STATE OF IOWA
1930

Courses of Study for High Schools

CHEMISTRY

Issued by the Department of Public Instruction
AGNES SAMUELSON, *Superintendent*

Published by
THE STATE OF IOWA
Des Moines

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CONTENTS

Note

Owing to the variety of textbooks used in the high schools of the state, no effort has been made to follow the order of any one book in determining the arrangement of the topics treated in this course of study. The general order follows that of the periodic table and will therefore conform to the arrangement of some texts now in use. The course of study is so arranged, however, that the teacher will find no difficulty in changing the order to suit that of any text.

FOREWORD

This course of study is one of a series of curriculum publications to be presented the high schools of the state from time to time by the Department of Public Instruction. It has been prepared by a subject committee of the Iowa High School Course of Study Commission working under the immediate direction of an Executive Committee. If it is of concrete guidance to the teachers of the state in improving the outcomes of instruction, the major objective of all who have contributed to its construction will have been realized.

From the start the need of preparing working materials based upon cardinal objectives and adaptable to classroom situations was emphasized. The use of the course of study in the development of proper pupil attitudes, ideals, habits, and skills was the criterion for selecting and evaluating subject matter material. At the same time it was important to consider the relation of the single course of study unit to the variety of textbooks used in the high schools of the state. The problem before the committees was that of preparing suitable courses of study representing the best in educational theory, practice, and research, and organized in such a way as to guide the teachers in using the textbook to greater advantage in reaching specified outcomes of instruction.

The selection of texts in this state is a function of the local school boards. The Department of Public Instruction and the committees do not recommend any particular text as essential to the working success of this course of study. The titles listed on the following pages are not to be interpreted as having official endorsement as against other and newer publications of value. They were found upon investigation to be in most common use in the high schools of the state at the time the units were being prepared; a follow-up survey might show changes.

Although many valuable studies have been made in the effort to determine what to teach and how to teach it, and to discover how children learn, these problems have not been solved with finality. For that reason and because no fixed curriculum can be responsive to changing needs, this course of study is to be considered as a report of progress. Its revision in accordance with the enriched content and improved procedures constantly being developed is a continuous program of the Department of Public Instruction. Your appraisal and evaluation of the material as the result of your experience with it are sincerely requested.

ACKNOWLEDGMENTS

The Department of Public Instruction takes this opportunity of thanking the many college specialists, school administrators, and classroom teachers who have helped with this program. Without the active coöperation of the educational forces of the state it could not have been attempted. It has had that coöperation both in general and specific ways. The support given by the Iowa State Teachers Association and the High School Principals' Section has enabled the Executive Committee to meet and also to hold meetings with the Commission as a whole and with the chairman of subject committees.

Special acknowledgment is given the Executive Committee for its significant leadership in organizing the program and to Dr. T. J. Kirby for his valuable services in directing its development. Sincere gratitude is also expressed to the various committees for their faithful and skillful work in completing the subject matter reports assigned them and to Dr. C. L. Robbins for his careful and painstaking work in editing the manuscripts. The state is deeply indebted to the High School Course of Study Commission for its expert and gratuitous service in this enterprise. Credit is due the publishers for making their materials accessible to the committees and to Professor L. B. Schmidt, Head of the Department of Government, Iowa State College, Ames, and to Professor O. B. Clark, Professor of History, Drake University, Des Moines, and to all others who served in advisory or appraisal capacities. Many of their names may not have been reported to us, but we acknowledge our appreciation to every one who has shown an interest in this significant program.

In the following committee list, the positions held by members are given as of the school year 1928-1929.

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AGNES SAMUELSON
Superintendent of Public Instruction

GENERAL INTRODUCTION

At the first general meeting of the various subject committees a suggestive pattern for the courses of study, embodying the fundamental needs for teaching, was projected. Four crucial factors that should be emphasized in any course of study to make it an instrument that would cause teachers to consult it for guidance in the performance of their daily work were set forth as follows: objectives, teacher procedures, pupil activities, and evidences of mastery.

Objectives—The meaning of objectives as here used is those concepts which are set up for pupils to achieve. As used in current practice, there is a hierarchy of objectives as shown by the fact that we have objectives of general education, objectives for various units of our educational system such as those proposed by the Committee on Cardinal Principles, objectives for subjects, objectives for a unit of instruction, and objectives for a single lesson. In each level of this hierarchy of objectives a constant element is expressed or implied in the form of knowledge, a habit, an attitude, or a skill which pupils are expected to acquire.

In the entire field of secondary education no greater problem confronts us than that of determining what these fundamental achievements are to be. What shall be the source of those objectives, is a problem of too great proportions for discussion here, but it is a problem that each committee must face in the construction of a course of study. A varying consideration of objectives by the various committees is evident in the courses of study they have prepared. The value of the courses varies in terms of the objectives that have been set up, according to the value of the objective in social life, according to the type of mental techniques which they stimulate and exercise, and according to the objectivity of their statement.

Pupil Activities—In our educational science we are attaching increasing significance to self-activity on the part of the learner. Recognition is made of the fundamental principle that only through their own activity pupils learn and that the teacher's rôle is to stimulate and direct this activity. No more important problem faces the curriculum-maker than that of discovering those fundamental activities by which pupils learn. In a well-organized course of study, the series of activities, in doing which pupils will attain the objectives set up, must be provided. These activities must not be chosen in a random fashion, but care must be taken that appropriate activities for the attainment of each objective are provided.

Teacher Procedures—With the objectives determined and the activities by which pupils learn agreed upon, the function of the teacher in the pupil's learning process must be considered. In a course of study there should appear those teacher procedures of known value which make learning desirable, economical, and permanent. Here our educational science has much to offer. Where research has demonstrated with a high degree of certitude that a given technique is more effective in the learning process than others, this technique should be included in a course of study. Common teaching errors with sug-

gested procedures to replace them may be included. Pupil difficulties which have been discovered through research should be mentioned and methods of proven value for meeting these difficulties should be included. Suggested ways of utilizing pupils' experiences should be made. And as important as any other feature is the problem of motivating learning. Whatever our educational research has revealed that stimulates the desires of pupils to learn should be made available in a course of study. Valuable types of testing should be incorporated as well as effective type assignment. The significance of verbal illustrations as evidence of comprehending the principle at issue should be featured as a procedure. Where there is a controlling procedure of recognized value such as is recognized in general science—bringing the pupil into direct contact with the phenomena studied—forceful effort for the operation of this procedure should be made.

Evidences of Mastery—What are to be the evidences of mastery of the objectives set up? There are all degrees of mastery from the memoriter repetition of meaningless terms up to a rationalized comprehension that shows grasp of both the controlling principles involved and the basic facts necessary to a clear presentation of the principles. These evidences of mastery may be in the form of dates *to be known,* formulae *to be able to use,* types of problems *to be able to solve,* quality of composition *to produce,* organization of materials *to be made,* floor talks *to be able to give,* papers *to be able to write.*

In no part of educational procedure is there need for more effort than in a clear determination of those evidences, by which a well-informed teaching staff can determine whether a pupil has a mastery of the fundamental objectives that comprise a given course. As we clarify our judgments as to what comprises the essential knowledge, habits, attitudes, and modes of thinking involved in a certain course, we can set forth with more confidence the evidences of mastery. Teachers are asking for the evidences of mastery that are expected of pupils, and courses of study should reveal them.

While these four elements constitute the basic pattern, the principle of continuity from objective to pupil activity, to teacher procedure, to evidence of mastery was stressed. The maker of a course of study must bear in mind that what is needed is an objective having accepted value; a pupil activity, in performing which, pupils gain a comprehension of the objective that is now being considered; that a teacher procedure is needed which evidence has shown is best adapted to stimulating pupils to acquire this objective for which they are striving; and that evidences of mastery must be incorporated into the course by which to test the degree of comprehension of the objective now being considered.

The courses of study vary in the degree to which these four fundamental features have been objectified and in the degree to which the principle of continuity from objective to evidence of mastery has been cared for. On the whole they will provide effective guides which teachers will use.

Realizing that these courses of study were prepared by school men and women doing full time work in their respective positions, one fully appreciates the professional zeal with which they worked and the splendid contribution to high school education which they made.

THOMAS J. KIRBY,
Chairman of the Executive Committee

COURSE OF STUDY FOR CHEMISTRY

INTRODUCTION

The importance of chemistry as a theoretical and practical science cannot be overestimated. It is decidedly a living, growing subject. It has preëminent value as a means of teaching intellectual integrity, of increasing the power of observation, of promoting the ability to reach accurate conclusions and of developing accuracy in manipulation and statement. The spirit of scientific research which has been developed through its laboratories is inspiring the highest ethical thought and action and is increasing the comforts of life and greatly adding to material welfare.

