CHEMISTRY
A Modern Course

SMOOT • PRICE • BARRETT

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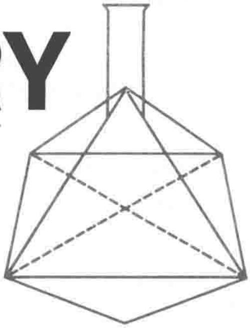

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A Merrill Science Text

Chemistry: A Modern Course
Chemistry: A Modern Course—Teacher's Annotated Edition and Solutions Manual
Chemistry: A Modern Course Spirit Duplicating Test Booklet

Laboratory Chemistry
Laboratory Chemistry Teacher's Annotated Edition

Graphic Chemistry Chart
Solving Problems in Chemistry

Cover photo

One of the most urgent problems for the modern chemist is the wise use of our water resources. Chemists are concerned with detergents, foam control, wetting agents, dispersing agents, emulsifying agents, and de-emulsifying agents.

Photo courtesy of Wyandotte Chemicals Corporation.

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PREFACE

The new 1971 edition of CHEMISTRY: A MODERN COURSE offers you a program which is vital and basic. The concepts of chemistry are discussed in sufficient detail to both satisfy and challenge today's high school chemistry student.

Throughout this text, the student is encouraged to think independently. Questions are frequently presented which require original reasoning. The student may be able to check his conclusion by performing a simple experiment or by turning to further reading. A minimum of emphasis has been placed on the memorization of facts. Whenever possible, principles have been illustrated by references to evidence obtained through experiment. Examples have been selected that are closely related to the average student's past experience, following that most basic learning principle of proceeding from the known to the unknown. The approach of the text recognizes that a certain amount of repetition is helpful to the learning process. Principles of structure, matter-energy relationships, the mole concept, thermodynamics, and chemical equilibrium appear several times in the text in varying degrees of emphasis. A sense of confidence is thus established as the student recognizes familiar concepts presented in greater depth.

The initial chapters present some descriptive chemistry as well as the "mechanics" of chemistry. This approach facilitates the early introduction of laboratory work. Several chapters are devoted to the structure of matter and the periodicity of the elements. The principles developed in these chapters provide the vehicle for the remainder of the text. The mole concept is introduced early in the book so that students may carry out meaningful quantitative laboratory work during the first few weeks of the course.

The text then deals with the behavior of matter in terms of acidity, oxidation-reduction, and electric potential. It concludes with descriptive material in nuclear, organic, colloid, coordinate, and analytic chemistry. Each of these sections leads naturally into the next, and yet can be set off as a pedagogically useful division.

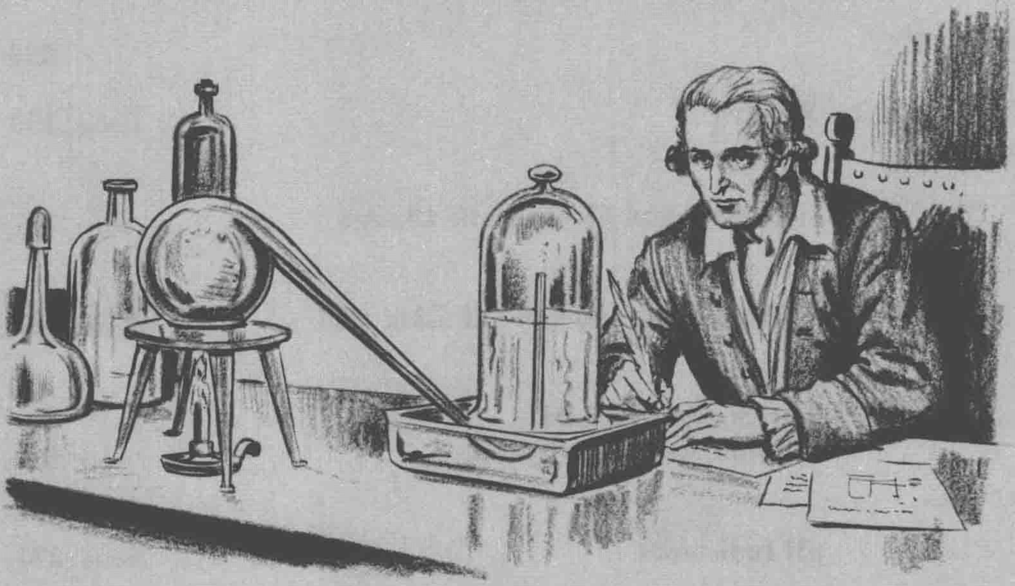
In many instances, problems follow immediately after the section pertaining to their solution. A comprehensive list of problems of a cumulative nature appears at the end of each chapter. These include numerical problems, as well as questions intended to test the student's understanding. Another feature is a series of problems entitled "One More Step," which may be used to lead the student into projects, papers, talks, or collections which can benefit the entire class. The new Suggested Readings section offers the student an opportunity to extend his learning and to pursue topics of particular interest to him. An extensive summary has been placed at the end of each chapter. A system of margin notes appears throughout the text to highlight salient points and to assist the student in organizing his study and review.

