboratories in the eight schools had a capacity of 3,010 pupils and an enrollment of 863, or 29 per cent. The biological laboratories were used 56 per cent of their capacity. In other words, the chemistry laboratories were idle 59 per cent of the time; physics laboratories, 71 per cent; and the biological laboratories, 44 per cent.

This waste is particularly noticeable in smaller schools. A recent study, made from statistics of the United States Bureau of Education and others, shows that between 80 and 85 per cent of all public high schools have but one instructor in the sciences, or the equivalent of but one full-time instructor. This means that not over one science class is or need be at work at any one time and therefore that not more than a single laboratory is or need be in use at one time. On the days when science classes are scheduled for classroom recitations and for lecture demonstration the laboratories in most cases are not in use at all. For all of these one-science-teacher schools a single laboratory, specially equipped, is sufficient and is a considerable economy in space and in building costs.

What Rooms Are Necessary For Science Classes

Science courses include, of course, both laboratory exercises performed by the pupils themselves, and classroom demonstrations by the instructor; also recitations. Provision must be made, therefore, for a place for recitations which may also be used for demonstrations by the instructor. In general science and biology the laboratories themselves are usually used, pupils remaining seated at their work tables. This is possible because work tables for these subjects are usually of the same height as ordinary laboratory tables.

In physics and chemistry laboratories, with the ordinary type of desks used, this plan can not be followed, as the tables are not suited for pupils to sit at in comfort. Three plans are followed: (1) A separate demonstration and recitation room is provided especially equipped for demonstration work, one for physics and one for chemistry in the very large schools, but in others a single lecture room usually placed between the chemistry and physics laboratories and used for both classes; (2) laboratories are made large enough so that space at one end may be fitted with a lecture table and students' tablet armchairs; (3) special furniture is used, of a newer type than the customary chemistry desks and physics tables, which permits work both standing and sitting and which may be used comfortably by pupils when watching a demonstration or engaged in a recitation.

The separate demonstration and recitation room has much to commend it, and certain points which are not of an educational advantage. When placed as stated above, with the supply rooms of the two laboratories adjacent to it, one on either side, equipment and apparatus are convenient to the instructor. The lecture room itself may be equipped with certain permanent apparatus, such as a stereopticon lantern, shades to cover the windows and darken the room for experiments in light, etc. The seating capacity should be double or triple that of any laboratory at any one time, so that two or three laboratory divisions may be combined for special demonstrations.

Such a lecture room is convenient but is an expensive room, not only because of the space occupied but because used relatively little of the time. Studies show that with this arrangemant the lecture room is usually vacant from 50 to 75 per cent of the hours schools are in session.

Classroom space in each laboratory is a decided educational advantage because of the convenience. The instructor may stop individual work at any time and assemble his class for instruction or demonstration. He also has a place available where the more rapid students, when they have completed their experiments, may sit and write up their notes or study, out of the way of others who are working and still under his observation. Its principal disadvantage is again the waste of space and also the necessity of duplicating certain pieces of apparatus used in both chemistry and physics. With this arrangement each laboratory requires from 25 to 35 per cent more floor space than under the third arrangement mentioned below.

FIGURE 1.—PHYSICS LABORATORY, LINCOLN SCHOOL OF TEACHERS COLLEGE, COLUMBIA UNIVERSITY, NEW YORK

By the use of especially designed furniture for physics and chemistry found satisfactory during the past half-dozen years, the students' work desks may be used for seated work, and the separate lecture-room or classroom space at the end of the laboratory omitted. The only additional space required over that necessary in the ordinary laboratory is enough for an instructor's demonstration table. This means usually a room from 6 to 8 feet longer than would be required otherwise. Details of this plan are given later. The Lincoln School of Teachers College, Columbia University, is equipped with such furniture. One of its laboratories, which is also a demonstration room, is illustrated in Figure 1.

Laboratory Furniture

There are certain features of laboratory furniture common to all laboratories.

The furniture must be well constructed, and its construction involves many points not understood by anyone except those who have made a special study of the subject. It must be remembered that laboratory furniture is subject to unusual hard usage.

In practice (1) furniture is obtained from factories specializing in laboratory furniture as a contract separate from the building contract but purchased from the general building fund, or (2) it is designed by the school architect and included in the general contract to be built by the contractor or by such millwork shop or cabinet shop as he may select.

The first method is the one to be recommended. The six or eight laboratory furniture manufacturers specializing in this product are able to produce a much better product than can be produced by others at a like cost. Their furniture is made by experts whose experience over years determines what is best in design, material, and construction. It must be remembered that the furniture in the school laboratory is subjected to many severe destroying agencies,—rapid and extensive changes in temperature and in humidity, and also direct water damage from spilled water on tops and sides; action of acids, alkalies, and chemical fumes of all sorts; rough student usage from standing pupils, particularly severe on cupboard doors, drawers, etc. Sinks and plumbing and drain pipes are all subjected to direct action of acids and other chemical reagents discharged through them. Laboratory experts understand all these problems and insure against them so far as possible. Building contractors and cabinetmakers, or furniture makers from whom they might obtain them, do not. In fact very few architects understand them or even realize that the laboratory presents furniture problems any different from the ordinary classroom.

When the architect's general plans for the building are completed, the furniture should be selected. The details for plumbing may then be determined upon, and floor lines for water, gas, electricity, and drainage, and for air pressure, hydrogen sulphide, and other accessories when desired may be properly provided for. Also, the artificial lighting may be placed to the greatest advantage. All of these details are best worked out by laboratory engineers, their plans being incorporated by the architects in their final drawings. Such engineering service is available from the better manufacturers of laboratory furniture usually without expense to the school board or architect.

General Specifications of Laboratory Furniture

The laboratory desks for students and instructor to be durable should be cabinet made of hardwood, oak to be preferred except for tops. Metal cabinets seem to be subject to deterioration due to chemical fumes. The wood must be selected and dried as for any other good furniture. Ply wood for panels, partitions, rears, and drawer bottoms should be used to lessen the dangers of splitting. The entire interiors should be varnished to prevent the absorption of water. The outside should be filled, stained, and varnished in harmony with the woodwork of the laboratory. From 3 to 4 coats of the best varnish is necessary to withstand the peculiar destructive agencies in the laboratory.

Laboratory tops in chemistry are usually wood or soapstone. Occasionally tile, glass, slate, composition board, or enamel ware are used, but experienced school and college men prefer the well-made wood tops or the soapstone. In physics, biology, and general science wood tops are used almost exclusively.

The wood tops which seem to be most satisfactory are made of 3 or 4 inch strips of hard birch put together with a glued tongued-and-grooved joint. Such tops are from 1½ to 2 inches in thickness and are made by the best manufacturers in one piece up to 36 feet in length. These are practically nonwarping and give rigidity to be secured in no other way. These tops are planed and sanded to a smooth surface, treated on the underside with a moisture and acid-resisting lead paint, and on the top with a standard acid-resisting treatment which leaves them with a black, velvety finish.[2] By

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[2] SOLUTION NO. 1

Black acid-proof finish

1½ lbs. copper sulphate.
1½ lbs. chlorate potassium.
2 gals. rain water, and boil until dissolved.
Always apply this solution hot.

SOLUTION NO. 2

Black acid-proof finish

3 qts. hydrochloric acid.
1 qt. aniline oil.
2 gals. rain water, and mix.
Add ½ pint of solution No. 1 to this solution to make a better black stain.
Always apply this solution cold.

Directions for applying acid-proof solution

Apply solution No. 1 hot, with a stove brush. Heat this solution by steam or hot water, not over a fire.

Let dry about 4 or 5 hours, then apply solution No. 2 cold and let dry for about 6 hours. Then apply solution No. 1, hot again, and let dry 6 hours. Then apply solution No. 2, cold again. Let this dry for 10 hours. Then oil the tops with half naphtha and half boiled linseed oil and let dry for 3 hours. Then scrape with a steel scraper, taking care not to cut through to show the white wood. Then rub with steel wool. Then sand smooth with fine sandpaper. Then apply prepared paraffin with a brush, hot, and rub off with sea moss or rags.

weekly washing with soap and water and by oiling[3] two or three times a year, these tops retain their clean, finished appearance for many years.

Soapstone tops are made of sawed and honed stone slabs 1¼ inches thick and up to 6 feet in length. Care must be taken to select stone without calcide streaks, which would disintegrate rapidly from acids; also from strictures which may result in tops cracking with any settling there may be in the building. Joints between slabs are made water-tight with litharge and pure glycerine cement, which must be renewed every few years. Center troughs for drainage are usually of wood, lead-lined, with burned joints, so that there will be no solder for acid action. This trough, if heavy lead is used, will prove as permanent as the building. Soapstone troughs are also used. Joints must be watched and cemented as soon as leakage takes place.

