AN EXPERIMENTAL STUDY CONCERNING THE COST OF INSTALLING A CHEMISTRY LABORATORY IN A SMALL SECONDARY SCHOOL USING HOME MADE AND SEMI-MICRO EQUIPMENT

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By

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Robert D. Morrison

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CHAPTER I

THE PROBLEM

Purpose

The purpose of this study was (1) to determine the cost of installing and maintaining a chemistry laboratory in a small high school which offers physics, biology, and general science, (2) to show how the laboratory could be equipped by making and using home made and semi-micro equipment, (3) to study the advantages, if any, of using this type of equipment, and (4) to show the types of experiments that could be performed with such equipment.

Need for the Study

Only fifty of the 870 accredited secondary schools of Oklahoma offered chemistry during the 1939-40 school year, and most of these schools were private schools and the larger city systems. Very few of the small high schools offered chemistry.[1] There may be many reasons why so few schools teach chemistry. Probably one of the main reasons is the cost of installing and maintaining a chemistry laboratory from year to year. Laboratory tables and apparatus for experimental work are the main installation costs.[2]

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[1] "List of Accredited Schools", Annual High School Bulletin 112-0. State of Oklahoma, Department of Education. June 30, 1940. Pages 25-52.

[2] A. H. Crane, "Unit Costs in the Guthrie Senior High School for the fiscal Years July 1, 1931 to June 30, 1935." (Unpublished Thesis, Oklahoma A and M College, 1936). Page 42.

It may be true that nearly every science teacher has made a few pieces of laboratory equipment, but thorough investigation of recent books and periodicals published during the last ten years revealed that only two articles have been published concerning methods of economizing in the science laboratory. In his earlier article C. H. Stone mentioned several substitutions that can be used in the chemistry laboratory in order to reduce expenses. Substitutions for deflagrating spoons, crystallizing dishes, graduates, glass plates, splints, bottles, and triangles were suggested as well as ways of saving chemicals, litmus paper, rubber tubing, matches, funnels, glass tubing, files, and breakage.[3] His later article mentioned several "do's" and "don't" for laboratory teachers and pupils in the handling of apparatus.[4] No literature was found concerning costs and methods of installing a chemistry laboratory in which home made equipment was used in place of the manufactured apparatus.

In the belief that more Oklahoma secondary schools would offer chemistry if low costs of installing and maintaining a high school laboratory were made possible, the author carried out an experimental study to determine whether or not a laboratory could be installed and maintained at a low expense.

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[3]C. H. Stone, "Economy in the Chemical Laboratory." <u>School Science and Mathematics</u>, Volume 35. Pages 34-37. January 1935.

[4]C. H. Stone, "More Economies in the Chemistry Laboratory." <u>School Science and Mathematics</u>, Volume 39. Pages 836-39. December 1939.

CHAPTER II

THE PRELIMINARY EXPERIMENT

A preliminary experimental study was carried out with a small chemistry class at Oklahoma A and M College during the 1940 summer session to get some ideas of the types of equipment that could be substituted and how the program should be carried out in the high school.

Four students regularly enrolled in the freshman chemistry course at Oklahoma A and M College were used as the experimental group in the laboratory. They took their theory with the regular chemistry class, and the laboratory work was done in a small room in the Chemistry building. This room was equipped with only a flat laboratory table piped with gas. At one end of the table a common water hydrant was connected over a sink. The table was not equipped with a trough.

During the summer the regular college laboratory class ran fourteen experiments. Each laboratory period was three hours long and students met twice weekly for a period of seven weeks. The experimental group spent the same time in the small laboratory room and ran the same number of experiments. These experiments were taken from several different high school laboratory manuals and were run similar to the semi-micro technique used in the manual by Burrows and Arthur.[1]

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[1] J. A. Burrows and Paul Arthur, _Semi-Micro Exercises in General Chemistry_. Crossman Multilith and Printing Co., Stillwater, Oklahoma, 1939. 85 pages.

Each exercise performed by the experimental class was similar to the one carried on by the regular class.

After the laboratory work was started, the experimental class was divided into two groups of two pupils each. The pupils studied the laboratory exercises assigned them and listed the apparatus and materials needed. Then wherever possible this material was obtained by purchasing such from the five and ten cent stores, or salvaging from junk piles and garages, and at times bringing articles and supplies from home. Eighty cents was spent by the class in gathering these "odds" and "ends". Supplies which could not be so obtained were checked out from the chemistry store room and charged to the course at list price. A very careful check was made of the amount and cost of everything used. The cost of all the chemicals used during the summer amounted to twenty-two cents. Apparatus that was purchased by the pupils and that was checked out from the store room amounted to $11.08. The total cost of installing and maintaining the course for the summer was $11.30, an average cost per pupil of $2.82. If the group had been larger, the installation and maintenance cost would have been lower per pupil, due to the fact that many pieces of the apparatus could have been used as easily by a group of twenty pupils as by a class of four.

CHAPTER III

ORGANIZATION OF THE COURSE

The procedure for carrying out the high school course was similar to the procedure of the experimental work at the college. However, more consideration was given to the organization of the course.

Fifteen pupils[1] with a grade average of "C" in their previous high school work were allowed to enroll in the subject. A laboratory fee of one dollar a semester for each pupil was charged for incidental expenses, such as the use of apparatus, breakage, mimeographed sheets for laboratory exercises, and the use of the texts and reference books kept in the classroom. No certain textbook was used. The reading assignments were given so that the pupils could get their lessons from one of the four general chemistry text books, three laboratory manuals, a physics and chemistry handbook, or one of the five other general reference books on chemistry. These books[2] either came from the pupils' homes or belonged to the teacher.

The common belief today that more is accomplished in high school work if the pupils study under the guidance of their teachers and do very little home work is well rooted in this school. Most of the pupils live on farms, have to

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[1]Two pupils withdrew from school at the end of the first semester, thus lowering the average enrollment in the class for the year to fourteen pupils.

[2]A list of all those books is found in the appendix, page41.

ride the school buses, and do chores around their homes before and after school hours. These circumstances therefore would require the pupils to do any home study work by artificial light. Lighting in the rural homes is generally by means of a kerosene wick lamp, which furnishes a very poor reading light. Therefore, assignments are prepared in school during the study hours that are provided. Likewise, these conditions, which are typical of many of the small high schools, require the course of study to be planned so that time can be given during school hours to the many school activities that occur during the spring. The laboratory requirements in such schools necessarily must be adjusted to meet these local conditions.

The chemistry class met during the first class period of the morning. This period was forty-six minutes long during the first semester. During the second semester the first hour was lengthened to one hour and six minutes to compensate for the tardiness of the school buses on days when the roads were muddy.

Three of the five weekly class periods were used for recitation. The other two periods were designated as laboratory periods. Work in the laboratory was planned so that the class would have time to clean up and be out of the room by the end of the period. The room was used every period of the day either for classwork or for supervised study.

Type of Laboratory

The room assigned to the chemistry class for recitation and laboratory was the regular high school science room. Its dimensions were twenty-five by thirty-seven feet. No special ventilation equipment was installed in the room.