Certain subjects have long been designated as cultural. This is true of chemistry because it enters so largely into our present-day civilization and is so generally recognized. It is the corner stone of sanitation, medicine, engineering, agriculture, and other sciences. It develops rational thinking and provides a ready means of solving practical and theoretical problems of great industrial importance. It is a most potent factor in this rapidly developing scientific age.

The study of chemistry is not unlike the study of a foreign language. One cannot expect to master it in one year of high school work. It is possible however for every student to grasp some of the fundamental laws and their applications to every-day life.

Objectives

1. To acquire a knowledge of subject matter
   The subject matter should cover a fundamental knowledge of topics common to all localities and yet provide for sufficient supplementary material to make direct contacts with the experiences and daily life of the student in his locality or in his future work.
2. To acquire training in scientific method
   Pupils should develop qualities of observation, reasoning, self-confidence, judgment, open-mindedness, desire for accuracy, honesty, neatness and system.
3. To acquire training for college or business
   There should be enough basic material of a theoretical nature to give the pupil some "advanced standing" in a college chemistry course without sacrificing that definite knowledge of facts which shall contribute to his appreciations through life contacts and which shall improve his skills for concrete problems.

N. D. McCOMBS, Chairman
H. W. BAKER
W. F. COOVER
R. W. GETCHELL
NEIL LUTES
WM. B. ZUKER

I. INTRODUCTION

Objectives	Teacher Procedures	Pupil Activities	Evidences of Mastery
To acquire an understanding of metric units employed in chemical work	A. Discuss important metric units and their English equivalents 1. Length 2. Volume 3. Capacity 4. Weight 5. Temperature a. Explain "C" scale b. Change "C" to "F" c. Change "F" to "C"	A. Use the metric system in scientific measurements B. Measure the magnitude of all units by comparison with familiar units in the English system C. Apply the metric system in problem solving	*Direct* Recognition of the logic in the use of the metric system in science. Knowledge of its simplicity Understanding of relative values *Indirect* Habit of thinking in terms of the metric system A desire for accuracy
To understand certain important concepts of introductory chemistry	A. Matter and its changes 1. Define matter, classify as to kind and give examples 2. Teach the meaning of and explain a. Density b. Vapor density c. Specific gravity 3. Distinguish between physical and chemical changes a. Define b. Demonstrate	A. Learn definitions essential to a full understanding of chemical terms	*Direct* Ability to use chemical terms intelligently Recognition of physical and chemical changes

II. OXYGEN

To learn essential facts concerning the discovery of oxygen and its occurrence in nature	A. Call attention to the difficulties encountered in early experimentation B. Assign reports on the lives and contributions of Priestly and Lavoisier C. Discuss the occurrence of oxygen in the earth's crust, the sea, the atmosphere and the human body	A. Learn the significance of the work of Priestly and Lavoisier B. Observe the abundance of oxygen	*Direct* A factual background for the scientific study of oxygen *Indirect* An appreciation of the scope of chemistry
To become familiar with the general methods by which oxygen may be prepared	A. Review methods of preparation including action of water on sodium peroxide and separation from mixtures such as air, directing attention to their advantages and disadvantages B. Emphasize the fact that not all oxygen compounds yield the element when heated C. Define catalytic agent and describe its use	A. Prepare oxygen by the following methods 1. Heating an oxygen compound a. Heat potassium chlorate 1. Without manganese dioxide 2. With manganese dioxide 2. Electrolysis of water B. Identify oxygen by the splint test C. Write word equations for the chemical change	*Direct* Recognition of general methods of preparing oxygen. Realization that each specific method of preparation may be classified under one of the general methods Knowledge of the use of catalytic agents *Indirect* Appreciation of the fact that attraction of some elements for oxygen is greater than that of others

Objectives	Teacher Procedures	Pupil Activities	Evidences of Mastery
To obtain a practical knowledge of the properties of oxygen	A. Direct laboratory procedure for the activities listed B. Discuss results which the individual has accomplished during the process of the experiment C. Outline the method of illustrating chemical changes by word equations, *i.e.*, carbon uniting with oxygen yields carbon dioxide D. Assign the writing of word equations for each chemical change in the work	A. Prepare oxygen in quantity by heating potassium chlorate with a catalytic agent B. Observe its chemical conduct 1. Non-combustible (burning splint test) 2. Supports combustion a. Glowing splint, sulfur, red phosphorus, charcoal, magnesium, iron 3. Activity a. Study the substances formed during combustion. Note particularly the properties b. Make a list of numerous oxides C. Observe physical properties 1. Color 2. Odor 3. Taste 4. Density 5. Solubility in water	*Direct* First-hand information of the properties of oxygen *Indirect* Appreciation of laboratory procedure as a method of gaining first-hand information
To understand the effect of heating metals in air	A. Discuss correct laboratory procedure B. Call attention to the characteristics of a chemical compound C. Assign the writing of a list of ten chemical compounds found in the laboratory and five found in the home	A. Experiment by heating known weights of such metals as iron, tin, or copper and determine the amount of the increase in weight B. Compare the individual result with the result obtained by a more accurate class demonstration C. Set up laboratory apparatus in accordance with accepted standards D. Observe changes taking place during the heating which characterize it as a chemical change 1. Substance loses characteristics by which it was identified 2. Substance formed possesses new characteristics	*Direct* Knowledge of metals gaining in weight as a result of combining with the oxygen of the air to form compounds *Indirect* Appreciation of correct laboratory procedure
To know the essential uses of oxygen	A. Discuss the Bunsen burner 1. Parts of the burner 2. The control of the flame 3. Locate and describe the parts of the flame B. Discuss the function of oxygen as an important factor in 1. The composition of foods 2. The growth of humans, plants, and lower animals 3. Decay of organic matter 4. Combustion, slow oxidation, etc.	A. Study the commercial uses of oxygen 1. The Bunsen burner 2. Gas stove burner 3. Oxyhydrogen and oxyacetylene flames B. Observe that oxygen is necessary for the maintenance of human, plant, and lower animal life C. Read scientific and current literature which indicates the necessity of oxygen for health as well as for comfort D. Observe the properties of the allotropic form of oxygen called ozone	*Direct* Recognition of various examples of oxidation Realization that the heat given off in oxidation is the same whether the action is slow or fast *Indirect* Appreciation of nature as a wonderful scientific laboratory

III. HYDROGEN

Objectives	Teacher Procedures	Pupil Activities	Evidences of Mastery
To gain a working knowledge of the methods of preparing hydrogen	A. Explain that all acids contain hydrogen which may be replaced by a metal B. Explain that not all metals react with acids to produce hydrogen C. Discuss hydrogen from the standpoint of its properties, both physical and chemical D. Demonstrate electrolysis of water 1. Explain the terms: anode, cathode, electrode, electrolyte E. Discuss the elemental nature of hydrogen	A. Prepare hydrogen by the following methods 1. Replacement of hydrogen in an acid by a metal (Test both active and inactive metals with strong and weak acids) 2. Decomposition of water by a metal	*Direct* Knowledge of the replacement of hydrogen in an acid by the use of the more active metals Recognition of water as a compound which may be broken up by an electric current Understand electrolysis as a form of simple decomposition *Indirect* The ability to obtain good results from careful manipulation
To learn the properties of hydrogen	A. Explain a proper set-up for the preparation of hydrogen B. Explain the reaction of hydrogen to a burning splint C. Discuss the reducing action of hydrogen emphasizing the fact that reduction is a special type of chemical change	A. Set up a gas generating apparatus B. Prepare hydrogen by the action of zinc on dilute sulfuric acid C. Observe the physical properties of hydrogen D. Observe its chemical conduct 1. With a burning splint 2. With copper oxide	*Direct* The use of the thistle tube as a safety device Differentiation between the glowing splint test for oxygen and the burning splint test for hydrogen Recognition of the importance of hydrogen as an element
To learn the uses of hydrogen	A. Aid pupils in class discussion of assigned topics B. Explain why helium is substituted for hydrogen in balloons and dirigibles C. Explain why acetylene is sometimes used in the place of hydrogen in blow torches	A. Explain briefly the following uses of hydrogen 1. Oxyhydrogen flame 2. Balloons and dirigibles 3. Hydrogenation of oils 4. As a reducing agent for metallic oxides	*Direct* Recognition of the relation between the properties of an element and its uses *Indirect* Appreciation of what chemistry is doing for industry

IV. WATER

To acquire a comprehensive knowledge of the distribution of water	A. Direct class discussion on the topics listed under "Activities" B. Discuss the influence of the distribution of water 1. Economically, physically, etc. C. Call particular attention to the importance of safeguarding our water supplies D. Study municipal water systems	A. Recall the various sources of water 1. Atmosphere 2. Soil 3. Surface water B. Study the impurities of water as affecting its uses 1. Impurities in solution 2. Impurities in suspension C. Study the water system of your own municipality	*Direct* Appreciation of Nature's most abundant solvent *Indirect* An appreciation of the importance of the chemical control of our city water systems