Great care must be taken in the cabinetwork. Drawers will stick unless made with the peculiar conditions of the laboratory in mind. Cupboard doors will soon crack and break from hard usage by standing students unless exceedingly well made. The space along the front of the desks prevents the marking of the furniture from boots and shoes and at the same time permits the student to stand close to the desk.

Sinks are chemical stoneware or soapstone. Enamel is sometimes used but is not very satisfactory. In the chemistry laboratory, in addition to the sinks on the desks, one wall sink should be provided. This should have a faucet 3 to 4 feet above the bottom of the sink to facilitate washing glass tubes, burettes, etc.

Hardware and plumbing fixtures in the laboratory require special care in the selection because of the severe effects on them of chemical fumes. As little metal as possible should be used in laboratory fixtures. Fittings should be of a high-grade red-metal, triple nickel-plated. Brass is used but does not resist the action of chemical fumes so well as red-metal. Brass is satisfactory, however, for hinges for doors and for locks. All piping for water, electricity, and air should be heavily galvanized iron. Gas pipe should be black iron. Joints must be made with particular care, using a deep thread and the best red lead or other standard joint compound. All drain piping should be of pure lead pipe of a heavy weight, with all joints burned instead of soldered.

Chemistry Laboratory

One-year High School Course

There is no special size that the chemical laboratory must be, except to be large enough to furnish space for students' desks so that each student will have working space, and for the additional equipment,

[3] A mixture of 1 part linseed oil and 1 part turpentine gives excellent results for this purpose.

including fume hoods, balance tables, and cabinets for apparatus. From 25 to 40 square feet per student is recommended by various authorities.

The size is determined largely by the number of pupils to be accommodated in the laboratory at one time. Common practice determines that not over 24 pupils may work in the laboratory at the same time under the supervision of a single instructor without neglect of the individual needs. Thirty pupils to the class is not an uncommon practice, although it makes a larger group than is desirable. In larger schools, where an assistant instructor is available, laboratories for 40 to 60 pupils are satisfactory.

FIGURE 2.—CHEMISTRY LABORATORY, JENKINTOWN (PA.) HIGH SCHOOL

For a class of 24 pupils, the room to be used as a laboratory only, the standard classroom 22 or 24 feet by 32 feet may be used, although a room 38 feet in length is very desirable. This permits the use of three double student tables each 3 feet high, 12 feet in length, and 4 feet wide, placed crosswise with the room.

This gives the best arrangement for lighting and gives ample room on the inner wall for cabinets, balance shelves, and fume hoods. Of course such a laboratory may be used by two classes of 24 pupils each day, or if extra storage space is provided to the drawers and closets in the desk, a third class may use the room. Figure 2 is a photograph of a standard 12-foot desk for accommodating 16 students in two sections. Each student has a cupboard, one large and one small drawer. A trough runs the length of the desk to the end sink. Water, gas, and electricity are provided in open plumbing underneath the lower reagent bottle shelf. A similar desk is often used, but with two center sinks and concealed plumbing. Many variations of these two forms are found in different schools.

The number of chemical fume hoods for the high-school laboratory depends to a large measure on the general ventilation system of the building and the room itself. If the building has a good system of supplying fresh air, and a gravity or plenum exhaust system for the removal of impure air, one 6-foot hood is sufficient. If the room has poor ventilation, additional work must be done under hoods, and two 6-foot hoods are d sirable. These hoods are connected to a chimney, and draft is assisted by gas burners in the upper part of the hood or, better, by electric exhaust fans.

One balance shelf or table, 8 feet long and 24 inches wide, is sufficient for the high-school laboratory. Cabinets must be provided for the storage of apparatus and chemicals unless a supply room is provided.

Physics Laboratory

Much of what has been said relative to the chemistry laboratory applies to the physics laboratory. For a class of 24 there should be provided 6 tables approximately 30 inches high and 6 by 3½ feet in size, each for four students. Some instructors prefer 12 or 18 or 24 foot tables for 8, 12, or 16 students, respectively. The majority seem to prefer the 6-foot tables, as each student has a corner to himself and may work from the side or the end. Figure 3 shows an ordinary type. The woodwork is of oak, the top of built-up birch, with an acid-resisting finish. Instead of wood uprights and crossbars, many prefer metal uprights which screw into flush plates set in the surface of the table and with either wood or metal crossbar. This is illustrated in Figure 4.

Physics tables are usually equipped with gas and electricity. Outlets are on the side in the end rails, so that the tops are clear. Electrical outlets should be inclosed in an iron box, as required by the National Electric Code. No sinks are required on the tables, but the laboratory should have two wall sinks, at opposite ends of the room, if possible. The physics laboratory must be equipped with cabinets for apparatus and supplies, unless a convenient storage room is provided.

Biology Laborato

For biology, tables of the ordinary desk height (30 inches) are required, as most of the work is done sitting down. Tables may be 6, 9, or 12 feet in length and arranged for students on one side or on both

FIGURE 3.—PHYSICS LABORATORY, KEWATIN (N. Y.) HIGH SCHOOL

FIGURE 4.—PHYSICS LABORATORY, J. STERLING MORTON HIGH SCHOOL, CHICAGO, ILL.

sides. For 24 students, 6 tables approximately 12 by 2 feet are very satisfactory, or 4 tables 18 feet long make a good arrangement. Figure 5 shows a laboratory with these 18-foot tables.

The laboratory should be equipped with an aquarium having plate-glass sides, with a museum case for the display of specimens, a germinating bed for planting specimens and watching the development of plant growth, a case for the storage of microscopes and a cabinet for other apparatus. Chemicals should never be stored with microscopes or other apparatus in the same case in any laboratory.

FIGURE 5.—BIOLOGY LABORATORY, FAIRPORT (N. Y.) HIGH SCHOOL

General Science

There is less general agreement among educators relative to the general-science laboratory and what equipment it should have. This is because of the great variety of subject matter included in textbooks and courses in general science, and to the different viewpoints of various authorities. The consensus of opinion is well summarized in the report of the Commission on the Reorganization of Secondary Education. The following is quoted from the report of its subcommittee on science:[3]

This introductory course in science is not a substitute for any one of the special sciences, but should provide a basis for discovery of interest in special sciences and of vocational opportunity. It should prove to be the best training for any pupils who can take only one course in science in high schools.

[3] Reorganization of Science in Secondary Schools. Bull., 1920, No. 26, U. S. Bu. of Educ.

Selection and organization of subject matter.—The subject matter of general science should be selected to a large extent from the environment. Science is universal and constant in the life of our citizens, and hence to be useful to all pupils, general science must accept the science of common things as its legitimate field. The science of common use and that of the classroom should be the same. General science should use any phase of any special science which is pertinent in the citizen's interpretation of a worth-while problem.

The particular units of study should be those that truly interest the pupils. Interest not only secures productive attention but is an evidence of attention. To be substantial educationally, interest must rest upon a sense of value, an evident worthwhileness in the topics considered.

No topic should be selected which is meagre in content or lacking in significant problems. The range of material which can be used is in reality limited only by the capacity, experiences, and needs of the pupils. The materials should be concrete and capable of leading to many avenues of new and untried experiences.

Another thought relative to general sciences should be kept in mind, as it has much influence on the course and on the laboratory equipment needed. General-science courses are given usually in the junior high school or in the first year of the regular four-year high school. This means that the boys and girls in general science classes are in their adolescent years when they turn from bookish knowledge to practical things and crave physical activities. General science is, therefore, found to be an excellent study for these ages when taught through the laboratory and project method. It takes its place, with manual training and industrial arts, as an outlet for physical activities. It satisfies the "practical" turn of mind on the part of the pupils by giving them the opportunity of making practical use of their arithmetic, geography, and ability to read. Educators are fast coming to the opinion that general science fulfills a long-felt need in the curriculum when taught, not as a textbook subject nor as a demonstration subject by the instructor, but as a laboratory subject with individual work by each student in the school laboratory and on the outside project.

