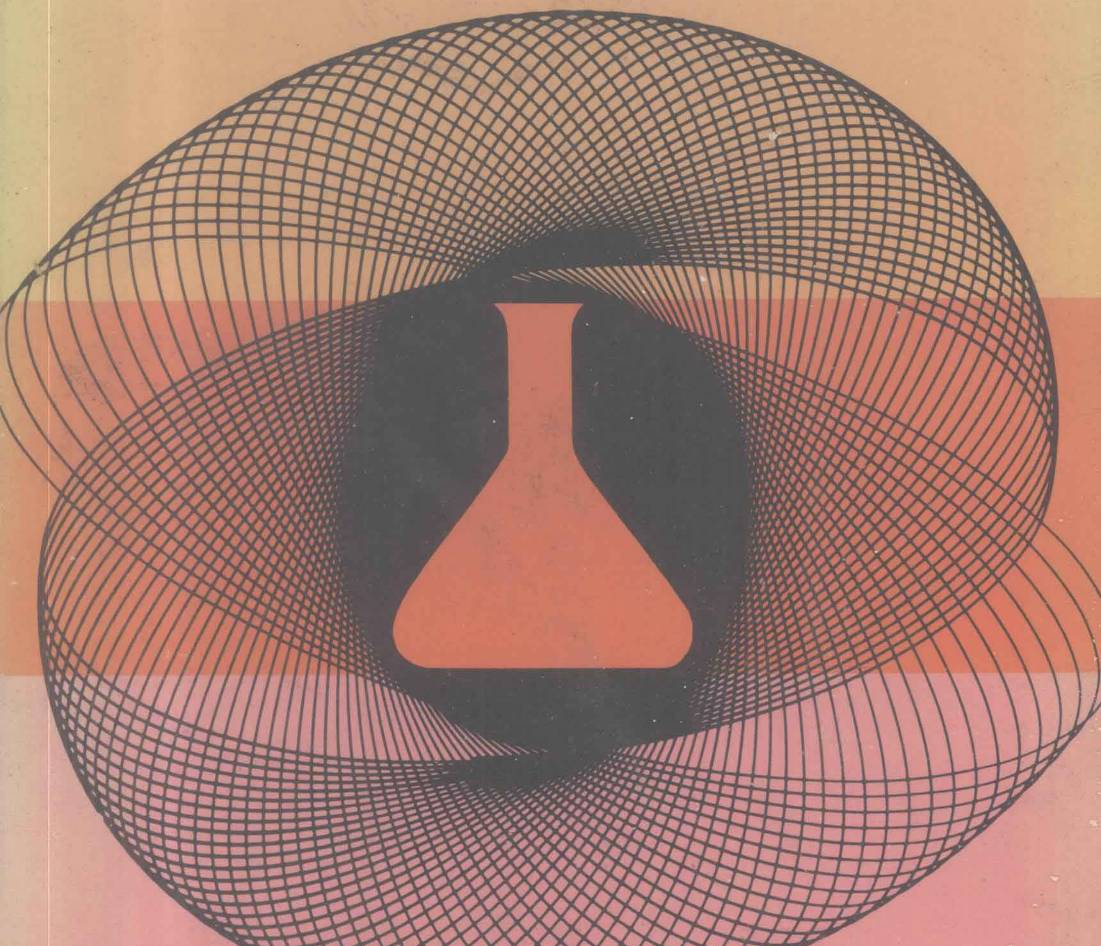
Floyd J. Quick

INTRODUCTORY COLLEGE CHEMISTRY



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Introductory College Chemistry

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Preface

This book has been written because the author believes there is a definite need for a college text that is not too heavy on theory but strong on the practical aspects of chemistry. The subject matter is presented in a manner calculated to stimulate the student's interest and apprise him of the importance and influence of chemistry in modern life. The text has been written especially for an introductory course in chemistry for students not majoring in science. Special effort has been made to use language as simple and popular as is consistent with scientific writing and yet prepare the way for the presentation of each successive topic. The material embodies the results of many years of experience in teaching college chemistry.

The scope of the text is quite broad and the content is sufficiently quantitative for a two-semester course. Much time has been devoted to the discussion of the principles of general inorganic chemistry. Several chapters lie in the field of elementary physical chemistry. For example, oxidation–reduction, chemical equilibria, pH, and ionic equilibria are treated quite extensively for a course of this type. The inclusion of a portion of organic chemistry material is considered to be a necessary segment of the text. The mere reproduction of imposing structural formulas is definitely not education. An attempt to overcome this difficulty is made by presenting a few theories of organic chemistry and by reducing long chemical reactions to a minimum.