Objectives	Teacher Procedures
To understand the physical properties of water	A. Explain the process of solution B. Discuss solution concentrations 1. Dilute, concentrated, unsaturated, saturated, supersaturated C. Explain the difference between water that is chemically pure and that which is potably pure
To understand the process of crystallization	A. Explain the terms 1. Crystalline 2. Amorphous 3. Efflorescent 4. Deliquescent
To understand hydrogen peroxide, a compound containing the same elements as water but in different proportion	A. Prepare it from barium peroxide B. Discuss the peculiarities of this compound
To understand that every compound has a definite composition by weight. Law of Definite Proportions	A. Explain text assignments regarding this law
To understand the Law of Multiple Proportions, illustrated by water and hydrogen peroxide	A. Direct the pupils very carefully in their study of this law 1. Avoid confusion between this law and the Law of Definite Proportions

V. COMPOUNDS AND MIXTURES

To learn the difference between a mixture and a compound	A. Outline the difference between a compound and a mixture B. Discuss numerous examples of each C. Demonstrate that a mixture may be separated into its constituent parts by mechanical means

VI. LAWS, HYPOTHESES AND THEORIES

To understand the Law of Conservation of Mass	A. Discuss and illustrate the Law of Conservation of Mass B. Direct the pupils in their observation of a burning candle C. Assign the selection of other illustrations

Pupil Activities	Evidences of Mastery
A. Test the solvent power of water on various solutes B. Test water to determine its hardness 1. Note principal compounds producing this condition C. Experiment to remove impurities 1. Filtration, boiling, distillation, chemical treatment	*Direct* A knowledge of the nature of a solution and of a suspension
A. Prepare crystals of various compounds B. Determine the percentage of water in a crystal	*Direct* Knowledge of the difference between the crystalline and the amorphous state
A. Observe the instability of the compound B. Study its uses 1. As a disinfectant 2. As a bleaching agent	*Direct* Knowledge of the ability of some elements to combine to form more than one compound
A. Observe that water is always composed of the same relative amount of the same substances B. Read textbook assignments regarding this law	*Direct* Understanding this law as a valuable tool to use in the study of chemistry *Indirect* Appreciation of the fact that Nature's processes follow fixed laws
A. Study the significance of the composition of water and hydrogen peroxide and its relation to these laws	*Direct* An understanding of some of the fixed laws of Nature
A. Review compounds formed by chemical changes studied B. List common illustrations of mixtures	*Direct* Ability to differentiate between compounds and mixtures
A. Observe a burning candle 1. Explain the phenomenon	*Direct* Realization that matter cannot be destroyed even though it may be changed from one state to another

Objectives	Teacher Procedures	Pupil Activities	Evidences of Mastery
To understand the molecular and atomic theories and the constitution of matter	A. Assignments, both text and current literature B. Explain the atomic theory	A. Study carefully the atomic theory in text and references	*Direct* Acceptance of the atomic theory as an aid in understanding the structure of matter
To understand the Laws of Charles and Boyle. To account for the changes in volume of gases	A. Explain why heat causes gases to expand B. Discuss standard conditions of temperature and pressure C. Review the process of changing from "F" to "C" scale D. Teach how to change from centigrade to absolute scale E. Discuss the application of these laws in problems 1. Temperature change only, over mercury 2. Pressure change only, over mercury 3. Combined temperature and pressure change a. Over mercury b. Adjusting levels c. Over water	A. Learn the laws and work carefully numerous problems illustrating their application under varying conditions B. Study explanations of the gas laws C. Employ the barometer and thermometer in gas computations in the laboratory D. Make a list of practical illustrations of these changes	*Direct* Knowledge that volume changes of gases are controlled by certain laws Understand the barometer and be able to use it
To understand Gay-Lussac's Law To understand the volume relation of gases in chemical changes	A. Explain and illustrate Gay-Lussac's Law	A. Study carefully the text material on volume relation of gases B. Compute the volume of gases produced by chemical changes	*Direct* Application of this law as an aid in explaining the atomic theory
To understand Avogadro's Hypothesis	A. Explain and illustrate Avogadro's Hypothesis	A. Study the assignment carefully B. Observe the demonstration given by the teacher	*Indirect* Mastery of laws, theories and hypotheses as the key to future scientific progress
VII. SYMBOLS, FORMULAS, WEIGHT AND VOLUME RELATIONS			
To become conversant with symbols, formulas, and valence	A. Explain the distinction between symbols and formulas B. Explain that formulas are not limited to compounds C. Show that symbols and formulas represent quantitative values, *e.g.*, one atom, a molecular weight, etc. D. Show how symbols are derived, *e.g.*, English or Latin names, first and second letters, etc. E. Explain valence by any of the accepted methods	A. List the names and symbols of the elements thus far studied; also the names and formulas of the substances, both elemental and compound encountered in previous assignments B. Prepare a list of elements to show the basis of selecting symbols C. Derive a few molecular weights from formulas D. Derive formulas when valence is given, and the reverse	*Direct* Ability to employ symbols and formulas as chemical shorthand *Indirect* Appreciation of the use of intelligent, applied brevity in sciences

Objectives	Teacher Procedures	Pupil Activities	Evidences of Mastery
To learn the use of equations	A. Carefully teach how to construct a skeleton equation and how to balance it B. Assist the pupils in writing equations as under "Activities" A C. Stress the fundamental significance and value of equations	A. Write equations for all reactions thus far studied	*Direct* Acquisition of the most valuable method of chemical expression *Indirect* Appreciation of the Law of Conservation of Mass. Realization of the precision of science
To use the mathematics of chemistry	A. Teach how to solve problems that apply principles illustrated in past assignments B. Introduce problems throughout the course, but not until the underlying principles have first been studied and illustrated	A. Solve such problems in weight and volume relations, both theoretical and applied, as the course to date has provided a basis for	*Direct* Knowledge of chemical arithmetic *Indirect* Realization that applied science is in no sense haphazard
VIII. ATMOSPHERE			
To know the composition of the atmosphere and understand its relation to plant and animal life	A. Demonstrate the burning of phosphorus in air (Explain) B. Show how the composition of air affects life 1. Carbon cycle 2. Nitrogen cycle 3. Percentages of oxygen and nitrogen C. Aid in reports on reference assignments regarding the atmosphere	A. Prepare nitrogen by burning phosphorus in a limited volume of air 1. Note the comparative volume of nitrogen and oxygen 2. Carefully describe the products B. Test air for 1. Carbon dioxide 2. Water vapor (humidity) 3. Oxygen C. Report on reference assignments	*Indirect* Acquiring knowledge that directly affects life
IX. NITROGEN			
To familiarize the student with pertinent facts concerning nitrogen	A. Discuss text assignment covering nitrogen 1. Occurrence 2. Chemical and physical properties B. Review the nitrogen cycle C. Discuss the oxides of nitrogen	A. Occurrence 1. Recall the experiment of burning phosphorus in a limited volume of air 2. Report on the occurrence of combined nitrogen B. Prepare nitrogen from ammonium nitrite. Study properties and uses	*Direct* Appreciation of the fact that air is a mixture of oxygen and nitrogen. Nitrogen in air prevents rapid oxidation
X. NITRIC ACID			
To learn the preparation, properties and uses of nitric acid	A. Refer to the oxides of nitrogen in relation to the corresponding acids B. Discuss the physical and chemical properties of nitric acid, demonstrating some of its chemical properties 1. Call attention to the equation illustrating the decomposition of nitric acid 2. Show how wool and charcoal are oxidized	A. Read the assignments covering nitric acid B. Prepare nitric acid in the laboratory C. Determine its physical and chemical properties D. Experiment to show the comparative instability of nitric acid 1. By putting wool yarn into the acid 2. Heat charcoal and put into nitric acid	*Direct* Recognition of the importance of nitrogen and nitrogen compounds

Objectives	Teacher Procedures
	3. Emphasize the use of nitric acid as an oxidizing agent C. Discuss the important industrial uses of nitric acid D. Review fixation of nitrogen, assigning reference work for a detailed report
	XI. AMMONIA
To acquire definite knowledge of the distribution of ammonia	A. Assign text material B. Call for a special report on the manufacture of coal gas, and carbureted water gas C. Explain the properties and uses of the gas 1. Emphasize its use as a refrigerating agent
To understand commercial processes for the production of ammonia	A. Assign the study of the Haber process and other processes B. Emphasize the importance of heat control. An illustration of equilibrium
	XII. ACIDS, BASES, AND SALTS
To understand their nature	A. Show how to identify acids and bases by their formulas B. Indicate their ionic definitions (After ionization has been presented)
To study neutralization	A. Point out the composition of salts B. List common cases of neutralization C. Discuss normal, acid, basic, mixed and double salts
To become familiar with the terminology of acids, bases and salts	A. Present the meaning of the terms: *ous, ic, ide, ite, ate, hypo,* and *per*
	XIII. THEORY OF IONIZATION
To find out what classes of substances will conduct electricity	A. List the classes of compounds which are and are not conductors B. Explain why aqueous acids, bases and salts will conduct electricity C. List other properties which depend upon their ionization
To become familiar with ionic actions	A. Definition of ion B. Explain displacement, metathesis and neutralization actions in terms of ions