In the four-year high school where the chemistry, physics, and biology laboratories are not in full use, they may be used for general science, the biology laboratory mostly, but the physics and chemistry as needed. Where the school uses these three laboratories full time for the work for which primarily intended, a separate general-science laboratory must be provided, and often two laboratories. This is because the school with enough pupils to use its chemistry, physics, and biology laboratories full time or nearly full time, will ordinarily have more pupils in general sciences than can be cared for in one laboratory. General science, it must be remembered, is usually a first-year subject in the secondary school curriculum, and the enrollment in this subject will be nearly twice the enrollment in a fourth-year subject, such as chemistry.

The general-science laboratory should be fitted with student desks 30 inches high, similar to those in the biology laboratory. A demonstration table for the instructor and chairs for pupils should be provided so that the classroom recitations and demonstrations may be held in the same room, with the pupils sitting at their worktables. Two kinds of tables give satisfaction, the long, double table with pupils working on both sides facing each other, or the narrow tables with students working on one side only and all facing the same direction. This latter is preferred by most instructors. With the wider tables the instructor's desk must be at the end of the pupils' tables, so that pupils may turn half facing the instructor when desired.

FIGURE 6.—GENERAL SCIENCE LABORATORY, JOHN BURROUGH'S SCHOOL, ST. LOUIS, MO.

This arrangement should be avoided if possible. With the narrow tables the instructor's desk is in the end of the room, faced by all pupils at all times. (See fig. 6.)

For a class of 24 in one section, three 12-foot double tables or six 12-foot single tables are necessary. Each table should be equipped with gas. The double tables are 36 inches wide, the single tables 24 inches.

The instructor's desk should be approximately 8 feet in length and 3 feet in width, with cupboard and drawers and an acid-resisting nonwarping top. It should be equipped with gas, water, electricity, a sink approximately 20 inches by 20 inches by 12 inches, with a cover fitting flush with the top of the table. It should have flush plates for fitting uprights to hold a crossbar as in physics tables.

In addition the general-science laboratory should have an aquarium similar to that of the biology laboratory and a germinating bed for work in plant life. Best for the latter purpose is a water-tight box 4 inches deep, 2 feet wide, and from 4 to 8 feet in length. It is mounted on a frame with legs 2 feet high and fitted with double roller swivel castors. Cabinets for specimens, and also for apparatus, chemicals, and other equipment are necessary unless a storage room is provided.

Lincoln School Special Furniture

The Lincoln School of Teachers College, Columbia University, has been referred to as an example of a secondary school equipped to use all of its laboratories for both individual and demonstration work. It is equipped with special furniture, mentioned previously, which makes this possible. This was designed by the director and the instructor in sciences after several years of experience and study.

For dual use under this plan, the chemistry and physics laboratories must be slightly greater in length to accommodate the instructor's demonstration table—6 to 8 feet additional is sufficient. This is less than one-half the space needed in the rather common arrangement where one end of the laboratory is used for classroom purposes, and very much less space than required when a special lecture room is provided.

In the Lincoln School the laboratories for physics and chemistry each provide space for 24 pupils. Each table is made up of T-shaped units, each unit for two students with one sink in common. All students face the instructor's desk. The floor plans shown on page 15 and the view of the physics desk on page 4 indicate the general features of the desk. The chairs for the pupils are placed under the ends of the wings of the table when not in use by the pupils.

Apart from the shape, these tables differ from other forms principally in height. They are 33 inches high, 3 inches higher than ordinary library tables, and 3 inches lower than other chemistry tables. The height has proven satisfactory for standing pupils, and is satisfactory for sitting pupils when a special chair, designed to accompany the furniture, is used. This chair is 2 inches higher than the ordinary chair and is equipped with a rail 2 inches wide on the front legs on which the student's feet may find rest and support.

Many high schools throughout the country are using similar tables for both chemistry and physics. This is a simple arrangement, provided cupboard and drawer and cabinet space is arranged for the extra apparatus. The chemistry reagents used by the pupils are in

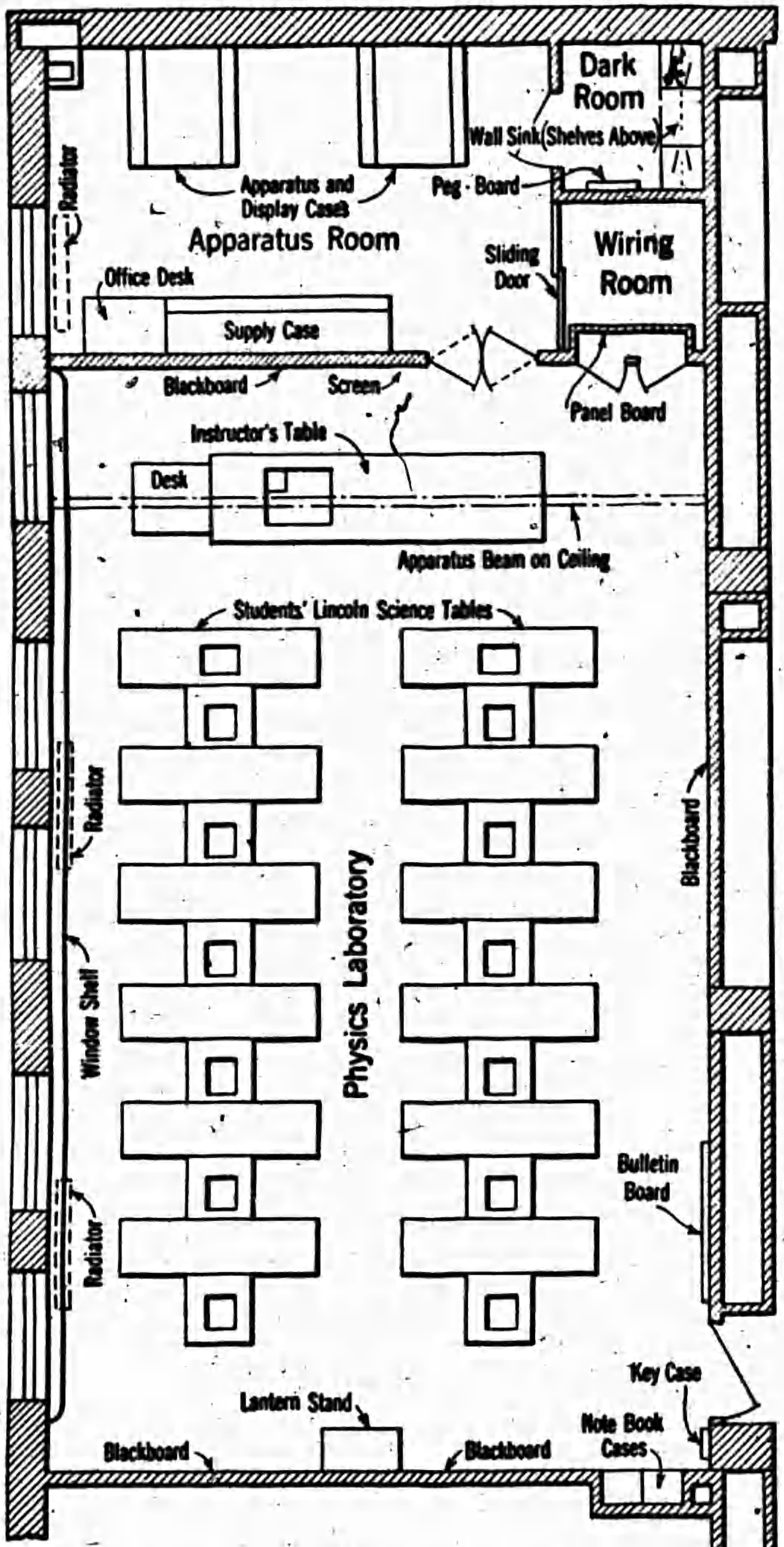

FIGURE 7.—PHYSICS LABORATORY, LINCOLN SCHOOL OF TEACHERS COLLEGE, COLUMBIA UNIVERSITY; NEW YORK

bottles in a tray instead of on a shelf. These trays are placed by the pupils inside the desk when not in use, or in some schools on wall or cabinet shelves. The tables, when used for both subjects, are fitted with flush plates, so that uprights and crossbars may be used.

The advantages of the use of this furniture are summarized by Dr. Otis W. Caldwell, director of the Lincoln School, as follows:

A. The science work can be done by the student in one room and in one place.

B. Students face the instructor all the time.

C. The desks provide for comfortable work in a standing or sitting position. Students may write notes, make drawings, or reference reading, perform laboratory experiments or observe demonstrations by the instructor without moving from their places.

