A STUDY OF THE UNIT PLAN OF TEACHING CHEMISTRY

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Contributions of the Graduate School

Indiana State Teachers College

Number 498

Submitted in Partial Fulfillment

of the Requirements for the

Master of Arts Degree

In Education

1943

The thesis of R. Paul Jones,

Contribution of the Graduate School, Indiana State Teachers College, Number 498, under the title

A STUDY OF THE UNIT PLAN OF

TEACHING CHEMISTRY

is hereby approved as counting toward the completion of the Master's degree in the amount of 8 hours' credit.

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Date of Acceptance May 3, 1943

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CHAPTER I

INTRODUCTION

With the gradual passing of the formal recitation, high school chemistry instructors have been confronted with the problem of organizing material to guide their students through valuable learning situations and experiences in chemistry. The task often is difficult because at present the majority of chemistry textbooks are written for the traditional methods of presenting the subject and because they include such an abundance of material that the attempts to "cover all the ground" in these conventional texts usually result in much superficial work.

Many chemistry workbooks have been published to meet the demands of chemistry instructors for a more flexible kind of instructional material, a more economical course and a more logical organization of the subject matter of chemistry. However, the use of workbooks has invited much criticism on the basis that they arouse very little thought on the part of pupils. Students are merely required to fill in the blanks from day to day, and they invariably drift to the "cookbook" method in laboratory work which results in much shallow thinking.

Science instructors realize that much time is needed by pupils for the formation of new chemical concepts, but this time may be decreased by integrating the learning devices around larger and more specific objectives and by correlating more closely classroom and laboratory work.

In view of this, the writer wishes to propose the Unit Plan as one vital approach in adapting progressive practices to our educational scheme; accordingly, he presents two specially prepared comprehensive units in chemistry, complete in every detail, which busy instructors may utilize either as instructional material or as a specific guide in organizing and developing additional units of their own for practical-minded students.

I. THE PROBLEM

Statement of the problem. It was the purpose of this study (1) to propose how the Unit Plan in teaching offers a practical solution to the problem of adapting progressive practices to the traditional high school course in chemistry; and (2) to prepare two comprehensive units in chemistry which illustrate in a concrete manner, the organization and administration of the Unit Plan in the school's instructional program.

Importance of the study. This problem is of vital importance, because the teaching of high school chemistry, like that of most other subjects, is undergoing rapid change.

The old aims, courses of study, methods, laboratory technique and the like are giving way to new methods, new aims and a new philosophy of education. Education is becoming a science. Scientific investigation is determining practices, and scientific methods of testing are measuring the products obtained and the standards reached. Much of this work of lifting science teaching up to a new plane is being done by teachers, and as time goes on, more of it will be done by them. In addition to this, many educators are convinced that pupil success in school depends upon progressive procedures adopted by the teacher and that pupil preparation for after school life depends upon rich and meaningful learning experiences provided by the school. With this outlook in mind the Unit Plan which is the core of this study appears to offer one vital approach to learning and teaching in our educational program.

The two elaborate units in chemistry which were organized and developed to accompany this study are of prime importance by virtue of the fact that they lend force to this study of the Unit Plan of teaching by illustrating the operation of the procedure in practice rather than in theory. These units with all the learning exercises organized in detail and accompanied with specific references will be welcomed by progressive teachers for several good reasons, viz.:

1. They lend themselves favorably to meeting the individual needs, interests, and capacities of students.

2. Teachers will have more time to impart that personal inspiration, without which all chemistry courses are apt to be failures.

3. The content of these units will appeal to the practical-minded student and is such that the knowledge gained has a real and positive value in the life of the student.

To further justify the employment of the Unit Plan of teaching chemistry, this procedure lends itself most adequately to the problem of adjusting the school to the pupil which is one of the underlying principles of progressive education. This principle is illustrated in the old proverb as quoted by Washburne. "If the mountain will not come to Mahomet, Mahomet will go to the mountain!"[1] In other words, if the pupil does not adjust to the school, the school must adjust to the pupil.

II. SOURCES OF DATA

Since there has been an enormous amount of material published in recent years, much of which is available to

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1 Carleton Washburne, Adjusting the School to the Child (Yonkers-on-Hudson, New York: World Book Company, 1932), p. iv.

any teacher, it was decided that reviewing literature available to the writer was an appropriate method of securing information. That which appears in this study was the result of careful examination of books and periodicals dealing specifically with the Unit Plan of teaching and with the teaching of science in general.

Following a critical study of the Unit Plan of teaching, many high school chemistry textbooks and science periodicals were examined and used as source material for organizing and developing two typical instructional units in chemistry which any progressive science instructor may use as a guide in developing further units for class instruction.

The philosophy of the writer was influenced by two sources, viz.:

1. Dr. B. H. Bode's book, Democracy as a Way of Life.

2. The Progressive Education Association publication, Science in General Education.

CHAPTER II

CRITICISMS OF HIGH SCHOOL CHEMISTRY

Before endeavoring to offer criticism of teaching procedures in the field of high school chemistry and to propose reform of a progressive nature in our educational practices, the writer wishes to present his philosophy with its implications which undoubtedly cast reflection upon the content of this study. Briefly stated his philosophy is:

> Democracy is the best method of advancing the brotherhood of man. Within the democratic way of life resides the possibility for the richest life of all. Education is necessary to meet the needs of individuals in the basic aspects of living in such way as to promote the fullest possible realization of personal potentialities and the most effective participation in a democratic society. The school should illustrate the democratic way of life at its best, and it should act as an agency in providing pupils with rich and meaningful experiences so that they can become vital members of our democratic social order.

The above philosophy leads to the following implications:

1. Each pupil must be provided with rich and meaningful experiences.

2. The pupil must be guided in the basic aspects of living.

3. The pupil must be trained in the meaning of a democratic way of life.

In light of this philosophy, the writer wishes to make a critical analysis of conventional practices in the field of high school chemistry as a basis for pointing out possible improvements which will facilitate the adaptation of progressive practices to our instructional program.

According to Powers[1] criticisms of high school chemistry may be classified into two groups, those coming from "circumstantial" evidence and those resulting from actual scientific investigation. These may be further classified into criticisms of the subject matter, texts, methods used, the teacher, results accomplished and many other things relating to the subject. Some of these criticisms apply to all high school science, while others apply only to chemistry.

Chemistry teachers ought to be interested in these criticisms because they may point out possible improvements in chemistry teaching. At least, they indicate the points of first investigation for those who wish to improve science teaching.

The following criticisms when carefully considered reveal many weaknesses.

1. Are American schools equal to European schools?

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[1] Ralph S. Powers, "Criticisms of Teaching Science," <u>Thirty-First Yearbook of the National Society for the Study of Education</u>, Part I (Bloomington, Illinois: Public School Publishing Company, 1932), pp. 13-26.

An investigation by Frank[2] reveals that our science is not well taught in the American high school; the teaching of this important field of knowledge is superficial. As a matter of fact, English, French and German boys are approximately two years ahead of our boys in accomplishment in science at the age which they finish their secondary school training.

2. Do pupils learn to think independently?

Our science teaching fails to develop individual resourcefulness. Too few high school graduates can make a living or otherwise stand on their own legs.

3. Does high school science develop understanding of basic facts of life?

Frank[3] points out that questions put to high school graduates entering our colleges seem to show that many of the most important facts of life and of our physical environment are not understood by them; that the great generalizations of science are not understood even by many who have been good students in high school science. Frank[4] claims

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2 J. O. Frank, The Teaching of High School Chemistry (Oshkosh, Wisconsin: J. O. Frank and Sons, 1932), p. 17.

3 *Ibid.*, p. 18.

4 *Ibid.*, p. 19.

that this is because high school science is taught in air-tight compartments as chemistry, as physics, or as biology and that pupils are not taught to recognize the great generalizations, except in the classroom. Pupils are never made to realize the universal truths; they learn only the isolated instances of the applications in the particular field.

4. Does high school science develop rational thinking?

It is said that high school science is unable to destroy the false beliefs that the average child acquires from the pseudo-science of cheap newspapers, from alley and street, from old wives' tales, from the beliefs left by "sayings" and "proverbs" and from the superstitions which have been shown to be very prevalent and quite potent in influencing human behavior.

5. Is high school science of vocational value?

As was previously stated, high school science teaching has been superficial, and it has left the pupil with but little gain in ability to meet the problems of life.

6. Do pupils develop interest in science?

Many students develop an attitude of dislike for science due principally to an inferior quality of teaching. This lack of interest causes students who have had high school chemistry to elect college chemistry in fewer numbers than those who have not had it in high school.

Most of the above criticisms are based on circumstantial evidence; however, this evidence bears much truth. Consideration is given to criticisms resulting from actual scientific investigations in the following paragraphs.

1. Textbooks are too large.

The chemistry teacher of today has to pose as a curriculum expert, for he must be able to select and reject materials from any modern text.

2. The vocabulary of texts needs standardization.

The vocabulary burden of a chemistry textbook is too large and that of one text is the heaviest of all high school subjects.

A study by Frank[5] showed that in nineteen different modern high school chemistry texts, there were sixteen distinct and different definitions of the word "valence".

3. Textbooks still dominate courses.

Questions asked teachers in many states show that the courses of study in high school chemistry are still determined almost entirely by the texts used. Most teachers still follow the textbook-recitation plan and try to teach the subject matter of the text, and they estimate results on the basis of the pupils' ability to pass back what is in

5 J. O. Frank, "Valence as Defined in High School Chemistry Texts," Journal of Chemical Education, 6:718-19, April, 1929.

the book. Few courses are based on the real needs of the pupils or have any provision for exceptional classes or exceptional individuals.

A study of the textbook-recitation plan reveals many disadvantages. One finds that the exclusive use of this plan leads to reduced accomplishment in both quality and quantity. Teachers become task masters and lesson hearers. Pupils develop the "get by" attitude, and come to memorize rather than learn. The course of study becomes a body of material, not to be agreeable assimilated and made a treasured part of the individual, but something to be gotten off hand--a disagreeable task to be done, or at least a duty to be performed. The goal becomes "passing the final examination," "getting the credit." One may say that the above mentioned disadvantages represent tendencies rather than facts. Then how can teachers use the textbook-recitation plan, perhaps combined with other methods, and accomplish better things?

A few principles are suggested at this point. First, the textbook is not to be something which a task master drives a group of pupils to engulf reluctantly. The textbook ought to be a source of information, inspiration, and enlightening ideas from which a group of interested young people stimulated and assisted by the teacher gather the materials with which they build new and higher viewpoints for themselves. Secondly, the textbook is not to be taught; neither is the subject. The pupils are to be taught. The teacher is not to drive the pupils, nor does he choose a method of work because it causes his pupils to pass. He chooses a method in terms of its value to his pupils. In fact, it is not the subject matter that the pupils carry away, but a method of study and work, a way of attack, ideas, attitudes and the like.

4. Pupils learn facts as ends in themselves.

Many investigators have shown that most of the facts which the pupils acquire from their study of high school chemistry are soon forgotten. This alone would seem to prove that the emphasis formerly placed on subject matter was unjustified. Psychologists now insist that subject matter is merely the material with which we teach science. Subject matter is not the end for which teaching is done, but rather the materials or tools which are used in instructing. The final objective is to bring pupils to really know the principles, laws, generalizations, and the like that make up science and be able to use the methods of science in solving problems. Facts are chiefly useful in illustrating, demonstrating, and describing that which pupils are encouraged to learn.

Since it is desired that principles learned in the classroom shall be useful to the pupil in everyday life, it is desirable to use illustrations, whenever possible, from everyday life and to bring to the pupils' attention all possible applications of each principle which are found in his environment.

The above mentioned criticisms reveal a lack of comprehensive growth in pupils in the field of science and point out the need of more progressive practices in the school's instructional program in order to permit the fullest possible development of each individual pupil.

CHAPTER III

THE UNIT PLAN IN A PROGRESSIVE PROGRAM

Since the school is the primary agency in our educational system it is fitting that consideration be given to its functions with reference to the youth and to the adult population before attempting to propose the Unit Plan as a progressive practice in our instructional program.

The school has as its primary purpose that of discovering the possibilities of the pupil and making available every opportunity for the fullest development of these individual powers through education, which as Bode[1] claims, is a process of continuous growth. The school is established for him, and the curriculum and the program of instruction are to be woven around the needs, interests, aptitudes, capacities and abilities of the pupil. This may not be limited to the child of school age, but it may be expanded to include those of the entire community. It is the responsibility of the school to blaze the trail for the future welfare of the boys and girls and help them to find themselves and their positions in life.

The school is looked upon by most patrons of any community as a redemption from a possible chaotic condition,

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1 Boyd H. Bode, Fundamentals of Education (New York: Macmillan Company, 1924), p. 8.

and as a satisfying consoling feeling that a part of the duties of civilization have been met.

In order that the school may adequately perform its functions and meet its objectives, teachers must properly select and organize the subject matter of their courses and adopt efficient classroom methods. At the present time, few schools have courses in chemistry made up of subject matter selected and organized on a basis of the actual needs of the pupils. All too often, the teacher simply selects a text and attempts to teach everything it contains. Obviously, this is not conducive to good teaching.

When discussing methods of teaching and learning, Dr. Thomas H. Briggs says in the <u>Seventh Yearbook of the Department of Superintendence</u>:

> To use in all courses as largely as possible, methods that demand independent thought, involve the elementary principles of research, and provide intelligent and somewhat self-directed practice, individual and cooperate, in the appropriate desirable activities of the educated person. Methods of the secondary school should continuously demand of students independent thinking. Stressing independence of thought, approaching research in its most elementary forms. It requires that students understand each problem to be solved, whether initiated by themselves or by the teacher, appreciate its value and importance, propose means of solution, and when satisfactory ones are found, apply them under direction toward the achievement of a solution. Such a method demands more of teachers than mere lesson-hearing, but the results are greater.

It gets from students more work, more intelligent work, and therefore more economical work.[2]

Favorable features of the Unit Plan. During recent years a few progressive high schools and some progressive high school teachers scattered here and there throughout the country have been experimenting with methods of teaching which are more or less new; they have been seeking for a vital approach to learning and teaching. This desire for change is typical of man for he is constantly making improvements in all forms of endeavor, even though small and unnoticed. Someone has said, "Progress results from the accumulation of minute advantages."[3] So it is in education. Our schools will not be suddenly remade by any new discovery or new device or new method. But by the constant accumulation of small improvements directed by wise philosophy, the whole tone of a school can be changed.

The teachers of these progressive schools believe that the methods with which they are experimenting are more effective, when well handled, than the traditional recitation method. Prominent among these methods, especially has been

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[2] Thomas H. Briggs, "Methods of Teaching and Learning," Seventh Yearbook of the Department of Superintendence (Washington, D. C.: Dept. of Superintendence of N. E. A., 1929), p. 205.

[3] H. G. Spalding, "Vitalized Education," The High School Teacher, 9:6, January, 1933.

the method of teaching which is based on the learning unit. The method, having at its heart the true learning unit, is generally referred to as the Unit Plan. These teachers who are familiar with the Unit Plan cite numerous advantages of the plan over those of the traditional recitation method and other plans of teaching.

Outstanding among the advantages of the Unit Plan is the ease with which it allows provisions to be made for the individual interests, needs and capacities of pupils. For as pointed out by Howard,[4] teachers find it necessary to give serious consideration to methods of teaching when they realize they have just as much obligation to the less gifted as to the brilliant student. By using the Unit Plan, provisions not only for differences in rates of learning, but also for differentiated content or subject matter may be made with comparative ease by the teacher.

Another advantage of this plan, often cited, is that it places major emphasis upon pupil activity and minimizes the importance of teacher activity in pupil learning.

A third major advantage of this plan is that it allows the teacher of one subject to draw from the other subject fields, subject matter and activities which are

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[4] R. S. Howard, "Some Aspects of the Unit Method of Teaching Chemistry," _Journal of Chemical Education_, 8:910, May, 1931.

related to the subject being studied. In other words, the plan allows the teacher to break down the barriers between his subject and other subjects and to present materials in their natural relationships; this makes it possible to integrate materials.

Another advantage claimed for this unit type of course organization is that it enables pupils to have a constant sense of mastery. When a student pursues in high school, a subject like biology, chemistry or physics, he feels lost in a big field. He wanders about in it for weeks and months not knowing just where he is going nor exactly what he is responsible for getting out of his journeyings. He comes to his final examination with fear and trembling, hoping that he has chanced to pick up the information needed to pass it, but always apprehensive that some important areas have been missed in his wanderings. When, however, the subject matter of the course is organized in units small enough to be clearly apprehended, each with a perfectly definite outcome of which the student is finally aware, then he works to a purpose and is quite conscious when he has achieved its mastery. If the end-product of a unit is the mastery of some principle which the student can actually use in the solution of problems of the sort that arise in his life or if it is the acquisition of skill in the use of some of the elements or safeguards of scientific thinking so that he can think through his problems with certainty, then he can be provided with tests to ascertain whether or not he has really acquired the thing he set out to accomplish. He either can solve such problems or else cannot. Of course, he could be faced with problematic situations involving the principle that would be beyond his range of experiences and so complex that he could not solve them. But if the problems used to exercise his skill and test his mastery are of the sort common to his age level, then apparently the line between mastery and non-mastery is pretty sharply defined.

In pointing out the advantages of the unit assignment, Billet presents a good argument for the Unit Plan. He says:

> No provision now being made in secondary schools for the individual differences of pupils offers greater promise than the unit assignment. If the unit assignment did no more than place the emphasis on the activity of the pupil in the classroom rather than on the activity of the teacher, it would justify its existence. Pupils clearly prefer the unit assignment to the traditional classroom work--an important fact if the pupil's emotional set toward his tasks be regarded as significant. The unit assignment is the basis of remedial work and of work with slow pupils; and it affords interesting challenges to bright pupils. It is the key to differentiated content and teaching procedure whether classes are homogeneous or heterogeneous.[5]

[5] Roy O. Billet, "Plans Characterized by the Unit Assignment," The School Review, 40:668, November, 1932.

Undoubtedly, there are other advantages to the Unit Plan beside those mentioned, but these, to a large extent, constitute its major advantages.

Probably many teachers do not realize the advantages to be derived from the use of the Unit Plan, because they do not understand exactly what constitutes a learning unit. Accordingly, it may be desirable to consider at this point the nature of the learning unit and to arrive at some conclusion as to an adequate definition of it.

The true learning unit does not represent merely time-to-be-spent or ground-to-be-covered; it means more than either of these things. Morrison refers to the learning unit as ". . . a comprehensive aspect of the environment, of an organized science, of an art, or of conduct, which being learned results in an adaptation in personality."[6]

Another definition of the learning unit deserves mention. This definition is the one made by Ruediger in which he says, "A unit is any division of subject matter, large or small, that when mastered gives one an insight into, an appreciation of, or a mastery over, some aspect of life."[7]

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[6] Henry C. Morrison, The Practice of Teaching in the Secondary School (Chicago: University of Chicago Press, 1931), pp. 24-25.

[7] William C. Ruediger, "The Learning Unit," The School Review, 40:176, March, 1932.

Now in order to represent how the plan adapts itself to the teaching of chemistry, attention must be given to several important features which the Unit Plan has to offer in chemistry instruction.

A typical unit in chemistry represents a comprehensive and significant aspect of the science of chemistry that when learned will result in an adaptation in the personality of the learner. It generally centers about one or more generalizations or a central idea which applies not merely to the science of chemistry, but to its functions in contributing to our understanding of our environment.

The unit is capable of being presented or developed "as a whole" rather than as a series of separate daily assignments. Then it must be mentioned that the unit possesses flexibility not only of content but of teaching procedure, which provides for the incorporation of points of current interest in the science and for changes in the personality of the teacher.

Finally, one can say that a unit in chemistry provides for the development of a sense of responsibility in the student through the student's planning and carrying out of his own work.

A treatment of the logical procedure or technique for the development of a chemistry unit at this point will explain the administration of the Unit Plan in the instructional program.

Teaching procedure. The teaching procedure according to Thayer[8] consists of three steps or periods; viz., the assignment period, the working period, and the discussion period.

Following this plan, the teacher will devote the first part of the assignment period to a pre-test. The results of this test will provide the teacher with a basis upon which to make a psychological approach to the unit. This period is for the purpose of orienting the student and presenting him with the major problems of the unit.

During the working period, the students will work at their own rates, studying the assimilative or subject matter materials of the unit and performing the laboratory experiments. The guide sheets provide sufficiently detailed "directions" to enable the students to carry out their work with very little loss of time in locating materials of study, including books, laboratory equipment, reagents, etc. Moreover the students' study during this period will be carried out under the careful supervision of the teacher. The teacher can inspect, stimulate, and guide all, in a very informal way.