Pupil Activities	Evidences of Mastery
A. Show the presence of nitrogen in protein material such as hoofs, hides, horns, and gelatin, by heating with soda lime B. Distill coal and examine the products of distillation C. Visit the local gas plant. Study the method used in the manufacture of gas 1. Look for evidence that there is ammonia in coal	*Direct* Gaining an added appreciation of the value of nitrogen and its compounds in chemical industry *Indirect* Renewed interest in the study of chemistry
A. Describe in detail important commercial processes for the preparation of ammonia B. Read popular articles on synthetic ammonia	*Direct* Increased knowledge of the extensive use of nitrogen compounds
A. Examine acids as to litmus test, taste (dilute), action with a metal; bases, as to litmus test, feeling (of solution); salts, (NaCl, K_2SO_4) with litmus	*Direct* Knowledge of the true significance of acid and alkali
A. Neutralize a base with an acid and examine the (dried) product B. Examine the most common salts and list their properties and their corresponding acids	*Direct* Realization of the counteracting effects of acids and bases *Indirect* Appreciation (from titration practice) of the refined technique required in science
A. Practice the naming of compounds from their formulas and the reverse	*Direct* Understand that the formidable technical names in science are logically selected
A. Use electrodes with a lamp in circuit to test aqueous solutions of acids, bases, salts, sugar, alcohol, glycerine, and pure water A. Examine previous experiments dealing with displacement, metathesis and neutralization	*Direct* Appreciate the nature of electrolysis *Direct* Knowledge of the mechanics of chemical actions taking place in water solutions

XIV. PHOSPHORUS

Objectives	Teacher Procedures	Pupil Activities	Evidences of Mastery
To acquire knowledge of the properties of phorphorus	A. Discuss allotropy B. Explain spontaneous combustion C. Outline the process of match manufacture	A. Compare the properties of red and yellow varieties B. Evaporate a few drops of a CS_2 solution, on filter paper C. Examine the cover of a safety match box D. Reference work on matches	*Direct* Knowledge of phosphorus, its properties and uses
To study certain compounds of phosphorus	A. Discuss the uses of phosphorus compounds in fertilizers, matches, smoke screens	A. Prepare reports on the application of phosphorus compounds in industry B. Test for phosphate in bone ash dissolved in nitric acid, with ammonium molybdate	*Direct* Knowledge of the common phosphorus compounds

XV. PERIODIC TABLE

To become familiar with attempts at classifying the elements	A. Examine some of Doebereiner's triads B. Explain Newlands' octaves C. Indicate the relationships in the periodic chart as to valence, metals and non-metals, similarities and progressive changes within the groups and within the series D. Refer briefly to Moseley's atomic numbers	A. List the families of elements as they are grouped in the text B. Report on the work of early investigators: Prout, Stas, Dumas, Newlands, Doebereiner, Meyer and Mendeleeff	*Direct* Appreciation of the necessity of overcoming preconceived notions and prejudices and recognition of the fact that scientific knowledge must grow progressively and slowly
To understand the value of classification of the elements	A. Compare the properties of a later discovery element with those which Mendeleeff predicted for it B. Refer to the position and placing of the zero group, also to illinium (recently discovered) C. Show how unknown elements are predicted D. State the periodic law and explain	A. Report on other types of classification, such as graphs, spirals and helixes B. Study the properties of a given element (in the long series) in relation to the four adjacent elements	*Direct* Conviction that the apparent magic of science is in reality rational, factual and useful

XVI. SODIUM

To learn the properties of the metal	A. Emphasize the meaning of the word "metal" B. Point out the activity of this metal C. Discuss the spectroscope and its uses D. Discuss the physical properties of this metal (Contrast with other metals)	A. Add sodium to water; test the gas with a flame, the water with litmus B. Examine the sodium (and postassium) spectrum	*Direct* Knowledge of the rôle of the spectroscope in scientific discovery
To become familiar with the occurrence and uses of compounds of sodium	A. Consider the geological formation, method of obtaining and uses, of sodium chloride	A. Sodium chloride 1. Examine and list its physical properties 2. Obtain specimens of the different forms on the market, such as table salt, rock salt, etc.	*Direct* Knowledge of this important compound *Indirect* Appreciation of man's dependence upon Nature's geological formations

Objectives	Teacher Procedures
Sodium hydroxide	B. Describe the manufacture of sodium hydroxide by electrolysis and its relation to soap manufacture, to water softening and to mercerizing
Sodium carbonate	C. Study the Solvay process Explain the water softening power of sodium carbonate Explain hydrolysis and predict it from the formulas of various salts
Sodium bicarbonate	D. 1. Point out the chemistry of the leavening process 2. Describe the action of the carbon dioxide type of fire extinguisher 3. Refer to other types of extinguishers
Sodium nitrate	E. List the industrial uses of sodium nitrate

XVII. COPPER, GOLD, AND SILVER

Copper To understand its occurrence, production and properties	A. Direct assigned readings B. Show how its occurrence and metallurgy typifies that of other metals
To learn the use of copper	A. Direct studies and reports B. Show the relation of copper to industrial progress
Gold To study its sources, refining, and uses	A. Direct studies and reports B. Explain the economic phase of gold production, gold rushes, etc.
Silver To study its sources and uses	A. Assign and discuss text and reference material B. Consider the use of the metal in coinage and of its salts in photography

Pupil Activities	Evidences of Mastery
B. Sodium hydroxide 1. Test it for its basic nature, deliquescent property and action on hard water 2. Prepare reports on soap manufacture	*Direct* Knowledge of the properties and uses of this (and succeeding) sodium compound
C. Sodium carbonate 1. Examine and list its physical properties 2. Test it for its action on litmus and on hard water 3. Test such salts as sodium carbonate, sodium sulfide, copper sulfate and ferric chloride for their hydrolyzing power	*Direct* Knowledge of hydrolysis
D. Sodium bicarbonate 1. List its physical properties 2. Treat it with an acid and explain the result in terms of ions 3. Mix a dry acid (tartaric) with a dry salt; then add water and explain the results 4. Add water to baking powder and explain the resulting phenomenon	*Direct* Knowledge of leavening and of fire extinction
E. Sodium nitrate 1. Recall the manufacture of nitric acid from salt peter 2. Report on the Chilean nitrate industry	
A. Examine ores and products of the metal B. Prepare reports on assigned topics	*Direct* A conception of how useful metals are obtained
A. Prepare a list of uses B. Collect specimens of articles of copper and its alloys C. Report on the composition and uses of alloys	
A. Study in terms of the "Objectives" B. Prepare reports on gold mining C. Interview jewelers in regard to "carat" and cost figures	*Direct* Knowledge of this important metal *Indirect* Appreciation of the monetary standard
A. Study carefully the textbook material B. Prepare from experience and reference a list of its uses	*Direct* Knowledge of the value of silver in daily experience

XVIII. CALCIUM AND ITS COMPOUNDS

Pupil Activities	Evidences of Mastery
To become familiar with the compounds of calcium	A. Assign and discuss text and reference material B. Exhibit forms of calcium compounds

XIX. ALUMINUM

To learn the properties and uses of the metal and its compounds	A. Assign and discuss material concerning 1. Preparation of the metal 2. Uses a. Electrical, structural and industrial B. Discuss the clay industries of Iowa

XX. CARBON

To understand the occurrence and production of the various forms of free carbon	A. Assign and discuss the distribution and great value of carbon compounds B. Discuss commercial carbon compounds 1. Charcoal 2. Artificial graphite 3. Carborundum 4. Calcium carbide C. Discuss its occurrence in plant and animal bodies D. Explain the meaning of adsorption and of destructive distillation E. Discuss gas masks

XXI. OXIDES OF CARBON

Carbon monoxide To learn its occurrence, properties and uses	A. Demonstrate its preparation B. Direct the study of its preparation and principal uses 1. Industrial reducing agent 2. Constituent of water gas, coal gas and producer gas C. Discuss poisoning by carbon monoxide 1. Emphasize exhaust from automobile engines