Many topics have been purposely omitted. Naturally, such topics as entropy, chromatography, and stereoisomerism are not considered a necessary part of the training of the particular audience for which the course is designed.

A set of exercises will be found at the end of each chapter, which may either be used as a basis for an oral review of the content in each chapter or assigned for homework. Much effort has been expended by including exercises of the intrusive quality which have a tendency to throw light on obscure facets and thus emphasize comprehension rather than memory. These exercises contain a wide variety of mathematical problems, the answers to which appear in Appendix XII. It is believed that one's ability to solve a problem is a valuable aid in understanding the chemistry underlying the principle involved.

The text is illustrated with a number of excellent photographs, selected with great care for their teaching value. Because diagrams, wisely used, are also an invaluable aid in the learning process, many appear throughout the text.

Special thanks are due to Dr. Dale Burtner of Fresno State College who has given generously of his time in reading the manuscript and has offered many constructive suggestions. I wish to express deep appreciation to my wife who typed the manuscript and whose artistic skill proved helpful in preparing the drawings.

Fresno, California FLOYD J. QUICK

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Chapter 1 Introduction

History of Chemistry

The artisan of 5000 B.C. could reduce copper from its *ores*, and use it to make objects that have come down to us intact. Prehistoric man used such metals as gold, mercury, tin, lead, copper, iron, and silver. Even though there is no written record of this period, we have a concept of the methods and the materials that were used, by studying and analyzing the weapons, implements, and utensils that have been dug up from ancient civilizations. As early as **3000 B.C.** man had discovered the method of making *alloys* by melting certain metals together. He made *bronze* from *copper* and *tin* and other *alloys* from *silver* and *gold*.

The Greek philosophers were the great thinkers of early times and they had many ideas regarding the nature of matter and the method of making things. There were two schools of thought relative to the composition of matter. Some of them thought that matter was composed of great numbers of tiny, indivisible bodies called "**atoms**." Those who believed this theory considered matter to be **discontinuous**. Democritus (460–362 B.C.) was a proponent of this theory. Another group believed that matter was **continuous**, that there were no ultimate particles of any substance to which one could ascribe certain definite *properties*. They thought that if a sample of gold, for example, were divided, then each piece could be divided again and again indefinitely. Thus, no matter how tiny the resulting particles were, they still could be further divided. **Aristotle** (384–322 B.C.) held to this belief that matter was **continuous**. He also believed that many questions in the realm of science could be answered by subjecting them to deductive reasoning. However, in his writing he incorporated many wrong conclusions which persisted for centuries even after the results by experimentation proved them to be wrong.