The discussion period will give the students an opportunity to react in their own way to the unit. During this period the major problems of the unit will be discussed,

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8 V. T. Thayer, The Passing of the Recitation (Chicago, Illinois: D. C. Heath and Company, 1928), Part IV, p. 214.

the students conducting the discussion and the teacher playing the role of spectator and advisor. A few student projects also will be presented during this period. The work of the discussion period should be carried out as a real social event and should possess none of the undesirable characteristics of the traditional recitation.

In discussing this teaching procedure, it has been necessary to set off each period rather sharply for the purpose of explanation. However, in actual practice the wise chemistry teacher will conduct the work in each unit in such a way that the activities of each period will grow naturally out of those of the preceding period. In this way, the student will be made conscious of a continuous progression of activities within the unit, rather than a series of sharply defined stages of learning on a formal basis.

Various pupil reactions to the Unit Plan are reported by Dorothy Emig, a teacher in Texas, who from these reactions was encouraged to note an expression of independence and cooperation. One pupil said, "It makes you depend more on yourself, instead of depending on the teacher. When we work in groups, it makes us cooperate and help one another."[9]

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[9] Dorothy Emig, "Parents and Pupils Reactions to the Unit Method," El Paso School Standard, 14:10, October, 1936.

Another pupil said, "I like unit work because it teaches us cooperation, self-reliance, and dependability. We like unit work better than ordinary work because we enjoy it more."[10]

Thus in retrospect we are made more conscious of the fact that the Unit Plan contributes much toward achieving the desired outcomes which seem most significant in the life of every individual. Furthermore, this study of the Unit Plan should encourage teachers as well as administrators to grasp at every opportunity to adapt progressive practices to their instructional program; it should help them to look ahead and plan for that which contributes most to the welfare of the child, the school and society.

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10 Ibid., p. 11

CHAPTER IV

UNIT ON CARBON AND ITS OXIDES

("Lead" Pencils and Diamonds)

By way of introduction, Chapters IV and V present two elaborate units in chemistry which were organized and developed to accompany this study in order that the significant features of the Unit Plan may be illustrated in a concrete manner. Special attention has been given to the organization and administration of these units in actual practice rather than in theory.

General opinion points to the fact that textbooks and workbooks organized by units today are too limited and merely represent material in skeletal form. This type of organization is far from meeting the requirements of a typical learning unit. Consequently, it is the hope of the writer that these accompanying units with their wealth of material will serve as a guide to progressive and energetic chemistry instructors who desire to construct units for their own course of instruction.

For convenience, the writer has organized these chapters into sections, and at the beginning of each chapter he has listed the sections in a "Table of Content" for each chapter.

TABLE OF CONTENTS

I. PRELIMINARY

In planning a unit for a chemistry course, the first great task is to determine the purposes or outcomes which will be achieved or furthered. It is suggested that a number of large concepts or major generalizations be set up which will serve as criteria for selecting the content of this chemistry unit.

These generalizations appear at the beginning of this unit and the specific activities in which the pupils will engage have been selected in view of the fundamental fact that they develop within the pupils better understandings of these fundamental concepts, major generalizations, laws or principles of chemistry that will enable them better to interpret natural phenomena, common applications of chemical principles, and industrial applications and uses of the principles of chemistry.

It is quite evident that these fundamental principles are the keys that unlock the environment and become functional in interpreting our experiences of living. Therefore, attention should be centered upon these principles continuously throughout the time spent upon the unit. Some of these generalizations will appear in other units as well, and consequently, they will come to be better understood as they reappear.

The content outline in this unit furnishes a comprehensive source of all the subject matter needed in this particular study. It is not likely that an instructor will care to present and develop all this material; therefore, a list of minimum essentials is suggested that appear to be the "high points" in this unit on Carbon and its Oxides.

The bibliography offers a wide variety of chemistry textbooks and other books of a chemical nature. It is not likely that every instructor would have access to all these books, but if part of them are available, any teacher can teach this unit very effectively.

The exploration questions are suggested to provide a means of making any inventory of the pupils' intellectual background on such phases which the present unit is planned to give. For only with such individual diagnosis, can the teacher proceed intelligently with the work of the unit.

The learning exercises are presented in the form of a guide sheet. They include chiefly special topics to study and activities to be done. The various topics to study may be assigned to different individuals and then reported upon later. The pupil should be made to understand at all times that the mere writing of an exercise is not the end of his preparation or responsibility, but that by working out an exercise he is expected to carry over into the class discussions which follow the major ideas suggested in the exercises. The experiments are presented in the guide sheet and are designed to help the pupils learn chemistry in the laboratory. A few of the experiments have been suggested as teacher demonstrations in order to illustrate more vividly certain processes and principles.

The suggested projects and trips will serve as valuable means in making certain phases of this unit more meaningful to the pupils. Several lectures for the instructor have been suggested in outline form, so that the teacher may deliver these in an informal manner, whenever they seem appropriate.

The visual aids suggested, can be purchased, borrowed or made by pupils or teacher and may be introduced at opportune times to develop certain points or be displayed around the classroom to create a favorable atmosphere.

The self-testing exercise as the name implies, may be used by the pupil near the end of the study of the unit to check himself on his mastery of the unit. The answers may be checked in class if the instructor wishes, or a few minutes may be given to a discussion of the more difficult questions.

The final test which is accompanied with a key can be presented at the end of the unit and should serve as a means in evaluating the pupils' comprehension of the important features of the unit.

II. GENERALIZATIONS

1. Every substance is one of the following: a chemical element, a chemical compound, or a mechanical mixture.

2. Every substance has a definite chemical composition, since its molecules are each composed of the same sorts of atoms similarly arranged.

3. When a chemical change takes place, the substances that are involved are changed in such a way that they no longer behave as they did before this reaction occurred.

4. In a chemical change, a quantitative relationship exists between the amounts of substances reacting and the amounts of the substances that are the products of the reactions.

5. During a chemical reaction, an element may lose some of its planetary electrons and so gain positive valence or become oxidized, while some other element will combine with these electrons and gain negative valence or be reduced.

6. The properties of the different elements depend upon the number and arrangement of the electrons and of the protons contained in their atoms.

7. Matter and energy cannot be created or destroyed, but they may be changed from one form to another.

8. Chemical changes are accompanied by energy changes.

9. The kinetic energy of the molecules determines the physical states of matter.

10. The properties of elements and their compounds determine their applications.

11. Some compound substances have the ability, under certain conditions, to decompose and form two or more different substances.

12. By varying the temperature and pressure, practically every substance can be changed from one state to another.

III. GENERAL OBJECTIVES

1. To gain some knowledge of the three allotropic forms of carbon.

2. To learn about the physical and chemical properties of the two chief oxides of carbon.

3. To gain an understanding of the energy transformations within an electric resistance furnace.

4. To learn how charcoal and coke are made by the process of destructive distillation.

5. To learn about the absorbing and reducing properties of carbon.

6. To investigate the structure of the carbon atom.

7. To be able to trace the carbon dioxide cycle in nature.

8. To investigate the chemical reaction involved in the process of photosynthesis.

9. To learn how carbon dioxide may be transformed from one physical state of matter to another.

10. To gain some knowledge of the application of chemistry to the commercial uses of carbon dioxide.

11. To investigate how the properties of carbon and its two oxides determine their applications.

12. To gain a better understanding of oxidation and reduction from both the valence and the electronic standpoints.

13. To infect the students with the scientific spirit and to provide training in the scientific method.

14. To draw from the activities and subject matter accurate, valuable conclusions or generalizations, such as are listed for this unit.

IV. CONTENT OUTLINE ON CARBON AND ITS OXIDES

I. Carbon.

- A. Allotropic Forms of Carbon.
  - 1. Diamond.
    - a. Found in South Africa, South America, and the East Indies.
    - b. Properties.
      - 1). Hardest substance known.
      - 2). Appear as rough stones until ground and cut.

c. Uses.

1). Made into gems.

2). Cutting glass.

3). Diamond drills.

2. Graphite.

a. Occurs abundantly in nature.

b. Also manufactured from hard coal.

1). By electric resistance furnace.

c. Properties.

1). Glistening, black substances.

2). Is crystalline, soft, and greasy.

d. Uses.

1). Used in making stove polishes and paint.

2). Made into crucibles.

3). "Lead" pencils.

3. Noncrystalline carbon.

a. Different forms.

1). Wood charcoal.

2). Coke.

3). Lampblack.

4). Carbonblack.

5). Animal charcoal.

6). Coal.

a). Anthracite.

b). Bituminous.

B. Chemical Behavior of Carbon.

1. Chemical properties.

a. Inactive at ordinary temperatures.

b. At high temperatures, unites with metals and non-metals.

c. Acts as a reducing agent.

C. Structure of the Carbon Atom.

1. Electron picture.

a. Nucleus with a positive charge of 6 protons surrounded by 6 electrons.

2. Amphoteric element.

a. Can behave as a metal or non-metal.

b. Can have a valence of plus 4 or minus 4.

II. Carbon Dioxide.

A. How Carbon Dioxide Is Produced.

1. Formed when carbon or carbon compounds burn or decay.

2. How prepared.

a. By burning charcoal in air or oxygen.

b. By the action of acids on carbonates.

1). $CaCO_3 + 2HCl \rightarrow CaCl_2 + H_2CO_3$

$H_2CO_3 \rightarrow H_2O + CO_2\uparrow$

B. Occurence in the Air.

1. Varies from 4 parts in 10,000 parts of air in country to about 1 per cent in crowded rooms.
2. Occurs in natural waters and in the soil.
3. Occurs in deep valleys and mines.

C. Carbon Dioxide Cycle.

1. Plants remove carbon dioxide from the air and convert it into compounds.
   a. Process of photosynthesis.
      1). $6\ CO_2 + 5\ H_2O \longrightarrow C_6H_{10}O_5 + 6\ O_2\uparrow$
2. Animals consume food and oxygen and liberate or exhale carbon dioxide.

D. Properties of Carbon Dioxide.

1. A colorless gas, slightly soluble in water, and suffocating, but not poisonous.
2. Is about 1.5 times as heavy as air.
3. Liquifies easily.
4. Evaporating the liquid produces solid carbon dioxide.

E. Test for Carbon Dioxide.

1. Does not burn nor support combustion.
2. Produces a milkiness in limewater.
3. Combines with water to form carbonic acid, which reacts with bases.

F. Commercial Uses.

1. Used in making carbonated beverages.
2. Used in certain types of fire extinguishers.
    a. Water or carbon dioxide fire extinguishers.
    b. Foam extinguisher.
3. Used in ice machines.
4. Used as "dry ice".

III. Carbon Monoxide.

A. How Formed.

1. When carbon or carbon compounds burn in a limited supply of air.
2. By the reduction of the dioxide.
3. By action of warm concentrated sulfuric acid on formic acid.
    a. $HCOOH + H_2SO_4 \longrightarrow H_2SO_4 \cdot H_2O + CO\uparrow$

B. Properties of Carbon Monoxide.

1. A colorless gas, and practically odorless.
2. Slightly lighter than air, and insoluble in water.
3. Very poisonous.
4. Burns with a blue flame, forming the dioxide.
5. Acts as a reducing agent, taking oxygen from hot metallic oxides, such as copper and iron oxides.

C. Commercial Uses.

1. Good reducing agent.

2. Fuel.

IV. The Electric Furnace.

A. A device for producing very high temperatures by using a large arc between carbon terminals.

B. Chemical reactions that occur in the electric furnace are due to the high temperature.

C. Carbon compounds produced.

1. Calcium carbide. ($Ca\ C_2$).

2. Silicon carbide--Carborundum. (SiC).

3. Carbon disulfide. (CS_2).

V. MINIMUM ESSENTIALS IN THE CONTENT OUTLINE

I. Allotropic Forms of Carbon.

A. Diamond.

B. Graphite.

C. Noncrystalline carbon.

II. Physical and Chemical Properties of Carbon

III. Carbon Dioxide.

A. Its preparation.

B. Occurrence in the air.

C. Carbon dioxide cycle.

D. Physical and chemical properties.

E. Test for carbon dioxide.

F. Commercial uses.

IV. Carbon Monoxide.

A. Its preparation.

B. Physical and chemical properties.

C. The danger of this gas.

D. Uses.

V. Electric Furnace.

A. Its operation.

B. Carbon compounds produced in electric furnace.

1. Calcium carbide.

2. Silicon carbide.

3. Carbon disulfide.

VI. BIBLIOGRAPHY

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Howe, H. E., Chemistry in Industry. "Coal, Coke, and Their Products," pp. 58-74. New York: The Chemical Foundation, Inc., 1924. 404 pp.

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VII. SUGGESTED CLASS PROCEDURE

Several days previous to the time of beginning this unit, it is suggested that the teacher display on the bulletin board any available pictures or current topics dealing with carbon and its two oxides. This will tend to create interest among the pupils and arouse many questions in their minds. Also the teacher can place several samples of the crystalline and amorphous forms of carbon on the demonstration table. This will tend to attract the pupils' attention and start them to thinking about the new unit. The teacher may introduce the unit as a whole by means of a short overview story similar to the following:

Headline: *High School Boy Dies in Closed Garage!*

And many similar deaths occur each year either because many persons do not know that carbon monoxide is poisonous or because they fail to remember it and to act accordingly. Yet the same property of carbon monoxide which causes it to form such a stable compound in the blood makes it so eager to unite with more oxygen that it is a valuable reducing agent and fuel.

It is easy to see why the same is not true of the very similar and much more common carbon dioxide which is full of oxygen and will have no more of it. How such a slight difference in the composition of two chemical compounds can cause such a great difference in their properties and hence in their uses is one of the "high points" you should not miss in this unit.

What to stress in this unit. The properties and uses of the allotropic forms of carbon are so varied that you never will have any difficulty in keeping interested in them. It is a far cry from diamonds through coke to "lead" pencils, but chemistry bridges the gaps with ease by showing that each of them burns to form carbon dioxide, a gas which is useful in putting out our fires, raising our bread, keeping our ice cream cold, making our plants grow, and carbonating our soft drinks. Few new principles are introduced in this unit, but the use of the electric furnace in preparing calcium carbide, carborundum, carbon tetrachloride and carbon disulfide should be understood.

Following the overview, the exploratory and correlation questions may be presented in the class in order to bring the pupils' experiences and abilities accumulated from past units into a sharper focus on this unit on carbon and its oxides.

After the above questions have been thought through and answered, provide for a directed-study period by allowing pupils to read books which have been placed on the reading table. Secure as large a variety of textbooks and supplementary material as possible.

Give each pupil a mimeographed guide sheet before he starts studying which includes the special topics to study and the activities to be done on carbon and its oxides.

VIII. TEACHER HINTS

No. 1. These exploration questions will be of great value to teacher and pupil. They will serve the purpose of arousing a deep interest in the new unit and providing an excellent review of the learning acquired in previous units.

No. 2. Encourage the pupils to apply scientific thinking in explaining the significance of the geographical location of the two great iron and steel centers mentioned.

No. 3. This is a splendid opportunity for a teacher to impress upon pupils who have studied biology, the close relationship and the points of contact existing between the study of chemistry and biology. A teacher of chemistry should at all times attempt to show this inter-weaving of sciences, because all sciences overlap in their effort to explain natural phenomena.

No. 4. Have pupils get a good understanding of the carbon dioxide cycle, so that they will readily see the interdependence of plants and animals. Be very specific in pointing out how all life depends upon this cycle.

No. 5. This gives the teacher an opportunity to point out the importance of so many by-products produced in our industrial plants today. It also gives a chance to explain how lowly products of the farm, the mine, the forest--even of air and water--are transformed by the magic wand of chemistry into things of thrilling beauty and marvelous utility.

No. 6. These key words are the bricks without which a pupil cannot build in science. They should be used often enough by each pupil in describing experiences to really become concepts. A word with a memorized definition without a background of experience is "just a word." Therefore, impress upon the pupils that these key words should represent concrete ideas based on experience so far as possible.

No. 7. The value of using a variety of visual aids cannot be overestimated. Many manufacturing concerns or companies will kindly supply a teacher with booklets, pamphlets, charts, samples and other pictorial aids free of charge, if the teacher will just write to them, requesting the type of material needed.

IX. EXPLORATORY AND CORRELATION QUESTIONS[1]

1. We have studied the allotropic forms of what elements? Can you name any of the allotropes of carbon?

2. Name a reducing agent we have studied. Carbon, likewise, has a strong affinity for oxygen. Will you expect it to be a good reducing agent?

3. Why may one be misunderstood when he speaks of a "lead" pencil?

4. What is the most useful form of carbon? Explain.

5. What is the most expensive form of carbon?

6. From its place in the periodic table, what valence do you expect carbon to have?

7. How is the quantity of carbon dioxide in the atmosphere kept nearly constant?

8. What are the commercial uses we have for carbon dioxide?

9. India ink is extremely difficult to remove from clothing. Does this give you a hint as to the solubility of carbon?

10. CO_2 snow commonly called "dry ice" is prepared by "freezing" CO_2 gas. How is the low temperature obtained?

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[1] No. 1, Teacher Hint, p. 43.

11. Upon what properties of carbon dioxide does its use in fire extinguishers depend?

12. Why does soda water effervesce?

13. Why did the World War gas masks contain carbon?

14. Why is it dangerous to run an automobile in a closed garage?

15. What is the chemical test for carbon dioxide?

16. How is carbon monoxide a friend and enemy to man?

17. What relation does carbon dioxide bear to the process of photosynthesis?

18. One form of carbon, the diamond, is a precious stone. Can you recall any other elements or compounds we have studied which may constitute precious stones?

19. Recalling Henry's Law, what conditions will be brought to bear in dissolving large quantities of carbon dioxide in water?

20. Neither carbon dioxide nor nitrogen burns. Suggest a method of distinguishing them.

21. Recalling what you know about the formation of diamonds, how might artifical diamonds be made?

22. When alcohol burns, carbon dioxide is formed. What does this show about the composition of alcohol?

23. What practical use have baking powders? Explain.

24. Why is charcoal sometimes placed in a refrigerator?

25. Why does a physician sometimes prescribe charcoal tablets?

26. If there were no carbon dioxide in the atmosphere, how would it affect us?

27. Why is coke used in a blast furnace?

28. Why is Death Valley dangerous?

29. What effect does carbon have upon iron and steel?

30. Why is carbon monoxide poisonous?

X. SPECIAL TOPICS

1. Activated Charcoal, Useful in Peace and in War.

References

Dull, Modern Chemistry, pp. 290-92.

Hopkins, and Others, Chemistry and You, p. 430.

Jaffe, New World of Chemistry, pp. 287-88.

McPherson, Henderson, and Fowler, Chemistry for Today, p. 142.

2. How the Plant Manufactures Its Food.

References

Black and Conant, New Practical Chemistry, p. 225.

Brownlee, and Others, First Principles of Chemistry, p. 412.

Dull, Modern Chemistry, pp. 236-37.

Hopkins, and Others, Chemistry and You, pp. 27-8.

Wilson, Descriptive Chemistry, pp. 27-8.

3. Carbon Monoxide, A Friend and Foe of Man.

References

Black and Conant, <u>New Practical Chemistry</u>, pp. 233-36.

Dull, <u>Modern Chemistry</u>, pp. 307-8.

Hopkins, and Others, <u>Chemistry and You</u>, pp. 443-5.

McPerson, Henderson, and Fowler, <u>Chemistry for Today</u>, p. 151.

4. <u>Baking Powder As a Leavening Agent</u>.

References

Brownlee, and Others, <u>First Principles of Chemistry</u>, pp. 421-2.

Dull, <u>Modern Chemistry</u>, pp. 301-2.

Hopkins, and Others, <u>Chemistry and You</u>, pp. 441-2.

Wilson, <u>Descriptive Chemistry</u>, p. 48.

5. <u>Advantages and Disadvantages of Carbon Dioxide. "Dry Ice," as a Refrigerant</u>.

References

Black and Conant, <u>New Practical Chemistry</u>, p. 228.

Brownlee, and Others, <u>First Principles of Chemistry</u>, pp. 416-7.

Dull, <u>Modern Chemistry</u>, pp. 302-3.

Wilson, <u>Descriptive Chemistry</u>, pp. 51-5.

6. <u>Carbon Dioxide Fire Extinguishers</u>.

References

Black and Conant, <u>New Practical Chemistry</u>, pp. 229-30.

Dull, Modern Chemistry, pp. 300-01.

Hopkins, and Others, Chemistry and You, pp. 439-40.

Wilson, Descriptive Chemistry, p. 65.

7. Moissan's "Artificial" Diamonds.

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Dull, Modern Chemistry, p. 283.

Foster, The Romance of Chemistry, pp. 342-5.

Jaffe, New World of Chemistry, pp. 284-5.

Kruh, Carleton, and Carpenter, Modern Life Chemistry, pp. 599-601.

McPherson, Henderson and Fowler, Chemistry for Today, p. 137.

8. Allotropic Forms of Carbon.

References

Black and Conant, New Practical Chemistry, pp. 217-21.

Dull, Modern Chemistry, pp. 282-3.