Objectives	Teacher Procedures
A. Calcium carbonate 1. List its varieties 2. Study its relation to hard water 3. Connect the topic with water softening previously studied 4. Report on its relation to lime B. Calcium oxide 1. Report on its manufacture and its various uses C. Calcium sulfate 1. Study the uses of gypsum and plaster of Paris 2. Report on "setting" of plaster of Paris and of cement D. Report on the uses of other calcium compounds, as carbide and acid phosphates	*Direct* Knowledge of the usefulness of so-called "lime" compounds
A. Report on the work of Hall B. Demonstrate the heat conductivity and non-corrosive powers of the metal C. Observe the taste of alum and its acid nature toward soda D. Report on the Goldschmidt process	*Direct* Knowledge of the industrial uses of aluminum and its products
A. Report on the occurrence of diamonds and graphite B. Study the manufacture of graphite, bone black, lamp black, nut charcoal, wood charcoal and coke C. Collect samples of the forms of carbon 1. Note properties and determine uses	*Direct* Knowledge of the wide distribution and universal value of carbon and its compounds in nature and in industry
A. Study its formation in stoves, in exhaust gases, in the blast furnace, and in illuminating gas B. Report instances of its use as a heat source, a reducing agent, and its action in asphyxiation	*Direct* Knowledge of carbon monoxide Inculcation of caution where carbon monoxide might be present

Pupil Activities	Evidences of Mastery
Carbon dioxide To learn of its occurrence and preparation	A. Refer to its presence in the atmosphere and in certain caves, etc. B. Review its various methods of preparation C. Show its relation to plant and animal life
To learn its properties and uses	A. Discuss its physical and chemical properties as suggested in "Activities" B. Assign reference for reports on commercial fire extinguishers C. Discuss other applications 1. Refrigerating 2. Beverages 3. Leavening agent

XXII. SULFUR AND SULFIDES

To become familiar with the occurrence, extraction, properties and uses of sulfur, and to consider briefly its most important sulfides	A. Conduct preliminary discussion of assignments for reading B. Describe laboratory experiments C. Demonstrate the formation of sulfides 1. Precipitations with hydrogen sulfide D. Show charts of the Frasch process

XXIII. OXIDES OF SULFUR

To gain a knowledge of the oxides of sulfur	A. Introduce the subject of the occurrence, properties and principal uses of sulfur dioxide B. Discuss experiments to be performed by the pupils C. Liquefy sulfur dioxide, bleach flowers, and reduce potassium permanganate as a class demonstration D. Describe sulfur trioxide 1. Prepare it before the class and discuss its use

Objectives	Teacher Procedures
A. Demonstrate its presence 1. In expired air 2. From the combustion of carbon and its organic compounds 3. From an acid with a carbonate 4. From reduction of an oxide by carbon	*Direct* Familiarity with its properties and varied methods of production
A. Prepare the gas in the laboratory B. Experimentally show its 1. Relative density 2. Action on a flame 3. Very weak acidic nature 4. Other physical properties C. Report on its applications 1. In fire extinction 2. As a leavening agent 3. In the "setting" of mortar 4. In producing "lime hardness" in water D. Report on references assigned concerning commercial fire extinguishers	*Direct* Appreciation of the contributions of the gas to human welfare
A. Assignment for study 1. Textbook and reference work covering occurrence of sulfur, free and combined, Frasch process for mining, uses of sulfur and periodic table relations B. Experimental 1. Physical properties of sulfur a. Behavior when heated, allotropic forms and properties of each 2. Chemical conduct—Direct union with metals and with oxygen 3. Preparation of hydrogen sulfide 4. Properties of hydrogen sulfide a. Physical and chemical	*Direct* Understanding of the Frasch process and of the physical and chemical properties of sulfur and its importance in everyday life *Indirect* Appreciation of American resources
A. Assignment for study 1. Textbook and references covering preparation, and physical properties of sulfur dioxide 2. Uses of sulfur dioxide a. Refrigerant, bleaching agent, reducing agent, food preservative, disinfectant, and manufacture of H_2SO_4 B. Experimental 1. Preparation of sulfur dioxide 2. Properties of sulfur dioxide 3. Preparation of sulfurous acid and one sulfite	*Direct* Knowledge of the preparation, properties and uses of the oxides of sulfur *Indirect* The relation of non-metallic oxides to oxygen acids. An appreciation of the importance of sulfur dioxide in the home and in the community and of sulfur dioxide and sulfur trioxide in industry

XXIV. SULFURIC ACID

Objectives	Teacher Procedures	Pupil Activities	Evidences of Mastery
To become acquainted with the preparation, properties and uses of sulfuric acid	A. Discuss varous methods of manufacture B. Prepare sulfuric acid by the lead chamber and the platinum contact processes (Demonstration) C. List products depending on sulfuric acid at some point in their production D. Discuss reference assignments on the industrial uses of the acid	A. Assignment for study 1. Study carefully the textbook assignments and other references describing the uses of sulfuric acid in the preparation of other acids, of sulfates, of fertilizer and in refining of petroleum and the pickling of metals 2. Discuss in detail acid anhydrides B. Laboratory assignment 1. Show the properties of sulfuric acid as an oxidizing agent, as a dehydrating agent, and a means of preparing volatile acids and sulfates 2. Learn the test for a sulfate	*Direct* Appreciation of the importance of sulfuric acid and knowledge of its preparation, properties and uses *Indirect* Recognition of the interdependence of industries upon sulfuric acid

XXV. HALOGENS

To learn the methods or preparation, properties and uses of the halogens and their compounds, and to learn the relationships of the members of a family in the periodic table	A. Discuss assignments covering the preparation, properties and uses of the halogens, placing particular emphasis upon chlorine B. Explain laboratory experiments covering the halogens and their principal compounds C. Conduct demonstrations 1. Etching of glass 2. Show the solubilities of the halogens in organic compounds such as ether, alcohol, carbon tetrachloride and chloroform	A. Assignment for study 1. Study chlorine in detail Refer to the important uses of other members of the halogen family 2. Discuss chlorine as a germicide, a bleaching agent, oxidizing agent and chlorinating agent B. Laboratory experiments 1. Prepare chlorine, bromine and iodine 2. Study their properties and individual tests 3. Compare the relative stability of the acids of these three elements and the relative activity of the elements themselves	*Direct* Understand what is meant by a chemical family *Indirect* To learn how to apply the principles of the periodic table to the study of one of its families *Direct* To learn how to identify members of the group by chemical tests

XXVI. IRON

To learn the sources of iron ore and the manufacture, properties and uses of cast iron, wrought iron and steel	A. Assign text and reference material covering the following topics 1. Metallurgy 2. Cast iron: properties and uses 3. Steel manufacture 4. Protective coatings to prevent corrosion of iron and steel 5. Compounds of iron—ferrous and ferric B. Explain the tests for ferrous and ferric iron C. Demonstrate a small model of a blast furnace. Use educational films to show important phases of the steel industry	A. Assignment for study 1. Cover the work listed in "Teacher Procedures" 2. Special assignments: mining and shipping ore in Minnesota; the blast furnace; Bessemer converter; open hearth; special steels for special purposes; tempering steel B. Laboratory assignment 1. Prepare and use blue print paper 2. Interconversion of ferrous and ferric compounds and tests for each	*Direct* Knowledge of the processes of preparing iron and steel and an appreciation of the magnitude of the iron and steel industry Realization of the importance of, and methods used, to protect exposed surfaces of these substances

XXVII. ORGANIC COMPOUNDS

Objectives

To become familiar with some sources of organic compounds and the value of chemistry in separating them from complex mixtures, identifying them and discovering their uses; to study briefly a few important organic compounds; to learn something about the relationship of chemistry to industry

Teacher Procedures

A. Discuss the scope of organic chemistry and assign text and reference material covering the suggested pupil activities
B. Fractionally distill gasoline
C. Show the solvent action of ether or of alcohol (Use denatured alcohol)

Pupil Activities	Evidences of Mastery
A. Assignment for study	
1. Sources of organic compounds	
a. Destructive distillation of wood producing	
1. Methanol	
2. Acetone	
3. Acetic acid	
4. Charcoal	
b. Destructive distillation of coal producing	
1. Gas	
2. Benzene	
3. Ammonia	
4. Tar	
5. Coke	
c. Distillation and cracking of petroleum producing	*Direct* Knowledge of the value of chemistry to industry and to every-day life
1. Gasoline	
2. Kerosene	
3. Lubricating oils	
4. Vaseline	*Indirect* A brief insight into the rôle which chemistry is playing in modern civilization
5. Paraffin	
d. Fermentation producing	
1. Ethanol	
2. Acetone	
3. Butanol	
4. Acetic acid	
e. Synthesis	
2. Some important organic compounds	
a. Ethyl alcohol, acetic acid, sugar, starch, classes of food stuffs	
B. Laboratory experiments	
1. Subject coal or wood to destructive distillation	
a. Describe the products	
2. Examine starch (from various sources) under the microscope	
3. Test for starch with iodine	
4. Test for reducing sugar	
5. Hydrolyze starch and test the resulting sugar	
6. Apply selected tests to food stuffs	