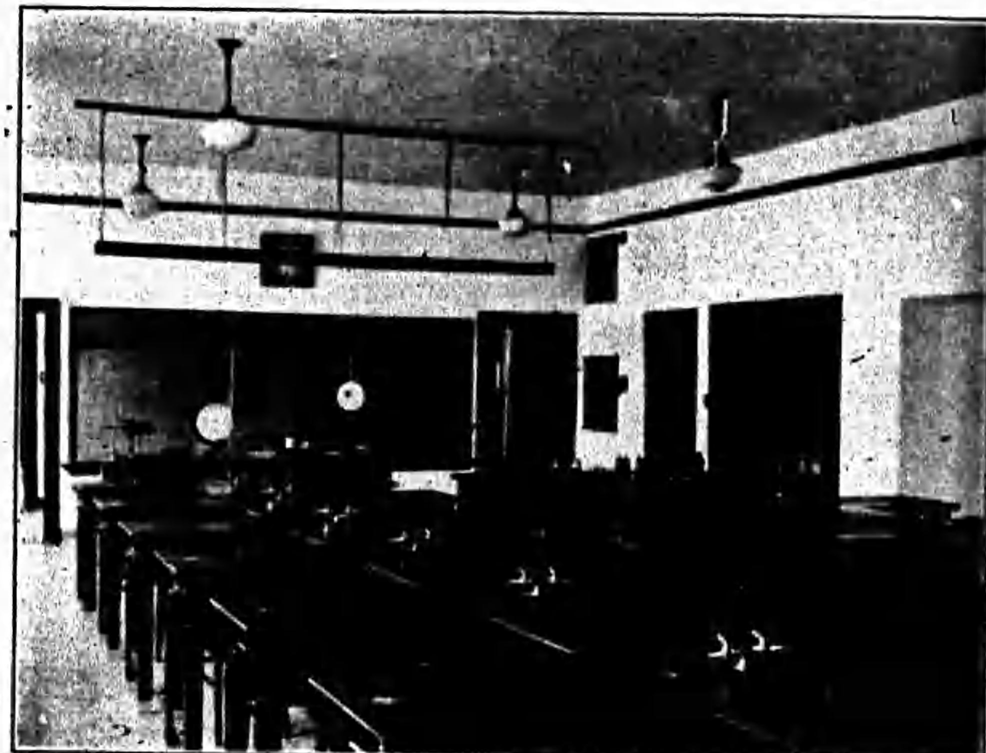

FIGURE 8.—PHYSICS LABORATORY, PRINCETON TOWNSHIP HIGH SCHOOL, ILLINOIS

D. The instructor may give demonstrations, quizzes, direct reference work and hold class discussion in the same room at any time during the science period, thus eliminating fixed laboratory and demonstration schedules.

E. Instructor can see any student in the entire class from any location in the room, which allows better laboratory control, at the same time the pupils wherever seated can see demonstrations by the instructor on his desk.

F. Apparatus is stored where used, and individual storage spaces for students are provided.

G. The instructor's labor is reduced by concentrating all tools, materials, and equipment in a much smaller floor space than is usual in the design requiring separate lecture room and laboratory.

Lecture Room

When necessary to provide a recitation and demonstration room separate from the chemistry and physics laboratory it should be equipped with an 8 or 12-foot instructor's table, and with student chairs which permit easy writing of notes. Arm-table chairs are satisfactory.

The instructor's table should have sufficient cupboard and drawer space for equipment and should have an acid-resisting wood top. The table should be provided with water, gas, and electricity, and should have a large sink with a flush cover. In the better-equipped schools, lecture tables are supplied with hot as well as cold water, both alternating current and direct current, and other accessories. Flush plates and uprights and crossbars are also provided.

FIGURE 9.—DEMONSTRATION AND LECTURE ROOM, CORTLAND STATE NORMAL SCHOOL, NEW YORK

A question is often raised relative to the floor of the lecture room, whether it should be flat or terraced as in an amphitheater. If the room is to be used only for classes of the ordinary size, or for two or three sections combined, the flat floor is satisfactory, and the increased cost of the construction of raised platforms is avoided.

The lecture and demonstration room should be provided with shades, so that it may be darkened, a good stereopticon lantern, an opaque projector, and a screen on a roller at the front of the room.

Equipment for Chemistry

Three kinds of apparatus are required: (1) General apparatus for the demonstration and laboratory use of pupils and instructors; (2) special demonstration apparatus for class demonstrations by the

FIGURE 10.—LECTURE ROOM, J. STERLING MORTON HIGH SCHOOL, CHICAGO, ILL

FIGURE 11.—CHEMISTRY AND PHYSICS LABORATORY, PUBLIC HIGH SCHOOL, SWEDESBORO, N. J.

instructor only; (3) individual student apparatus. In addition, a supply of chemicals is needed for students and instructor and extra reserves of glass and other destructible equipment for replacements. Lists of all three are given below. Special mention is made of a few of the important pieces.

Balances.—One analytical balance is sufficient for most high-school laboratories. In addition, one to three accurate balances of the triple-beam type should be provided, depending upon the size of the school. The trip scales in the list will be used for all rough work.

Distilled water is essential in the laboratory. Satisfactory automatic stills may be obtained for from $25 up. For the small school, self-contained stills for use on hot plates may be obtained for $15.

Gas is also essential for the best work. If public gas is not available, a private gas-making machine should be installed or compressed gas stored in cylinders used. The cost is from $200 upward. For schools that can not afford this, alcohol lamps must be used, supplemented by special gasoline torches. If electricity is available, very satisfactory results may be obtained with specially arranged electric heaters, which will serve all purposes except bending and blowing glassware, for which a gasoline torch may be used.

One gasoline blowtorch or a blast lamp with foot bellows (or other source of air pressure) for use with city gas is desirable.

Drying oven and water bath are very desirable. They may be heated by electricity or gas. Complicated and expensive types are not needed for elementary courses such as are included in the high-school curriculum.

A gas generator for hydrogen sulphide, hydrogen, carbon dioxide, and other gases should be in any well-equipped laboratory. A simple form in glass may be obtained for a few dollars; others in stoneware and metal cost from $20 to $100.

LABORATORY EQUIPMENT FOR FIRST-YEAR CHEMISTRY

List A—Desk Apparatus (for 24 Students)

24 alcohol lamps, 4 oz. (or 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. 111, for sodium hydroxide.
12 reagent bottles, No. 102, for sulphuric acid.
24 burette clamps.
24 crucible tongs.
24 cylinders, plain, 2 by 12 inches.
24 deflagration spoons, iron.
24 files, round, 4 inches.
24 files, triangular, 5 inches.
24 guaze squares, iron, asbestos centers, 5 inches.
24 mortars, with pestles, porcelain, 80 mm.
24 pneumatic troughs, galvanized armco iron.
24 ringstands, 2 ring.
24 sand baths, shallow, 4 inches.
24 test tube racks.
24 tripods.

Approximate cost, $140.

List B—Individual Apparatus (for 24 Students)

24 asbestos sheets, 5 by 5 inches.
24 beakers, 100 cc.
24 beakers, 250 cc.
24 beakers, 400 cc.
48 bottles, wide-mouthed, 2 oz.
72 bottles, wide-mouthed, 8 oz.
24 burettes, 50 cc.
24 cobalt glass plates, 50 mm. by 50 mm.

24 crucibles, porcelain, No. 0.
24 dishes, evaporating, porcelain, 75 mm. No. 00A.
24 flasks, 250 cc.
24 flasks Erlenmeyer, 125 cc.
24 funnels, 75 mm.
24 gasometers, 50 cc.
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.
24 rubber stoppers, 1 hole No. 8.
24 rubber stoppers, 2 hole No. 4.
24 rubber stoppers, 2 hole No. 8.
24 rulers, Eng. and met., 12 inches.
24 spatulas, horn, 150 mm.
24 test tubes, ignition, 6 by ¾ inch.
24 test tube brushes.
24 test tube racks.
24 thermometers, −10° to 110° C.
8 thistle tubes.
424 watch glasses, 3 inches.
Approximate cost, $185.