The tabular material and the appendices includes supplementary data. This enables the teacher to compose his own problems without resorting to the preparation of extra tables for the students.

Separating the chapters are brief biographies of men of science who contributed discoveries upon which the principles in the succeeding chapters are based. These biographies are also intended to show the student that scientists are active socially and sometimes politically in their communities. Such a historical perspective gives the student an appreciation of the great developments in chemistry and endows him with some sense of responsibility for future progress.

Throughout, this text reflects the consensus of recent recommendations made by committees studying the chemistry curriculum. In harmony with the best current thinking of scientists and educators, it takes into account a realistic appraisal of the capability and maturity of the typical student.

The authors wish to express their sincere thanks to the many chemistry students, teachers, and science educators who have made suggestions for changes as a result of their use of CHEMISTRY: A MODERN COURSE.



Antoine Laurent Lavoisier
(1743-1794)

Often referred to as the father of modern chemistry, Lavoisier was certainly one of the outstanding scientists of the eighteenth century. He was the first to grasp the true explanation of combustion, overthrowing the phlogistic doctrine that had handicapped the development of chemistry for more than a century.

Lavoisier contended that fire was the result of rapid union of the burned material with oxygen. Nothing, however, he maintained, was lost through this action. His theory directly opposed the phlogistic notion that combustible bodies lost something when burned.

Founded on Lavoisier's oxygen theory, a new system of nomenclature was evolved; one which held that oxygen was an essential constituent of all acids. His theories were the basis for great advances in chemistry.

As a young man of many interests, he studied astronomy, botany, and mathematics, as well as chemistry at the Collège Mazarin near his Paris home. Of key significance in his later life was his study of law and his admission to the bar. This led to an interest in French politics, whereupon he obtained a position as tax collector at the age of 26. While in government work he helped develop the metric system to secure uniformity of weights and measures throughout France.

His governmental interests, however, eventually proved his undoing. As one of 28 French tax collectors Lavoisier was branded a traitor by revolutionists in 1794 and guillotined at the age of 51. Ironically, Lavoisier was one of the few liberals in his position and had striven for many years to alleviate the hardships of the peasants.

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EXPERIMENTATION AND CHEMISTRY 1

One of the most significant scientific achievements of this century was the first landing of man on the moon. Men have always been interested in the moon; for thousands of years men feared and worshipped it. When a few men became scientifically interested in the moon research was limited because only a distant visual observation was possible. With successful manned moon landings, samples of the moon rock were brought back to earth. In order to make the study of lunar materials more comprehensive, samples of moon rock were studied by chemists, physicists, geologists, and biologists around the world. In a relatively short time all types of measurements that men had made on comparable earth materials were made on the lunar samples. By studying the samples scientists have determined such things as composition, approximate age, and possible origin of the moon.

Not until scientists could actually work with materials from the moon could so much be learned about it, but more exploration, through the use of science and technology, is needed to completely answer the questions about the moon.

Curious and interested men have experimented with rockets for centuries. The first rockets used black powder (gunpowder) for fuel. The rockets and black powder were unique because no outside oxygen was needed for the combustion which supplied the thrust. But scientists felt they could increase thrust, so they began experimenting to improve fuels.

Chemists in the laboratory created and tested new compounds on a small scale. Chemical engineers developed efficient means of producing the fuels on a large scale. Rocket engineers designed complex pumping systems, ignition systems, and control mechanisms for the rocket fuels. All of these scientists communicated their discoveries easily by using the symbolic language of chemistry. They were able to understand each other because all used similar scientific procedures.

SCIENTIFIC PROCEDURES

Some scientific procedures: observation inference hypothesis experimentation

In real life, as in mystery tales, criminals are often apprehended because they show certain recognizable patterns of behavior. The police observe the method of operation in a crime, draw inferences as to the possible culprits, predict where the next similar crime may occur, and often apprehend the criminals quickly. This method is known as "scientific crime detection." It is probably called this because, in investigations of unanswered questions, scientists usually follow similar procedures which have been found to be helpful. Among these procedures are the activities of *observation, inference, hypothesis*, and *experimentation*. Many other activities can be involved but these are the most common.