Kruh, Carleton and Carpenter, Modern Life Chemistry, pp. 135-41.

McPherson, Henderson and Fowler, Chemistry for Today, pp. 135-42.

9. Commercial Uses of Carbon Dioxide.

References

Black and Conant, New Practical Chemistry, pp. 229-30.

Dull, Modern Chemistry, pp. 300-04.

Hopkins, and Others, Chemistry and You, p. 441.

Kruh, Carleton and Carpenter, Modern Life Chemistry, p. 612.

10. Destructive Distillation of Wood.

References

Dinsmore, Chemistry for Secondary Schools, pp. 279-80.

Dull, Modern Chemistry, p. 289.

McPherson, Henderson and Fowler, Chemistry for Today, pp. 130-40.

Wilson, Descriptive Chemistry, pp. 68-9.

11. Uses of the Amorphous Forms of Carbon.

References

Black and Conant, New Practical Chemistry, pp. 219-21.

Brownlee, and Others, First Principles of Chemistry, pp. 401-7.

Dull, Modern Chemistry, pp. 289-95.

McPherson, Henderson and Fowler, Chemistry for Today, pp. 138-41.

12. Carbon Dioxide Cycle in Nature.

References

Black and Conant, New Practical Chemistry, pp. 273-4.

Deming, In the Realm of Carbon, pp. 259-61.

Dull, Modern Chemistry, pp. 237-8.

Hopkins, and Others, Chemistry and You, p. 426.

Kruh, Carleton and Carpenter, _Modern Life Chemistry_,

pp. 371-2.

13. _Destructive Distillation of Coal_.

References

Dinsmore, _Chemistry for Secondary Schools_, pp. 278-9.

Hopkins, and Others, _Chemistry and You_, pp. 426-9.

McPherson, Henderson, and Fowler, _Chemistry for Today_,

pp. 138-9.

Wilson, _Descriptive Chemistry_, pp. 75-7.

14. _Commercial Production of Graphite_.

References

Black and Conant, _New Practical Chemistry_, pp. 218-9.

Dull, _Modern Chemistry_, pp. 285-8.

Foster, _The Romance of Chemistry_, pp. 345-6.

Hopkins, and Others, _Chemistry and You_, pp. 432-3.

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p. 138.

15. _Oxidation and Reduction_.

References

Black and Conant, _New Practical Chemistry_, pp. 507-8.

Dinsmore, _Chemistry for Secondary Schools_, pp. 466-8.

Dull, _Modern Chemistry_, pp. 613-4.

Kruh, Carleton and Carpenter, _Modern Life Chemistry_,

pp. 325-9.

XI. ACTIVITIES TO BE DONE

1. Occurrence of Carbon.

Everyone is more or less familiar with carbon. In the uncombined state this element is found in nature in several forms. You are asked to list the crystalline and noncrystalline forms of carbon in the following columns.

(Crystalline Forms)	(Noncrystalline Forms)
1.	1.
2.	2.
	3.
	4.
	5.

2. Properties of Carbon.

We have learned that carbon exists in a number of different physical forms. Because of the importance of the element, it is desirable that we should know something of its physical and chemical properties.

In performing this experiment, you should work with several others in order to save materials. Your group will need the following materials: several test tubes; Bunsen burner; ring stand with test tube clamp; pieces of charcoal, hard coal, soft coal, and graphite; powdered carbon; black copper oxide; limewater; and very dilute ammonium sulfide.

When you have these materials, you may do the experiment in the following steps and answer the questions.

Carbon:

1. Examine the samples of charcoal, hard and soft coal and graphite, and note the ways in which they are alike and how they differ, if at all, in odor, taste, color and form.

2. Try to dissolve particles of each in water.

3. Try to burn small amounts of each by heating in an iron spoon.

Questions:

1. How are these forms of carbon alike? ____________.

2. How do they differ? ______________________________.

3. Did any of the samples dissolve in water? ______.

4. Did they burn? __________________________________.

Absorption:

1. Heat a small amount of pulverized charcoal to complete dryness in a test tube; cool and then add about 3 ml. of a dilute ammonium sulfide solution.

Questions:

1. Describe the odor before and after performing the experiment. ____.

2. What does this prove? ____________________________.

Reduction:

1. Mix a small amount of powdered carbon with an equal amount of the black copper oxide and heat red hot for five minutes in a hard glass test tube as shown in the diagram.

2. Test for the gas given off with limewater.

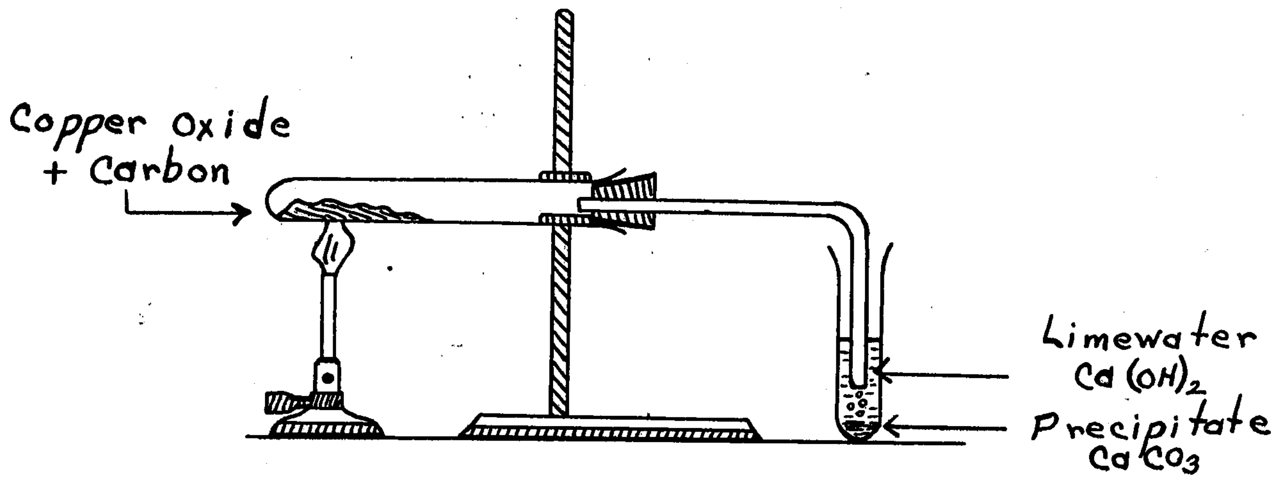

FIGURE I

REDUCTION OF COPPER OXIDE WITH CARBON

Questions:

1. What indication is there of a reaction? ________.

2. Write the equation for this reaction. __________.

3. Did heating the carbon with the copper oxide remove the oxygen and leave copper? ______________________.

4. What property of carbon does this prove? _______.

5. What two processes have been illustrated? ______.

6. Write the equation for the test. _______________.

In your conclusion to this experiment, state two or more physical properties and two chemical properties of carbon.

Physical Properties ______________________________.

Chemical Properties ______________________________.

References

Black and Conant, New Practical Chemistry, pp. 217-23.

Brauer, Chemistry and Its Wonders, pp. 442-5.

Brownlee, and Others, First Principles of Chemistry, pp. 398-9.

Dinsmore, Chemistry for Secondary Schools, pp. 281-2.

Foster, The Romance of Chemistry, pp. 348-51.

Jaffe, New World of Chemistry, pp. 282-4.

McPherson, Henderson and Fowler, Chemistry for Today, pp. 141-2.

3. Occurrence of Coal.

In order to determine where the chief coal deposits are found in the United States, you are asked to read the references and then locate these areas with a dark color on this outline map of the United States.

Be prepared to tell the class where the chief coal deposits are found in our country as well as to explain the significance of the geographical location of Pittsburg, Pennsylvania, and Birmingham, Alabama, as great iron and steel centers.[2]

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[2] No. 2, Teacher Hint, p. 43.

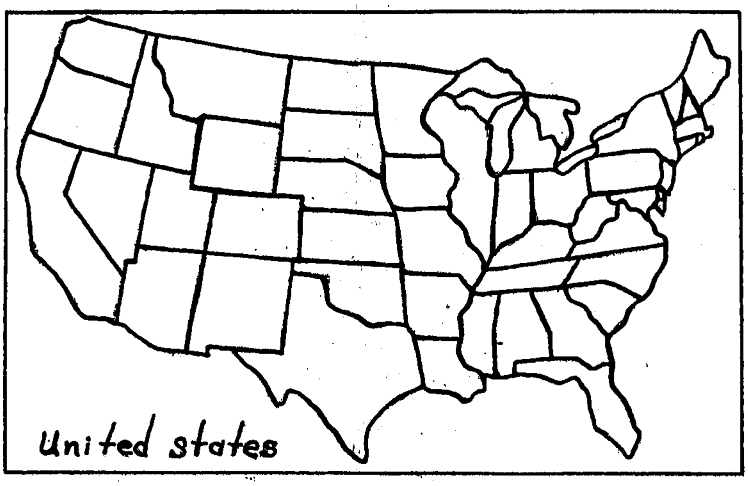

FIGURE 2

COAL DEPOSITS OF UNITED STATES

References

Brownlee, and Others, First Principles of Chemistry, p. 404.

Dull, Modern Chemistry, pp. 316-7.

Hopkins, and Others, Chemistry and You, pp. 425-6.

Jaffe, New World of Chemistry, pp. 289-91.

Kruh, Carleton, and Carpenter, Modern Life Chemistry, pp. 618-20.

Wilson, Descriptive Chemistry, pp. 73-4.

4. Carbon Dioxide.

We have learned that carbon dioxide is a compound of carbon and oxygen. It is possible to make a compound of carbon and oxygen in the laboratory.

In performing this experiment, you will need the apparatus shown in the accompanying diagram, marble chips, dilute Hcl, limewater, litmus and a candle.

When you have your apparatus set up, proceed with the following steps and answer the related questions.

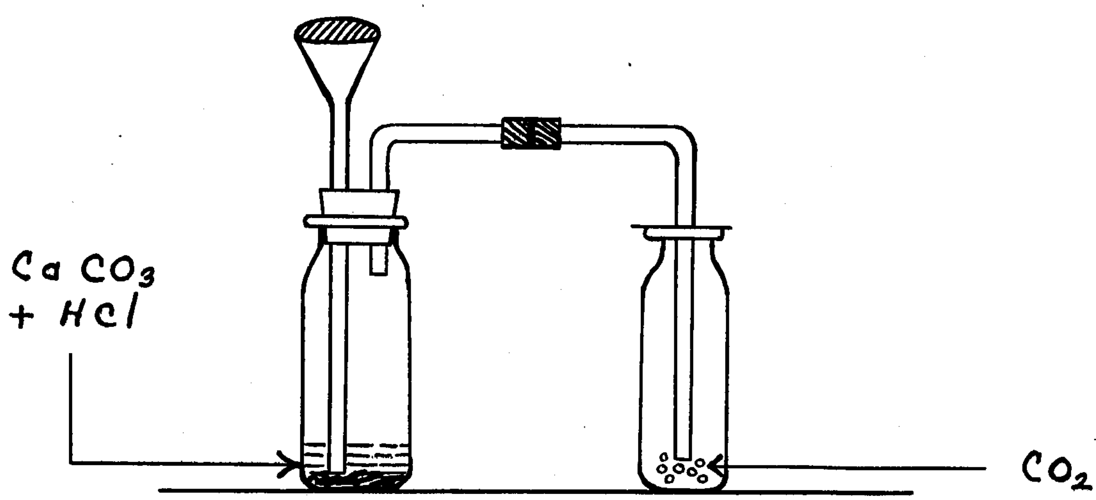

FIGURE 3

PREPARATION OF CARBON DIOXIDE

<u>Preparation</u>:

1. Place about 20 grams of marble chips in the generator and cover with 10 ml. of water. (If dilute HCl is used later, do not add water).

2. Have four bottles ready for gas collection. Add a small amount of hydrochloric acid and add small amounts from time to time to insure a steady evolution of gas.

3. The action starts at once, and the gas may be collected in the bottles.

Question: Write the equation for the above reaction.

Properties:

1. Lower a lighted candle into a bottle and observe what happens.

Question: What property does this show? __________.

2. Dip a stirring rod into some limewater and then withdraw it so that a clear drop hangs from its end. Lower the rod into a bottle of the gas and observe the color change in the drop of limewater.

Question: This is the test for CO_2. Write the equation for this chemical reaction. ______________________.

3. Lower a short piece of lighted candle into a wide mouthed beaker and then pour the gas from one of the bottles over the candle. Observe the results.

Question: What does this show about the relative densities of this gas and air? ___________________________.

4. In the third bottle place 10 ml. of distilled water; cover with your hand and shake vigorously.

Question: What physical evidence is there of solution? ____.

References

Black and Conant, New Practical Chemistry, pp. 225-8.

Brownlee, and Others, First Principles of Chemistry, pp. 413-20.

Dinsmore, Chemistry for Secondary Schools, pp. 314-6.

Dull, Modern Chemistry, pp. 297-300.

Hopkins, and Others, Chemistry and You, pp. 436-8.

Jaffe, New World of Chemistry, pp. 200-01.

Kruh, Carleton and Carpenter, Modern Life Chemistry, pp. 608-11.

McPherson, Henderson and Fowler, Chemistry for Today, pp. 146-7.

5. Uses of Carbon Dioxide.

Read the following references and then prepare a sentence outline listing the commercial uses of carbon dioxide.

Also be able to explain to the class the relationship existing between the chief properties of CO_2 and the applications which these properties make possible.

References

Black and Conant, New Practical Chemistry, pp. 229-30.

Brauer, Chemistry and Its Wonders, pp. 460-2.

Brownlee, and Others, First Principles of Chemistry, pp. 420-4.

Dinsmore, Chemistry for Secondary Schools, pp. 318-21.

Dull, Modern Chemistry, pp. 300-04.

Jaffe, New World of Chemistry, pp. 302-5.

Wilson, Descriptive Chemistry, pp. 47-51.

6. How Plants Use Carbon Dioxide.[3]

We have learned that plants use CO_2. The question how plants use this raw material to manufacture food can be answered after observing this demonstration by the teacher.

Procedure:

1. In advance of the class period prepare some carbonated water by generating CO_2 and passing it through water.

2. Set up the apparatus as shown in the diagram. Partly fill the beaker with carbonated water. Fill the funnel with spinach or parsley and place the funnel upside down in the beaker of carbonated water. The stem of the funnel must be under water. Fill a test tube with carbonated water and invert over the funnel stem. There must be no air bubbles in the test tube. Set the apparatus in bright sunlight and watch it for an hour or two. If necessary, leave it until the next class period.

Question: What happens? ______________________________.

If a gas has collected, carefully remove the test tube without admitting any air bubles; close it with your

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3 No. 3, Teacher Hint, p. 43.

thumb, invert it, and test the gas with a wood splint having a glowing tip.

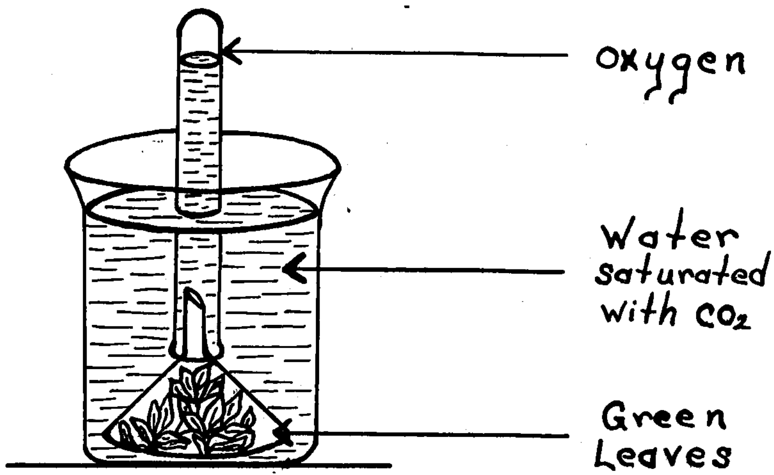

FIGURE 4

ABSORPTION OF CO_2 AND LIBERATION OF O_2 BY PLANTS

<u>Questions</u>:

1. What is the result? ______________________.

2. What gas is probably formed? ________________.

3. What does sunlight furnish to bring about the change? ________________________________.

4. What is there in the leaf that acts like a catalyst? ________________________________.

In view of this demonstration and the following diagrammatic representation to show how starch is formed in the leaves of plants from water and the carbon dioxide of the air, write a brief description of the process of photosynthesis including the equation for the chemical reaction involved.

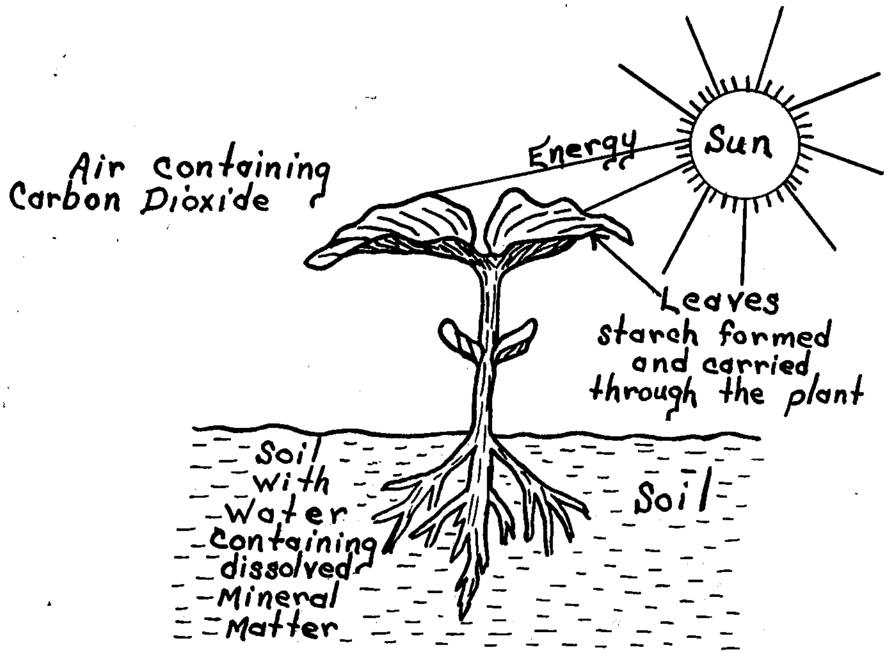

FIGURE 5

ILLUSTRATION OF THE PROCESS OF PHOTOSYNTHESIS

References

Black and Conant, New Practical Chemistry, p. 225.

Brauer, Chemistry and Its Wonders, pp. 124-5.

Brownlee, and Others, First Principles of Chemistry, p. 412.

Dull, Modern Chemistry, pp. 236-7.

Hopkins, and Others, Chemistry and You, pp. 27-8.

Jaffe, New World of Chemistry, pp. 299-300.

Wilson, Descriptive Chemistry, pp. 27-8.

7. Carbon Dioxide Cycle.[4]

From your description of the process of photosynthesis, you realize the important use that plants make of carbon dioxide and this shows at once that plants and animals are complements of each other as regards the supply of oxygen and carbon dioxide in the air. In order that you will have an understanding of the carbon dioxide cycle in nature, read

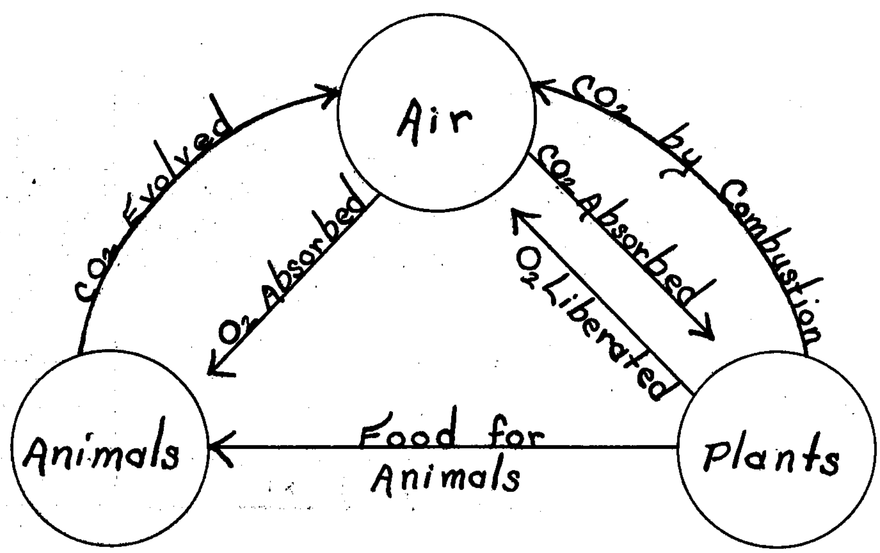

FIGURE 6

CARBON DIOXIDE CYCLE

[4] No. 4, Teacher Hint, p. 44.

the references and analyze the the diagram. Then, to sum up this cycle, prepare a sentence outline listing the important features.