APPENDIX

TOPICS FOR SUPPLEMENTARY STUDY

(To Be Added to the Course as Time Permits)

Alloys, other than those containing copper
Antimony, properties and uses
Arsenic insecticides
Bismuth, important uses
Bleaching powder
Catalysis
Chromium, commercial uses
Colloids, common examples and their application
Electromotive series
Hydrogen equivalent (reacting weights, not atomic weights)
Hydrogen sulfide with special reference to testing for certain metals not covered in Section 22
Lead, properties, uses and compounds
Magnesium, properties, uses and compounds
Mercury, properties and uses of the metal and of the chlorides
Nickel and platinum, important uses and special properties
Potassium, treated as sodium, use in agriculture
Radium and radio-activity
Rare gases in the air
Silicon and its compounds
Strontium and barium, properties and uses
Tungsten, properties and commercial uses
Zinc, metallurgy, properties, uses and salts

LIST OF TOPICS FOR SUPPLEMENTARY READING

(Taken from the report of the Committee on a Standard Minimum High School Course in Chemistry, American Chemical Society)

These topics may be introduced in greater detail to add interest to the topics in the preceding course of study. They should be selected according to local importance and at the discretion of the teacher. Other topics may be added as suggested by this list

Adhesives:	Gums, paste, dextrin, glue, casein, water glass (sodium silicate)
Artificial stone:	Lime, plaster, mortar, hydraulic cement, concrete, stucco, plaster of Paris
Beverages:	Charged water, soda, mineral infusion, tea, coffee, fruit juices (artificially flavored) fermentation
Clay products:	Brick, pottery, stoneware, chinaware, porcelain

Cleaning agents:	Acids, oxalic, hydrochloric; alkalies; sodium hydroxide, soap (emulsification); special solvents, carbon tetrachloride, benzene Composition of trade-marked cleaning agents
Coal:	Composition and fuel values of different varieties, distillation of coal tar, light oil, middle oil, heavy oil, tar and pitch Relation to dyes and explosives
Dyeing:	Direct and mordant dyes
Explosives:	Black powder, nitroglycerine, dynamite, gun-cotton, trinitrotoluene
Fertilizers:	Soil fertility, elements needed by growing plant and function of each; photosynthesis and carbon dioxide cycle; nitrogen cycle and function of nitrogen fertilizers; use of limestone and phosphate rock
Foods:	Classification, carbohydrates, fats, proteins, mineral matter; starch, preparation from corn, cooking to dextrin and to paste, hydrolysis to glucose; sugars, preparation and refining of beet and cane varieties, conversion to caramel, inversion; fats, olive oil, cotton-seed oil, butter, oleomargarine, hardening oils by hydrogenation; proteins, albumins, casein, gluten, peptones, gelatins, vitamins
Glass:	Manufacture of crown, flint, lead, and special glasses; coloring of glass
Ink:	Iron ink; organic-dye ink; carbon ink
Leavening agents:	Baking powders (composition and reaction), yeast, soda
Matches:	Ordinary and safety types
Metals:	Used for basic purposes: iron, copper, aluminum, lead Used for ornament: gold, silver, nickel, platinum Used for alloys: bronze, brass, solder, type metal, anti-friction or bearing metals, fusible metal, alloy steels Tests for metallic iron
Nitrogen fixation:	Manufacture by the arc, Haber, and cynamid processes; relation to fertilizers, explosives and dyes
Paint, varnish, etc.:	Oil paints and driers, varnish, shellac, copal, linseed oil, oil cloth, linoleum Pigments, white lead, red lead, iron oxide, lead chromate, zinc white, lithopone
Paper:	Manufacture, treated briefly
Petroleum:	Fractional distillation into burning oils, solvent oils, lubricants, paraffins; problem of gasoline supply and possible exhaustion of petroleum
Photography:	Blue prints, plates, films, prints, toning, technicolor
Poisons:	Common antidotes, common inorganic drugs
Preserving:	Sterilizing, pasteurizing, dessicating, pickling by salt and sugar, common chemical preservatives and tests for them

Refuse disposal: Sewage and garbage, fermentation and putrefaction, civic problems, disinfectants and deodorizing agents

Silicates: Treated briefly

Textile fibers: Natural and artificial silk; wool; scouring, bleaching, felting, etc.; cotton, bleaching, mercerizing, etc.

EXPERIMENTS INCLUDED IN THE HIGH SCHOOL COURSE IN CHEMISTRY

The following experiments are merely suggestive. Since it has already been stated that the teacher is free to use his own order in developing the topics listed in this course of study, it follows that he is also free to change the order of the experiments to correspond and to modify them to meet his own working conditions. It is not intended that the teacher should cover all of the experiments in this list. Whenever possible it is advised that each student work individually and the average student should complete at least thirty-six experiments in a year. Those experiments which are a specific part of the course of study are marked with a star, all others may be considered as supplementary. Experiments not well suited for individual work are marked as lecture experiments.

Introductory Work

1. Proper handling of apparatus; using the Bunsen burner; cutting, bending and annealing glass; weighing, decanting, filtering, etc.

Oxygen Topic

*2. Distinguish between physical and chemical changes
*3. Prepare oxygen from potassium chlorate, study its properties, and recover the potassium chloride and manganese dioxide
*4. Heating of metals in air, and examination of materials formed
*5. Determine the change in weight on heating a metal in air
6. Determine the weight of 22.4 liters of oxygen at standard conditions
*7. The Bunsen burner: study the structure of the flame; the oxidizing and reducing flame

Hydrogen Topic

*8. Prepare hydrogen by the action of metals (iron and zinc) on dilute hydrochloric and sulfuric acids; properties of hydrogen
*9 Reduce copper oxide by hydrogen (or illuminating gas)
10. Determine the weight of magnesium (or aluminum) that displaces one gram of hydrogen
*11. Electrolysis of water (Lecture experiment)

Water Topic

*12. Study solutions, the solvent power of water, saturation
*13. The purification of water: filtration, boiling, distillation, etc.
*14. Study crystallization
15. Determine the percentage of water of hydration in a hydrated salt, *e.g.*, copper sulfate, barium chloride
*16. Preparation and properties of hydrogen peroxide, uses

Compounds and Mixtures

*17. Distinguish between mixtures and compounds

Laws, Hypotheses, and Theories

*18. Application of the laws of Boyle and Charles, use of the barometer and thermometer

Symbols, Weights, Volume Relations

19. Determine the weight of copper (or nickel) that will combine with one gram atomic weight of sulfur
20. Study the relation of energy to chemical changes as illustrated by the evolution or absorption of heat, light, and electricity in chemical reactions (Lecture experiment to assist the pupil in learning the use of equations)
21. Study a few simple cases of reversible reactions

Atmosphere

*22. Determine the respective percentages of oxygen and of nitrogen in air

Nitrogen

*23. Prepare nitrogen from ammonium nitrite; study its properties and uses

Nitric Acid

*24. Prepare nitric acid; study its physical and chemical properties
*25. Show the comparative instability of nitric acid, using wool, heated charcoal, or excelsior

Ammonia

26. Prepare ammonia from an ammonium salt and study the properties of the gas
*27. Show the presence of nitrogen in protein material by heating with soda lime
*28. Distill coal and examine the products of distillation

Acids, Bases, and Salts

*29. Study the common properties of acids and of bases
*30. Neutralization

Theory of Ionization

*31. Electrolytes and non-electrolytes

Phosphorus

*32. Properties of the red and yellow varieties

Sodium

*33. Study the action of sodium on water, with recognition of the products formed
34. Study quantitatively by titration the neutralization of ten normal solutions of sodium hydroxide and hydrochloric acid (Lecture experiment)
*35. Sodium salts, their properties and uses

Calcium and Its Compounds

*36. Study the preparation and properties of calcium oxide, hydroxide, and carbonate

*37. Study hard waters and common methods of softening each type

Aluminum

*38. Study the properties of the metal and the salt, alum

Carbon

39. Study the absorptive and reducing powers of carbon

Oxides of Carbon

*40. Prepare carbon monoxide and study its properties (Lecture experiment)
*41. Prepare carbon dioxide and study its properties
42. The chemical fire extinguisher

Sulfur and Sulfides

*43. Study the allotropic forms of sulfur
*44. Hydrogen sulfide: preparation, properties, and uses

Oxides of Sulfur

*45. Prepare sulfur dioxide: (1) by burning sulfur; (2) from a sulfite and an acid; and study the properties of the gas
*46. Prepare sulfurous acid and one sulfite
*47. Prepare sulfur trioxide (Lecture experiment)