List C—Apparatus and Stock for General Use

24 aprons, rubber.
3 balances, trip scales, agate bearings.
3 sets weights, iron, on holder, 10–500 g.
6 hand balances, improved.
6 sets weights, in blocks, 1 ctg.–20 g.
48 bottles, wide-mouth, glass stoppers, 4 oz.
12 calcium chloride tubes, 6 inches.
12 combustion tubes, 45 by 1.9 cm.
12 combustion boats, porcelain, 60 by 10 by 10 mm.
12 condensers, Liebig, 15 inch.
12 condenser clamps.
12 condenser clamp holders.
3 sq. ft. copper sheet, No. 30.
3 spls. copper wire, bare, No. 28, 4 oz.
3 pkg. corks, asstd. 0–11 (144).
3 cork borers, (6 in set).
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., asstd.
5 lbs. glass tubing, 5–7 mm. asstd.
3 hydrometers, universal.
3 hydrometer jars, 2 by 15 inches.
3 spl. iron wire, No. 28.
12 vials litmus paper, blue.
12 vials litmus paper, red.
8 magnifiers, tripod.
12 platinum loops, in glass handles.
1 roll picture wire, No. 1 (25 yds.).
8 retorts, glass stopper, 125 cc.
60 ft. rubber tubing, $\frac{3}{16}$ inch.
30 ft. rubber tubing, ¼ inch.
288 test tubes, soft, 4 by ½ inch.
144 test tubes, soft, 6 by ¾ inch.
8 water baths, copper, 5 inches.
Approximate cost, $225.

List D—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 potassic.
1 lb. aluminum, metal turnings.
1 lb. aluminum, metal powder.
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, lumps, 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, metal.
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.
4 oz. copper oxide, wire, C. P.
2 oz. eosin.
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, 3 per cent U. S. P.
hydrogen sulphide (make in laboratory).
2 oz. iodine, resub. cryst.

5 lbs. iron filings, clean.
5 lbs. iron powder.
2 sq. ft. lead, metal, sheet, 1/16 inch.
2 lbs. lead acetate, cryst., com'l.
2 lbs. lead nitrate, cryst., com'l.
5 lbs. lime (quicklime), in tin can.
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, medium.
4 oz. phenolphthalein, U. S. P.
8 oz. phosphorus, red.
1 lb. phosphorus, yellow, sticks.
5 lbs. plaster of Paris.
1 lb. potassium bitartrate, U. S. P.
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.
4 oz. potassium perchlorate, cryst., U. S. P.
2 lbs. potassium sulphate, C. P.
1 lb. rosin.
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 (procure locally).
2 lbs. sugar, glucose (dextrose) lump.
5 lbs. sulphur, roll.
1 lb. tartaric acid, U. S. P., cryst.
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.

Approximate cost, $100.

List E—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.
24 thistle tubes

Approximate cost, $50.

Summary

Desk apparatus for 24 students	$140.00
Individual apparatus for 24 students	185.00
General apparatus	225.00
Chemicals	100.00
Reserve stock	50.00
Approximate total cost	700.00
Annual replacement	240.00

Additional Desirable Apparatus for Lecture Desk and Laboratory, with Approximate Costs

1 Alpha Ray track apparatus, for showing path of helium atoms	$35.00
1 balance, analytical, cap. 200 g., sensibility 1/10 mg., with rider beam and rider, in case	65.00
1 set balance weights, 1 mg. to 50 g., in block with hinged cover	12.00
1 barometer, mercurial	27.50
1 bellows, foot, for blast lamp	10.50
1 blast lamp, for artificial gas	4.00
1 chart, atomic weight	3.60
1 chart, periodic law	3.50
1 chart, spectrum, common elements	5.75

1 distilling apparatus, for gas	$25.00
1 drying oven, for gas	15.00
1 electrolysis apparatus, on support	12.00
1 eudiometer, 100 cc.	3.20
1 grating spectroscope	40.00
1 spectrum tube, neon	6.00
1 water bath, electric	25.00

Physics Laboratory

It is generally conceded that the outline for the students' laboratory course should contain 35 to 45 selected experiments, although instructors differ as to what these experiments should be. Whatever they are, however, the ideal equipment would provide each student with the necessary apparatus, time, and opportunity to

FIGURE 12.—PHYSICS LABORATORY, ROCHESTER (N. Y.) HIGH SCHOOL

investigate and demonstrate the principle involved in each. For the most commonly accepted experiments this ideal equipment would consist of one set of apparatus and supplies for each experiment for each student. Practical conditions, such as the lack of space, funds, and in some cases the nature of the experiment itself, render this impossible or inadvisable. It is therefore found necessary to have two or even four students work together on a given exercise, with apparatus provided accordingly. Where particularly costly apparatus is required and funds are not plentiful different groups may work on two or more different exercises at the same time, alternating these experiments among the groups from laboratory period laboratory period, thus effecting a saving in the amount of individual apparatus required.

If this plan is followed, care should be taken that the alternate exercises be sequential and of the same general subject matter, so as to violate as little as possible the general tenets of pedagogy and not to add too greatly to the difficulties of the instructor.

Below is given a suggestive list of students' apparatus, which should be modified to suit local conditions in accordance with the foregoing statements:

General Equipment

A manual training bench or its equivalent, fitted with a small machinist's vise, preferably of the swivel-jaw type, and a small assortment of metal and woodworking tools, is a necessity in the larger high schools and will be found convenient and economical even in the smaller ones.

Sources of electrical current.—Direct current of 6–8 volts commercial is a necessity. Its source may be dry cells and Daniel cells; or storage batteries or motor-generator outfit, where 110-volt A. C. is available. Dry cells are useful in most experiments but do not furnish a constant current and are expensive where heavy current is required. Storage batteries for the smaller high schools, with a rectifier for recharging from 110-volt A. C. lighting line will be found very satisfactory. The Edison type of storage battery is to be preferred, as it can not be overcharged and is not damaged by short-circuiting or undercharging. It may be allowed to sit idle during the summer vacation and recharged for successful use in the fall. Lead-plate storage batteries are easily injured by short-circuiting. They must be kept constantly charged and are easily damaged by misuse. Motor-generator sets are now available with A. C. motors and D. C. generators, having double commutators which furnish 45 watts of direct current at 6 to 8 volts and 200 watts at 110 volts simultaneously. The costs of motor-generator sets without switchboards vary from $75 to $140, the larger sets with switchboard in proportion.

A switchboard with the necessary fuses, switches, resistances, meters, and current leads to laboratory desks is also useful and a necessity in the larger schools. Switchboards cost from $60 up to $700 or $800, depending upon specifications.

A laboratory clock with seconds pendulum and mercurial contact, or its equivalent, should be provided if possible.

A mercurial barometer of fairly reliable accuracy for general use in laboratory and lecture room should be considered a necessity. Some of the above items are included in the lists given below.

Physics Lecture-Room Apparatus

The equipment for the lecture room should be built around four or five main pieces, which are suggested as follows:

Rotator.—This piece may be hand operated, although a motor-driven type with variable speed and revolution counter is much to be preferred. If the revolution counter is of the type which may be thrown in and out of gear with the rotator by means of the thumb, quantitative experiments may be done by one person. If of the other type two are required, one to check the time and the other to check the number of revolutions. Such accessories as the centrifugal hoop, centrifugal force apparatus, acoustic and color disks, manumetric flame apparatus, etc., furnish material for useful demonstration by the instructor. A good rotator is sometimes required for some experiments in the students' laboratory.

Air pump.—For a physics class the air pump should be of the best possible type to be afforded, the rotary cam type giving best results. It may be hand operated or motor driven. The two advantages of this type are, first, they have a high degree of vacuum, and second, they do not need adjustments or repairs over a number of years. The ordinary hand pump and pump plate of the automobile type and the platform type with hand lever and pump plate may be used, although they need constant care and repair, and are frequently found inoperative when most needed. The Geryk air pump, with pump plate, has been very popular and found fairly efficient, but strongly subject to the handicap last named above. Accessories suggested are small and large bell jars, hand and bladder glass, baroscope, weight of air apparatus, vacuum wax for sealing joints, etc. If a vacuum of the order of 0.01 mm. or better is available from the pump in use, a good vacuum tube for demonstrating electrical discharge in rarified gases will be found worth while.

Static machine.—This may be large or small, and of the Toepler-Holtz or Wimshurst type. The latter is more reliable in operation and the principle of the former more easily explained to students. With proper accessories, the static machine is useful in the study of electrostatics and always stimulates the interest of students.

Optical disk.—This piece is, from the standpoint of the instructor, practically the whole thing in the demonstration of reflection, refraction, and diffraction in light. While this piece may be used with direct sunlight, it will be found much more efficient, more easily manipulated, and more satisfactory if provided with a thoroughly efficient illuminator. Those on the market are so constructed that they plug in on any 110-volt lighting circuit. The accessories most commonly required are usually provided with the outfit. Additional parts for special demonstrations are listed by the apparatus houses and may be found useful in some situations.