References

Black and Conant, New Practical Chemistry, pp. 273-4.

Brownlee, and Others, First Principles of Chemistry, pp. 318-9.

Dull, Modern Chemistry, pp. 237-8.

Foster, The Romance of Chemistry, pp. 356-7.

Hopkins, and Others, Chemistry and You, pp. 435-6.

Jaffe, New World of Chemistry, pp. 299-300.

Kruh, Carleton and Carpenter, Modern Life Chemistry, pp. 371-2.

8. Use of the Electric Furnace.

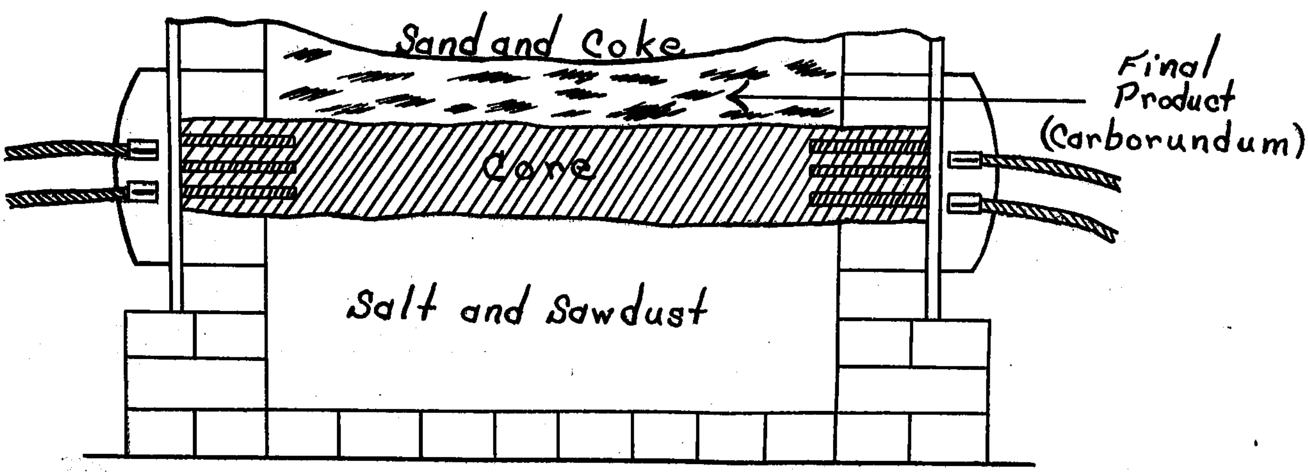

FIGURE 7

ELECTRIC RESISTANCE FURNACE

In studying about carbon and its inorganic compounds, we find that the electric furnace is used extensively in preparing calcium carbide, carborundum, carbon tetrachloride, and carbon disulfide. After reading the references and observing the diagram of the electric resistance furnace, write a brief paragraph explaining how the electric furnace operates and how it is used to prepare the inorganic compound of carbon known as carborundum.

References

Black and Conant, New Practical Chemistry, pp. 417-8.

Brownlee, and Others, First Principles of Chemistry, pp. 399-401.

Dinsmore, Chemistry for Secondary Schools, pp. 372-3.

Dull, Modern Chemistry, pp. 462-3.

Jaffe, New World of Chemistry, pp. 455-6.

Kruh, Carleton and Carpenter, Modern Life Chemistry, p. 491.

McPherson, Henderson and Fowler, Chemistry for Today, pp. 323-4.

9. Destructive Distillation.

We have learned that charcoal and coke are both amorphous forms of carbon. They are produced by the destructive distillation of wood and coal respectively.

In order that you may understand the process of destructive distillation and know the products formed in distilling wood and coal, you are asked to read the references and then fill in the following diagrams which will show the by-products of wood and coal.[5]

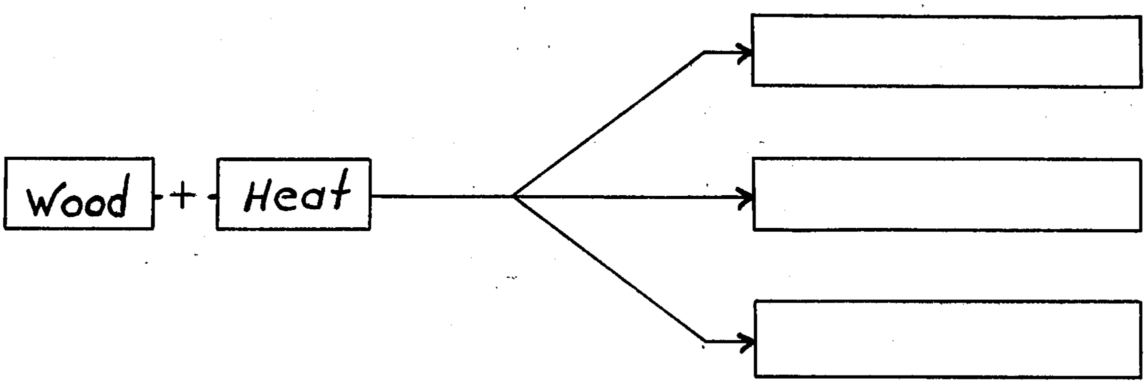

FIGURE 8

WOOD PRODUCTS

You can make gas from coal as follows: Get a clay pipe and fill about half of the bowl with fine coal; cover with moist clay or mud and dry it.

Now place the bowl of the pipe over a gas flame; heat it slowly and after about two minutes hold a lighted match at the end of the stem. If the bowl of the pipe is hot enough, gas will be coming out of the stem. It is coal gas and will of course burn.

Question: Why must the coal be covered with clay?___

____.

---

5 No. 5, Teacher Hint, p. 44.

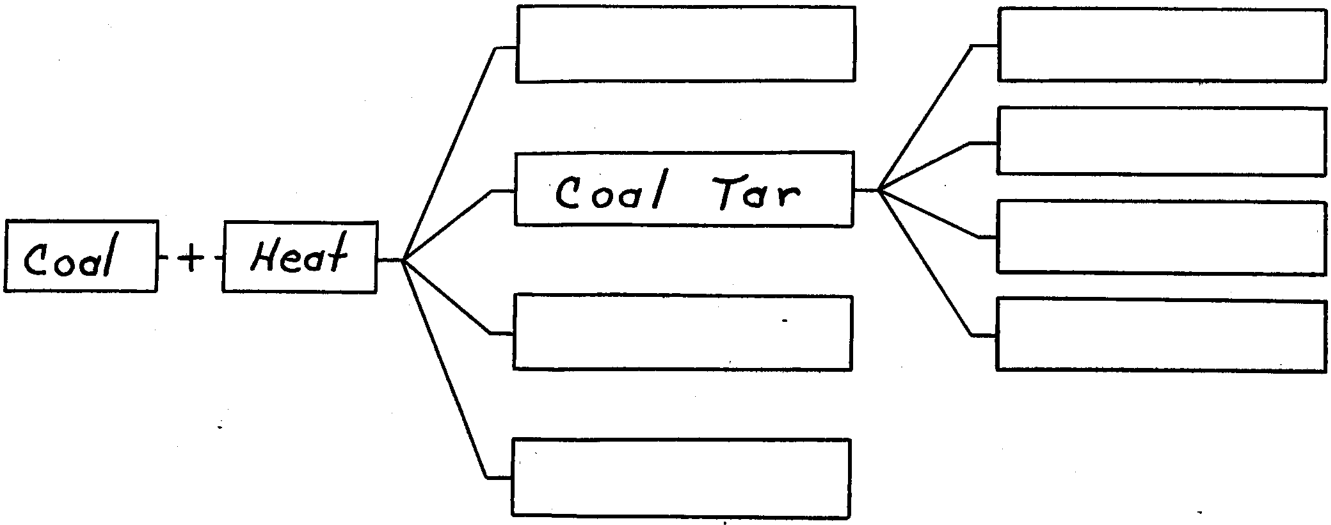

FIGURE 9

COAL PRODUCTS

References

Black and Conant, New Practical Chemistry, pp. 219-21.

Dinsmore, Chemistry for Secondary Schools, pp. 278-80.

Dull, Modern Chemistry, p. 289.

Hopkins, and Others, Chemistry and You, pp. 426-9.

McPherson, Henderson and Fowler, Chemistry for Today, pp. 138-40.

Wilson, Descriptive Chemistry, pp. 68-9; 75-7.

10. Oxidation--Reduction.

We have been discussing oxidation and reduction reactions from both the valence and the electronic standpoints in previous units.

Be able to tell in your own words what reaction each of the following equations represents, and be able to point out and explain all examples of oxidation and reduction as illustrated in the following example.

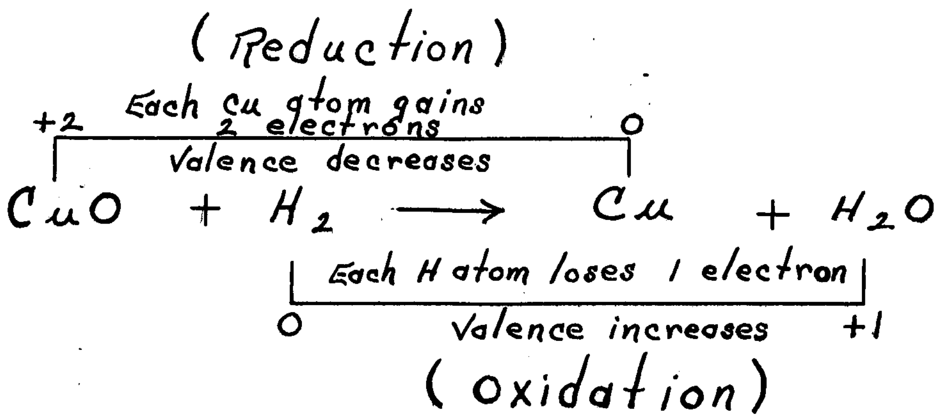

FIGURE 10

OXIDATION--REDUCTION REACTION

1. $CO_2 + C \longrightarrow 2CO$
2. $CuO + C \longrightarrow Cu + CO$
3. $CS_2 + 3CO_2 \longrightarrow 2SO_2 + 2CO_2$
4. $3C + SiO_2 \longrightarrow SiC + 2CO$
5. $CaCO_3 + 2HCl \longrightarrow CaCl_2 + H_2O + CO_2\uparrow$

References

Black and Conant, <u>New Practical Chemistry</u>, pp. 507-8.

Dinsmore, <u>Chemistry for Secondary Schools</u>, pp. 466-8.

Dull, <u>Modern Chemistry</u>, pp. 613-4.

Hopkins, and Others, Chemistry and You, pp. 300-05.

Jaffe, New World of Chemistry, pp. 145-6.

Kruh, Carleton and Carpenter, Modern Life Chemistry, pp. 325-39.

11. Scientific Vocabulary.[6]

Referring to all the chemistry references as well as the dictionary, write out the meaning of the following terms:

1. amorphous ____________________
2. allotropic ____________________
3. carbonated water ____________________
4. dry ice ____________________
5. effervescence ____________________
6. foamite ____________________
7. reduction ____________________
8. oxidation ____________________
9. absorption ____________________
10. lamp black ____________________
11. photosynthesis ____________________
12. carbona ____________________
13. carbon ____________________
14. destructive distillation ____________________
15. amphoteric ____________________
16. coal tar ____________________
17. bituminous ____________________
18. anthracite ____________________

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6 No. 6, Teacher Hint, p. 43.

19. black damp ________________________

20. reducing agent ________________________

21. fermentation ________________________

22. leavening ________________________

XII. SELF-TESTING EXERCISE

In the parentheses preceding each of the following, place the letter of the item in the second list which corresponds with an item in the first list.

First List

1. ( ) Composition of the "lead" in a pencil.
2. ( ) Source of coke.
3. ( ) Solid carbon dioxide.
4. ( ) Necessary ingredient of baking powder.
5. ( ) Commercial name for carbon tetrachloride.
6. ( ) Weight of one liter of carbon monoxide at standard conditions.
7. ( ) The gas absorbed by plants.
8. ( ) Hardest substance known.
9. ( ) A crystalline form of carbon.
10. ( ) Gas which is deadly poisonous.
11. ( ) Used as an abrasive.
12. ( ) Source of charcoal.
13. ( ) Used in obtaining metals from their ores by reduction.

14. ( ) Used in gas masks.

15. ( ) Formula of acid in carbonated water.

16. ( ) Gas which turns limewater milky.

17. ( ) Used as a lubricant for high speed machines.

18. ( ) Heating coal out of contact with air.

19. ( ) Gas formed by a poorly banked furnace.

20. ( ) An element which may behave as a metal or nonmetal.

Second List

a. Graphite

b. Clay and graphite

c. Oxygen

d. Coal

e. Carbon

f. Wood

g. Dry ice

h. Lead and clay

i. $Na\ HCO_3$

j. CO

k. 1.25

l. Fractional distillation

m. Carbon monoxide

n. H_3PO_4

o. Charcoal

p. Carbona

q. 1.43

r. Carbon dioxide

s. H_2CO_3

t. Diamond

u. Carbonrundum

v. Destructive distillation

w. CO_2

x. Coke

y. Coal gas

z. Graphite

XIII. SUGGESTED CLASS DEMONSTRATIONS

1. Reducing action of carbon monoxide.

The reducing action of carbon monoxide may be well shown by the following experiment: The gas is prepared by treating formic acid with warm concentrated sulfuric acid in a special generator. The gas is first washed by passing it through a bottle of water. This gas is then allowed to enter a heated tube containing copper oxide. The metallic oxide is reduced by the gas to reddish metallic copper and the carbon monoxide is oxidized to carbon dioxide. The presence of this latter gas can be shown by passing it through limewater which produces a milky appearance.

2. Testing the carbon dioxide in the breath.

Prepare some freshly filtered calcium hydroxide solution (limewater). Blow your breath through this limewater and note the formation of a white precipitate. This precipitate ($Ca\ CO_3$) is a test for carbon dioxide. Continue to blow through the solution until the precipitate dissolves. The excess of carbon dioxide forms carbonic acid, which dissolves the carbonate.

3. Decolorizatión with charcoal.

Place a folded filter paper in a funnel. Fill it half full of boneblack. Pour through this some highly colored vinegar or water containing a little dye and note the decolorization.

4. Effect of heat on baking soda.

Place a teaspoonful of dry baking soda in a dry test tube. Fit the test tube with an exit tube. Heat the tube, gently at first, and then vigorously. At the same time, place the outer end of the exit tube in a test tube of limewater. Note the carbon dioxide gas given off and its effect on the limewater. Since carbon dioxide will not support combustion, one can readily understand why baking soda makes a good fire extinguisher.

5. Operation of a chemical fire extinguisher.

Partly fill a 250 ml. wide-mouth bottle with a water solution of baking soda. Fit the bottle with a stopper having an exit tube and a "small acid" bottle with lead stopper attached. When the model extinguisher is turned upside down, the lead stopper of the sulfuric acid bottle falls out, and the acid mixes with the baking soda solution. The action of the acid on the baking soda (sodium bicarbonate) liberates great quantities of carbon dioxide gas which exerts a pressure that pushes the water solution out through the nozzle of the tube. The water smothers the flames and cools the burning substance.

XIV. SUGGESTED PROJECTS

1. Working model of a continuous carbon dioxide generator.

2. Working model of a carbon dioxide fire extinguisher.

3. Model for the preparation of water gas.

4. Working model of an electric furnace.

5. Test samples of tooth paste at home with vinegar to determine if they contain precipitated chalk, or other carbonates.

6. Chart of the carbon dioxide cycle in nature.

7. Model of the carbon atom.

8. Obtain some litmus paper and test one or more carbonated beverages for acidity.

XV. SUGGESTED TRIPS

1. A field trip to a coal mine.

2. An excursion through a by-product coke oven plant.

3. A visit to a plant where wood charcoal is made.

4. A trip to a plant where coal gas and its by-products are made.

5. A visit to a fire department to secure information about the chemical fire apparatus.

XVI. SUGGESTED LECTURES IN OUTLINE FORM

I. The Diamond.

A. Occurrence.

1. Kimberely, South Africa.

2. Australia.

3. Ural Mountains.

4. Brazil, South America.

B. Origin of the Diamond.

1. Formed at vast depths under great pressure and high temperature.

2. Formed by the slow crystallization of carbon from iron or molten rock.

C. "Artificial" Diamonds.

1. Prepared in 1903 by H. Moissan, Professor of Chemistry in the University of Paris.

2. Chemical procedure.

a. Carbon is dissolved in molten iron, which is cooled quickly in ice water, causing the carbon to crystallize out as minute diamonds.

D. Properties of the Diamond.

1. High index of refraction.

2. Hardest substance known.

3. Pure diamond is colorless and transparent.

4. When heated in air or oxygen to a high temperature it burns to form carbon dioxide.

5. Has an octahedral crystal structure.

E. Uses.

1. Used as a precious gem or stone.

2. Cutting and grinding.

F. Famous Diamonds.

1. Cullinan diamond.
    a. Largest ever found; discovered in South Africa in 1905.
    b. Weighed in the rough state, 3025 carats (1.37 lb.).
    c. It was presented to King Edward VII.
2. Orloff diamond.
    a. It weighed 194.75 carats.
    b. It is tinged with yellow.
    c. After being stolen several times, it was presented to Empress Catherine II of Russia.
3. The Pitt or Regent diamond.
    a. A magnificent colorless diamond which weighed 136.25 carats.
    b. It is located in the Louvre in Paris.
4. The Kohinoor diamond.
    a. One of the British crown jewels which weighs 106 carats.
    b. Its authentic history begins before the birth of Christ.
5. The Hope diamond.
    a. Weighs 44.25 carats, and has an exquisite blue color.

6. The Tiffany diamond.
    a. Weighs 125.5 carats, and has a magnificent orange-yellow color.
7. The Victoria diamond.
    a. This diamond which weighs 180 carats was cut from a stone weighing 457.5 carats.
    b. It was sold to the Nizam of Hyderabad for L400,000, which was at the rate of $20,000,000 per pound troy.

References

Black and Conant, New Practical Chemistry, pp. 217-8.

Brauer, Chemistry and Its Wonders, pp. 442-4.

Collins, The March of Chemistry, pp. 197-200.

Foster, The Romance of Chemistry, pp. 342-5.

Jaffe, New World of Chemistry, pp. 284-5.

II. The Role of Carbon Dioxide in the Air.

A. Amount of CO_2 in the Air.

B. Processes Supplying CO_2 in the Air.
1. Respiration of animals.
2. Combustion of fuels.
3. Decay of organic matter.

C. Oxygen-carbon dioxide cycle.
1. Plants.
    a. Absorb CO_2 from the air.

b. Liberate O_2 to the air.

c. Plants when burned liberate CO_2 to the air.

2. Animals.

a. Absorb O_2 from the air.

b. Exhale CO_2 to the air.

3. How composition of air is kept nearly constant.

a. By processes of combustion, respiration, photosynthesis, and oxidation.

b. Circulation of air.

c. Living plants and animals preserve the balance and keep the composition of the air nearly constant.

D. Importance of Carbon Dioxide as a Component Part of the Air.

1. The dependency of all life on this gas.

References

Black and Conant, _New Practical Chemistry_, pp. 273-4.

Brauer, _Chemistry and Its Wonders_, pp. 124-5; 456-8.

Deming, _In the Realm of Carbon_, pp. 259-62.

Foster, _The Romance of Chemistry_, pp. 352-7.

Jaffe, _New World of Chemistry_, pp. 298-300.

Wilson, _Descriptive Chemistry_, pp. 27-8.

III. Origin of Coal.

A. The Coal Age.

1. What happened during the coal age.
   a. Land would alternately sink and rise.
   b. Formation of swamps.
   c. Animals with vegetation became covered with water, sand and mud in these swamps.
   d. Land would rise again, produce another forest, and then sink again under water.
   e. The rising and falling of the land continued for thousands of years, and accounted for the formation of layers of vegetation under the present earth's surface.
   f. This plant and animal matter began to change under the influence of heat and pressure.
   g. Transformations of these buried forests.
      1). Formation of peat.
      2). Peat transformed into lignite.
      3). Lignite changed into bituminous coal.
      4). Bituminous coal transformed into anthracite coal.
   h. Time necessary to produce coal from vegetation.
      1). It is estimated that it took almost ten thousand years for plants to grow and then be changed into a layer of coal one foot thick.

B. Our Coal Resources.

1. Location of our coal deposits.

2. The conservation of our coal resources.

References

Brownlee, and Others, First Principles of Chemistry, pp. 401-4.

Dull, Modern Chemistry, pp. 315-7.

Foster, The Romance of Chemistry, pp. 350-1.

Howe, Chemistry in Industry, pp. 59-62.

Jaffe, New World of Chemistry, pp. 289-91.