Sulfuric Acid

*48. Prepare sulfuric acid by at least one process (Lecture experiment)
*49. Study the properties of sulfuric acid
*50. Test for a sulfate

Halogens

*51. Prepare chlorine, bromine, and iodine; compare their properties
52. Prepare hydrogen chloride (hydrochloric acid) and study its properties

Iron

*53. Replace hydrogen by iron
*54. Study the change from ferrous chloride to ferric chloride and vice versa; oxidation-reduction; to test for the ferric and ferrous ions

Organic Compounds

*55. Test for starch; test for sugar; the hydrolysis of starch
*56. Starches and sugars in common food stuffs

EXTRA EXPERIMENTS

57. Test for sodium, barium, strontium, and copper by flame coloration
58. Test for nitrate, sulfide, chloride and carbonate ions
59. Test for zinc, aluminum, and magnesium by cobalt nitrate test
60. Test for cobalt, manganese, chromium and iron by the borax bead test
61. Identify simple salts, using the above named tests
62. Iron salts in photography; blue prints
63. Quantitative replacement of silver
64. Silver salts in photography

65. Qualitative separation of lead, silver and mercury
66. Fermentation
67. Preparation of ethereal salts (esters)
68. Soap making
69. Constituents of milk
70. Substantive, salt, or direct color for cotton

LIST OF SUPPLIES

The following list is an estimate of the material that should be purchased for a class of ten pupils, provided each pupil performs all of the experiments described in this course of study. A reasonable allowance has been made for breakage. In case of somewhat expensive apparatus it has been assumed that two or more pupils will use the same piece of apparatus. In some instances where individual experimentation is desirable it is practicable to arrange the laboratory work so that all the members of the class do not work the same experiment at a given time. In such cases economies may be realized in the amount of apparatus necessary.

A minus sign (—) follows those items on the list that are relatively less necessary.

10 alcohol lamps, 4 oz. (If not supplied with gas)
10 burettes, 50 cc
5 burette clamps
10 Bunsen burners (if supplied with gas)
5 Bunsen burner wing tops —
20 beakers, 150 cc
20 beakers, 250 cc
10 beakers, 500 cc —
50 bottles, wide-mouthed, 8 oz.
10 blowpipes, brass 10″
15 crucibles, porcelain, No. 0
15 crucible covers for No. 0 crucible
10 crucible tongs
10 cobalt glass plates, 50 mm x 50 mm
5 calcium chloride tubes, 4″
15 dishes, evaporating, porcelain No. 0
10 dishes, evaporating, porcelain, No. 1
5 dishes, lead, 75 mm
10 deflagrating spoons
10 files, triangular 5″
10 forceps
12 flasks, Erlenmeyer, 125 cc
6 flasks, Erlenmeyer, 250 cc
12 flasks, Florence, 100 cc
10 funnels, glass 75 mm
50 glass plates, 10 cm x 10 cm
2 pounds glass tubing, 5——8 mm
10 graduates, cylindrical, 25 cc
10 mortar with pestle, porcelain, 60 to 80 mm

10 nichrome or pipestem triangles, 2″
10 pinch-cocks, screw compression —
10 pneumatic troughs, Armco iron
10 platinum loops, in glass handle
10 rubber stoppers, 1 hole, No. 1
10 rubber stoppers, 1 hole, No. 2
10 rubber stoppers, 1 hole, No. 5
10 rubber stoppers, 2 hole, No. 1
10 rubber stoppers, 2 hole, No. 3
10 rubber stoppers, 2 hole, No. 5
10 rubber stoppers, 2 hole, No. 7
12 feet rubber tubing, 3/16″
12 feet rubber tubing for Bunsen burners
10 rulers, English and Metric, 12″
100 reagent bottles, 4 to 8 oz.
10 ringstands, two rings
5 retorts, medium
10 spatulas, horn, 150 mm
10 stencils for drawing figures —
10 sand baths, shallow 4″
5 thermometers, —10° to 110° C
10 tripods, 6″ for alcohol lamps (if used)
12 test tubes, ignition, 6 x 5/8″
288 test tubes, 6 x 5/8″
144 test tubes, 4 x 1/2″
10 test tube brushes
10 brushes, small tube
10 test tube racks
10 test tube holders, wire clamp
12 thistle tubes
10 watch glasses 3″
10 wire gauze squares, 4″

ITEMS OF GENERAL APPARATUS

2 balances, trip scales
5 balances, hand, improved
1 barometer
1 blast lamp for gas —
2 battery jars, 5 x 7″ —
2 burettes, glass stopcock, 50 cc
6 beakers, 600 cc
2 beakers, 1000 cc
25 reagent bottles
5 combustion tubes, 45 x 1.9 cm
5 condensers, Liebig, 15″ with condenser clamps and clamp-holders
1 square foot copper sheet, No. 30
1 spool copper wire, bare, No. 16, 4 oz.
1 spool copper wire, bare, No. 20, 4 oz.
1 spool copper wire, bare, No. 28, 4 oz.

1 package corks, assorted, 0-11
1 set cork borers
10 candles, paraffin, 12's
1 electrolysis apparatus
1 funnel, 150 mm
1 flask, pyrex 1000 cc
1 flask, pyrex 500 cc
1 glass cutter
1 gas generator, Kipps, 500 cc
1 graduate, cylindrical, 500 cc
1 graduate, cylindrical, 1000 cc
1 hydrometer, light liquids
1 hydrometer, heavy liquids
2 jars, waste, 5 gallon
2 magnifiers, tripod
10 medicine droppers
4 pinch-cocks, large
1 thermometer, —10° to 250° C
10 tubes, gas measuring, 50 cc graduated to 1/10 cc
2 sets weights, iron, on holder, 10-500 g
1 set weights, in block, 1 cg too 20 g
2 shears

CHEMICAL AND SPECIAL MATERIALS

The supply of chemicals listed is adequate for all ordinary contingencies in a class of ten students. Chemicals followed by an asterisk are relatively less necessary and may be omitted as desired.

1 lb. acid, acetic, 30% c.p.
4 oz. acid, boric, c.p.
2 oz. acid, citric, c.p.
*8 oz. acid, formic
12 lb. acid, hydrochloric, c.p.
7 lb. acid, nitric, c.p.
1 lb. acid, oxalic, crystalline, c.p.
9 lb. acid, sulfuric, c.p.
2 oz. acid, tannic
2 qt. alcohol, ethyl, 95%
1 qt. alcohol, methyl (wood alcohol)
1 lb. aluminum sulfate
1 lb. aluminum turnings
2 lb. ammonium chloride (commercial)
12 lb. ammonium hydroxide
2 lb. ammonium molybdate (solution)
8 oz. ammonium sulfate
4 oz. antimony, powder
1 lb. baking powder
1 lb. barium chloride, cryst. c.p.
8 oz. barium nitrate

1 lb. bleaching powder
1 lb. bone black
*2 oz. bromine
5 lb. calcium carbonate (marble chips)
1 lb. calcium chloride, granular, for drying tubes
1 lb. calcium fluoride, powder
3 lb. calcium oxide, (lime)
4 lb. calcium sulfate, plaster of Paris, fine
1 lb. carbon disulfide
*8 oz. carbon tetrachloride
12 blocks charcoal, for use with blowpipe
8 oz. chloroform
4 oz. chromium sulfate, c.p.
1 yd. cloth, calico, for bleaching
1 yd. cloth, cotton, bleached fine goods
3 yd. cheesecloth
½ yd. cloth, woolen
2 oz. cobalt nitrate, cryst. c.p.
*6 oz. copper foil, 1/100″ thick
2 lb. copper turnings
4 oz. copper oxide, powder
4 oz. copper sulfate, anhydrous
1 lb. copper sulfate, cryst.
1 lb. ether
8 oz. Fehling's solution, two solutions in separate bottles
1 lb. ferrous sulfate
8 oz. hydrogen peroxide, 3% solution
*2 oz. iodine, resublimed
8 oz. iron chloride, ferric c.p.
1 lb. iron filings, fine, clean
8 oz. iron sulfide, ferrous, in sticks for H_2S
4 oz. lead acetate
8 oz. lead nitrate
*1 oz. lithium nitrate
1 oz. litmus cubes
72 litmus paper sheets, red
72 litmus paper sheets, blue
*2 oz. magnesium powder
8 oz. magnesium ribbon
1 lb. magnesium sulfate
1 lb. manganese dioxide, fine, granular, free from carbon
8 oz. mercury
1 lb. mercuric oxide, red
2 oz. nickel nitrate
10 g. phenolphthalein
2 oz. phosphorus, red
2 oz. phosphorus, yellow
1 lb. potassium alum
1 lb. potassium bromide