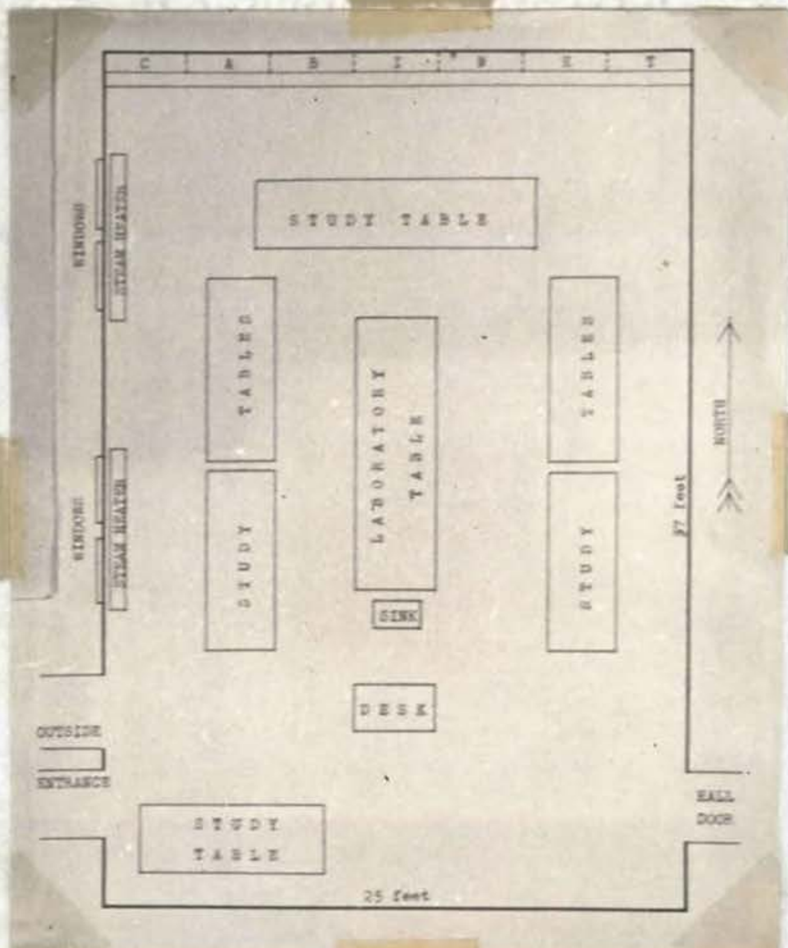

Figure 1. Diagram of the Laboratory

A fourteen compartment cabinet, six study tables, chairs, a teachers desk, and a sink were the original permanent fixtures of the room. During the previous years the room had been piped with water and butane gas. There was no laboratory table available for the class. Other pieces of chemistry laboratory equipment were limited.[1]

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[1]A list of this equipment is shown in table IV, page 25.

Before any chemistry experiments could be performed, reagent shelves had to be provided, and a laboratory table had to be built. Pieces of equipment for individual lockers such as gas burners, test tube holders, test tube racks, ring stands, tripods, pinch clamps, etc., had to be constructed.

The solid chemical reagents and some apparatus were shelved in alphabetical order in four upper compartments of the cabinet. Acids, bases, solutions, glass tubing, and the rest of the apparatus were placed in four of the lower compartments. The shelves were thirty-three inches long, and from eighteen to twenty-four inches deep. The space between the shelves varied, being ten to eighteen inches from shelf to shelf.

Figure 2. Reagent Supply Shelves

The cabinet doors were never locked, but the room was locked before and after school and during the noon hour. The pupils were permitted to get chemicals and apparatus without having to ask the instructor's permission. They were instructed to get only the necessary amounts of reagents and not to waste any of the chemicals.

CHAPTER IV

COLLECTION AND CONSTRUCTION OF EQUIPMENT

On the first day of school the pupils were asked to bring empty bottles, hammer, saw, pliers, brace and bits, and any other tools or material that they thought might be necessary for building a laboratory table, burners, ring stands, tripods, or other pieces of apparatus that could be made in the laboratory. Within the first week of school there was as assortment of bottles such that no trouble was encountered in finding a desirable container for most of the chemicals that were used during the year. Enough tools and materials were brought to the laboratory to enable the class to divide into small groups for planning and constructing the various pieces of equipment needed for the course.

On the first laboratory day the teacher and pupils planned and started constructing the laboratory table and some of the equipment. Arrangements were made with the town blacksmith so that the pupils, under the supervision of the instructor, were allowed to cut and thread pipe and to use other necessary tools. No charge was made by the blacksmith.

The laboratory table was built thirty-eight inches high, ten feet long, and seventeen inches wide on each side of a six inch drain trough, making a total width of forty inches. Third grade yellow pine lumber was bought to supplement some scrap lumber for constructing the table.

Eight drawers, fourteen by eighteen inches and ten inches deep, were built from scrap lumber and attached under the table top. The auxillary shelf over the trough

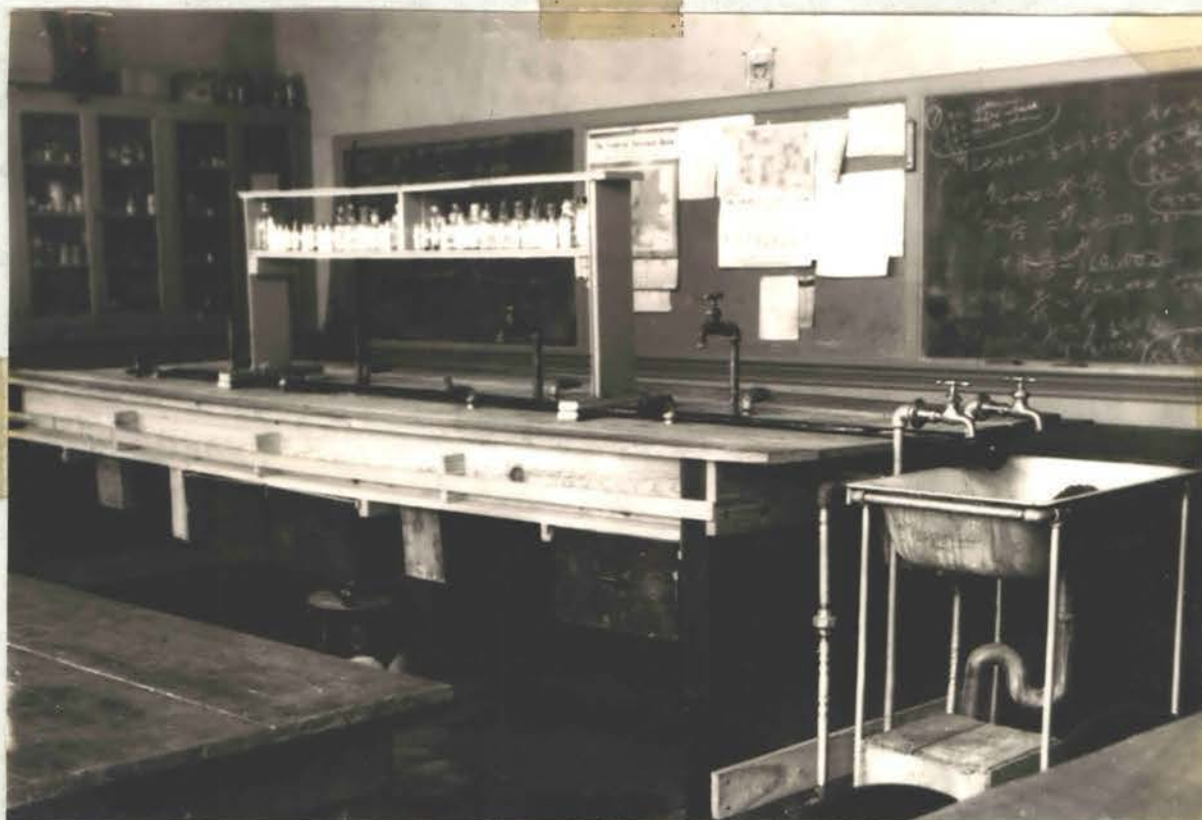

Figure 3. The Laboratory Table

had seventy-eight holes drilled partly through the lower board for the twelve milliliter vials that contained most of the common reagents used in the course. This reagent shelf, bottles and all, was removed from the table at the end of each laboratory period and placed on the floor in the northwest corner of the room. The shelf was then out of the way of the other classes that met in the room during the day.