Wilson, Descriptive Chemistry, pp. 68-77.

XVII. VISUAL AIDS[7]

1. Slides:

a. Slides for showing the coal deposits of the United States.

b. Slides showing the electron diagram of the carbon atom and of the carbon dioxide molecule.

c. Slides showing the allotropic forms of carbon.

d. Slides showing the formation of carbon monoxide when hard coal is burned in a stove.

2. Films:

a. A film for showing the operation of an electric resistance furnace in making graphite.

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[7] No. 7, Teacher Hint, p. 44.

b. A film for showing the foamite method of fighting oil fires.

c. A film for showing modern by-product coke ovens.

d. A film illustrating the manufacture of "dry ice."

e. A film illustrating the process of photosynthesis in plants.

3. Charts:

a. Chart for showing the origin of coal.

b. Chart showing a diagram of the heating apparatus in the home.

c. Drawing illustrating the modern method for the production of charcoal.

d. Chart showing a cross section of an electric furnace employed for the production of graphite.

e. A chart illustrating a "carbon tree" in which the trunk is carbon, the main limbs are the different forms of carbon, and the products formed by their combustion are the secondary limbs.

4. Bulletin board material:

a. Pictures showing the diamond mines of South Africa.

b. Pictures of various types of fire extinguishers.

c. Pictures of coal mines.

d. Articles or newspaper clippings about people who were overcome by carbon monoxide gas.

e. Pictures and articles concerned with the commercial uses of carbon dioxide.

f. Articles dealing with scientific research.

g. Pictures of various substances containing carbon.

XVIII. SUMMARY OF UNIT

In order to review and make a summary of the unit, the following statements show the relation between the chief properties of carbon and its compounds and the applications which these properties make possible.

Explain or expand upon each property listed and discuss fully all the applications suggested.

Properties	Applications
1. Carbon burns in a sufficient supply of air to form carbon dioxide thereby liberating much heat.	1. Most fuels are carbon or carbon compounds.
2. Charcoal absorbs many gases.	2. Gas masks contain charcoal.
3. Coke combines with oxygen so readily that it withdraws oxygen from many ores.	3. Coke is used in obtaining metals from their ores by reduction.
4. Graphite is soft and leaves a black mark.	4. "Lead" pencils contain graphite.
5. Diamond has a high index of refraction and is the hardest mineral known.	5. a). Precious gems. b). Used in stone saws and drills.

6. Lampblack does not dissolve in any solvent.	6. India and printers' ink.
7. Graphite is heat-resisting	7. a). Crucibles and other refractory materials. b). Lubricant for high speed machines.
8. Carbon combines directly with certain non-metals in the terrific heat of the electric furnace.	8. a). Carbona is a good solvent for fats and greases. b). Carborundum is a good abrasive. c). Carbon disulfide is a great solvent.
9. Carbon combines directly with many metals to form carbides	9. Calcium carbide has a variety of uses.
10. Carbon monoxide combines vigorously with more oxygen forming carbon dioxide.	10. a). Carbon monoxide is used as a fuel. b). Carbon monoxide is a splendid reducing agent.
11. Carbon monoxide combines with the hemoglobin of the red blood cells forming a very stable compound.	11. Dangers of running an automobile is a closed garage.

12. Carbon dioxide combines with hydroxides such as calcium hydroxide forming carbonates most of which are insoluble.	12. Test for carbon dioxide.
13. Carbon dioxide is released by the action of an acid material on carbonates or bicarbonates.	13. a). Baking powders. b). Fire extinguishers.
14. In the sunlight carbon dioxide combines with water under the catalytic influence of the chlorophyll in green plants to form starch.	14. Photosynthesis

Before the final test, require each pupil to prepare a well-ordered analytical outline in class of the unit as a whole, and then have the pupils discuss briefly various phases of the unit following the outline.

XIX. FINAL TEST ON UNIT

A. Complete the following statements by filling in the blanks.

1. From the position of carbon in the periodic table, we would expect its valence to be ______________________.

2. Three allotropic forms of carbon are ____________, ______________ and ______________.

3. Two crystalline forms of carbon are ____________ and ____________.

4. The "lead" in your pencil is largely ____________.

5. Carborundum is used as an ____________ and has the formula ____________.

6. The physical property of diamonds which makes them useful in drills and stone saws is their ____________.

7. The gas liberated by all baking powders is ______.

8. "Dry ice" has the formula ____________.

9. Three important by-products formed in the process of making coke are _________, _________ and _________.

10. Carbonated water contains the acid whose formula is ___________.

11. The formula of a carbon compound which is an indispensable plant food is ____________.

12. One liter of carbon dioxide at standard conditions weighs __________ grams.

13. Charcoal is valuable in gas masks because of its ability to _____________ certain poisonous gases.

14. Three important uses of carbon dioxide are ___________, ___________ and ___________.

15. When carbon or carbon compounds burn with insufficient oxygen for complete combustion ______________ is formed.

B. **Underline the word or group of words that makes each statement true.**

16. Solid carbon dioxide is a convenient refrigerant

because it (loses its heat easily; is cheaper than ice; is an element while ice is a compound; sublimes; fumes.)

17. India and printers' inks are difficult to remove from clothing because carbon (has united with the cloth; is too soluble; is a good reducing agent; is insoluble; absorbs the solvent.)

18. Carbon monoxide is dangerous to man because it (has a foul odor; is lighter than air; combines with the hemoglobin of the blood; is not soluble in water; burns.)

19. Carbon is used in a blast furnace to purify iron ore chiefly because (it is a decolorizer; it is an absorber of gases; it unites with the iron forming a compound; it is a reducing agent; the intense heat cannot melt it.)

20. When carbon dioxide is passed through limewater, the precipitate formed is (H_2CO_3; $CaCO_3$; $NaHCO_3$; $Ca(OH)_2$.)

C. <u>State whether the following statements are true or false</u>.

21. Artificial graphite is made from hard coal. ____.

22. Carbon dioxide supports combustion. _______.

23. Charcoal is made from coal. _______.

24. Calcium carbide is used to generate acetylene gas _______.

25. Plants give off carbon dioxide. _______.

D. <u>Write equations for the following reactions</u>.

26. The action of hydrochloric acid on marble chips.

_______ + _______ → _______ + _______ + _______

27. The reduction of copper oxide with carbon.

__________ + __________ → __________ + __________

28. Neutralization of carbonic acid with amonium hydroxide. ________ + __________ → ________ + ________

29. Test for carbon dioxide.

__________ + __________ → __________ + __________

30. The action of sulfuric acid on sodium bicarbonate.

________ + ________ → ________ + ________ + ________

E. Solve the following problems.

31. Determine the weight of carbon in one pound of cane sugar ($C_{12}H_{22}O_{11}$). ans. __________.

32. How many grams of $CaCO_3$ will be precipitated when the CO_2 liberated from 200 grams of marble chips is passed through limewater? ans. __________.

33. How many liters of carbon dioxide are formed when hydrochloric acid reacts with 200 grams of limestone? ans. __________.

34. How many grams of Fe_2O_3 can be reduced by 50 liters of carbon monoxide? ans. __________.

35. Compare the weights of liters of CO and CO_2 at standard conditions. ans. __________.

XX. KEY FOR FINAL TEST

Count one point for each blank correctly filled and each statement correctly underlined in the first thirty questions; and five points for each problem solved correctly. (The highest possible score is 80).

1. 4
2. Diamond - Graphite - Amorphous
3. Diamond - Graphite
4. Graphite
5. Abrasive - CSi
6. Hardness
7. Carbon dioxide
8. CO_2
9. Coal gas - Ammonia - Coal tar
10. H_2CO_3
11. CO_2
12. 1.96
13. Absorb
14. Refrigerant -Extinguisher of fire - Carbonated beverages
15. Carbon monoxide
16. Sublimes
17. Is insoluble
18. Combines with hemoglobin of blood
19. It is a reducing agent
20. $CaCO_3$
21. True
22. False

23. False

24. True

25. False

26. $2HCl + CaCO_3 \longrightarrow CaCl_2 + N_2O + CO_2$

27. $2CuO + C \longrightarrow 2Cu + CO_2$

28. $H_2CO_3 + 2NH_4OH \longrightarrow (NH_4)_2CO_3 + 2H_2O$

29. $Ca(OH)_2 + CO_2 \longrightarrow CaCO_3 + H_2O$

30. $2NaHCO_3 + H_2SO_4 \longrightarrow Na_2SO_4 + 2H_2O + 2CO_2$

31. .421 lbs. or 6.736 oz. C.

32. 200 g. $CaCO_3$

33. 44.8 L. CO_2

34. 119.04 g. Fe_2O_3

35. CO = 1.25 g. - CO_2 = 1.96 g.

CHAPTER V

UNIT ON IRON AND STEEL

(From Mines to Skyscrapers)

I. PRELIMINARY

This unit on Iron and Steel was planned on the same basis as the former unit on Carbon and its Oxides. The large concepts or major generalizations set up at the beginning of the unit served as criteria for selecting the content of this chemistry unit.

The specific activities in which the pupils will engage have been selected in view of the fundamental fact that they develop within the pupil better understandings of these fundamental concepts, major generalizations, laws or principles of chemistry that will enable them better to interpret natural phenomena. Therefore, attention should be centered upon these principles continuously throughout the time spent upon the unit.

The organization, content, method of procedure, and the presentation of the unit in general has been elaborated upon in the former unit on Carbon and its Oxides. By virtue of the fact that these units are flexible in their organization, the teacher will be able to adapt the learning material to local conditions very satisfactorily.

TABLE OF CONTENTS

II. GENERALIZATIONS

1. Iron and steel are basic to all present-day civilization.

2. The present-day industrial civilization depends upon an abundance of iron and steel.

3. Iron and steel manufacture tends to develop in a locality that has a supply of both coal and iron.

4. Every substance is one of the following: a chemical element; a chemical compound; or a mechanical mixture.

5. When a chemical change takes place, the substances that are involved are changed in such a way that they no longer behave as they did before this reaction occurred.

6. Matter and energy cannot be created or destroyed, but may be changed from one form to another.

7. Chemical changes are accompanied by energy changes.

8. In industry and in the home man can accomplish more in less time by the use of machines.

9. By varying the temperature and pressure, practically every substance can be changed from one state to another.

10. The kinetic energy of the molecules determines the physical states of matter.

11. The properties of elements and their compounds determine their applications.

12. During a chemical reaction an element may lose

some of its planetary electrons and so gain positive valence or become oxidized, while some other element will combine with these electrons and gain negative valence to be reduced.

13. In a chemical change a quantitative relationship exists between the amounts of substances reacting and the amounts of the substances that are the products of the reactions.

14. We have reached a high standard of civilization through the use of iron and steel, but when all of the people are considered, much remains to be done.

III. GENERAL OBJECTIVES

1. To learn why iron and steel are adaptable to an enormous number of uses.

2. To find out about the different kinds of alloy steels; their characteristics and chief uses.

3. To learn about the various heat-treatments to which steel may be subjected, and their effects.

4. To learn the importance of the iron and steel industry in the United States.

5. To gain some knowledge of the application of chemistry to the metallurgy of iron and steel.

6. To find out the geographic locations of the principal iron ore areas of the United States.

7. To learn the various forms in which iron occurs in nature.

8. To find out the names of the most important ores of iron.

9. To learn which ores are the chief sources of metallic iron.

10. To learn how the compound ferric oxide (hematite) may be decomposed into the elements iron and oxygen.

11. To find out how iron and oxygen differ in chemical properties from ferric oxide.

12. To learn how the heat energy of coal or coke is transformed into chemical energy by the decomposition of ferric oxide.

13. To gain an understanding of the chemical reactions which occur in the blast furnace.

14. To learn how cast iron is converted into steel by removing the impurities through the process of oxidation.

15. To learn how iron ore is reduced in a blast furnace.

16. To find out how steel is made by the three processes, namely: Acid Bessemer Process; Basic Open-Hearth Process; and the Electric Furnace.

17. To learn the effect of heat upon steel.

18. To gain some knowledge of oxidation and reduction as applied to iron salts.

19. To find out the relation between iron and blue-printing and inks.

20. To draw from the activities and subject matter accurate, valuable conclusions or generalizations, such as are listed for this unit.

21. To afford in some measure an opportunity to show the importance of scientific research, and to stimulate the spirit of investigation and invention on the part of the student.

22. To make pupils able to read more intelligently and with greater interest, articles on chemistry in magazines and scientific books of a popular character.

23. To infect the students with the scientific spirit, and to provide training in the scientific method.

IV. CONTENT OUTLINE ON IRON AND STEEL

I. Importance of Iron.

A. Most valuable metal in the world.

B. We live in the age of steel and concrete.

C. Yearly output of iron and steel industry in normal times.

1. Approximately thirty-million tons.

II. Iron Ores.

A. Names of Ores.

1. Hematite (Fe_2O_3).
2. Magnetite (Fe_3O_4).
3. Limonite ($Fe_2O_3 \cdot 3H_2O$).
4. Siderite ($FeCO_3$).

B. Where found.

1. Near Lake Superior Region.
   a. In the states of Minnesota, Wisconsin and Michigan.
2. Also found in Alabama and other states.

C. Chemical Name of Hematite.

1. Ferric Oxide (Fe_2O_3).
2. Composed of iron and oxygen.

III. Reduction

A. Extracting the iron from its ore is known as smelting or reduction.

B. Chemical explanation.

1. Carbon is used to take the oxygen away from the iron in the ore.
2. $Fe_2O_3 + 3CO \rightleftarrows 2Fe + 3CO_2\uparrow$

   $Fe_2O_3 + 3C \longrightarrow 2Fe + 3CO\uparrow$

IV. The Blast Furnace

A. Iron ore is reduced in a blast furnace.

B. Materials put into furnace.

1. Iron ore.

2. Flux (Limestone).

3. Coke.

C. Materials taken out of furnace.

1. Cast iron or molten iron.

2. Slag.

3. Gas.

D. Parts of blast furnace.

1. Shown in the accompanying diagram of blast furnace.

E. What happens in the furnace.

1. Reduction of iron ore.

2. Combustion of coke generates heat.

3. The flux unites with the impurities to produce slag.

4. Carbon in the form of coke unites with the oxygen of the (Fe_2O_3).

5. Melted iron drops to bottom of furnace.

F. Chemistry of blast furnace.

1. $Fe_2O_3 + 3CO \rightleftharpoons 2Fe + 3CO_2\uparrow$

   $Fe_2O_3 + 3C \longrightarrow 2Fe + 3CO\uparrow$

V. Cast Iron.

A. How formed.

1. Molten iron from the blast furnace is run into molds and the resulting metal is called cast iron or pig iron.

VI. Wrought Iron

A. How formed.

1. By heating cast iron in a reverberatory furnace on a bed of iron oxide.

VII. Acid Bessemer Process.

A. Process of making steel.

B. The converter (Furnace).

1. Parts of converter shown in the accompanying diagram.

C. What happens in the converter.

1. Pig iron is put into the furnace, compressed air is forced in and carbon and silicon are burned out.

2. After the air blast is turned off, materials containing carbon are added to give the steel the right amount of carbon.

3. Resulting product is steel.

VIII. Basic Open-Hearth Process.

A. Comparison with Bessemer Process.

1. Basic open-hearth process makes a better quality of steel.

2. It removes the phosphorus; while Bessemer process does not remove it.

3. Open-hearth process is slower and can be kept under better control.

B. Parts of the hearth.

1. Shown in the accompanying diagram of the open-hearth furnace.

C. What happens in the furnace.

1. The carbon, silicon, phosphorus and manganese are burned out of the iron.

2. Resulting product is steel.

IX. Electric Furnace.

A. Growth of the process.

1. Steadily increasing in the United States.

B. Heat for the furnace is furnished by an electric arc.

C. What happens in the furnace.

1. Oxygen and sulfur are removed.

X. Teeming.

A. Meaning.

1. Pouring into molds and cooling.

B. Why important.

1. Because of great chance for waste due to bad places which came during the cooling process.

C. Imperfections.

1. Cavities due to presence of gases.

2. Ingotism (Coarse crystals).

3. Segregation (Uneven mixture of iron and other materials).

4. Checks and scabs.

XI. Heat-Treatment of Steel.

A. Annealing.

1. A process of making the steel softer by heating and then slowly cooling.

B. Hardening.

1. A process of heating steel to a high temperature and then cooling quickly.

C. Tempering.

1. A process of reheating steel to a definite temperature and then suddenly cooling.

D. Case-hardening.

1. A process of adding carbon to the surface of steel to give the steel a hard surface.

E. Oil-treating.

1. A process of heating steel and then plunging it into an oil bath.

F. Effects of each kind of treatment.

1. Annealing--Softens steel.
2. Hardening--Hardens steel.
3. Tempering--Hardens steel to a certain degree.
4. Case-hardening--Gives steel a hard surface.
5. Oil-treating--Makes the steel tougher.

XII. Mechanical Treatment of Steel.

A. Hot and cold working, and effects of each on the steel.

1. Working steel while hot makes it become softer.

2. Working steel while cold makes it become harder and stronger.

XIII. Welding and Cutting.

A. Molecules.

1. Small bodies which compose all matter.

2. Molecules close together in a cold steel bar.

3. Molecules spaced farther apart in a heated steel bar.

B. What happens when iron or steel is heated?

1. Molecules become active when two pieces of steel to be joined are heated.

2. The molecules of the one piece of steel exchange places with those of the other pieces of steel.

3. Two streams of liquid steel will join together

C. Methods of welding.

1. Electric resistance.

2. Electric arc.

3. Oxy-acetylene.

4. Thermite or Goldschmidt process.

XIV. Alloy Steels.

A. Steel which contains another metal is called an alloy steel.

B. Materials added to steel.

1. Vanadium (Vanadium steel).

2. Chromium, Tungsten or Molybdenum (High-speed steels).

3. Manganese (Manganese steel).

4. Nickel (Invar).

5. Titanium (Titanium steel).

6. Silicon (Duriron).

C. Why added.

1. These elements when added to steel give it the character it needs to perform the job it is to do.

XV. Properties of Steel.

A. Expansion.

1. Iron grows larger when heated.

B. Specific gravity.

1. Relation by weight between a metal and an equal volume of water.

2. The specific gravity of steel is 7.816.

C. Conduction of heat.

1. Carrying of heat by iron and steel conductors.

D. Elasticity.

1. Quality of steel to bend and return to its original shape.

E. Tensile strength.

1. Determined by number of pounds of weight

necessary to pull iron or steel apart when it is an inch wide and an inch thick.

2. Tensile strength of wire--37000 pounds.

F. Malleability.

1. The quality of a metal which permits it to be rolled or hammered into thin sheets.

2. Steel when hot is rolled to make steel sheets.

G. Hardness.

1. Diamond is the hardest substance known.

2. Steel is made hard in the process of heat-treatment.

H. Brittleness.

1. The quality of being easily broken.

2. Steel is hard and tough.

I. Magnetic properties.

1. Iron and steel are the only substances used in making magnets.

2. Without the magnetic properties of iron, we would not have our electric motors and generators.

Compounds of Iron

I. Two Series of Compounds.

A. Ferrous compounds.

1. Iron is bivalent.

B. Ferric compounds.

1. Iron is Trivalent.

C. Ferrous compounds may be oxidized to ferric compounds.

D. Ferric compounds may be reduced to ferrous compounds.

II. Oxidation and Reduction.

A. Oxidation is a reaction which increases the valence of the positive element in a molecule.

B. Reduction is a reaction which decreases the valence of the positive element in a molecule.

C. Oxidation is the removal of electrons.

D. Reduction is the addition of electrons.

III. Common Compounds.

A. Iron hydroxides.

1. Ferrous hydroxide $[Fe(OH)_2]$

2. Ferric hydroxide $[Fe(OH)_3]$

B. Iron sulfides.

1. Ferrous sulfide $[FeS]$

2. Iron pyrite (Fool's Gold) $[FeS_2]$

C. Ferrous sulfate (Green vitriol $[FeSO_4 \cdot 7H_2O]$

D. Ferrocyanides.

1. Potassium ferrocyanide $[K_4Fe(CN)_6]$

E. Ferricyanides.

1. Potassium ferricyanide $[K_3Fe(CN)_6]$

F. Tests for ferrous and ferric salts.

1. We can test for a ferrous ion by using potassium ferricyanide.
   a. Dark-blue precipitate of ferrous ferricyanide (Turnbull's blue) is formed.
2. We can test for a ferric compound by using potassium ferrocyanide.
   a. Deep-blue precipitate of ferric ferrocyanide (Prussian blue) is formed.