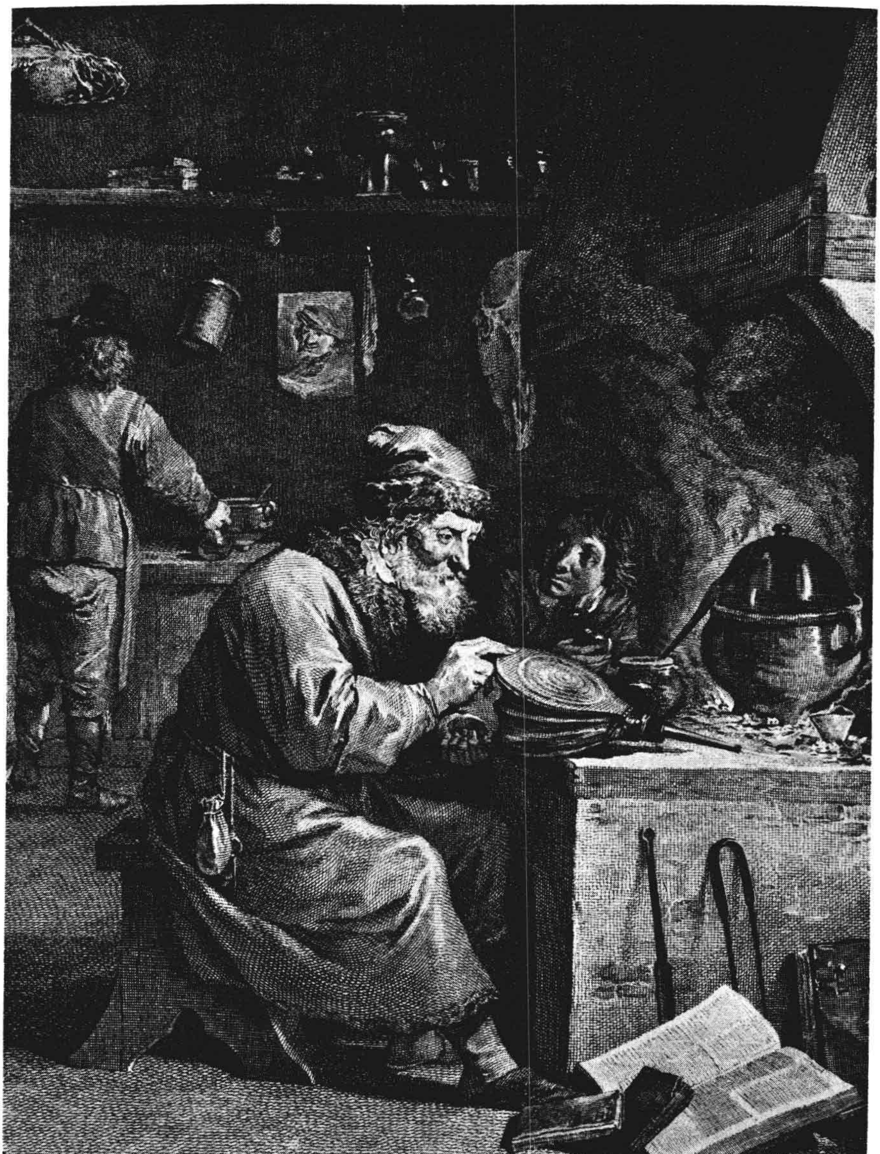


Figure 1–1. A typical alchemist of the seventeenth century. (*Courtesy of Fisher Scientific Company.*)

The **alchemist** during the *Middle Ages* did some experimenting, but a great deal of his time was spent in trying to convert the base metals, such as copper and mercury, into **gold**. Naturally all efforts failed, so some of the alchemists began directing their efforts toward a more worthwhile goal, namely, the application of chemistry to medicines. *Paracelsus* (1493–1541), a Swiss medical practitioner, was the illustrious scholar of this era. He persuaded many alchemists to devote their time and skill to the making of drugs and medicines, for he believed the real objective of alchemy should be the curing of diseases. With this objective in mind, **iatrochemistry**, or **medical chemistry**, was born. Paracelsus had the idea that the human body was composed of certain chemical substances, such as mercury, sulfur, and carbon, and when a person was well, the various substances were in the body in the proper portions; but when he was ill, there was an imbalance of the body substances. In this case it was necessary to supply the deficiencies. The ideas of Paracelsus and his colleagues possessed some germs of truth and there was some logic in their methods in the light of present day chemistry and medicine.

Meanwhile some of the great alchemists of that period began changing their ideas and moving further forward. Roger Bacon (1214–1294) was one who emphasized strongly that there was no other way of having competent *scientific knowledge* other than by *experimentation*.

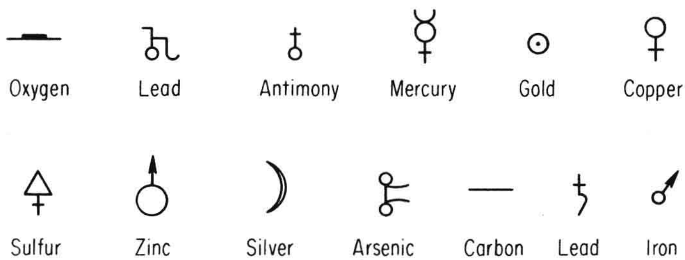


Figure 1–2. Some alchemical symbols.

Early in the eighteenth century, a new and challenging problem arose. What happens when a substance burns? In an effort to explain the process of burning, the *phlogiston theory* was proposed. A theory in which it was assumed that all combustible matter contained some mysterious etherlike substance called *phlogiston*. The process of burning was believed to cause the escape of phlogiston from the combustible material. A residue, called the *calyx* or ash, was left in some cases, and it was discovered that it weighed more than the original. This was true when metals were heated. The phenomenon was hard to account for, but the theory considered phlogiston to have a negative weight. Thus when some substances burned in air and the calyx gained in weight, it was due to a loss of negative phlogiston. They considered substances like **carbon** as being nearly pure *phlogiston*, since there was no ash left after the burning. This false theory ruled the minds of the chemical world for 75 years, but experimentation showed that it could not be true. It was **Lavoisier** who demonstrated the *true nature of combustion*. He had made many experiments on the subject