Second hand half-inch pipe, gates, fittings, faucets, and gas outlets were used in the plumbing of the table. The fixtures were bought from junk dealers and second hand stores. A blacksmith constructed a drain trough for the table using galvanized sheet iron. One coat of acid resisting paint was brushed on the trough before it was installed. The total cost for building the table amounted to $14.38, as itemized below:

Lumber-----------	$3.20
Plumbing---------	10.68
Trough-----------	.50
Total---	$14.38

The construction of the small burners for butane gas required a great deal of experimenting in order to obtain a correct flame. Difficulty arose in getting the proper air-gas mixture due to the richness of butane gas. A successful burner was finally obtained in the following manner:

The burner base was made from a piece of one by two inch board two inches long. The two and one-half inch barrel for the burner was cut from a five-sixteenths inch copper gasoline feed line that had been discarded in a garage junk pile. The butane gas feed line was cut three and one-half inches long from a piece of quarter inch copper pipe. Half way between the ends of this pipe a very small pin hole was punched through the wall for a gas outlet.

A five-sixteenths inch air hole, lettered A in the picture below, was drilled horizontally through the upper part of the burner base. The supply feed line, B, was wedged into a hole drilled horizontally through the lower part of the burner base and perpendicular to the air hole. The supply pipe was adjusted so that the gas could flow out through the small opening and up through the burner barrel, C. The barrel was wedged into a hole that was

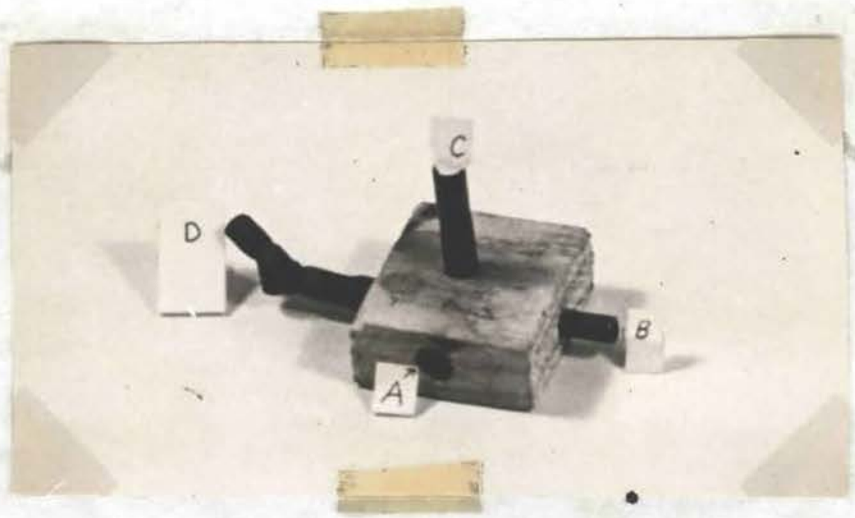

Figure 4. Semi-micro Bunsen Burner

bored vertically into the burner base so that the air hole, the pin-hole opening in the supply line and hole for the barrel met at one point. The knotted piece of rubber tubing shown fastened over one end of the supply line was used merely for plugging one end of the line.

The burner was so well adjusted that it was difficult to see the flame at a distance of ten feet unless certain lighting conditions in the room were obtained. Many times the pupils singed the hairs on their arms before noticing that a burner was lighted. There was no expense in constructing the burners.

The test tube holders, pictured below were cut from a piece of copper alloy sheeting about the thickness of a dime. The strips were about one-half inch wide. They were

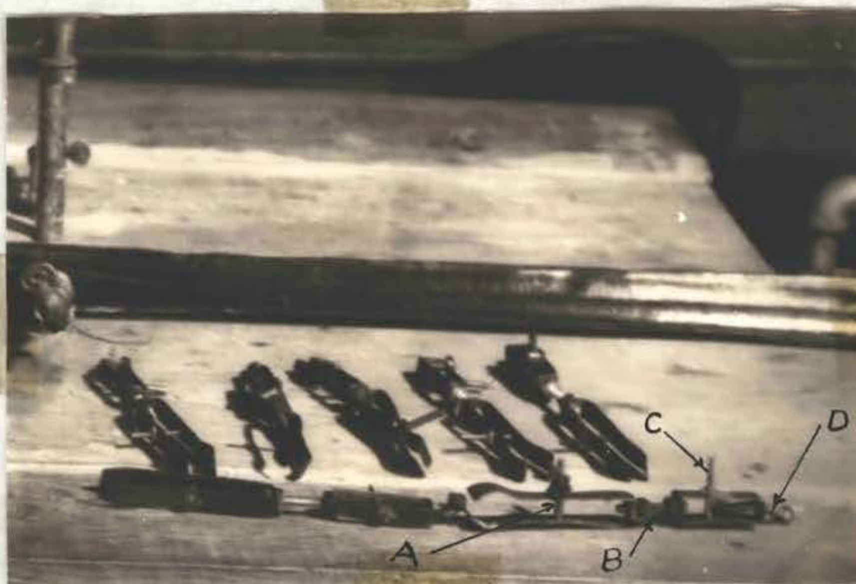

Figure 5. Test Tube Holders

shaped by using a vise and a pair of pliers. The one-eighth inch stove bolt, lettered A in the picture, was two inches long. It was used to adjust the grip of the jaws of the holder. The quarter-inch stove bolt, B, was fitted with taps so that the jaws of the holder could be rotated at any angle. The heel of the holder was constructed so that the rod of the ring stand could be slipped between the stove bolt, C, and the end of the stove bolt, D. The stove bolt, D, was bent near the middle in order to obtain enough leverage to fasten the holder securely to the ring stand.

The holders were about seven inches in length. They were not as sturdy as the manufactured test tube holders, but they were usable without serious disadvantages. No money had to be spent in constructing these pieces of equipment.

The tripods, ring stands, and test tube racks were made easily. Each tripod was merely three pieces of bailing wire about fourteen inches long that were twisted together with a pair of pliers. When completed, the tripods were about five inches high and were easily adjusted for leveling by slightly spreading or narrowing the distance between the legs.

Figure 6. Tripods, Test Tube Racks, and Ring Stands

The base for each ring stand was made from a scrap piece of two by six inch board about six inches long. A three-sixteenths inch hole was bored through the block about two inches from one end. The ring stand rod was then wedged through this hole. A counter sunk hole was drilled on the bottom side of the block so that a set tap could be used to hold the rod firmly in the block. The rod, which was about thirty inches long, was cut from a piece of discarded brake rod off of a car, and was threaded at the blacksmith shop. A staple was driven in one end of the base so that the stand could be hung under the laboratory table and be out of the way.

The test tube racks were made from one by four inch lumber about fourteen inches long. Seven-eighths inch holes were drilled nearly through the boards along one edge of the top for the twelve milliliter vials. Five-eighths inch holes were bored along the other edge to hold the test tubes and medicine droppers.

The screw clamp, pictured below, was made by using some small copper pipe, a short stove bolt, and a piece of copper alloy sheeting that was left after making the test tube holders.

Figure 7. Screw Clamp

A water condenser jacket was made by fitting a three-fourths inch galvanized pipe about twelve inches long with a two hole stopper at each end. One of the holes in each stopper was used for the condenser tube. The other hole was fitted with a piece of bent glass tubing which served as a connection to either the inlet or outlet hose for tap water.

Although the laboratory was equipped with a Babcock milk tester, which was used for a centrifuge, the home made centrifuge pictured below was constructed, tested, and proved successful. A more detailed description of this apparatus is found in the appendix.