IV. Blueprints.

A. They are made on paper coated with a reducible ferric salt and potassium ferricyanide.

B. The ferric salt is reduced by light to ferrous.

C. On being treated with water, the potassium ferricyanide and ferrous salt combine, forming Turnbull's blue.

D. The unchanged chemicals are washed away.

E. A blue and white picture remains and is called a blueprint.

V. Inks.

A. Black inks are made from ferric tannate, a black insoluble material.

B. Blue-black inks contain ferrous tannate, which slowly oxidizes in the air to ferric tannate.

VI. Ink Spots and Other Stains.

A. Ink spots can be removed by treating with a reducing agent that will reduce the ferric salts to ferrous.

1. Ammonium oxalate, oxalic acid or lemon juice (citric acid) are suitable for this purpose.

B. Rust stains.

1. They are rendered soluble by the same treatment as that used for ink spots.

C. Coffe and tea stains.

1. They can be washed out of cotton or wool by boiling water if applied at once.

D. Sugar and sirup stains.

1. Water may be used.

E. Grease.

1. Such solvents as carbon tetrachloride or gasoline are necessary.

VII. Iron, Nickel and Cobalt.

A. They are neighboring elements in the eight group of the periodic system.

V. MINIMUM ESSENTIALS IN THE CONTENT OUTLINE

I. Importance of iron.

II. Chief ore of iron.

A. Where found.

III. Process of reduction or smelting.

A. Chemical explanation.

IV. Chemistry of the blast furnace.

V. Important processes of making steel.

A. Acid-Bessemer.

B. Basic Open-Hearth.

C. Electric Process.

VI. Heat Treatment of steel and its effects.

VII. Alloy steels.

A. Characteristic qualities.

B. Uses.

VIII. Properties of iron and steel.

IX. Two series of iron compounds.

A. Tests for iron.

X. Common compounds of iron.

A. Their uses.

XI. Oxidation and reduction.

XII. Chemistry of blueprints and inks.

VI. BIBLIOGRAPHY

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Blanchard, A. A., and F. B. Wade, Foundations of Chemistry. "Metallurgy," pp. 239-52. Cincinnati: American Book Company, 1938. 760 pp.

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McPherson, W. and W. E. Henderson, An Elementary Study of Chemistry. "Iron," pp. 482-502. Boston: Ginn and Company, 1930. 588 pp.

Noyes, W. A., Textbook of Chemistry. "Iron," pp. 539-52. New York: Henry Holt and Company, 1923. 602 pp.

Wilson, Sherman R., Descriptive Chemistry. "Iron in Industry," pp. 261-70. New York: Henry Holt and Company, 1936.

VII. SUGGESTED CLASS PROCEDURE

Several days previous to the time of launching upon this unit, it is suggested that the teacher display on the bulletin board[1] any available pictures or current topics dealing with the iron and steel industry. This will tend to create interest and orient the pupils so that when the time arrives, their minds will be filled with many questions.

The teacher may introduce the unit as a whole by means of a short overview story similar to the following:

"An Element Made Valuable by Impurities"

In the great scheme of things, iron must have been meant to play an important part, because it is so widely and so generously distributed in nature. Unlike many of the common elements, pure iron is both useless and novel. Then what is this giant which has given its name to the age through which we are not passing--The Iron Age? The answer is steel, which is iron that has been purified and then alloyed with carbon and with many other elements, both metallic and non-metallic, each giving to steel peculiar properties for special uses. Some examples are steel for burglar-proof safes, steel for high speed cutting tools, steel for skyscraper construction, and various types of steel for automobile parts.

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[1] No. 1, Teacher Hint, p. 111.

"How Iron Becomes Steel"

Coal, properly coked, iron ore, and limestone come together, usually from widely separated points, in a massive blast furnace where they are treated with a blast of heated air. The molten pig iron, which is suited only for castings, is then refined by the quick and spectacular Bessemer process, by the slower but more practical open-hearth process, or for special uses by various types of electrical furnaces. The ingots or the large blocks of steel from these processes must then be uniformily heated, rolled, drawn, pressed, or must undergo a combination of these treatments before the finished steel product is ready for the market.

Additional features of the unit. There are many alloys of steel. Tempering and case-hardening the steel fits it for many additional uses. Galvanizing and tin-plating the steel produces cheaper and more durable products. You will find that the two classes of iron compounds lend themselves well to an experimental study of oxidation and reduction. The relation of iron to the preparation of inks and blueprints should be noted as well as some general facts about iron's close--but not so well known--relatives, cobalt and nickel.

Following the overview, the exploratory and correlation questions[2] may be presented to the class in order

[2] No. 2, Teacher Hint, p. 111.

to make an inventory of the pupils' intellectual background on such phases which the present unit is planned to give.

After the above questions have been answered and discussed, provide for a supervised-study period by allowing pupils to explore books which have been placed on the reading table. Secure as large a variety of textbooks, science books of a popular nature, and science magazines as possible.

Give each pupil a mimeographed guide sheet before he starts studying, which includes the topics to study and the activities to be done on this unit of iron and steel.

VIII. TEACHER HINTS

No. 1. The bulletin board is an indispensable part of any science classroom. It can be used as a clearing house for the pictorial aids in teaching the lesson, for clippings of science interest, which pupils should be encouraged to bring; or for exceptional project work done by members of the class. Pictures with several key questions attached beneath, help stimulate thought among the pupils.

No. 2. These exploratory questions should provide a means of making an inventory of the pupils' present acquisition of the learning products which the unit is planned to give. This inventory may serve the purpose of arousing a deep interest in the new unit and provide an excellent review of the learning acquired in previous units.

No. 3. If it is not possible to purchase or borrow lantern slides, some artistically-inclined student may take pleasure in making slides for class use and consequently his interest in the subject will be enhanced by the activity. The subject for a lantern slide may be a particularly good diagram from a text not available to the class, or better still, an original drawing or diagram to show the production steps in the manufacturing of steel.

The steps in the making of a lantern slide are simple: a piece of glass of the proper size is cleaned and covered with a thin coating of gelatin solution. When the glass is dry, the drawing of a size to fit, is placed under the glass and traced with india ink on the dry, gelatinized surface. Portions of the slide may be colored at this time if desired. A frame of paper is then placed around the drawing, a clear glass of the same size is laid over it, and the two glasses are bound together by strips of "passe partout" binding.

For specific suggestions, these home-made slides may be made to represent such things as:

1. A diagram showing the input and output of a blast furnace.

2. Vertical section of a blast furnace.

3. Diagram of a reverberatory furnace.

4. Cross section of a Bessemer converter.

5. Diagram of an open-hearth furnace.

6. Diagram of an electric furnace.

7. Diagram illustrating the tests for ferrous and ferric ions.

8. Chemical equations to represent oxidation and reduction.

IX. EXPLORATORY AND CORRELATION QUESTIONS

1. How important is the iron and steel manufacturing industry in the United States?

2. Why is iron regarded as the most valuable metal in the world?

3. In what various forms does iron occur in nature?

4. Why does iron rust?

5. Why does not iron occur in the native state?

6. What are the names of the four most important ores of iron?

7. What is meant by the metallurgy of iron and steel?

8. Where are the chief iron deposits in the United States?

9. Why does the geographical location of Cleveland, Ohio, make this city a great iron and steel center?

10. What is meant by the smelting or reduction of iron ore?

11. Why is carbon an important element in the reduction of ferric oxide?

12. What four materials must be supplied to a blast furnace?

13. Why is a blast furnace kept in continuous operation?

14. What was the primitive method of obtaining iron from its ores?

15. What has been the important modern inventions in the iron and steel industry?

16. Would our present civilization be possible without the blast furnace?

17. Why is the air forced into a blast furnace, dried and preheated?

18. Why is the furnace in which cast iron is made called a blast furnace?

19. What are the three methods by which steel is made?

20. Why is steel made by the open-hearth process generally superior to that made by the Bessemer process?

21. How does steel differ from pig iron?

22. What effect does the amount of carbon have upon steel?

23. What is meant by the heat-treament of steel?

24. How do the annealing and tempering processes differ in their effects upon steel?

25. What advantages has the electric furnace over other forms of furnaces for making steel?

26. What is meant by an alloy steel?

27. Name four special or alloy steels and give uses to which each is adapted.

28. Why does the process of welding depend upon increased molecular activity in heated iron or steel?

29. Why does iron or steel expand when heated?

30. What are some of the characteristic properties which iron and steel possess?

31. What are the three members of the iron family?

32. What are the names of the two series of iron compounds?

33. Distinguish between oxidation and reduction in terms of valence and electrons?

34. What are the names and formulas of some of the common iron compounds.

35. What two tests are applied for distinguishing between ferrous and ferric salts?

36. For what special purposes are blueprints adapted?

37. What is the composition of ink?

38. How are ink spots generally removed?

39. What is the composition of Turnbull's blue and Prussian blue?

40. What is the chemical name of green vitriol or copperas?

X. SPECIAL TOPICS

1. Importance of Iron and Steel Manufacturing Industry in the United States.

References

Black and Conant, New Practical Chemistry, pp. 490-1.

Brauer, Chemistry and Its Wonders, pp. 289-90.

Collins, Wonders of Chemistry, pp. 64-5.

Wilson, Descriptive Chemistry, p. 261.

2. Ores of Iron; Names; Where Found.

References

Black and Conant, New Practical Chemistry, pp. 491-3.

Brownlee and Others, First Principles of Chemistry, pp. 521-4.

Bruce, High School Chemistry, p. 421.

Dull, Modern Chemistry, pp. 591-2.

3. The Operation of a Blast Furnace.

References

Black and Conant, New Practical Chemistry, pp. 496-501.

Bruce, High School Chemistry, pp. 422-5.

Collins, Wonders of Chemistry, pp. 65-6.

McPherson, Henderson and Fowler, Chemistry for Today, pp. 485-6.

4. Modern Processes of Manufacturing Steel.

References

Black and Conant, New Practical Chemistry, pp. 496-501.

Bruce, High School Chemistry, pp. 427-34.

Collins, Wonders of Chemistry, pp. 67-9.

Wilson, Descriptive Chemistry, pp. 263-7.

5. Useful Steel Alloys.

References

Black and Conant, New Practical Chemistry, p. 503.

Brauer, Chemistry and Its Wonders, p. 300.

6. Chemistry of the Blast Furnace; Bessemer Converter; and Open-Hearth Furnace.

References

Black and Conant, New Practical Chemistry, pp. 493-500.

Brownlee and Others, First Principles of Chemistry, pp. 527-38; 548-53.

Dull, Modern Chemistry, pp. 594-603.

Wilson, Descriptive Chemistry, pp. 261-67.

7. <u>Heat Treatment of Steel</u>.

References

Black and Conant, <u>New Practical Chemistry</u>, pp. 501-3.

Brownlee and Others, <u>First Principles of Chemistry</u>, pp. 556-60.

Bruce, <u>High School Chemistry</u>, pp. 434-6.

Dull, <u>Modern Chemistry</u>, pp. 606-7.

8. <u>Welding and Cutting</u>.

References

Black and Conant, <u>New Practical Chemistry</u>, pp. 520-1.

Bruce, <u>High School Chemistry</u>, pp. 310-1; 457-9.

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9. <u>Properties of Iron and Steel</u>.

References

Black and Conant, <u>New Practical Chemistry</u>, pp. 495-6.

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Dull, <u>Modern Chemistry</u>, pp. 593-4.

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10. <u>The Chemistry of Inks</u>.

References

Black and Conant, <u>New Practical Chemistry</u>, pp. 510-1.

Bruce, High School Chemistry, pp. 440-41.

Dull, Modern Chemistry, p. 615.

McPherson, Henderson and Fowler, Chemistry for Today, pp. 499-500.

11. Galvanizing.

References

Bruce, High School Chemistry, p. 415.

Dinsmore, Chemistry for Secondary Schools, p. 433.

Dull, Modern Chemistry, pp. 552-3.

Wilson, Descriptive Chemistry, p. 283.

12. Oxidation and Reduction.

References

Black and Conant, New Practical Chemistry, pp. 507-8.

Dinsmore, Chemistry for Secondary Schools, pp. 466-8.

Dull, Modern Chemistry, pp. 613-4.

McPherson and Henderson, An Elementary Study of Chemistry, pp. 628-9.

XI. ACTIVITIES TO BE DONE

1. Uses of Iron and Steel.

The most important metal in industry is iron. It has more uses in the world than gold or silver. To get an idea of the many uses for iron as compared to other metals, you are asked to list here some uses for the metal. Think of the things in this school which are made of iron and steel.

Then list them in the proper column. Do the same for gold and copper.

Iron and Steel	Gold	Copper
1.	1.	1.
2.	2.	2.
3.	3.	3.
4.	4.	4.
5.	5.	5.

Question: Which metal has the most uses? __________.

2. Importance of Steel Industry.

Read carefully the following references with this question in mind: "How important is the iron and steel industry in America?" Summarize your reading in a brief answer to the question.

References

Black and Conant, New Practical Chemistry, pp. 490-1.

Blanchard and Wade, Foundations of Chemistry, pp. 240-1.

Deming, General Chemistry, p. 455.

Greer and Bennett, Chemistry for Boys and Girls, pp. 174-7.

3. Iron Ore.

The iron of commerce is produced from iron ore. Iron ore is not pure iron. It does not look like iron. Iron ore is a compound of iron with some other substances.

To be acquainted with the different ores of iron, read the following references and then fill in the table below as completely as possible.

ORES OF IRON

Common Name of Ore	Chemical Name of Ore	Formula of Ore

<u>Questions</u>: Examine a piece of iron ore.

1. What is its name? ______________________________.
2. What is its color? ______________________________.
3. Does it look like iron? ________________________.
4. Does it look more like iron rust than iron? ____.

References

Black and Conant, New Practical Chemistry, p. 491.

Blanchard and Wade, Foundations of Chemistry, pp. 239-41.

Deming, General Chemistry, p. 455.

Greer and Bennett, Chemistry for Boys and Girls, pp. 744-5.

McPherson and Henderson, An Elementary Study of Chemistry, pp. 611-4.

Noyes, Textbook of Chemistry, p. 540.

4. Occurrence of Iron Ore.

In order to determine where the chief ore deposits are found in the United States, you are asked to read the references and then locate these areas with a dark color on this outline map of the United States.

Be prepared to tell the class where the chief ore deposits are found in our country as well as to explain the significance of the geographical location of Cleveland, Ohio, and Pittsburgh, Pennsylvania, as great iron and steel centers.

References

Brauer, Chemistry and Its Wonders, pp. 289-90.

Deming, Genэral Chemistry, pp. 456-7.

Emery and Others, Chemistry in Everyday Life, pp. 298-301.

McPherson and Henderson, An Elementary Study of Chemistry, pp. 612-3.

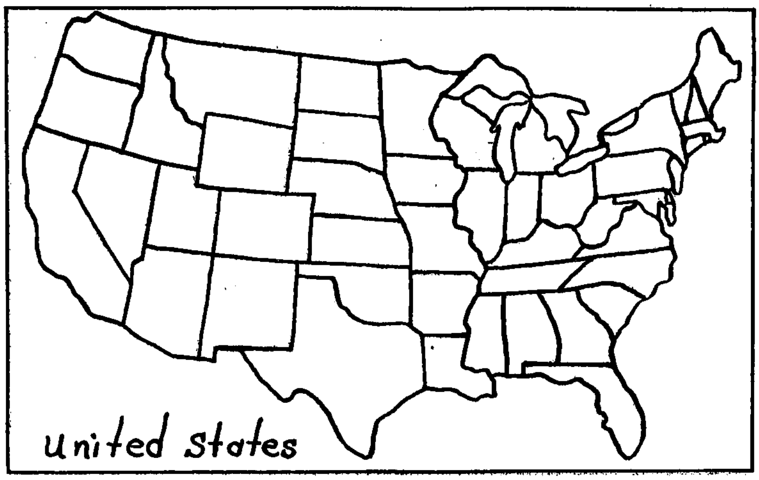

FIGURE 11

IRON ORE DEPOSITS OF UNITED STATES

5. The Rusting of Iron.

We have learned that hematite is a compound of iron and oxygen. It is possible to make a compound of iron and oxygen in the laboratory. In performing this experiment, you should work with four or five others in order to save materials.

Your group will need the following materials: one test tube; one beaker; one right stand with test tube clamp;

and a small pinch of iron fillings, When you have these materials, you may do the experiment in the following steps:

a. Fill the test tube with water. Pour the water out.

b. Scatter the iron filings over the inside of the wet test tube.

c. Fill the beaker with water. Invert the test tube over the beaker with the open end just below the level of the water as in the drawing. Clamp the test tube in this position. When completed, your apparatus should resemble the drawing.

d. Set your apparatus aside until the next science period. Be sure your name is on it.

e. At the next class period, examine the iron filings and write in the answers to the following questions.

Questions:

1. What is the color of the iron filings? __________.

2. The iron has combined with some of the oxygen from the air. Why has the water risen in the test tube?

____.

3. What is the chemical name of hematite? __________.

4. From the appearance of the material in the test tube, do you think that it contains ferric oxide? __________.

5. Hematite iron ore is composed of iron plus ______.

6. Is the rusting of iron a physical or chemical change? ______________________________.

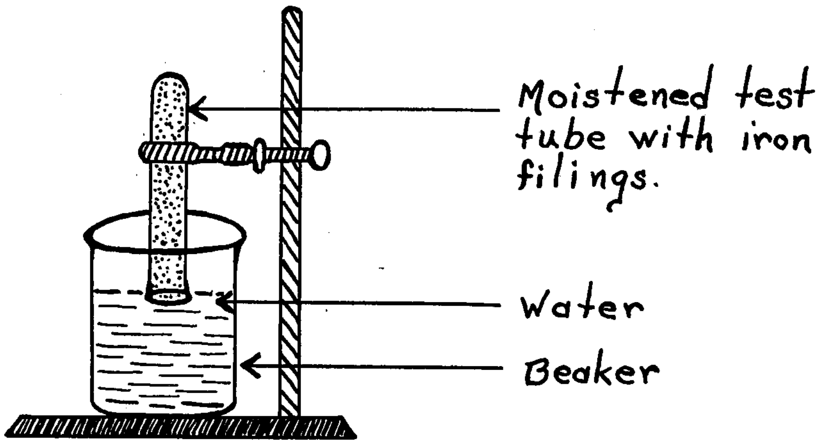

FIGURE 12

RUSTING OF IRON

References

Deming, General Chemistry, pp. 470-1.

Greer and Bennett, Chemistry for Boys and Girls, pp. 165; 177-8.

6. Reduction.

Extracting the iron from its ore is known as smelting or reduction. We have learned that hematite is a compound of iron and oxygen. How can we take this oxygen away from the iron? This question can be answered after observing the following demonstration by the teacher:

Problem:

How is a metal separated from its ore by the process of reduction?

Procedure:

The process of reduction may be illustrated by using lead oxide and charcoal. We cannot reduce iron ore in the laboratory because of the high temperature required. We can, however, reduce lead ore (take the oxygen away from the lead). The principle is the same.

1. A small hole a quarter of an inch deep is hollowed out in a small block of charcoal.

2. The lead oxide is then placed in this hole.

3. The flame of a Bunsen burner is now blowed against the lead oxide in the charcoal by means of a blowpipe.

After observing this demonstration, read the following references and answer these questions. Furthermore, be prepared to explain to the class the process of reduction or smelting of iron ore.

Questions:

1. What is the color of the material on the outside of the oxide? ______________________________.

2. Is this lead? ______________________________.

3. What did the lead oxide lose? ______________________________.

4. What took the oxygen away from the lead oxide? __ ______________________________.

5. With what did the oxygen unite? ________________.

6. What metal was left behind? ____________________.

A similar experiment may be performed using cupric oxide to obtain copper.

References

Brownlee and Others, First Principles of Chemistry, pp. 525-5.

Greer and Bennett, Chemistry for Boys and Girls, pp. 744-50.

McPherson and Henderson, An Elementary Study of Chemistry, pp. 613-7.

7. The Blast Furnace.

In industry, iron ore is reduced in a blast furnace. The chemical process is essentially the one we have been explaining. Carbon in form of coke is used to take the oxygen away from the iron ore. Iron ore contains other materials besides ferric oxide. To remove these materials a flux is added which is usually limestone. The limestone unites with these other materials to produce slag. The following diagram will show what happens in the blast furnace. Study this diagram carefully and write out the answers to the questions which follow.