Alternating-current apparatus.—Some sort of apparatus for demonstrating a few of the laws of alternating currents has not been as common a piece of apparatus in the high-school laboratory as the subject warrants. In every high-school physics course an attempt should be made to give the student some conception of the difference between the laws governing alternating currents and direct currents. Apparatus of various types are on the market, and the acquisition of one of them should be seriously considered.

Other pieces are suggested in the list below.

PHYSICS APPARATUS AND EQUIPMENT

List A—Apparatus for Students' Experiments

24 meter sticks, English and metric.
24 rulers, maple, English and metric, 30 cm.
1 vernier calipers.
1 micrometer calipers.
12 trip scales, with agate bearings.
12 sets weights, iron, slotted, with holder, 10–500 g.
3 sets specific gravity metal cylinders.
3 wooden cylinders, waterproofed.
3 wood blocks, rectangular, waterproofed.
3 wooden blocks, rectangular, loaded.
1 lead sinkers, about 175 g.
3 plumb bobs.
4 pressure gages.
30 ft. rubber tubing, ¼ inch.
12 overflow cans.
12 catch buckets.
4 Boyle's law apparatus, J tube.
24 prisms, hardwood for fulcrum.
4 hydrometers, for light liquids.
4 hydrometers, for heavy liquids.
24 spring balances, 2,000 g. 64 oz.
6 composition of Force boards.
12 pulleys, single, bakelite.
12 pulleys, double, bakelite.
12 pulleys, triple, bakelite.
3 center of gravity blocks.
6 inclined planes, with graduated arc.
6 Hall's cars, for inclined plane.
3 wheel and axle, aluminum.
12 resonance tubes, glass 4 by 45 cm.
12 thermometers, −10° to 110° C.
12 air thermometer bulbs, 50 mm.
3 planes, grooved, with steel ball and powder.
12 steam generators.
12 calorimeters, nickeled brass, 75 by 125 mm.
12 tuning forks, C, 128.
12 tuning forks, C, 256.
2 vibrographs (fork-rating apparatus).
2 tuning forks, for above.
24 mirrors, plane, 4 by 15 cm.
12 refraction plates, glass, 7 by 7 cm. by 6 mm.
12 refraction plates, triangular, 75 mm. faces by 7 mm.
6 optical benches.
12 lenses, convex, 15 cm. focus.
12 lenses, convex, 10 cm. focus.
12 prisms, equilateral, 75 mm. with 28 mm. faces.
3 lodestones.
6 rods, soft steel for magnetizing in earth's field, 6 mm. by 10 cm.
24 bar magnets, 1 by 1 by 15 cm.
12 magnets, U-shape.
24 magnet compasses, 25 mm.
24 dry cells.
12 voltaic cells, students' single fluid.
3 dip needles.
6 galvanoscopes.
6 bot. iron filings (4 oz.) in shakers.
12 electromagnets.
4 telegraph sounders, 4 ohm.
4 telegraph keys.
4 telegraph relays.
12 electric bells, 2½-in. gong.
2 electrolysis apparatus, battery-jar type.
2 storage cells.
4 resistance boxes, standard, 0.1–111 ohms.
6 D'Arsonval galvanometer, jeweled pivots.
4 ammeters, DC, double range, 0–3 and 0–30 amps.
4 voltmeters, DC, 0–130 v. in 1-v. divisions and 15 v. in 0.01-volt divisions.
4 wheatstone bridges.
2 commutators, simple form.
24 coils of wire, DCC, 40 turns No. 24.
2 speed indicators.
6 electroscopes.
6 Leyden jars, pint.
6 friction rods, vulcanite, 25 cm.
6 friction rods, glass, 25 cm.
48 pith balls.
6 cat skins, half.
3 fish lines (card).
4 telephone transmitters.
4 telephone receivers.
12 ringstands, 3-ring.
12 test-tube clamps.
24 double connectors, brass.
24 jars, battery, 150 by 200 mm.
24 marbles, glass, ¾-inch.
24 thistle tubes, 20 cm. stem.
12 barometer tubes, thick wall, 80 cm.
3 ball and ring.
3 linear expansion apparatus, lever type.
24 candles, paraffin, 12's.
Approximate cost, $1,130.

BEST COPY AVAILABLE

List B—Tools, Stock, and Supplies

6 knife switches, single throw, single pole.
6 knife switches, double throw, double pole.
24 asbestos squares, 6 in.
2 sets cork borers, 1-3.
24 wire gauze squares, 5 inch.
24 pinchcocks, screw compression.
6 spls. copper wire, DCC, No. 24 (4 oz. spls.).
6 spls. copper wire, DCC, No. 28 (4 oz. spls.).
3 lbs. copper annunciator wire, No. 18.
3 spls. German silver wire, bare, No. 28 (4 oz. spls.).
3 spls. iron wire, bare, No. 28 (4 oz. spls.).
3 spls. piano wire, No. 2.
3 rolls piano wire, No. 9 (4 oz. roll).
3 spls. piano wire, No. 7.
3 spls. piano wire, No. 5.
1 spl. fuse wire, 1/2 ampere.
1 spl. fuse wire, 1 ampere.
1 spl. fuse wire, 2 ampere.
1 spl. fuse wire, 5 ampere.
6 files, round, 6 inch.
6 files, triangular, 6 inch.
2 wrenches, monkey, 8 inch
3 pliers, side cutting, 5 inch.
3 pliers, round nose, 6 inch.
3 screw drivers, small, 4 inch.
3 screw drivers, large, 8 inch.
3 hammers, claw, 7 1/2 oz.
3 snips, metal, 2 1/2 inch cut.
3 pkgs. corks, asst. 0-11 (144).
12 graduates, cylindrical, 100 cc.
6 graduates, cylindrical, 250 cc.
3 lbs. rubber stoppers, 2 hole, 0-0 asstd.
36 ft. rubber tubing, 3/16 inch.
36 ft. rubber tubing, 1/4 inch.
9 lbs. glass tubing, 5 mm.
6 spls. spring brass wire, No. 22.
6 spls. spring brass wire, No. 28.
3 soldering sets.
24 bottles, glass stopper, for reagents, 4 oz.
12 lamp chimneys, students'.
12 hydrometer jars, 15x2 inches.
9 flasks, 250 cc., Pyrex.
12 funnels, 90 mm.
3 lbs. thermometer tubing.
3 sq. ft. copper sheets, No. 20.
3 sq. ft. lead sheet, 1/16 in. thick.
3 sq. ft. zinc sheet, 1/16 in. thick.
27 lbs. acid, sulphuric, com'l.
15 lbs. copper sulphate, cryst., tech.
6 lbs. ether, sulphuric, U.S.P.
9 lbs. mercury.
6 lbs. nickel ammonium sulphate, com'l.
6 lbs. paraffin, hard.
15 lbs. potassium bichromate.
6 lbs. sulphur, roll.
3 lbs. vaseline (petrolatum), yellow.
6 lbs. zinc sulphate.
12 Bunsen burners.

Approximate cost, $180.

List C—Classroom Demonstration Apparatus

(Suggested minimum list)

2 cohesion plates, glass.
1 capillary tube, set of 7, mounted.
1 osmometer.
1 membrane.
1 table rotator (see motor-rotator, List D).
1 centrifugal hoop.
1 acoustic and color disk.
1 second law of motion apparatus.
1 lift pump, glass model.
1 force pump, glass model.
1 Pascal's vase, with metallic diaphragm.
1 air pump and plate on one base.
1 bell jar, 2 gallon.
1 jar vacuum wax.
1 seven-in-one apparatus (spirometer).
1 barometer tube with mercury well.
1 barometer, aneroid.
1 barometer, mecurial, Fortin principle.
1 compound bar.
1 steam engine model.
1 electrophorus.
1 electromagnet, lifting.
1 induction coil, demonstration, 6 mm.
1 wire spiral, showing wave motion.
1 organ pipe with movable piston.
1 optical disk.
1 disk illuminator.
1 hydraulic press, glass model.
1 seconds pendulum, with mercury contact.
1 sonometer.
1 motor, shunt wound, 110 v. D. C., 1/4 h. p.
1 motor brake and mounting.

Approximate cost, $250.

List D—Additional List of Demonstration Apparatus

(Selections should be made from this list as needs require and funds permit)

1 elasticity of flexure apparatus, contact method.
1 torsion apparatus.
1 motor-rotator, 110-v. A. C. motor.
1 centrifugal globe.
1 Arago's magnetic rotation apparatus.
1 gyroscope (medium size).
1 sand pendulum.
1 Magdeburg hemisphere.
1 water motor, demonstration.
1 Boyle's law apparatus.
1 rotary blower, electric, 110-v. A. C.
1 rotary vacuum pump.
1 vacuum tube.
1 bell in vacuo.
1 guinea and feather tube.
1 manometer for air pump.
1 maximum density of water apparatus.
1 radiometer.