Figure 8. A Home Made Centrifuge

The picture below shows the equipment that was in each locker. Most of the equipment was either brought from the pupils' homes or constructed in the laboratory. However, a few pieces had to be purchased.

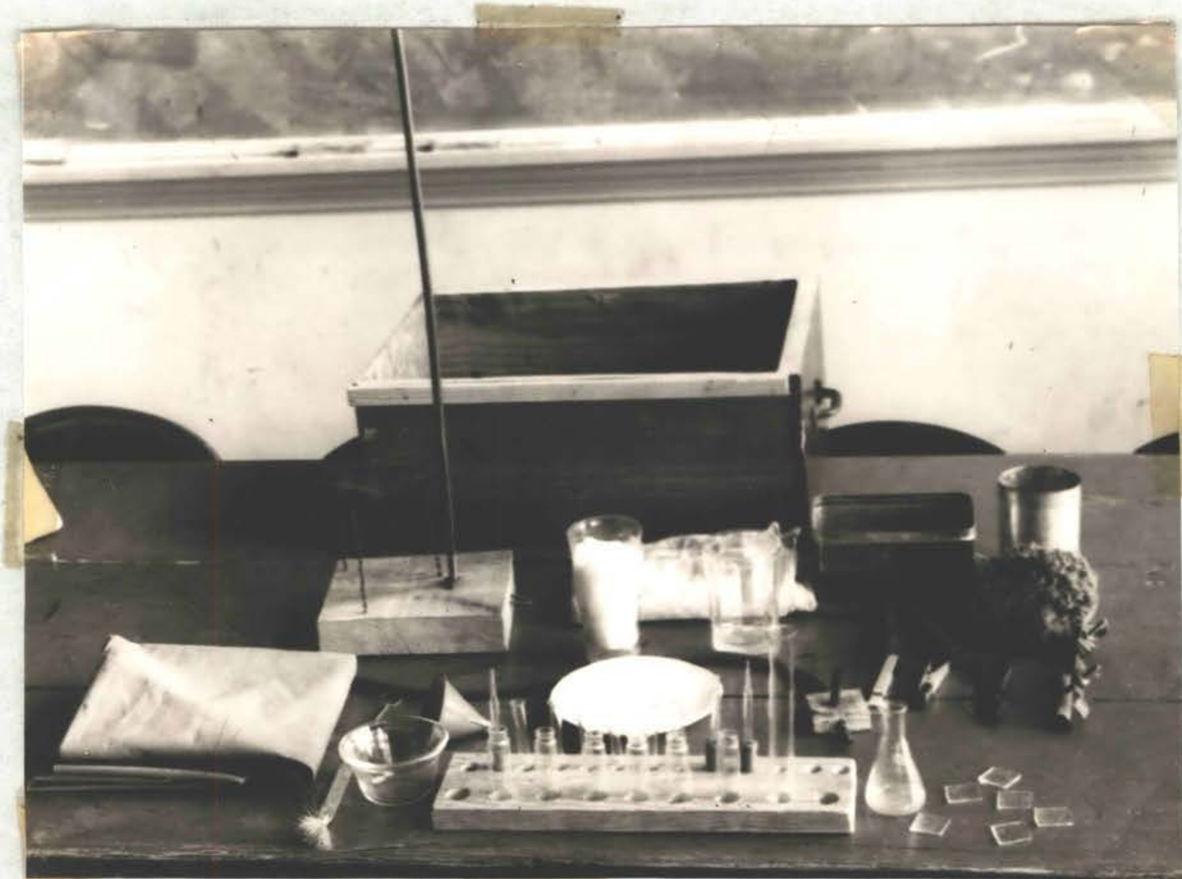

Figure 9. Equipment for Each Locker

The total cost for equipping each locker was $1.52, as itemized below:

1 Apron- - - - - - - - - - - - -	$ .48
1 Erlenmeyer Flask, 50 ml. - -	.20
3 Medicine Droppers- - - - - -	.07
3 Feet Rubber Tubing, 3/16 in.	.21
1¼ Feet Rubber Tubing, ¼ in.- -	.13
1 Sponge - - - - - - - - - - - -	.10
6 Test Tubes, 10x75 mm. - - -	.15
1 Test Tube, 5/8x6 in. - - - - -	.03
6 Vials, 12 ml. - - - - - - - -	.15
Total - - -	$1.52

The following pieces of equipment were either furnished or built by the pupils. There was no cost in obtaining these articles.

Apparatus	Substitution
Beaker, Large	Water Glass
Beaker, Small	Pyrex Custard Bowl
Charcoal	Charred Match Stem, Completely Pulverized
Evaporating Dish	White Saucer or Bowl
Forceps	Pliers
Funnel	Bakelite Funnel
Magnet	"V" Magnet off a Model T Ford
Pneumatic Trough	Metal Chalk Box
Steam Bath	Tin Can
Test Tube Clamp	Clothes Pin
Watch Glass	Bottom of Custard Bowl
Wire Gauze	Screen Wire, Doubled
Wood Splints	Pine Board Splinters

CHAPTER V

DETERMINING THE LABORATORY COSTS

The following procedure was used in determining the laboratory costs:

An inventory was taken on all the equipment in the laboratory that could be used in the course.

An itemized list was also made of all the usable chemical reagents in the laboratory.

Thirty-six experiments that could be performed in high school were selected from Burrows' and Arthur's laboratory manual[1], and a list was made of the reagents required for performing these exercises. A similar list was made of the equipment required for performing the thirty-six exercises.

A list of reagents that had to be purchased was determined by checking off from the list the reagents that were either on the laboratory inventory or could be brought from home.

The equipment order list was compiled in the same manner as the reagent order list, except that the substitutions which could be made were also cut off from the equipment list.

The items on these two revised lists were obtained from the chemistry department of Oklahoma A and M College and billed to the school. Tables I and II on the following

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[1] Burrows and Arthur, op. cit.

pages show, respectively, itemized costs of the reagents and equipment that were purchased.

Tables III and IV on pages 24 and 25 show, respectively, itemized lists of the reagents and equipment in the laboratory before the course was installed.

TABLE I

REAGENTS PURCHASED

Item	Amount Bought	Cost	Ounces used	Cost
Acid, Acetic	2½ lb	$ .95	2	$ .05
Acid, Hydrochloric	6 lb	1.20	8	.10
Acid, Nitric	3 lb	.70	8	.12
Acid, Pyrogallic, tech	1 oz	2.00	0	.00
Acid, Sulfuric	9 lb	1.80	16	.20
Aluminum Chloride	1 lb	.30	0	.00
Aluminum Nitrate	1 oz	.60	0	.00
Aluminum Sulfate, tech	1 lb	.10	1	.01
Ammonium Carbonate	5 oz	.17	1	.04
Ammonium Chloride	1 lb	.18	0	.00
Ammonium Hydroxide	4 lb	1.10	8	.14
Ammonium Iodide, tech	1 oz	2.70	1/14	.20
Ammonium Nitrate, tech	1 lb	.17	0	.00
Ammonium Sulfate	1 lb	.10	0	.00
Antimony, Metal powder	1 oz	.65	¼	.16
Arsenic, Metal powder	1 oz	1.66	1/14	.12
Barium Chloride	7 oz	.16	1	.03
Barium Hydroxide	2 oz	.32	2	.32
Bismuth, lump	1 oz	1.95	0	.00
Calcium Chloride, tech	7 oz	.34	1	.05
Calcium Monophosphate	2½ oz	.29	0	.00
Calcium Oxide, tech	1 lb	.12	1	.01
Carbon Disulphide, tech	3 lb	.10	8	.02
Carbon Tetrachloride	2 L	.40	200 ml	.04
Cobalt Nitrate, tech	1 oz	1.36	0	.00
Copper Chloride	5 oz	.28	0	.00
Copper Nitrate, pure	1 lb	.38	0	.00
Copper Oxide, tech	4 oz	.30	½	.03
Copper Sulfate, tech	3 lb	.45	4	.04
Ether, Petroleum	3 lb	.90	0	.00
Glycerine, C. P.	1 lb	.16	0	.00
Gum Labels, boxes	5	.50	1	.10
Iodine	1 oz	.30	1/3	.10
Iron Sulfide, gran.	1 lb	.20	6	.09
Lead Dioxide	1 oz	.70	1/7	.10
Litmus Paper, bottles	12	.65	2	.12
Magnesium Carbonate, tech	2 oz	.05	¼	.02
Magnesium Chloride, tech	1 lb	.10	1	.01
Magnesium Oxide, tech	4 oz	.05	½	.01
Mercuric Chloride, tech	1 oz	.50	0	.00
Mercuric Oxide, U. S. P.	1 oz	2.05	3/7	.57