Questions:

1. What is the name of the furnace? ________________.

2. What materials are dumped into it? ______________.

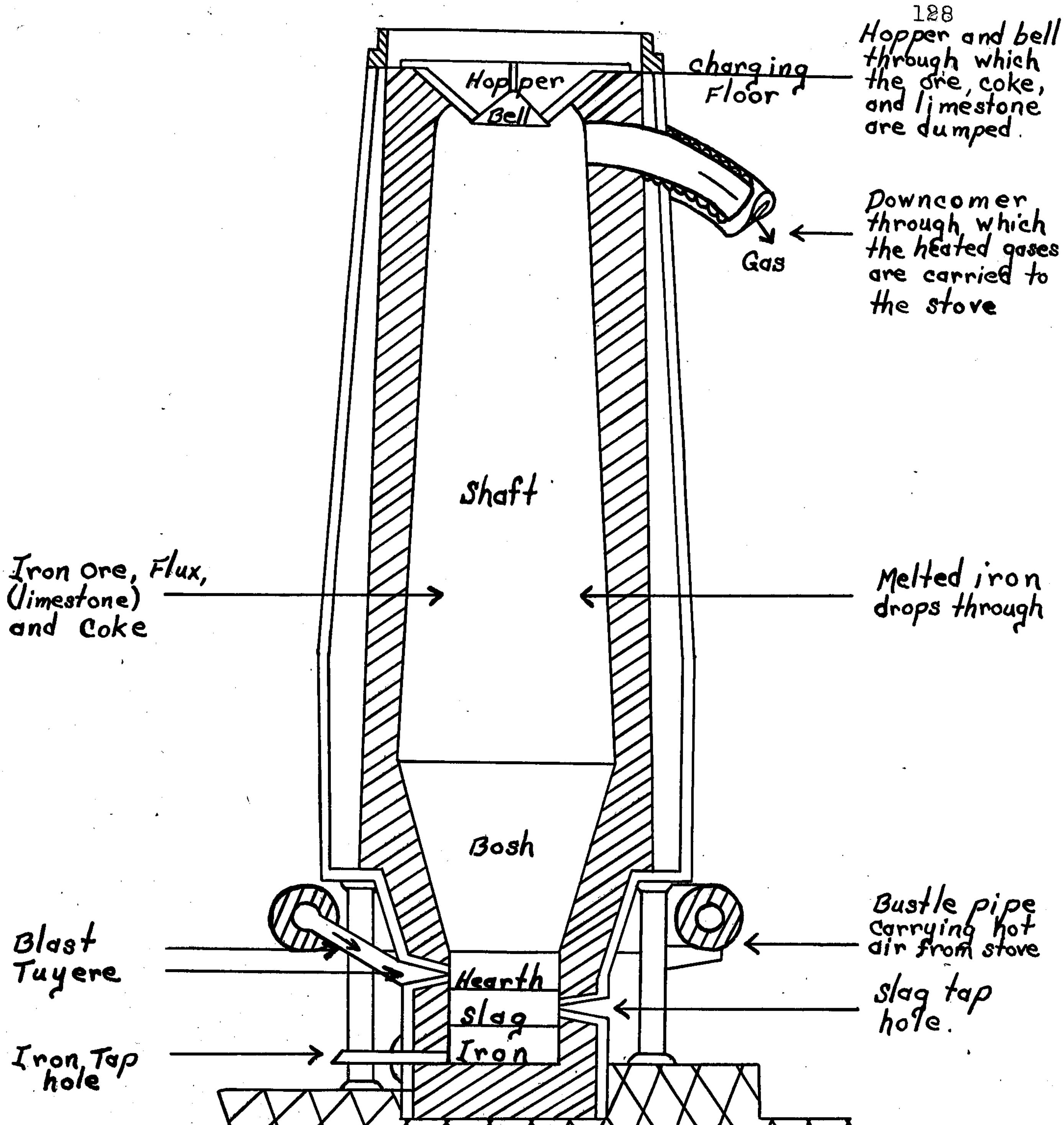

FIGURE 13

BLAST FURNACE

3. Through what do these materials enter? ________.

4. What three things leave the furnace? ________.

5. Through what do the hot gases leave? ________.

6. Through what does the slag leave? ________.

7. Through what does the iron leave? ________.

8. What pipes carry hot air from stove to furnace?

____.

References

Black and Conant, New Practical Chemistry, pp. 492-5.

Blanchard and Wade, Foundations of Chemistry, pp. 241-5.

Brownlee and Others, First Principles of Chemistry, pp. 525-8.

Deming, General Chemistry, pp. 457-60.

Emery and Others, Chemistry in Everyday Life, pp. 301-3.

Greer and Bennett, Chemistry for Boys and Girls, pp. 747-50.

McPherson and Henderson, An Elementary Study of Chemistry, pp. 613-7.

8. Acid Bessemer Process.

Steel is made from the product of the blast furnace. The commonest process is the Acid Bessemer. The furnace used in this process is called the converter. Pig iron is put into the furnace, compressed air is forced in, and carbon and silicon are burned out. After the air blast is turned off, materials containing carbon are added to give the steel the right amount of carbon.

Study the following diagram; read the references and then answer the questions.

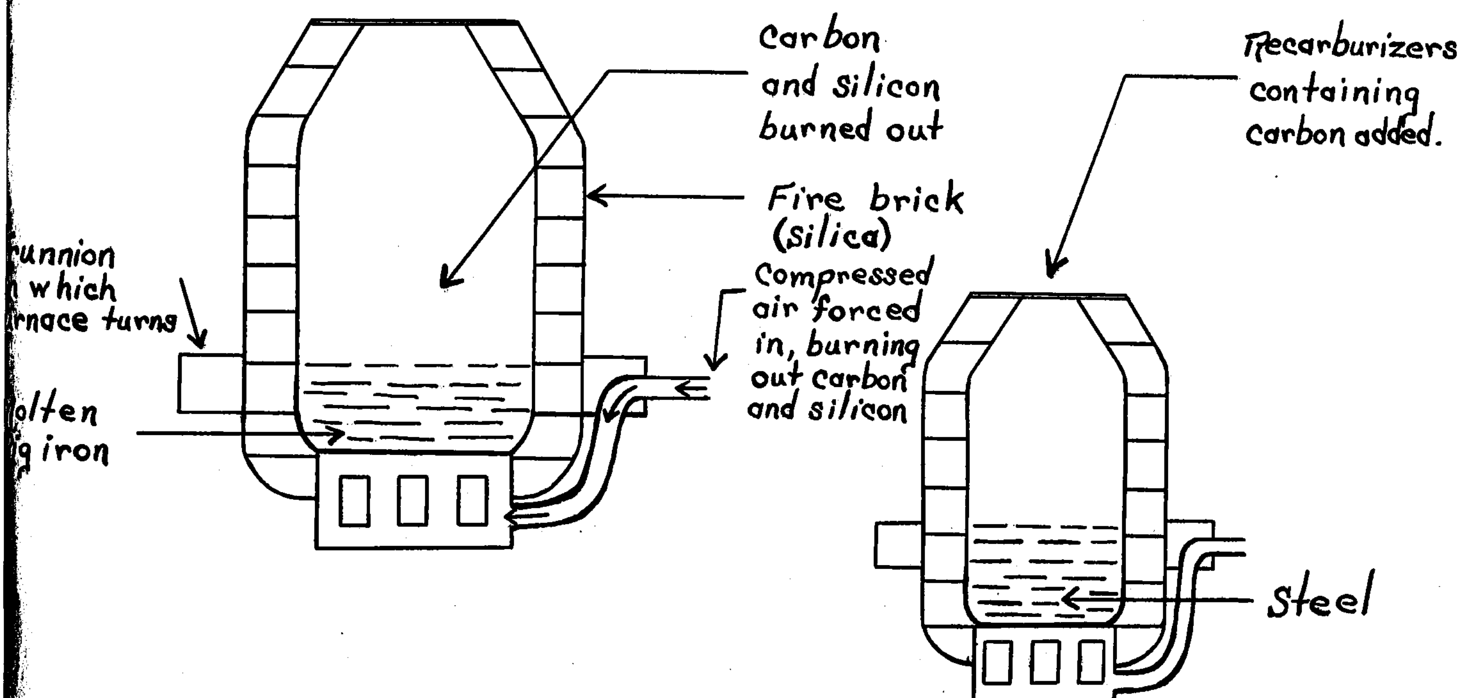

FIGURE 14

BESSEMER CONVERTER

Questions:

1. What form of iron is put into the converter? ____.

2. What is the furnace lined with? ________________.

3. What is burned out of the cast iron? ____________.

4. After the air blast is turned off, what is put into the converter? ______________________________________.

5. What is the name of the part on which the converter revolves when it turns over? ______________________________.

6. What is the product made in the converter? ______.

References

Black and Conant, New Practical Chemistry, pp. 497-9.

Blanchard and Wade, Foundations of Chemistry, pp. 245-7.

Brownlee and Others, First Principles of Chemistry, pp. 548-50.

Deming, General Chemistry, pp. 461-3.

Emery and Others, Chemistry in Everyday Life, pp. 304-7.

Greer and Bennett, Chemistry for Boys and Girls, pp. 750-3.

McPherson and Henderson, An Elementary Study of Chemistry, pp. 618-20.

9. Basic Open-Hearth Process.

The basic open-hearth process is another method of making steel. It takes longer but is able to remove the phosphorus and other materials. A better quality of steel may be made from pig iron containing phosphorus when the open-hearth process is used. The acid Bessemer process does not remove the phosphorus, but the open-hearth does. Furthermore, it is easier to burn out just the right amount of carbon. There is also less danger of overheating the metal.

Study the diagram and references and answer the questions which follow.

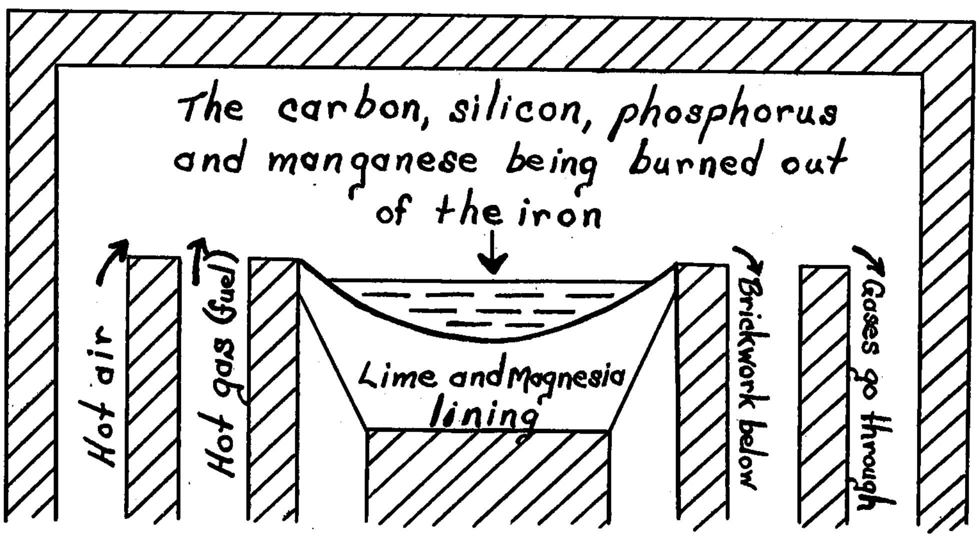

FIGURE 15

OPEN-HEARTH FURNACE

Questions:

1. What fuel is used? ______________________________.

2. With what is the hearth lined? ____________________.

3. What materials are taken from the iron in this process? ____.

4. What is the product of the open-hearth? _________.

References

Black and Conant, New Practical Chemistry, pp. 499-500.

Blanchard and Wade, Foundations of Chemistry, pp. 247-9.

Brownlee and Others, First Principles of Chemistry, pp. 550-3.

Emery and Others, Chemistry in Everyday Life, pp. 307-8.

Greer and Bennett, Chemistry for Boys and Girls, pp. 754-55.

McPherson and Henderson, An Elementary Study of Chemistry, pp. 620-1.

10. Alloy Steels.

Other elements when added to steel in the converter or open-hearth give it different qualities. These elements when added to steel in the furnace give it the character it needs to do the job it is to do. Steel which contains another metal is called an alloy steel. After referring to the references, complete the following four column table. List the names of the special or alloy steels; names of elements added to the steel; characteristic qualities of each respective alloy steel; and the uses made of each alloy steel.

ALLOY STEELS

Name	Elements Added	Qualities	Uses

References

Black and Conant, New Practical Chemistry, p. 503.

Blanchard and Wade, Foundations of Chemistry, pp. 249-50.

Brauer, Chemistry and Its Wonders, p. 300.

Deming, General Chemistry, pp. 468-70.

Emery and Others, Chemistry in Everyday Life, pp. 310-2.

Greer and Bennett, Chemistry for Boys and Girls, pp. 755-7.

McPherson and Henderson, An Elementary Study of Chemistry, pp. 623-4.

11. Heat Treatment of Steel.

Refer to the references and study the various heat-treatments to which steel may be subjected. Write a definition for each of the following treatments; also tell the effects of each kind of treatment

Treatment	Definition	Effect on Steel
a. Annealing	__________	__________
b. Hardening	__________	__________
c. Tempering	__________	__________
d. Case-hardening	__________	__________
e. Oil-treating	__________	__________

The following demonstration may be performed by a pupil or the teacher:

Problem:

To determine the effects of several heat-treatments on steel.

Procedure:

To perform the following demonstration, secure an eight-penny finishing nail; a pair of tongs; a Bunsen burner; and a beaker of water.

1. Try to bend the eight-penny nail with your fingers. If you are able to bend this nail, get a larger sized nail and begin again.

2. Heat the nail over a Bunsen burner until it is red hot. Heat it just as hot as you can. Hold it with the tongs.

3. Let it cool slowly by holding it a few inches from the burner as it cools.

4. Try to bend it as soon as it is cool enough to touch. The nail should bend. If it does not bend, you should get a smaller sized nail and begin again. The fact that the nail bends when it would not do so originally, shows that you have annealed it.

5. Straighten the nail and reheat it to redness as before. When very red hot, plunge it swiftly into a beaker of water. Try to bend it again and observe what happens.

References

Black and Conant, New Practical Chemistry, pp. 501-3.

Brownlee and Others, First Principles of Chemistry, pp. 556-60.

Deming, General Chemistry, pp. 466-8.

Greer and Bennett, Chemistry for Boys and Girls, pp. 758-9.

McPherson and Henderson, An Elementary Study of Chemistry, pp. 621-2.

12. Molecular Theory and Welding.

Read the following references and determine what relation exists between the Kinetic Molecular Theory and the process of welding. Also find the different methods of welding. Summarize your reading in the form of a sentence outline.

References

Black and Conant, New Practical Chemistry, pp. 85-6; 438-9; 520-1.

Brownlee and Others, First Principles of Chemistry, pp. 438-40; 537.

Deming, General Chemistry, pp. 26-7; 443-4.

Emery and Others, Chemistry in Everyday Life, pp. 303-4.

Greer and Bennett, Chemistry for Boys and Girls, pp. 204-17.

McPherson and Henderson, An Elementary Study of Chemistry, pp. 419-22.

13. Properties of Iron and Steel.

Expansion. You have learned that a piece of metal will grow larger when heated. This is called expansion. The following experiment will prove the truth of this to you.

The materials necessary to do this experiment are: two ring stands with rings; Bunsen burner; iron or steel rod; and a ruler.

Procedure:

1. Set up the apparatus as in the diagram with the iron rod resting on the rings.

2. Set the ruler against the end of the rod at "B" so that it will just fall over if a pencil is lightly tapped against the ring stand at "A".

3. With the ruler in position again, heat the iron or steel rod in the middle with the Bunsen burner.

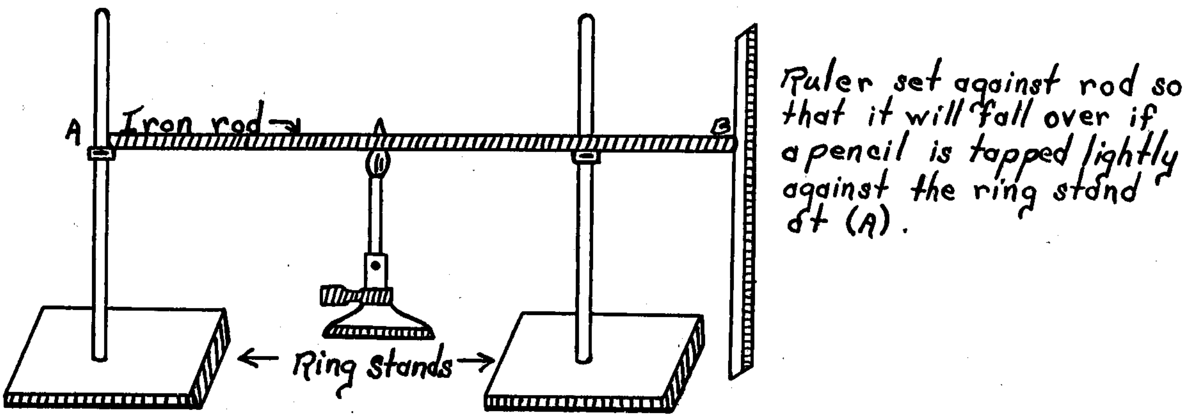

FIGURE 16

EXPANSION OF IRON

Questions:

1. What happens to the ruler? ______________________.

2. What did the iron or steel do when heated? _____.

<u>Specific Gravity</u>. A bar of steel will not have the same weight as a bar of cast iron the same size. The steel bar will be a little heavier. White cast iron is 7.655 times as heavy as an equal volume of water. We say, therefore, that the specific gravity of white cast iron is 7.655. Wrought iron is 7.698 times as heavy as an equal volume of water. Its specific gravity is 7.698 of course. Steel is 7.816 times as heavy as water.

<u>Question</u>: What is its specific gravity? ___________.

<u>Conduction</u>. Steel and iron are good conductors of heat. To show this, perform the following experiment.

The materials you will need are: Bunsen burner; glass rod; and steel rod.

<u>Procedure</u>:

1. Hold the end of the steel rod in the flame of the burner. Your hand should be about six or eight inches from the flame.

<u>Question</u>: What happens? ___________________________.

2. Hold one end of the glass rod in the flame of the burner.

<u>Questions</u>:

1. What difference do you note? ____________________.
2. Which is the better conductor of heat? _________.

Consult the references and determine to what degree iron and steel possess the following properties: Elasticity;

Tensile strength; Malleability; Hardness and Brittleness; and Magnetic properties.

References

Brownlee and Others, First Principles of Chemistry, pp. 567-77.

Deming, General Chemistry, pp. 469-70.

Emery and Others, Chemistry in Everyday Life, pp. 259-61; 310-2.

Greer and Bennett, Chemistry for Boys and Girls, pp. 174-7; 743-4.

14. Tests for Ferrous and Ferric Ions.

We have found in previous study that definite chemical tests can be worked out for showing the presence or absence of certain definite ions or substances. Our first step then is to show suitable tests for the ferrous and ferric ions.

Ferrous Ion: In each of four test tubes place 5 ml. of a freshly prepared solution of ferrous sulfate. To each test tube in order, add potassium ferricyanide (positive test); potassium ferrocyanide; potassium sulfocyanide; and amonium hydroxide (positive test). Write the equations for the positive tests.

Equations:

1. ______________________________.

Color: ______________________.

2. ______________________________.

Color: ______________________.

Ferric Ion: In each of four test tubes place 5 ml. of a freshly prepared solution of ferric chloride. Add potassium ferricyanide; potassium ferrocyanide (positive test); potassium sulfocyanide (positive test); and ammonium hydroxide (positive test). Write the equations for the positive tests.

Equations:

1. ______________________________.

   Color: ______________________.

2. ______________________________.

   Color: ______________________.

3. ______________________________.

   Color: ______________________.

From what you found in this experiment and the following references, state the chemical tests for ferrous and ferric ions.

References

Black and Conant, New Practical Chemistry, pp. 509-10.

Dinsmore, Chemistry for Secondary Schools, pp. 465-6.

Dull, Modern Chemistry, pp. 615-6.

McPherson and Henderson, An Elementary Study of Chemistry, pp. 629-31.

15. Oxidation and Reduction.

According to our new meaning of oxidation and reduction, we find that oxidation is an increase of the valence of an element and reduction is a decrease of the valence of an element.

After consulting the following references, fill in this table on oxidation-reduction reactions.

OXIDATION-REDUCTION REACTIONS

Reaction	Reducing Agent	Oxidizing Agent	Reduced	Oxidized
$Fe + HCl \longrightarrow$				
$FeCl_2 + K_3Fe(CN)_6 \longrightarrow$				
$FeCl_2 + Cl_2 \longrightarrow$				
$FeCl_3 + [H] \longrightarrow$				
$Fe_2O_3 + Al \longrightarrow$				
$Fe_2O_3 + CO \longrightarrow$				
$Fe_3O_4 + H_2 \longrightarrow$				

References

Black and Conant, New Practical Chemistry, pp. 507-8.

Dinsmore, Chemistry for Secondary Schools, pp. 466-8.

Dull, Modern Chemistry, pp. 613-4.

McPherson and Henderson, An Elementary Study of Chemistry, pp. 628-9.

16. Scientific Vocabulary.

Referring to the chemistry references as well as the dictionary, write out the meaning of the following terms:

1. alloy ________________.
2. anneal ________________.
3. carbon ________________.
4. carbon dioxide ________________.
5. carbon monoxide ________________.
6. cast ________________.
7. compound ________________.
8. conductor ________________.
9. element ________________.
10. expansion ________________.
11. flux ________________.
12. industry ________________.
13. molecule ________________.
14. oxygen ________________.
15. ore ________________.
16. oxidation ________________.
17. reduced ________________.
18. reduction ________________.
19. slag ________________.
20. smelting ________________.
21. teeming ________________.
22. temper ________________.