1 lb. potassium carbonate, (commercial)
2 lb. potassium chlorate, cryst. c.p.
*4 oz. potassium chromate
*4 oz. potassium cyanide
1 lb. potassium dichromate
1 lb. potassium ferricyanide
8 oz. potassium ferrocyanide
2 lb. potassium hydroxide, c.p.
2 oz. potassium iodide, c.p.
1 lb. potassium nitrate
8 oz. potassium permanganate
1 lb. potassium sulfate
4 oz. silver nitrate, c.p.
2 oz. sodium
4 oz. sodium acetate, fused
1 lb. sodium bicarbonate
1 lb. sodium carbonate, washing soda
5 lb. sodium chloride, common salt
1 lb. sodium hydroxide, c.p., by alcohol
1 lb. sodium nitrate, c.p.
8 oz. sodium peroxide
8 oz. sodium phosphate
2 lb. sodium sulfate
1 lb. sodium sulfite, dry
2 lb. sodium thiosulfate (hypo)
1 lb. sodium tetraborate (borax)
1 lb. starch, corn
1 lb. starch, potato
2 oz. strontium nitrate, c.p.
8 oz. sulfur, flowers of
2 lb. sulfur, roll
1 lb. tin, granulated
1 tumeric paper, sheet
*1 pt. vinegar, cider
*1 pt. vinegar, white
2 oz. wool, glass, fine Bohemian
1 package, wool, steel, fine
8 oz. zinc dust
2 lb. zinc, granulated, mossy
8 oz. zinc sulfate
distilled water

REFERENCES

High School Texts

Black, N. H., and Conant, J. B., *Practical Chemistry,* Macmillan
Blanchard, A. A., *Introduction to General Chemistry,* Doubleday
Blanchard, A. A., and Wade, F. B., *Foundations of Chemistry,* American Book Co.
Brownlee, R. B., Fuller, R. W., Hancock, W. J., Sohon, M. D., and Whitsit, J. E.,

Elementary Principles of Chemistry, Allyn and Bacon
Bruce, George H., *High School Chemistry,* World Book Company
Dull, Chas. E., *Essentials of Modern Chemistry,* Holt
Emery, F. B., Downey, E. F., Davis, R. E., and Boynton, C. E., *Chemistry in Every-day Life,* Lyons and Carnahan
Gordon, Neil E., *Introductory Chemistry,* World Book Company
Gray, C. W., Sandifur, C. W., and Hanna, H. J., *Fundamentals of Chemistry,* Houghton Mifflin
Holmes, H. N., and Mattern, L. W., *Elements of Chemistry,* Macmillan
Kendall, James, *Elementary Chemistry,* Century
McPherson, W., and Henderson, W. E., *Chemistry and its Uses,* Ginn
McPherson, W., Henderson, W. E., and Fowler, G. W., *Chemistry for To-day,* Ginn
Meyer, Martin, *First Problems in Chemistry,* Heath
Newell, Lyman C., *Practical Chemistry,* Heath

High School Manuals

Black, N. H., *Laboratory Experiments in Chemistry,* Macmillan
Blanchard, A. A., and Wade, F. B., *Laboratory Manual,* American Book Company
Brownlee, R. B., and others, *Loose-Leaf Laboratory Exercises* (also in book form) Allyn and Bacon
Dull, Charles E., *Laboratory Exercises in Chemistry,* Holt
Emery, F. B., Downey, E. F., and others, *Applied Chemistry,* Lyons and Carnahan
Gray, C. W., and Sandifur, C. W., *Interlinear Chemistry Manual,* Houghton Mifflin
Irwin, F. C., and others, *Laboratory Manual and Notebook,* 1927, Row Peterson
Jaques, Agnes F., *Laboratory Chemistry for Girls,* Heath
Jones, Mary E., *Laboratory Study of Household Chemistry,* Allyn and Bacon
Lincoln and Banks, *Laboratory Manual in General Chemistry,* Prentice Hall, Inc.
McPherson, W., and Henderson, W. E., *Laboratory Practice in Chemistry,* Ginn
Newell, Lyman C., *Laboratory Exercises,* 1927, Heath
Richardson, L. B., and Scarlet, A. J., *Laboratory Manual of General Chemistry,* Holt
Smith, Herbert, and Mess, Harry, *Modern Experimental Chemistry,* Holt

General References

Armstrong, H. E., *Chemistry in the Twentieth Century,* Macmillan
Berry, P. G., *Chemistry Applied to the Home and Community,* Lippincott
Blanchard, J. Maud, *Household Chemistry,* Allyn and Bacon
Holmes, H. N., *General Chemistry,* Macmillan
Kendall, James, *General Chemistry,* Century
Latimer, W. M., and Hilderbrand, J. H., *Reference Book of Inorganic Chemistry,* Macmillan
McPherson, W., and Henderson, W. E., *A Course in General Chemistry,* Ginn
Mellor, J. W., *Modern Inorganic Chemistry,* Longmans Green
Weed, Henry T., *Chemistry in the Home,* American Book Company

Dictionaries and Encyclopedias

Condensed Chemical Dictionary, The Chemical Catalog Co., 419 Fourth Ave., New York

Gardner, W., *Chemical Synonyms and Trade Names,* Lockwood
Hackh, I. W. D., *Chemical Reactions and Their Equations,* Blakiston

Popular Books

Chamberlain, J. S., and Browne, C. A., *Chemistry in Agriculture,* Chemical Foundation, 85 Beaver Street, New York
Chemistry in Medicine, Chemical Foundation
Darrow, Floyd L., *Boy's Own Book of Science,* Macmillan
Darrow, F. L., *Story of Chemistry,* Bobbs Merrill
Duncan, *Chemistry of Commerce,* Harper
Foster, W., *The Romance of Chemistry,* Century
Hendrick, E., *Everyman's Chemistry,* Harper
Howe, H. E., *Chemistry in Industry,* Chemical Foundation
Kahlenberg, Louis, and Hart, Edwin B., *Chemistry and its Relation to Every-day Life,* Macmillan
Moore, F. J., *History of Chemistry,* McGraw Hill
Sadtler, S. S., *Chemistry of Familiar Things,* Lippincott
Slosson, E. E., *Creative Chemistry,* Century
Smith, E. F., *Chemistry in America,* Appleton
Farrell, Hugh, *What Price Progress,* Chemical Foundation

Tests and Books on Testing

Columbia Research Bureau Test in Chemistry, World Book Company
Gerry, H. L., *Harvard Test in High School Chemistry,* Ginn
Glenn, E. R., and Welton, L. E., *Achievement Tests in Chemistry,* Test I—First Semester, Test II—Second Semester, World Book Company
Glenn, E. R., and Welton, L. E., *Instructional Tests in Chemistry,* World Book Co.
Horton, R. E., *Measurable Outcomes of Individual Laboratory Work in High School Chemistry,* Educational Test Bureau, Minneapolis
Joffe, Bernard, *Chemical Calculations,* World Book Company
Orleans, J. S., and Sealy, G. A., *Objective Tests,* World Book Company
Paterson, D. G., *Preparation and Use of New Type Examinations,* World Book Company
Powers, S. R., *General Chemistry Test,* World Book Company
Review Questions in Chemistry, to accompany *Elementary Principles of Chemistry,* Allyn and Bacon
Rich, S. G., *Chemistry Tests for High School,* Public School Publishing Company
Ruch, G. M., *Improvement of the Written Examination,* Scott Foresman
Ruch, G. M., *The Objective or New Type Examination,* Scott Foresman
Ruch, G. M., and Stoddard, G. D., *Tests and Measurements in High School Instruction,* World Book Company
Russell, Charles, *Classroom Tests,* Ginn
Sandiford, P., *Educational Psychology,* Longmans Green
Smith, H. L., anad Wright, W. W., *Bibliography of Educational Measurements* (Second Revision), Bureau of Coöperative Research, Indiana University, Bloomington, Indiana
Stoddard, G. D., and Conoy, L., *Iowa Placement Examination: Chemistry* (Revised), Bureau of Educational Research and Service, Iowa City, Iowa
Symonds, P. M., *Measurements in Secondary Education,* Macmillan

Tests in Chemistry, covering every phase of elementary chemistry, 57 units, Lyons and Carnahan

Books and Articles on the Teaching of Chemistry

Brownell, H., and Wade, F. B., *The Teaching of Science and the Science Teacher*, Century

Carpenter, W. W., *Certain Phases of the Administration of High School Chemistry*, Teachers College, Columbia University, Contributions to Education, No. 191

Frank, J. O., *Teaching First Year Chemistry*, Blakiston

Handbook of Chemistry and Physics, Chemical Rubber Co.

Powers, S. R., *Diagnostic Study of the Subject Matter of High School Chemistry*, Teachers College, Columbia University, Contributions to Education, No. 149

Smith, Alexander, and Hall, *Teaching Chemistry and Physics in the Schools*, Longmans Green