TABLE I (continued)

REAGENTS PURCHASED

Item	Amount Bought	Cost	Ounces used	Cost
Methyl Orange	½ oz	$ 3.69	1/100	$ .04
Nickel Nitrate, tech	1 oz	.30	0	.00
Paraffin	1 box	.10	0	.00
Phosphorus Chloride	1 oz	1.80	0	.00
Phosphorus Pentoxide	1 oz	.30	0	.00
Phosphorus, Red, tech	1 oz	.20	1/20	.01
Potassium Bromide, tech	2 oz	.10	1/10	.01
Potassium Chlorate, tech	1 lb	.20	3	.04
Potassium Chloride, tech	2 oz	.05	½	.01
Potassium Hydroxide, tech	4 oz	.30	1/3	.03
Potassium Iodide, tech	1 oz	.20	¼	.05
Potassium Nitrate, tech	7 oz	.65	1	.09
Potassium Permanganate	4 oz	.20	½	.02
Sodium, Metal	2 oz	.06	1/10	.01
Sodium Acetate, tech	4 oz	.10	½	.02
Sodium Bromide, tech	4 oz	.10	1½	.02
Sodium Chlorate	1 lb	.30	2½	.05
Sodium Dichromate, tech	1 lb	.15	1	.01
Sodium Hydroxide, tech	4 oz	.05	2	.03
Sodium Nitrate, tech	1 lb	.10	0	.00
Sodium Potassium Tartrate	3 oz	.10	0	.00
Sodium Stannate, tech	1 oz	2.40	0	.00
Sodium Sulfate, tech	1 lb	.50	½	.02
Sodium Sulfite, tech	5 oz	.05	1	.01
Sodium Thiosulfate, tech	1 lb	.15	2	.02
Zinc, tech	1 lb	.35	3	.08
Totals		$39.49		$3.37

TABLE II

EQUIPMENT PURCHASED*

Item	Quantity	Value	Breakage
Aprons**	17	$ 8.13	$ .00
Bottles, Glass Stoppers	12	3.60	.30
Brushes, Small Test Tube	12	1.20	.00
Burette, 25 ml.	1	.50	.00
Corks, No. 1	3 doz	.36	
Corks, No. 3	4 doz	.48	
Corks, No. 4	1 doz	.12	
Corks, No. 6	2 doz	.24	.12
Corks, No. 7	1 doz	.12	
Corks, No. 9	1 doz	.12	
Cylinder, Graduated	1	.50	.00
Flasks, Erlenmeyer, 50 ml.	1 doz	2.40	.80
Funnels, Bakelite***	6	.30	.00
Glass Tubing, 6 mm.	25 ft	.63	.63
Glass Tubing, 8 mm.	15 ft	.45	.03
Lubraseal	10 grains	1.00	.10
Medicine Droppers	4 doz	.80	.12
Rubber Stoppers, No. 0	1 doz	.60	
Rubber Stoppers, No. 1	1 doz	.60	
Rubber Stoppers, No. 2	1 doz	.60	
Rubber Stoppers, No. 3	1 doz	.60	
Rubber Stoppers, No. 4	1 doz	.60	.50
Rubber Stoppers, No. 5	½ doz	.30	
Rubber Stoppers, No. 6	2/3 doz	.40	
Rubber Stoppers, No. 9	1 doz	.60	
Rubber Tubing, 3/16 in.	24 ft	1.68	.28
Rubber Tubing, ¼ in.	16 ft	1.60	.20
Sponges	10	1.00	.10
Tubes, Calcium Chloride	8	1.20	.00
Tubes, Test 10 x 75 mm.	10 doz	2.60	.52
Vials, 12 ml.	12 doz	2.65	.44
Totals		$35.98	$4.14

*This table does not show the $14.38 cost for building the laboratory table.

**These aprons were purchased from The Chemical Rubber Co.

***These funnels were bought at a five and ten cent store.

TABLE III

REAGENTS ON HAND BEFORE SCHOOL STARTED*

Item	Amount on hand	Cost	Ounces used	Cost
Aluminum Sulfate, tech	1 lb	$ .20	1	$ .02
Ammonium Carbonate, tech	4 oz	.10	0	.00
Lead Acetate, tech	2 oz	.05	3/4	.01
Lead Nitrate, tech	4 oz	.18	1/5	.01
Manganese Dioxide, tech	4 oz	.06	2	.03
Magnesium Ribbon	1 oz	.40	¼	.10
Nickel Sulfate, tech	1 lb	.48	0	.00
Paper, Filter 9 cm.	1 pkg	.12	1/3 pkg	.04
Phenolphthalein, U. S. P.	4 oz	.50	¼	.04
Phosphorus, yellow stick	4 oz	.57	½	.08
Potassium Chlorate	4 oz	.15	0	.00
Potassium Dichromate	2 oz	.05	0	.00
Rubber Stoppers, assorted	1 doz	.60	0	.00
Silver Nitrate, U. S. P.	½ oz	.25	1/10	.03
Sodium Borate, tech	1 lb	.23	0	.00
Sodium Carbonate, tech	1 lb	.20	1	.02
Sodium Nitrate, tech	1 lb	.16	1	.01
Sodium Peroxide	4 oz	.23	½	.03
Strontium Nitrate, tech	4 oz	.20	0	.00
Sulfur, roll	1 lb	.20	5	.06
Zinc Sulfate, tech	1 lb	.25	0	.00
Totals		$5.18		$ .48

*These prices were calculated from the 1941 price lists of the Central Scientific Co.

TABLE IV

EQUIPMENT ON HAND BEFORE SCHOOL STARTED*

Item	Quantity	Value	Breakage
Balance, Double Beam	1	$ 9.00	$ .00
Balance Weights, 10-500 g.	1 set	2.50	.00
Barometer, Aneroid	1	15.40	.00
Beaker, Pyrex, 250 ml.	1	.15	.00
Beaker, Pyrex, 600 ml.	1	.26	.00
Burette, 50 ml.	3	1.95	.00
Burner, Bunsen**	1	2.50	.00
Flask, Erlenmeyer, 250 ml.	3	.54	.00
Flask, Round Bottom, 500 ml.	2	.76	.00
Flask, Round Bottom, 100 ml	2	1.10	.00
Milk and Cream Tester, Bab.	1	27.00	.00
Mortar, Porcelain, 65 mm.	1	.27	.00
Thermometer, Mercury	6	3.90	.00
Tubes, Test, 5/8 x 6 in.	18	.39	.13
Totals		$65.72	$ .13

*The Value column in this table was taken from the 1941 price lists of the Central Scientific Co. All the equipment was assumed to be new for calculating these prices.