Figure 1–3. Antoine Laurent Lavoisier (1743–1794), France. He established the true nature of combustion, introduced system into the naming and grouping of chemical substances. Was unjustly accused of political crimes and guillotined during the French revolution. (*Courtesy of Fisher Scientific Company.*)

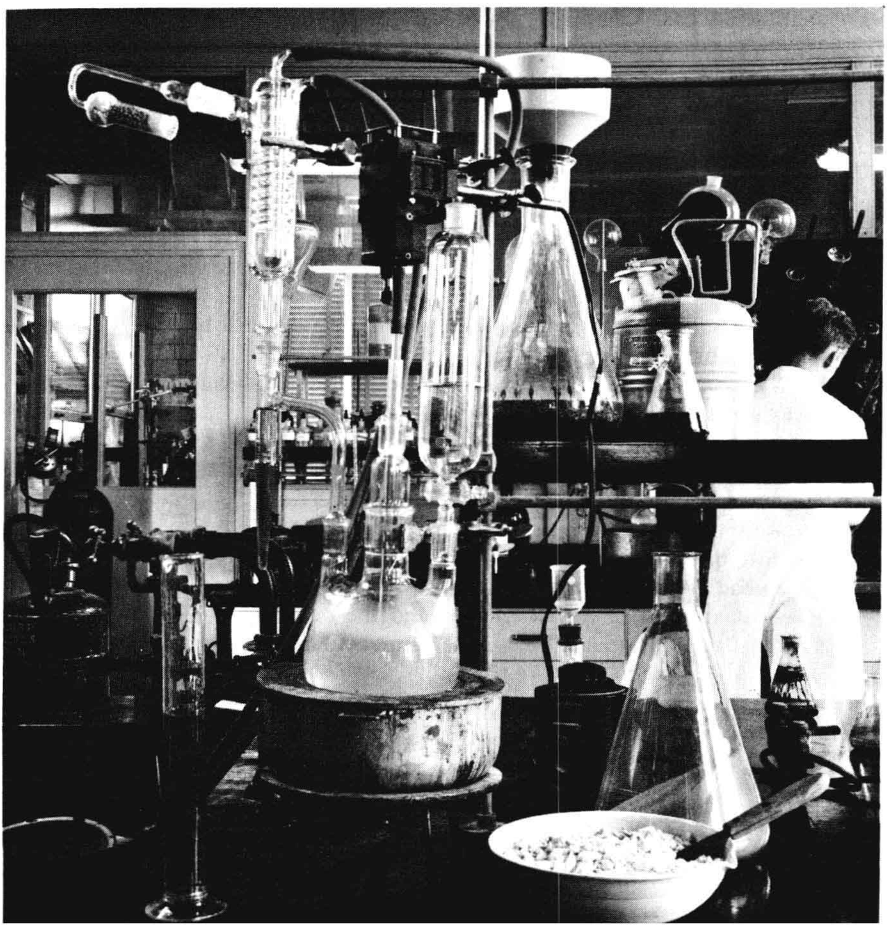
and with the discovery of *oxygen* by **Priestley**, he quickly proved that combustion was a chemical reaction between oxygen and the combustible material. With this discovery the phlogiston theory was overthrown.

It is somewhat indefinite as to when the modern age of chemistry began, but we can state conservatively that practically all the chemistry we know at the present time has been developed during the past 175 years.

Nature of Chemistry

Chemistry is the science of the *structure of matter*, the composition of substances, and their reactions. Two great divisions of the sciences are the **natural** and **physical** sciences. Some of the natural sciences are chemistry, physics, astronomy, and the biological sciences, while the physical sciences, for example, are chemistry, physics, geology, astronomy, and meteorology. *Chemistry* is intimately related to the other *sciences*, and in fact, underlies most of them. It is for this reason that chemistry is included in such training

Figure 1–4. A modern research laboratory in the field of organic chemistry. (*Courtesy of The Upjohn Company. Photograph by Ezra Stollen.*)



objectives as premedical, predentistry, prelaw, preforestry, nursing, agriculture, biology, and others.

The **scope of chemistry** is so broad that its influence affects every part of our everyday life. Clothing, food, gasoline, building materials, fertilizers, and, in fact, all articles of commerce have been synthesized, improved, or influenced in some way by the principles and applications of chemistry.