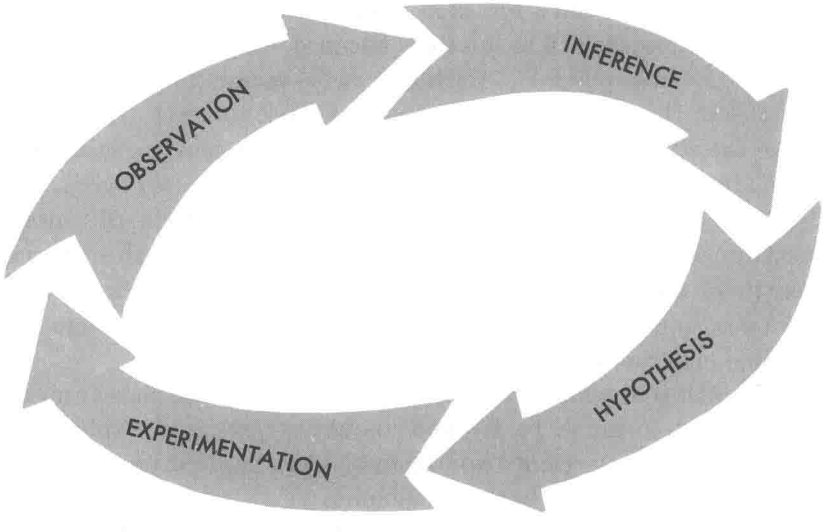

FIGURE 1-1. The scientific procedures, observation, inference, hypothesis, and experimentation can be used in most problem solving situations.

Let us examine a typical sequence of these procedures. Remember, each one may play a key role in the solution of a problem being investigated.

1:1 Observation

Often before a problem is investigated, the first step toward its solution has already occurred; it has been noticed or *observed.* If someone had not observed a phenomenon he found interesting or that he could not explain, a question would not have been asked.

To observe means to take notice.

Observations can be made with any of the five primary senses Therefore, the observer can see, hear, smell, taste, or feel something which arouses his curiosity. (In reality, we have more than five senses—for example, our senses of temperature and balance—but the five senses mentioned here are our most usual means of observing the environment.) Frequently, an observer uses some instrument—for example, a microscope or telescope—to supplement his sight. He may use an amplifier or stethoscope to supplement his hearing. There are also instruments to supplement the senses of smell, taste, and touch.

Observations are made by our senses.

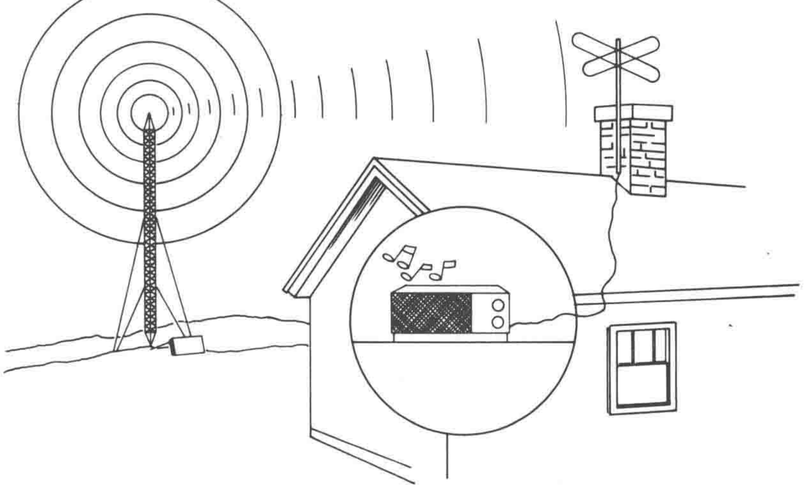

FIGURE 1-2. A radio receiver detects, transforms, and amplifies radio waves.

Many events cannot be detected by our senses. Instruments have been devised which not only detect these events, but transform them in a manner that enables us to observe the event. A familiar example is the radio. We are unable to detect radio waves in the air, but a radio receiver does. It detects the radio waves which cause it to produce sound waves that we can easily detect or hear.

Instruments can convert events from one form to another.

1:2 Inference

Knowledge and experience aid reasoning.

The things that we observe are facts. With the proper knowledge and experience, we are able to relate certain observed facts to similar events within our experience, and assume that a particular event has taken place. For instance, upon hearing a radio produce intelligible sounds, we may logically suppose that a broadcasting station is producing radio waves which are carrying those sounds. This supposition is called an *inference*. The process of inferring is "reasoning through" the observed facts. It is another one of the scientific procedures. The example of the relationship between a radio and a broadcasting station is a very simple one. Most inferences require more complex reasoning.

To infer means to reason from observed facts.