**The price of this particular burner could not be found. The price quoted was for a similar type of burner.

Since the laboratory table was the only piece of home made equipment that cost anything, the installation costs were found by totalling the costs of reagents purchased, equipment purchased, and cost of building the laboratory table.

The tabulation below shows these costs:

Reagents Purchased, Table I, pages 21 and 22- -	$39.49
Equipment Purchased, Table II, page 23- - - - -	35.98
Construction of Laboratory Table- - - - - - - - -	14.38
Total Cost for installing Course- - - -	$89.85

The maintenance cost for the laboratory was determined after school closed. The amounts of chemicals used and the apparatus breakage were determined by finding the difference between the amounts of the original and remaining supplies. These costs were calculated and tabulated in the right hand columns of Tables I-IV on pages 21 to 25.

The following tabulation briefly summarizes the maintenance costs:

Reagents Used, Table I, pages 21 and 22 - - - - -	$3.37
Reagents Used, Table III, page 24 - - - - - - - - -	.48
Equipment Breakage, Table II, page 23 - - - - - - -	4.14
Equipment Breakage, Table IV, page 25 - - - - - -	0.13
Total Maintenance Costs - - - - - - -	$8.12*

*The amount of depreciation of the laboratory equipment was not included in the maintenance costs because the percent of depreciation is an arbitrary figure, and would have to be calculated accordingly.

Since the average enrollment for the year was fourteen pupils, the per capita maintenance cost, excluding depreciation, was fifty-nine cents. A yearly laboratory fee of $2.00 was charged; therefore, the school's expenditure for maintaining the laboratory was negligible.

CHAPTER VI

TYPES OF EXPERIMENTS

Twenty-one experiments were performed during the school year. Since the first six weeks of laboratory work was spent collecting and constructing the equipment, no laboratory exercises were assigned until the beginning of the seventh school week.

The pupils were given plenty of time to make their experimental observations and write up the results and conclusions of the experiments during the laboratory periods. The pupils wrote their observations and answered the general interpretation questions in the laboratory room. If an experiment was too long to complete during one laboratory period, the pupils made another set-up of the apparatus the next laboratory day and continued with the experiment. This kind of arrangement was possible because the apparatus was simple and easily assembled, the amounts of reagents were small which eliminated much waste, the reactions were short, and in the gas preparation experiments the amount of gas prepared was small. The exercise on the preparation of chlorine, generally considered dangerous for high school pupils to perform in individual groups, illustrates the above situation very nicely.[1]

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[1]A complete copy of this experiment is given in the appendix on pages 42-45.

Three laboratory periods were needed for preparing the chlorine gas, noting its properties, and writing up the experiment. The apparatus had to be assembled twice, thus exposing the students to the irritating gas twice. However, on both days the amount of escaped gas was so small that the arithmetic class which met in the room the following hour did not notice that this very irritating gas had been prepared.

Other advantages of this simplified method of laboratory presentation are of importance also. The apparatus was simple and in most cases home made, thus being very inexpensive. The amounts of reagents used for each exercise were so small that the maintenance cost of the laboratory was very low. In many cases the reagents were brought from home, thus further aiding in keeping the costs down. The use of small quantities practically eliminated chances of accidents. No acid burns occurred because of the very small quantities that happened to be spilled. The small portions used eliminated explosions in case some pupil accidentally mixed two highly reactive chemicals. The use of small quantities increased cleanliness and carefulness. Since several pieces of equipment and some of the reagents were brought from home, the parents were able to see that the pupils were showing interest in this class and that chemistry was helping the pupils to understand some of their everyday surroundings. Apparatus breakage and losses were minimized. The use of the household reagents and home made equipment also required the pupils to do co-operative planning in securing the necessary materials.

Several other experiments could have been run with very little additional cost if the pupils had been required to write up the reports of their experiments as a home assignment. It is the belief of the writer, however, that had this been permitted much copying would have occurred and the laboratory observations would have been made carelessly.

The collecting and constructing of the equipment also reduced the number of experiments that might have been performed. This loss was justified because during the time required for such the pupils were acquiring some skills in laboratory manipulation and technique that were valuable and essential. The pupils also learned that the success of the experiments did not depend upon expensive equipment, but that their own home made equipment worked as well as the manufactured articles. This construction work also showed them that the more technical apparatus is based on the same principle as the simple home made equipment.

In order that one might obtain some idea of the types of experiments that were performed during the year, the purpose of these experiments and materials needed for performing each of them are given on the following pages. The asterisk(*) indicates that the reagent was brought from home to perform the exercise.

Experiment I

Purpose: To construct a semi-micro burner and learn how to adjust it.

Materials Needed: Soft pine board one by two inches*, one fourth inch and five-sixteenths inch copper pipe, file, bits, brace, vise, sewing needle, a hack saw, and pliers.

Experiment II

Purpose: To learn some simple laboratory manipulations.

Materials Needed: Burner, file, test tube clamp, medicine dropper, funnel, centrifuge, glass tubing, cotton*, filter paper, lead nitrate solution, sodium dichromate.

Experiment III

Purpose: To get an understanding of the differences between physical and chemical changes.

Materials Needed: Sodium chloride*, hydrochloric acid, sugar*, copper wire*, magnesium ribbon, magnesium oxide, burner, test tubes, test tube holder, custard bowl and pliers.

Experiment IV

Purpose: To recognize mixtures, compounds, and elements; to notice the difference between an element, a mixture, and a compound.

Materials Needed: Clean iron filings*, sulfur, carbon disulfide, magnet, test tubes, watch glass, and burner.

Experiment V

Purpose: To separate a mixture into its components.

Materials Needed: Clean iron filings*, sulfur, carbon disulfide, magnet, test tubes, watch glass, and burner.

Experiment VI

Purpose: To learn how oxygen is obtained from some compounds.

Materials Needed: Mercuric oxide, sodium, and potassium. chlorate, sodium peroxide, lead dioxide, silicon dioxide*, burner, test tubes, wood splints, medicine droppers, cotton*, and manganese dioxide.

Experiment VII

Purpose: To prepare and study the properties of oxygen.

Materials Needed: Potassium chlorate, manganese dioxide, sulfur, charcoal*, red phosphorus, sodium, magnesium, pneumatic trough, vials, wire gauze, burner, test tubes, test tube holder, ring stand, test tube clamp, wood splints, six inch test tube, stopper, rubber tubing, and glass tubing.

Experiment VIII

Purpose: To study simple displacements.

Materials Needed: Test tubes, sulfuric acid, copper sulfate, zinc, iron filings*, sodium, magnesium, and litmus paper.

Experiment IX

Purpose: To prepare and study the properties and behavior of hydrogen.

Materials Needed: Six inch test tube, pneumatic trough, vials, zinc, sulfuric acid, wood splints, custard bowl, water bath, soap*, copper oxide, rubber tubing, ring stand, and test tube holder.

Experiment X

Purpose: To obtain chlorine from its compounds; to study the physical properties and chemical behavior of chlorine prepared in the laboratory.

Materials Needed: Manganese dioxide, lead dioxide, potassium permanganate, potassium chlorate, potassium iodide, hydrochloric acid, copper sulfate, sodium chloride*, boiled starch solution*, wood splints, powdered antimony, copper wire*, sodium thiosulfate, vials, tubing, medicine droppers, Erlenmeyer flask (50 ml), stoppers, cardboard*, green vegetable matter*, and two small bottles about 50 ml. in size.

Experiment XI

Purpose: To prepare hydrogen chloride and to study some of its chemical and physical properties.