1 mechanical equivalent of heat tube.
1 gas engine, model.
1 static machine.
1 Leyden jar, dissectible.
1 discharger.
1 set Geissler tubes (6) 15 cm. long.
1 contracting helix.
1 earth induction coil.
1 induction coil, 1 in. spark.
1 alternating current apparatus.
1 galvanometer, lecture table.
1 galvano-volt-ammeter (six-in-one).
1 lamp board resistance, 5 lamp.
1 electrolysis apparatus, improved, Hoffman.
1 sympathetic vibrating bar.
1 pr. singing tubes, Knipp's small form.
1 refraction tank for use with optical disk.
Approximate cost, $650.

SUMMARY

List A—Individual apparatus for 24 students, $1,150.
List B—Tools, stock and supplies, $180.
List C—Classroom demonstration apparatus, $260.
List D—Additional list of demonstration apparatus, $650.
Total, $1,590 to $2,240.
Annual replacements, $200 to $300.

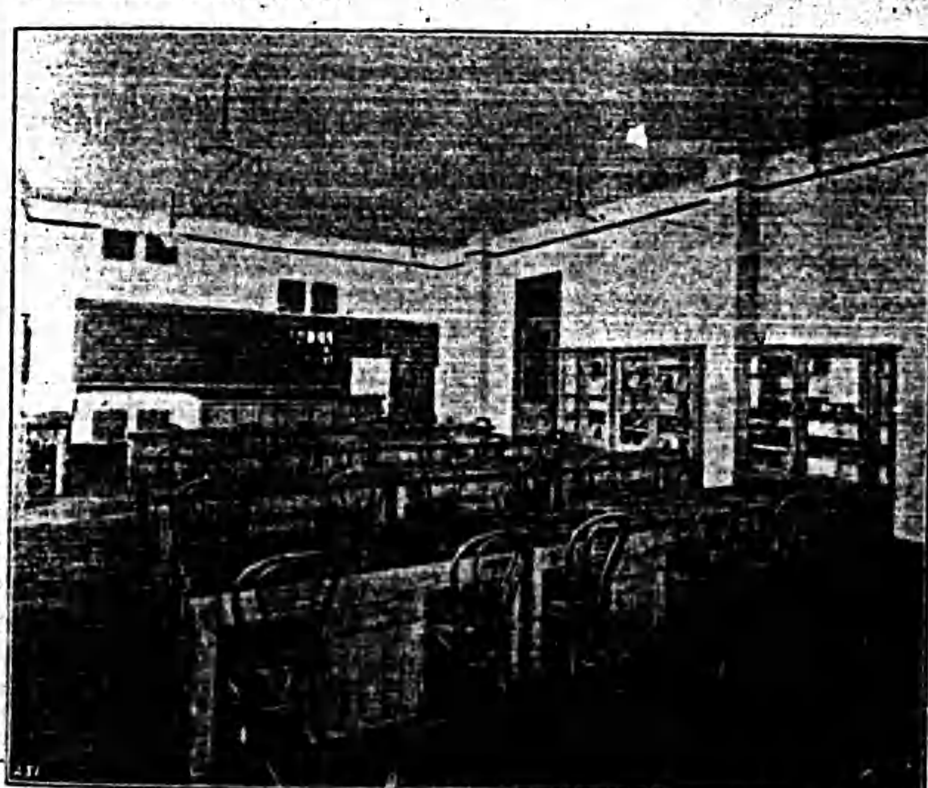

FIGURE 13.—BIOLOGY LABORATORY, CORTLAND STATE NORMAL SCHOOL, NEW YORK

Biology Laboratory

In the biology laboratory equipment, at least two compound microscopes should be included for a class of 24, and, if funds are available, one for every 4 or 5 students.

The ability to manipulate a compound microscope properly and skillfully and to interpret correctly the results obtained is very helpful to the student who pursues his science education beyond the high school. Accrediting institutions recognize this fact and usually ask that one compound microscope for every 4 or 5 students be a part of the equipment for the biological sciences in the accredited school. A student's type, costing from $60 to $75, is satisfactory. A demonstration eyepiece is highly desirable. This is attached to the compound microscope in place of the regular eyepieces and enables two persons to view the same object at the same time. One eyepiece contains a needle pointer with which the instructor may point out to the pupil observer any detail in the specimen under observation. Models and charts are important in the biological course. Carefully selected and complete sets of each should be purchased.

LABORATORY EQUIPMENT FOR BIOLOGY

INDIVIDUAL APPARATUS

12 battery jars, clear white glass, 5 by 7 inches.
48 bottles, wide mouth, 3 oz.
24 bottles, cyanide.
48 beakers, 250 cc.
24 dishes, crystallizing, 100 mm.
24 dishes, evaporating, 90 mm., No. 2.
24 dissecting sets, 6 pieces in case.
24 dissecting pans, wax bottom.
24 pkg. filter paper, 15 cm.
24 flasks, 250 cc.
24 glass plates, 4 by 4.
24 microscopes, dissecting.
24 pinchcocks, screw compression.
24 pneumatic troughs.
24 ring stands, 3 ring.
24 rubber stoppers, 2 hole, No. 3.
24 rubber stoppers, 2 hole, No. 8.
24 test tubes, hard, 6 x ¾.
48 thistle tubes.
96 watch glasses, 3 inches.
24 wire gauze squares, 5 inches.
12 Bunsen burners.
36 ft. rubber tubing, ¼ inch.

Approximate cost, $300.

GENERAL APPARATUS

2 aquariums, frame, 3 gal.
2 bell jars, open top, 1 gal.
2 bell jars, 3 gal.
2 bladders, for osmosis.
4 bottles, wide mouth, 16 oz.
1 pr. bone forceps, 190 mm. long.
2 trip scales, agate bearings.
2 iron weights, 10 g. to 500 g.
2 corks, asstd. 0–11 (144).
2 cork borers, set of 6.
2 corrosive sublimate tablets.
6 flasks, 500 cc.
100 flower pots, paraffined paper, 3 inches per C.
4 funnels, 75 mm.
2 funnels, 6 inches.
3 lbs. glass tubing, 5–7 mm. asstd.
6 lbs. glass tubing, 8 to 13 mm. asstd.
2 graduates, cylindrical, 250 cc.
2 insect nets, collapsible.
200 insect pins, No. 0, per C.
200 insect pins, No. 3, per C.
2 insect spreading boards, 12 by 4½ inches.
8 litmus paper, blue.
8 litmus paper, red.
24 medicine droppers.
40 petri dishes, 50 mm.
24 rubber stoppers, 1 hole, No. 2.
24 rubber stoppers, 2 hole, No. 9.
36 ft. rubber tubing, $\frac{3}{16}$ inche.
36 ft. rubber tubing, ¼ inch.
3 sq. ft. rubber dam.
144 test tubes, 4 by ½, per 12.
144 test tubes, 6 by ¾.
24 test tube brushes.
12 test tube racks.
6 thermometers, 110° C. and 220° F.
6 tripods, 6 inches.
2 vasculum, collecting case.
1 water bath, copper, constant water level, 6 inches.

Approximate cost, $150.

ADDITIONAL GENERAL APPARATUS

[Selections should be made from these lists according to requirements and funds]

1 air tester, for CO_2.
2 microscopes, compound, 2 oculars, 2 objectives, double, nose piece, in case.
2 gr. microscope slides, blanks, 3 by 1 inch.
2 gr. microscope cover glasses, round, No. 2, 18 mm.
1 microtome, hand.
1 Pasteurizing outfit.
1 set prepared slides, botany (25 in box).
1 set prepared slides, physiology (25 in box)
3 staining jars.
1 section razor.
1 sterilizer.

Approximate cost, $200.

Models and Charts

1 model, anatomical, human skull and brain.
1 model, anatomical, human ear.
1 model, anatomical, human torso.
1 set physiology, anatomy and hygiene charts.
1 set botany charts, beginners.
1 set natural history and mineralogy charts.
1 set life histories of insects, squash bug, cotton boll weevil, apple borer, cucumber codling moth, peach borer, lady bug, honey bee, silk worm, etc.
Approximate cost, $200.