XII. SELF-TESTING EXERCISE

In the parenthesis preceding each of the following, place the letter of the item in the second list which corresponds with an item in the first list.

First List

1. ( ) Formula for hematite.
2. ( ) Furnace used to make wrought iron.
3. ( ) Metal formed by the blast furnace.
4. ( ) Production of a metal from its ores.
5. ( ) Reducing agent in the blast furnace.
6. ( ) Furnace used in the acid Bessemer process.
7. ( ) Element which greatly influences the properties of iron.
8. ( ) Flux generally used in smelting iron ore.
9. ( ) Heat treatment that makes steel tougher.
10. ( ) Steel which contains another metal.
11. ( ) Heat treatment that gives steel a hard surface.
12. ( ) Quality of steel which permits it to be rolled or hammered.
13. ( ) Specific gravity of steel.
14. ( ) The alloy steel containing 36 per cent of nickel.
15. ( ) Common method of welding rails.
16. ( ) Series of iron compounds in which iron is bivalent.

17. ( ) Change from ferrous to ferric compounds.
18. ( ) A reaction which decreases the valence of the positive element in a molecule.
19. ( ) Process of iron rusting.
20. ( ) Chemical name for copperas or green vitriol.
21. ( ) An alloy of copper, zinc and nickel
22. ( ) Common name of ferric ferrocyanide.
23. ( ) Common name of ferrous ferricyanide.
24. ( ) Process of covering iron with a thin layer of zinc.
25. ( ) Chief compound composing black ink.

Second List

a. Invar
b. Fe_2O_3
c. Galvanizing
d. Oxidation
e. Open-hearth furnace
f. Thermite
g. Reverberatory furnace
h. Prussian blue
i. Ferrous
j. Smelting
k. Malleability
l. Ferrous sulfate
m. Cast iron
n. Case-hardening
o. Carbon
p. 7.816
q. German silver
r. Converter
s. Oxidation
t. Turnbull's blue
u. Oil treatment
v. Limestone
w. Reduction
x. Ferric tannate
y. Carbon
z. alloy

XIII. SUGGESTED CLASS DEMONSTRATION

1. Blue Printing.

Prepare some blue print paper solution. Do this by mixing solutions of 5 g. ferric ammonium citrate in 25 ml. water and 5 g. potassium ferricyanide in 25 ml. water. Coat the surface of well-sized paper by rubbing the solution evenly on the paper with a cotton swab. Allow to dry in the dark room. Place an opaque object as a key or plant leaf on the dry sensitized paper and cover with a clean glass plate. Expose to strong sunlight several minutes, and then wash the paper thoroughly in running water, and dry.

2. Removing Iron Compound Stains.

Stain several small strips of cloth with ordinary ink; bluing (Prussian blue); and with iron rust. A cloth may be stained with iron rust by rubbing the dampened cloth against rusty iron and drying. Try to clean each by soaking in warm water, oxalic acid solution, vinegar, lemon juice, or very dilute HCl solution.

XIV. SUGGESTED PROJECTS

1. Prepare a chart to show how iron compounds illustrate oxidation and reduction. Include appropriate equations.

2. Diagram a layout of a steel plant, including location of stock piles of raw materials; blast furnaces;

Bessemer converters; open-hearth furnaces; coke plant; rolling mills, etc.

3. Working model to illustrate thermite welding.

XV. SUGGESTED TRIPS

1. A trip to a welding plant.
2. A visit to a foundry.
3. An excursion through a steel plant.
4. A field trip to an iron ore mine, coal mine, or limestone quarry.

XVI. SUGGESTED LECTURES IN OUTLINE FORM

I. <u>How Iron Becomes Steel</u>.

- A. The Blast Furnace.
  - 1. Smelting of iron ore.
    - a. Process of reduction.
    - b. Chemical explanation.
  - 2. Materials put into and taken out of the furnace.
  - 3. Parts of a blast furnace.
- B. Acid Bessemer Process.
  - 1. Bessemer converter.
    - a. Parts of the converter.
    - b. What happens in the converter?
    - c. What is taken out?
  - 2. Chief characteristics of the process.

C. Basic Open-Hearth Process.

1. Open-hearth.

a. Parts of the hearth.

b. What happens in the open-hearth?

c. What is the product of the open-hearth?

2. Comparison between open-hearth and bessemer processes.

D. Electric Furnace.

1. Growth of process.

2. Electric arcs.

3. Material removed.

E. Heat Treatment of Steel.

F. Summary of the steel manufacturing processes.

References

Black and Conant, New Practical Chemistry, pp. 493-503.

Dinsmore, Chemistry for Secondary Schools, pp. 441-55.

Dull, Modern Chemistry, pp. 596-604.

Foster, The Romance of Chemistry, Chapter 8.

Holmes, Out of the Test Tube, Chapter 29.

II. Special Steels; Their Manufacture and Uses.

A. Names of alloy steels.

1. Characteristic qualities of each alloy steel.

B. How manufactured.

1. Chief processes.

C. Elements added to steel.

D. Uses made of each alloy steel.

E. The need for special steels.

1. In industry.

2. In the home.

F. Summary of special steels.

References

Black and Conant, _New Practical Chemistry_, p. 503.

Dull, _Modern Chemistry_, pp. 608-11.

Foster, _The Romance of Chemistry_, Chapter 18.

Wilson, _Descriptive Chemistry_, p. 270.

III. _Preparation of Inks and Blueprints_.

A. Inks.

1. How prepared.

2. Chemicals involved.

3. Chemical reaction in the drying of ink.

4. Kinds of ink.

B. Blueprints.

1. Special treated paper.

a. Coated with a reducible ferric salt and potassium ferricyanide.

2. Exposure of treated paper to light.

a. Chemical reaction involved.

3. Formation of Turnbull's blue.

C. Summary of the preparation of inks and blueprints.

References

Black and Conant, New Practical Chemistry, pp. 510-11.

Dinsmore, Chemistry for Secondary Schools, pp. 464-8.

Dull, Modern Chemistry, pp. 615-6.

Foster, The Romance of Chemistry, Chapter 18.

XVII. VISUAL AIDS

1. Slides:[3]

a. Slides for showing the iron ore deposits of the Lake Superior Region.

b. Slides showing the development of the iron and steel industry.

c. Slides showing microphotographs of iron and steel.

2. Films:

a. A film for showing a steel plant in operation.

b. A film for showing the following in action: Blast furnace; Reverberatory furnace; Bessemer converter; open-hearth furnace; and an electric furnace.

3. Charts:

a. Charts showing vertical sections of a blast furnace; reverberatory furnace; Bessemer converter; open-hearth furnace; and an electric furnace.

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[3] No. 3, Teacher Hint, p. 112.

b. Chart showing the input and output of a blast furnace.

c. Chart showing on a map the industrial centers for manufacturing iron and steel.

4. Bulletin Board Material:

a. Pictures showing the developmental stages of smelting iron ore from primitive days to the present.

b. Pictures displaying the multitude of uses we have for iron and steel.

c. Pictures of noted chemists and metallurgists in the field of research.

d. Map exhibiting the chief natural resources of the world.

e. Pictures illustrating and stressing the great need for the conservation of our natural resources.

f. Newspaper and magazine clippings describing recent achievements in the steel industry.

g. Colored pictures exhibiting important processes in the iron and steel industry.

h. Current topics on the developments and manufacturing of steel alloys.

XVIII. SUMMARY OF UNIT

In order to review and make a summary of the unit each pupil, using the suggestions shown in the chart which follows, should prepare to discuss at length the relations, between iron and each of the topics listed.

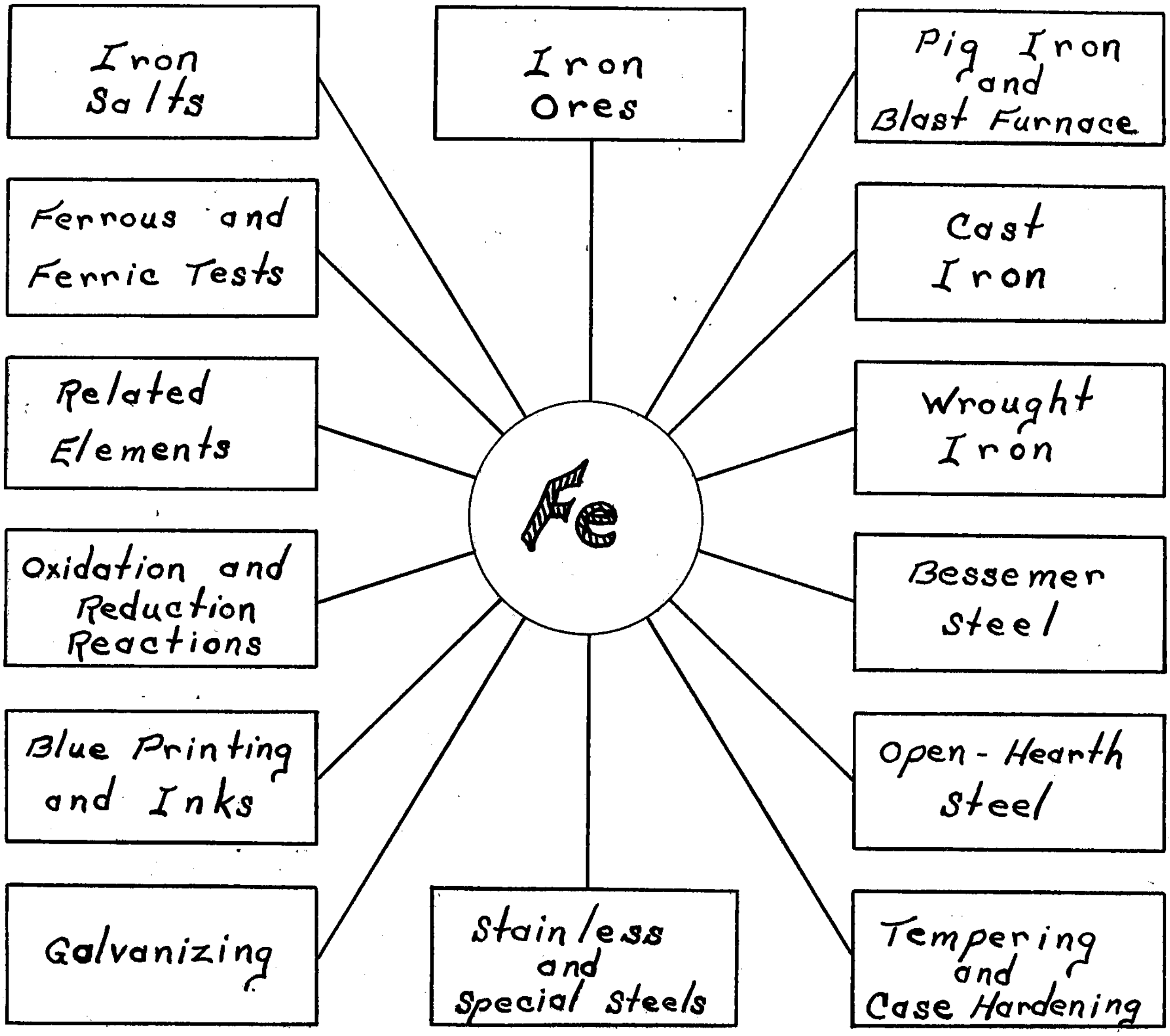

FIGURE 17

CHART FOR SUMMARIZING UNIT ON IRON AND STEEL

Before the final test require each pupil to prepare a well-ordered analytical outline in class on the unit as a whole, and then have the pupils discuss briefly various phases of the unit following the outline.

XIX. FINAL TEST ON UNIT

A. Complete the following statements by filling in the blanks.

1. The most valuable metal in the world is __________.

2. The four most important ores of iron are __________, __________, __________, __________.

3. The ores known as __________ are the chief source of metallic iron.

4. The chemical name of hematite is __________.

5. __________ in the form of coke is used to take the oxygen away from the iron.

6. Extracting the iron from its ore is known as _____.

7. In industry, iron ore is reduced in a __________.

8. Steel is made by the three processes, namely: __________, __________, __________.

9. The element which determines the degree of hardness in steel is __________.

10. The resulting metal formed by the blast furnace is called __________.

11. The materials taken from the iron in the basic open-hearth process of making steel are __________, __________, __________, __________.

12. Steel which contains another metal is called an ________________ steel.

13. Steel which is used to make high-speed lathe tools contains __________ and __________.

14. The furnace used in the acid Bessemer process of making steel is called the ________________.

15. Since steel can be rolled or hammered into thin sheets, it is said to be ________________.

16. Ferrous salts are readily ________________ to ferric salts.

17. The valence of iron in ferric salts is ________.

18. In galvanizing steel, large quantities of ____________ in the molten state are used.

19. Steel is usually pickled in H_2SO_4 preparatory to ________________ the steel.

20. Large quantities of ______________ a mixture of $CaCO_3$ and $MgCO_3$ are used in the open-hearth process of making steel.

21. Nickel and cobalt react in many ways and form salts similar to the element ________________.

22. If ferric chloride is boiled for a time with hydrochloric acid and some fragments of zinc, the proper test will show the presence of the ________________ ion.

23. The brick used in the lining of the Bessemer converter is made of the acidic anhydride ______________.

24. Pure iron has no commercial use. Its most common impurity is ____________.

25. The chemical name of copperas is ____________.

B. <u>Fill in the blanks of the following statements by inserting the correct item chosen from the following list</u>.

annealing	elasticity
hardening	expansion
tempering	specific gravity
case-hardening	ductility
oil-treating	welding
malleability	conduction

26. The quality possessed by steel which enables it to bend and return to its original shape is known as ______.

27. A process of making steel softer by heating and then slowly cooling is called ________________________.

28. The process of joining two pieces of steel by applying extreme heat is known as ________________________.

29. The quality possessed by iron or steel to grow larger when heated is called ________________________.

30. A process of reheating steel to a definite temperature and then suddenly cooling is known as ________.

31. A process of heating steel and then plunging it into an oil bath is called ________________________.

32. The relation by weight existing between a metal and an equal volume of water is known as the ____________ of the metal.

33. The quality possessed by a metal to be drawn out into wire is spoken of as ______________________.

34. A process of heating steel to a high temperature and then suddenly cooling is called __________________.

35. A process of adding carbon to the surface of steel to give the steel a hard surface is known as ________.

C. Underline the term or group of words that makes each statement true.

36. The chemical formula of hematite is (Fe_3O_4; Fe_2O_3; $Fe_2O_3 \cdot 3H_2O$; $FeCO_3$).

37. In the blast furnace the rocky impurities are removed from the iron ore by a substance called (coke; slag; flux; carbon).

38. The process of reduction is the opposite of (neutralization; smelting; forging; oxidation).

39. In the decomposition of ferric oxide into its elements, iron and oxygen, much heat is (absorbed; liberated).

40. The use of large quantities of scrap iron is a distinct advantage of the (Bessemer; crucible; electric; open-hearth) method of making steel.

41. Most of the iron ore used in the blast furnace is the (oxide; sulfide; carbonate; sulfate).

D. Write equations for each of the following reactions.

42. The action of hydrogen on magnetic iron oxide.

__________ + __________ → __________ + __________.

43. The action of sodium hydroxide on ferric chloride.

__________ + __________ → __________ + __________.

44. The chemical reaction of the thermit process.

__________ + __________ → __________ + __________.

45. Complete reduction of iron oxide by coke in the blast furnace.

__________ + __________ ⇄ __________ + __________.

__________ + __________ → __________ + __________.

E. Solve the following problems.

46. How many pounds of ferric oxide will be completely reduced by twenty pounds of carbon considering that carbon monoxide is formed? ans. __________.

47. How many liters of carbon monoxide are required to reduce 320 grams of ferric oxide? ans. __________.

48. An iron ore shows an analysis of 53.47 per cent iron. If the ore is ferric-oxide ore, how many pounds of impurities are present in one ton (2000 pounds) of the ore? ans. __________.

49. What is the valence of iron in $K_3Fe(CN)_6$?

ans. __________.

50. Find the percentage composition of iron in ferric oxide (Fe_2O_3). ans. __________.

XX. KEY FOR FINAL TEST

Count one point for each blank correctly filled and each statement correctly underlined in the first forty-five questions; and five points for each problem solved correctly. The highest possible score is 95.

1. Iron
2. Hematite - Magnetite - Limonite-Siderite
3. Oxides
4. Ferric oxide
5. Carbon
6. Smelting
7. Blast furnace
8. Bessemer - Open-hearth - Electric
9. Carbon
10. Pig iron (Cast iron)
11. Carbon - Silicon - Phosphorus - Manganese
12. Alloy
13. Tungsten - Chromium
14. Converter
15. Malleable
16. Oxidized
17. 3
18. Zinc
19. Galvanizing

20. Dolomite

21. Iron

22. Ferrous (Fe^{++})

23. Silicon dioxide (SiO_2)

24. Carbon

25. Ferrous sulfate

26. Elasticity

27. Annealing

28. Welding

29. Expansion

30. Tempering

31. Oil-treating

32. Specific gravity

33. Ductility

34. Hardness

35. Case-hardening

36. Fe_2O_3

37. Flux

38. Oxidation

39. Absorbed

40. Open-hearth

41. Oxide

42. $Fe_3O_4 + 4H_2 \longrightarrow 3Fe + 4H_2O$

43. $FeCl_3 + 3NaOH \longrightarrow Fe(OH)_3 + 3NaCl$

44. $2Al + Fe_2O_3 \longrightarrow Al_2O_3 + 2Fe\downarrow$

45. $Fe_2O_3 + 3CO \rightleftarrows 2Fe + 3CO_2\uparrow$

$Fe_2O_3 + 3C \longrightarrow 2Fe + 3CO\uparrow$

46. 88.89 lbs. Fe_2O_3

47. 134.4 L. CO

48. 330.6 lbs. impurities

49. 3

50. 70 per cent Fe

CHAPTER VI

SUMMARY AND CONCLUSIONS

In summarizing this study one can say that any plan of instruction which is to continue to have a place in the school life must justify itself by making definite contributions to the aims and objectives which are in line with the purposes of education. The manner by which the Unit Plan of teaching can justify its existence as a progressive practice in the school program can be summed up in the following values which are derived from its use. An efficient and progressive plan provides for individual interests, needs and capacities of pupils; serves as a vital approach to learning and teaching; provides for more pupil participation in a variety of purposeful activities; provides for the integration of related materials from various science fields; enables pupils to have a constant sense of mastery; develops social cooperation and social responsibility; is characteristic of being pupil centered rather than teacher centered; encourages initiative and fosters creative effort; and finally makes chemistry more appealing to the practical minded student.

Bossing[1] has summarized and illustrated in graphic manner the differences between the ideas that lie behind the

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[1] Nelson L. Bossing, Progressive Methods of Teaching in Secondary Schools (New York: Houghton Mifflin Company, 1935), p. 422.

progressive type of procedure and the older traditional method. The generally accepted characteristics of each method are contrasted in separate columns as follows:

Unit Plan Procedure	Formal Recitation Procedure
Pupil	
Natural interests	Artificial interests
Natural activities	Unmotivated tasks
Critical attitude	Passive attitude
Social conduct	Non-social conduct
Effort	Strain
Thinking	Memorizing
Expressing thoughts	Reciting information
Independence	Dependence
Self-control	Imposed control
Cognizance of values	Ignorance of values
Teacher	
Creating natural environment	Making artificial setting
Utilizing pupil activities	Imposing teacher purposes
Guiding natural activities	Dictating artificial tasks
Student with pupils	Teacher all wisdom
Interest primarily in pupils	Interest in subject matter
Attention on desirable ends	Attention on subject matter

The Educative Process

Taking into account present needs	Consideration of possible future needs
Natural student environment	Formalized schoolroom environment
Real life experiences	Artificial exposures
Reference books	Textbooks
Subject matter as means	Subject matter as end
Including concomitant learning	Emphasizing primary learning
Discussion	Recitation
Unification of effort	Division of effort

In conclusion, one can say that the Unit Plan of instruction makes a fairly good approach in helping the school illustrate the democratic way of life, for under this procedure the classroom would better be thought of as a conference room where the pupils come together willingly to discuss problems, and to do research on interesting problems. The classroom becomes a laboratory in which constructive creative work is accomplished. This is a vast improvement over the system that asks the pupil merely to recite memorized facts to the teacher.

Thus, if a chemistry instructor anticipates even a fair measure of success in the use of this plan, he must possess not only a wealth of subject matter in his own and related fields of knowledge, but at the same time he must have a comprehensive, clear and pragmatic philosophy of education and life.

ANNOTATED

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