Materials Needed: Erlenmeyer flask (50 ml.), vials, sodium chloride*, sulfuric acid, litmus paper, wood splints, ammonium hydroxide, magnesium ribbon, silver nitrate, nitric acid, sodium hydroxide, phenolphthalein, sodium carbonate, and magnesium oxide.

Experiment XII

Purpose: To learn what impurities can be removed from water by distillation.

Materials Needed: Erlenmeyer flask(50 ml.), condenser, ring stand, custard bowl, burner, copper sulfate, ammonium hydroxide, phenolphthalein, rubber tubing, tripod, wire gauze, tap water, and vials.

Experiment XIII

Purpose: To determine if a substance is a hydrate, and to learn a chemical test for water.

Materials Needed: Copper sulfate, sodium carbonate, potassium chlorate, alum*, sodium chloride*, alcohol*, kerosene*, test tubes, barium chloride, and a burner.

Experiment XIV

Purpose: To learn something about the methods used to provide healthful water.

Materials Needed: Muddy water, aluminum sulfate, lime water*, ammonium hydroxide, centrifuge, test tubes, filter paper, funnel, and vials.

Experiment XV

Purpose: To learn what factors affect the solubility of a substance.

Materials Needed: Copper sulfate crystals, potassium chlorate, sodium thiosulfate, burner, test tubes, bottle of pop*, alcohol*, kerosene*, and carbon disulfide.

Experiment XVI

Purpose: To determine the valence of metal.

Materials Needed: Magnesium ribbon, hydrochloric acid, thread*, glass tubing, stoppers, Erlenmeyer flask (50 ml.), pint bottle*, pinch clamp, custard bowl, tap water, thermometer, graduated cylinder, and a balance.

Experiment XVII

Purpose: To study the atmosphere and find out the percentage of oxygen in the atmosphere.

Materials Needed: Calcium chloride, lump of sodium hydroxide, barium hydroxide, yellow phosphorus, copper wire*, graduated cylinder, thermometer, barometer, large jar with a big mouth*, ring stand, and test tube holder.

Experiment XVIII

Purpose: To study the different forms of sulfur and its chemical and physical properties.

Materials Needed: Sulfur, carbon disulfide, alcohol*, iron filings*, copper turnings*, tin foil*, test tubes, and burner.

Experiment XIX

Purpose: To study the preparation and properties of sulfur dioxide.

Materials Needed: Sodium sulfite, potassium permanganate, magnesium ribbon, green vegetable matter*, barium chloride, copper turnings*, chlorine water, concentrated sulfuric acid, Erlenmeyer flask (50 ml.), pint bottle, vials, medicine droppers, glass tubing, and stoppers.

Experiment XX

Purpose: To prepare hydrogen sulfide and observe some of its physical and chemical properties.

Materials Needed: Iron sulfide, zinc sulfide, antimony sulfide (prepared in the laboratory), lead acetate, solutions of copper, zinc, antimony, and arsenic salts, calcium chloride, hydrochloric acid, and the necessary equipment for setting up an oxygen generator as described in experiment seven.

Experiment XXI

Purpose: To learn how to titrate an acid and a base; to determine the strength of an unknown base; and to determine the strength of some household vinegar.

Materials Needed: Ring stand, test tube holder, burette, pinch clamp, hydrochloric acid, sodium hydroxide, vinegar*, litmus paper, phenolphthalein, methyl orange, and a water glass.

CHAPTER VII

CONCLUSIONS

This experimental study brought forth the following conclusions:

1. Chemistry can be installed and maintained in the high school at a very low cost.
2. The use of home made equipment and apparatus demonstrated that:
   a. It helps reduce installation and maintenance costs.
   b. Home made equipment can be substituted satisfactorily for manufactured articles.
   c. Breakage costs are low because the substituted articles are much cheaper and are furnished by the pupils rather than by the school.
   d. In general this equipment can be used to perform all the experiments offered in a standard high school chemistry course.
   e. Pupils have the satisfaction of knowing they can do something for themselves.
   f. Parents were able to see that the pupils showed interest in this class.
   g. Co-operative planning and working toward a common goal is stimulated among the pupils.
   h. Pupils have the opportunity to learn that

the more technical pieces of apparatus work on the same principle as the home made equipment.

3. The semi-micro equipment has the following advantages:

   a. It helps to reduce installation and maintenance costs.

   b. It does not require high priced laboratory equipment.

   c. Chances for accidents are not as great as in the ordinary laboratory.

   d. Experiments are easy to perform.

   e. The amount of undesirable gases that escape in the laboratory are so drastically reduced that the poisonous gas preparation experiments can be run by laboratory groups in an ordinary classroom without installing special ventilation equipment.

   f. The small quantities ~~helps~~ help to increase neatness and carefulness.

APPENDIX

BOOKS IN THE LABORATORY ROOM

General Chemistry

Brownlee and Fuller, First Principles of Chemistry. McGraw-Hill and Co., 1936. 435 pages.

Dinsmore, Chemistry for Secondary Schools. Laurel Book Co., 1936. 586 pages.

Foster, Elements of Chemistry. D. Van Nostrand Co., Inc., Second Edition, 1932. 653 pages.

Holmes, and Mattern, Elements of Chemistry. The MacMillan Co., 1927. 519 pages.

Reference Manuals

Bailey, Laboratory Guide in General Chemistry. O. B. U. Press, 1936.

Belcher and Colbert, Experiments and Problems in College Chemistry. D. Appleton-Century Co., 1934.

Burrows and Arthur, Semi-micro Laboratory Exercises in General Chemistry. Crossman Multilith and Printing Co., 1939. 85 pages.

General Reference Books

Adams and Johnson, Elementary Laboratory Exercises in Organic Chemistry. The Macmillan Company, 1934. 363 pages.

Conant, The Chemistry of Organic Compounds. The MacMillan Co., 1934. 623 pages.

Getman and Daniels, Outlines of Theoretical Chemistry. John Wiley and Sons, Inc. Sixth Edition, 1937. 662 pages.

Hammett, Solutions of Electrolytes. McGraw-Hill Book Co., Inc., Second Edition, 1936. 238 pages.

Riegel, Industrial Chemistry. Reinhold Publishing Corporation, Third Edition, 1937. 851 pages.

Handbook of Chemistry and Physics. Chemical Rubber Publishing Co., Twenty-first Edition, 1936. 2023 pages.

A HOME MADE CENTRIFUGE

The base for the centrifuge was made from a scrap two by six inch board about forty inches long. The legs for the base were made of scrap pieces of three by three inch lumber.

The crankshaft and the shaft for the centrifuge arms were made from a scrap piece of a pump rod that had been discarded from a water well pumping system. The large pulley, lettered A in the picture, was sawed from the lid of an old discarded phonograph. This pulley was eighteen inches in diameter. A groove was sawed along the outer edge of the pulley so that the belt would stay on its track. The endless belt was made by fastening the two ends of a piece of one-fourth inch rubber tubing together. The belt was about three and one-half feet long.

The small "v" type pulley, C, was two inches in diameter. It was fastened to the centrifuge shaft by means of a set screw.

The bearings for the shafts were made from some brass protectors that cover the water inlet fittings of a new bathroom lavatory. The bearings were carefully dressed down by a file and emery cloth until they fitted nicely into an outer bearing made from a piece of brass pipe about an inch long. The outer bearings were split to allow for oiling and heat expansion. The outer bearings were wedged in opposite ends of a two by two inch board five inches long that had a hole bored lengthwise through its center. This square cornered board was a good housing for the bearings and was easy to wedge tightly into the base of the centrifuge.