Chemicals and Stains

1 lb. acid acetic, glacial, C. P.
2 lbs. acid hydrochloric, com'l.
2 lbs. acid nitric com'l.
6 lbs. ammonium hydroxide, com'l., 26°.
4 ozs. Benedict's solution, qualitative.
2 ozs. Canada balsam for mounting slides.
2 lbs. calcium phosphate (bi-monobasic) C. P.
2 lbs. calcium phosphate (mono) com'l.
2 lbs. calcium sulphate, plaster Paris.
5 ozs. carbolic acid (loose cryst.).
2 lbs. charcoal (lumps), wood.
10 gms. eosin, yellowish (water soluble).
1 lbs. ether, U. S. P.
2 lbs. ferric chloride, U. S. P.
10 lbs. formalin.
5 ozs. iodine solution in potassium iodide.
2 lbs. lime water.
12 ozs. lysol.
2 lbs. magnesium sulphate, U. S. P.
2 lbs. manganese dioxide.
20 gms. malachite green.
2 lbs. paraffin, med.
8 ozs. potassium bichromate, C. P.
2 lbs. potassium chlorate, cryst., pure.
2 lbs. potassium nitrate, pure.
2 ozs. pepsin, powd.
2 ozs. pancreatin.
2 lbs. sodium carbonate, com'l.
2 lbs. zinc, mossy.
2 lbs. zinc chloride, pure, gran.
Approximate cost, $80.

Summary of Approximate Costs

21 sets individual apparatus, $300.
1 set general apparatus, $150.
1 lot additional general apparatus, $200.
1 lot models and charts, $200.
1 lot chemicals and stains, $80.
Total cost, $700 to $900.
Annual replacement, supplies, and new apparatus, $50 to $200.

Laboratory Equipment for General Science

The following list of general science apparatus and supplies was prepared by a special class at the University of Wisconsin in the summer of 1925.

The list was read to and approved by the general science section of the Central Association of Science and Mathematics Teachers at their meeting at the University of Chicago in November, 1925. These lists may be regarded as a good minimum.

Student Apparatus (Class of 24)

5 test tubes, hard, Pyrex, 16 mm.
30 test tubes, soft, 6 by 5/8 inch.
15 test-tube brushes.
15 lbs. glass tubing, 6 mm.
18 ft. rubber tubing, 3/16-inch.
5 ft. rubber tubing, heavy wall, 1/4-inch.
12 files, triangular, 5 inches.
15 bottles, wide mouth, 4 oz.
15 bottles, wide mouth, 8 oz.
30 beakers, 100 cc.
6 beakers, 250 cc.
24 rubber stoppers, No. 1, one-hole.
24 rubber stoppers, No. 2, two-hole.
24 rubber stoppers, No. 5, two-hole.
24 rubber stoppers, No. 7, two-hole.
12 rubber stoppers, two-hole, assorted, No. 8–13.
15 ring stands, 5 by 8 base.
15 ring-stand rings, 3-inch.
15 ring-stand clamps, right angle.
24 flasks, Erlenmeyer, 125 cc.
15 dry cells.
12 thermometers, double scale, 110° C. and 220° F.
15 funnels, glass, 40 mm.
15 thistle tubes.
7 bar magnets, 1 by 1 by 15 cm.
8 horseshoe magnets, 4-inch.
1 spl. copper wire, DCC, No. 22 (1 lb.).
1 spl. copper wire, DCC, No. 30 (1 lb.).

18 meter and yard sticks.
12 push buttons.
12 magnifying glasses.
1 trip scale.
6 sets weights, brass in block, 1-500 g.
15 evaporating dishes, porcelain, 3-inch, No. 00A.
12 electric bells, 2½-inch gong.
15 single pulleys, bakelite.
10 double pulleys, bakelite.
12 lenses, 20 cm. focus.
4 prisms, 75 mm. long.
15 magnetic compasses, 10 mm.
15 forceps, laboratory, 5-inch.
15 test-tube holders (wire-clamp).
12 petri dishes, 75 mm.
12 mirrors, plane, 10 by 10 cm.
5 mirrors, convex, 4 cm.
12 wire gauze, (5-inch squares).
1 pkg. corks, assorted, 0-11 (144).
1 pkg. corks, assorted, 12-26 (144).
Total, $185.

Demonstration Apparatus

1 air pump, good grade, vacuum and pressure combined.
1 air-pump plate, with stopcock.
1 bell jar, fitted for stopcock.
1 stopcock for bell jar.
1 barometer tube, 80 cm. long.
1 barometer aneroid.
1 tuning fork, C′, 256 vps.
1 tuning fork, F′, 320 vps.
1 tuning fork, G′, 384 vps.
1 tuning fork, C″, 512 vps.
1 microscope, divisible objective.
1 force pump, glass model.
1 lift pump, glass model.
6 U-tubes, for distilling, 8 inches.
1 set cork borers (6 in set).
1 electrolysis apparatus, battery jar type.
1 St. Louis motor.
1 field for St. Louis motor.
1 graduate, cylindrical, 250 cc.
3 graduates, cylindrical, 50 cc.
1 model of steam engine.
1 dry-bulb thermometer.
1 wet-bulb thermometer.
Total, $115.

Suggested but not Essential

1 ammeter, battery jar type, 0-35 amps.
1 voltmeter, battery jar type, 0-10 volts.
1 aspirator, filter pump, for ¼-inch. I. P. (Coupling to be ordered according to conditions.)
1 aquarium, glass jar, round, 7 by 7 inches.
1 telegraph key.
1 telegraph sounder.
1 pony relay, 20-ohm.
Total, $15.

Chemicals and Supplies

24 candles, paraffin, 12's.
3 sq. ft. rubber dam.
4 ctn. iron filings (each 4 oz. with sifter tops).
1 vial litmus paper, blue.
1 vial litmus paper, red.
6 pkg. filter paper, 9 cm.
1 sq. ft. aluminum sheet, No. 20.
1 sq. ft. lead sheet, $\frac{1}{16}$ inch.
1 gal. alcohol, denatured.
1 qt. alcohol, wood, 95 per cent.
9 lbs. acid, sulphuric.
6 lbs. acid, hydrochloric.
7 lbs. acid, nitric.
5 lbs. mercury.
1 lb. potassium chlorate.
1 lb. zinc, mossy.
1 lb. manganese dioxide.
2 lbs. starch, corn.
1 lb. starch, wheat.
1 lb. starch, potato.
1 oz. iodine, resubl., U. S. P.
1 lb. ammonium hydrate.
1 lb. ether, sulphuric.
1 lb. sodium bicarbonate (baking soda).
5 lbs. sulphur, flowers.
1 lb. paraffin, med.
4 oz. phosphorus, yellow (can be shipped by frt only).
1 lb. carbon tetracloride, pure.
1 lb. copper, metal filings.
1 lb. tin, gran.
1 oz. silver nitrate.
1 pt. turpentine, spirits.
1 lb. ammonium nitrate, pure.
1 lb. cream of tartar, U. S. P.
5 lbs. copper sulphate.
1 lb. sodium hydroxide, sticks.
1 lb. Rochelle salt.
1 lb. borax.
Total, $35.

Summary

Student apparatus, class of 24, $185.
Demonstration apparatus, $115.
Demonstration apparatus (suggested), $15.
Chemicals and supplies, $35.
Approximate total cost, $350 to $500.
Annual replacement, $50 to $100.

Cost of Apparatus Equipment Supplies

At the end of each list is given a summary of approximate costs for apparatus, equipment, and supplies given in the lists. They are based on the needs of a class of 24 pupils in each subject. The range in the totals are due to omitting and including the additional demonstration apparatus with which every school ought to be equipped but without which small schools short of funds can get along and still give a worth-while course.

These figures are summarized below.

Approximate cost of apparatus, equipment, and supplies for high-school laboratories

	Chemistry	Physics	Biology	General science
Individual student	$325	$1,150	$300	$185
Demonstration	225	260	150	115
Demonstration (additional)	300	650	200	15
Chemicals, supplies	100	....	60	35
Tools, stock supplies	50	180	....	....
Models and charts	....	....	200	....
Total	$700 to $1,000	$1,590 to $2,240	$600 to $910	$300 to $350
Annual replacement	$240 to $360	$200 to $360	$50 to $200	$50 to $100

Small schools will have classes much smaller than 24. An estimate may be made of the cost of apparatus, supplies, and equipment for them from this summary. The cost for classes of eight, for instance, in each subject would be approximately—

Chemistry	$450 to $800
Physics	700 to 1,400
Biology	350 to 700
General science	190 to 250

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