As an example of the process of scientific reasoning, take an event which occurred a long time ago. Early in the seventeenth century a young Dane named Steno was studying medicine in Italy. Steno made a hobby of collecting minerals. If he were alive today we would probably call him a "rock hound." Some of the minerals Steno collected were crystals; that is to say, they were naturally occurring minerals or substances with their surfaces bounded at least in part by plane faces. Crystals have always fascinated people because they are often objects of great beauty, and Steno was particularly impressed by their regularity of form. It occurred to him that it might be interesting to measure the angles between the faces on some of the crystals. To do this he made a simple device known as a "goniometer," shown in Figure 1-3. The results were startling to Steno. He observed that in nearly all of his crystals of the mineral we now call "fluorite," there were one or more pairs of faces which intersected at an angle of 90°. On many of the crystals there were other pairs of faces which intersected at 109.5°. Steno was led by this striking uniformity in

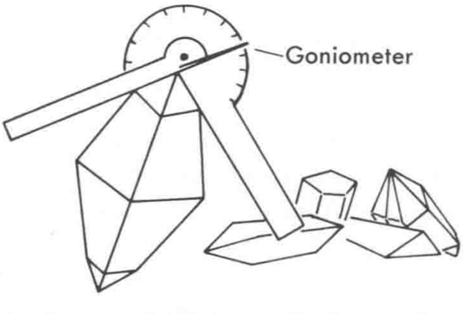

FIGURE 1-3. Crystals of the same substance have similar angles between corresponding crystal faces.

nature to collect and measure a great many crystals from many different localities. When his results were tabulated, he observed that for fluorite the interfacial angles fell naturally into groups with angles of 90° and 109.5°. Furthermore, while other angles also occurred, values differing only slightly from the dominant ones were not found. In other words, he did *not* find angles of 89° or 107°. If a pair of faces were found with an angle which looked like 90°, it was always 90°.

1:3 Scientific Laws

It is a natural tendency for people to generalize upon their experience, and scientists have a particular need to do this. They are always looking for uniformity in nature, and if they do not find it, the result is likely to be pain and frustration. In Steno's case, however, the uniformity was there and he did find it. Measurements of interfacial angles on crystals of a great many different substances from a great many different localities were made, and when the results were tabulated, Steno felt justified in making a broad generalization now known as the law of the constancy of interfacial angles: *the angles between corresponding faces of crystals of the same substance are constant.* Note the importance of the word "corresponding." A particular pair of faces may or may not occur on two different crystals of a given substance, but if it does occur, the angle will be the same on both crystals.

A scientific law is a generalization.

Let us ask ourselves what a scientific law is and what it is not. In the first place, it is always a generalization. It is based on the assumption that if a great many observations and measurements have been in agreement, new observations and measurements under the same set of conditions will also be in agreement. In the second place, a law does not compel the conformity of nature. It merely gives a clear statement of the uniformity which already exists or appears to exist. It has always been the great purpose of science to discover these uniformities. It is the unattained, and perhaps unattainable, goal to make all natural phenomena predictable. But whenever we predict the behavior of nature from a law we are always making the unstated assumption that if the law has held good in the past it will continue to do so in the future, and will apply to new situations so long as the basic conditions are kept constant.

A law describes a condition of uniformity.

1:4 Hypothesis

The natural impulse upon learning something new is for us to ask "why" and "how." Probably in scientists this tendency is developed to a higher degree than in other people. It is very likely that after he had discovered the law of the constancy of interfacial angles, Steno asked himself the question, "Why should this remarkable uniformity exist?" Unfortunately we do not have any record of whether he asked the question or whether he was able to come up with an answer. However, other people asked the question and quite a few of them came to similar conclusions. Very simply, the solution suggested was this: "Crystals must possess a structure too small to be visible to the eye or to any available form of microscope. If you take rectangular bricks and lay them up in a regular fashion you get a rectangular wall. Crystals must be built of small particles invisible to the eye or to the microscope, and all crystals of a given substance must have their particles arranged in the same regular way which produces the constant angles between the faces." A statement of this kind is called a hypothesis. Note that it does not state an observable fact; rather it is a tentative *explanation* of the observed facts. Hypotheses may take different forms. For example, an investigator may predict that a change in the conditions existing when he made his observation will produce a new set of facts that will enable him to answer the original question. On the other hand, he may predict that the fact which he has observed is related to other known facts in a particular manner. He may also infer the cause of the occurrence he has observed.

A hypothesis is a tentative explanation.

1:5 Experiments and Theories

The explanation must remain tentative unless one can think of an experiment whose outcome is predicted by the hypothesis. Then if the experiment is carried out and produces the predicted result, the hypothesis will be confirmed. A hypothesis which has been confirmed by repeated experiments is called a *theory*. Usually a considerable number of experiments and a consensus among a large number of scientists are necessary before a particular hypothesis can be regarded as having been promoted to the rank of a theory. Note that a theory and a hypothesis are the same *kind* of thing. They are both explanations for the observed results of experiments, but a hypothesis is advanced tentatively and lacks experimental verification. In the normal course of events some scientists will think of an experiment, the results of which ought to be predictable from the hypothesis. If the experiment is performed and the results turn out to be what was predicted from the hypothesis, this is regarded as confirmation. If other and different experiments are devised whose results are also predicted, then the hypothesis is