The arms for the centrifuge, lettered D in the picture, were made from a piece of copper alloy sheeting about the thickness of a dime. The strip was about eighteen inches long and three-fourths inch wide. Small blocks four inches long which had one-half inch holes drilled three inches deep lengthwise into one end of each block were used as buckets for the centrifuge. The buckets were fastened underneath the arms as shown in the picture so that they would be pressed against the metal strip by the centrifugal force when the shaft was being turned. The copper wire was used to prevent the centrifugal force from bending the arms to a horizontal position when the apparatus was being rotated.

Although it was not necessary, the long bolt, B, could be used to anchor the centrifuge to a table. There was no expense in constructing the centrifuge.

EXPERIMENT 10

TO PREPARE CHLORINE AND STUDY ITS PROPERTIES

OBJECT: To obtain chlorine from its compounds. To study physical properties and chemical behavior of chlorine prepared in the laboratory.

LEADING INTO THE EXPERIMENT: Since chlorine is found only combined in nature, it must be obtained from its compounds. In this experiment you will explore the possibilities of liberating combined chlorine. You will also collect some of the gas and study its properties. CAUTION: Chlorine is an irritating and somewhat poisonous gas. The greatest care must be exercised to prevent its excape into the room, and to avoid inhaling the gas in case it does escape. If directions are followed carefully, chlorine may be generated and studied without annoyance.

ANTIDOTE: Get quickly to fresh air. Pour some dilute ammonium hydroxide or alcohol upon a cloth and carefully inhale the gas given off. Be sure to notify your instructor at once.

MATERIALS NEEDED: Manganese dioxide, lead dioxide, potassium permanganate, potassium chlorate, potassium iodide, concentrated hydrochloric acid, copper sulfate, sodium chloride*, boiled starch*, wood splints, powdered antimony, copper foil*, sodium thiosulfate, 6 vials, glass tubing, medicine dropper, generating flask, stoppers, cardboard*, two small flasks (60 ml. approximately).

DIRECTIONS: Part 1. Heat a small amount (about the size of a match head) of each of the following solids in separate dry test tubes: lead dioxide, manganese dioxide, potassium chlorate, copper sulfate (dehydrated), and sodium chloride. Heat each sample slowly and test for the presence of oxygen by using a glowing splint. This shows which of these substances are good oxidizing agents, that is, which liberate oxygen readily. Record your results in the following type of chart.

Substance	Is oxygen given off?	Oxidizing agent?	Effect on adding HCl	Effect on Moist blue litmus	Effect on moist potassium iodide paper
PbO_2					
MnO_2					
$KClO_3$					
$CuSO_4$					
$NaCl$					

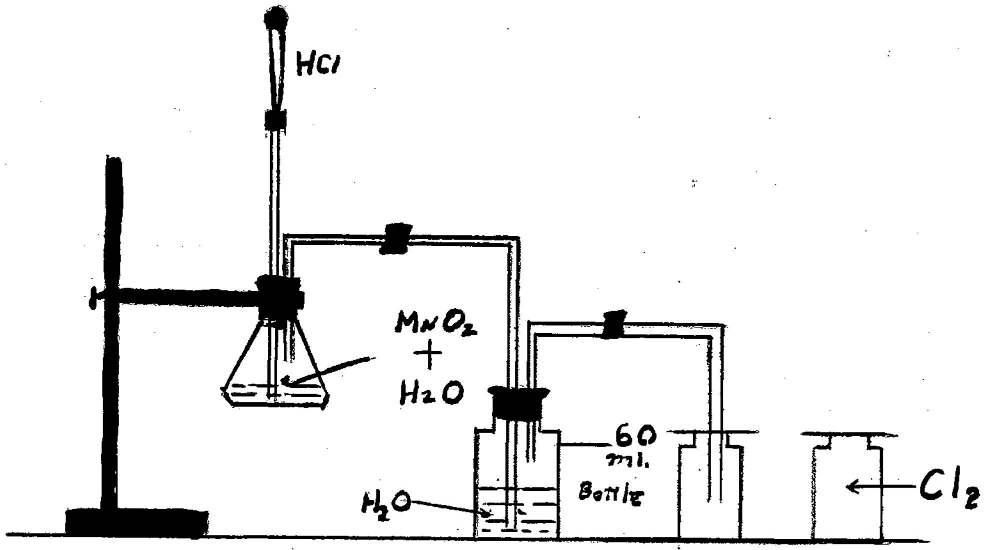
Using fresh materials, add 8-10 drops of concentrated hydrochloric acid to the separate test tubes. Note any action each case. If the action is slow, heat gently. By sniffing at the mouth of the test tube, very cautiously note the odor of any gas produced. Do not confuse the odor of chlorine with the sharp pungent odor of hydrogen chloride. Also note the color of any gas produced.

Test for the presence of chlorine by lowering into each test tube a piece of wire around which a small piece of moist blue litmus paper has been wrapped. Do not let the litmus touch the wall of the test tube. Further test for chlorine by repeating the above procedure with starch potassium iodide paper. Record your observations in the above chart.

1. What type of substance is needed with hydrochloric acid to release its chlorine?

2. What color change is used to identify chlorine by the use of starch potassium iodide paper?

Part 2. Preparation and properties of chlorine. Set up the apparatus shown on the next page.



Apparatus for Preparation of Chlorine

The flask contains four grams of manganese dioxide and ten ml of water. Fill the medicine dropper with concentrated HCl and place the dropper in the glass tubing as shown in the diagram. When the set-up has been approved by your instructor, squeeze a few drops of the acid into the flask. It may be necessary to heat the generator a little. The speed of the generated chlorine is controlled by the amount of acid that is dropped into the flask. Do not generate the gas too fast. Catch six vials of the gas and then run the excess chlorine gas into a bottle containing a previously prepared solution of sodium thiosulfate. Heat the generator then until all the chlorine has been passed over. A greenish color in the vials will appear as the vials are filled. Cork, or place a piece of glass over each vial as they are filled.

Part 3. Properties of chlorine. How would you describe the odor of chlorine? What property of the gas helps you to know when a bottle is full? Uncover a bottle of chlorine for a minute or so. Did much of the gas escape? Add a half test tube of water to the vial of gas, cover it with your hand and shake. Save for part five. What change did you notice in the water?

Part 4. Does chlorine support the combustion of a burning splint? Lower a small gas flame made by burning the laboratory gas from a fine glass tip into a bottle of chlorine. This tip is connected by a rubber hose to the gas supply.

4. Note whether the gas continues to burn, and if there is any change in the appearance of the flame. The labora-

tory gas is composed mostly of hydrogen and carbon.

5. Hold a piece of wet blue litmus paper in the vial of chlorine in chich the laboratory gas has been burned. What happens? Blow your breath across the mouth of the vial. Can you guess what formed in the vial when the gas flame was inserted? For comparison blow your breath across an open bottle of concentrated HCl.

6. Into another bottle of chlorine sprinkle a little antimony dust. What compound is formed? Warm a strip of thin copper and insert it in another bottle of chlorine. What happened? What compound is formed? (Shake the contents of the bottle with a little water and add a few drops of ammonium hydroxide. This may convince you.)

7. List four chemical properties of chlorine which you observed in this experiment.

Part 5. Test the bleaching action of chlorine by dipping into a vial of dry chlorine and also into a vial of moist chlorine (saved from part 3) pieces of litmus paper, newspaper print, paper with ink writing, and a small colored flower or piece of colored cloth. Note carefully any difference in action in the dry and in the moist chlorine.

8. What kind of results did you get in the above procedure?

9. What compound acts with chlorine to aid in bleaching?

10. Write the equation for this laboratory method of preparing chlorine.

11. What conclusion do you reach as to the ability of chlorine to support combustion?

12. Write an equation for the action of chlorine on antimony powder.

13. Write an equation for the action of chlorine on copper.

14. Describe briefly the commercial method of preparing chlorine.

15. Name four uses of chlorine.

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