Chapter Summary of New Terms and Concepts

Alloy. A mixture of two or more metals. This mixture is also called a solution.

Alchemist. The medieval practitioner of alchemy, a science and speculative philosophy aiming to achieve the transmutation of base metals into gold, the discovery of a universal "elixir," etc.

Iatrochemistry. Application of chemistry to medicine.

Phlogiston theory. Combustible material was believed to contain phlogiston that actually caused the substance to burn.

True nature of burning. The chemical combination of elements in combustible material with oxygen.

Physical sciences. Chemistry, physics, geology, astronomy and meteorology.

Natural sciences. Chemistry, physics, astronomy, and biological sciences.

Exercises

1. Seven metals and two nonmetals were known to prehistoric man or to the ancients. Can you name all nine of these elements?
2. What is your understanding of the term *alloy*? Name several combinations of elements that are used in making present day alloys.
3. What reasons can you give that one might have the idea today that there are several kinds of gold?
4. What explanation can you give for the fact that objects made of gold and silver have a longer life than those made of iron?
5. How is bronze made today?
6. What contributions were made to chemistry by the alchemist? List a few reasons for the alchemist thriving so well in his day.
7. Who were the iatrochemists? What contribution did they make to science?
8. Discuss briefly the phlogiston theory. What was the reason for stating that phlogiston had negative weight?
9. Distinguish between the continuous and the discontinuous nature of matter. According to our belief today, what is the nature and composition of matter?

Chapter 2

Fundamental Principles

Chemistry is the study of matter and the composition of substances, particularly as related to structure, analysis, synthesis, and utility. It is also concerned with the *properties* and *classification* of **substances**. Various changes in the composition of matter and the accompanying energy changes are of importance. Since the properties of substances are important in our study, let us begin by considering briefly the topic of physical properties.

Physical Properties

These are the characteristic and unique *qualities* that a particular substance possesses. As an illustration, you are familiar with sulfur and some of its **properties**. You know it is a solid, yellow in color, and insoluble in water. It has other physical properties with which you are not so familiar: its low melting point, its solubility in certain solvents, (such as carbon disulfide), and its crystalline structures. These are a few of the specific properties that could be used to *identify* this substance from any other species of matter. Such characteristics and qualities are referred to as the **physical properties** of a substance. An abridged list of the physical properties commonly used for identifying substances appears in Table 2–1.

It is not always necessary to observe or determine all of these **properties** in order to *identify a substance*; frequently three or four would suffice.

TABLE 2-1 Some Common Physical Properties

Odor	Specific gravity	Crystallinity
Color	Melting point	Solubility
Taste	Freezing point	Hardness
Luster	Boiling point	Malleability
Density	Conductivity	Ductility

If a *solid* is to be identified, such properties as color, density, solubility, melting point, and its crystal structure would be observed; while, in the case of *liquids*, the density, freezing point, and boiling point would be determined.

Substances

We have been discussing the **physical properties** of substances, but before proceeding farther, let us discuss the term "substance" for a moment. In the first place, **substance** is defined as a particular kind of *matter*. It is the material of which an object is composed. All samples and specimens of a certain substance have the same properties under the same conditions—referring, of course, to the same environmental factors as pressure and temperature. Let us assume that we collected a dozen different samples of pure silver nitrate. Each sample would have exactly the *same properties*; that is, each would have the same color, and if solubility and melting-point tests were made, each sample would have the same solubility and the same melting point. Thus the conclusion would be that the **properties** of a pure *substance* are *invariable*.

All substances may be grouped into two classes: **elements** and **compounds**.

Chemical Elements

An **element** is a substance which cannot be further decomposed by ordinary chemical means. It is a chemical unit, and its smallest division is the **atom**. You are familiar with many such substances in your everyday life, such as silver, tin, zinc, mercury, aluminum, oxygen, hydrogen, etc. One hundred and three different elements are known at the present time. These elemental substances combine to form several hundred thousand compound substances that we have now, and many new ones are being made each year. As stated, these elements cannot be decomposed by ordinary chemical means, they cannot be resolved into *simpler substances*, neither can they be produced by combination of other substances. Some of them are *radioactive* and thus decompose naturally, such as uranium, radium, and francium. Some elements have also been converted into other elements by bombarding them with fast-moving particles from *radio-elements*. As for example, nitrogen has been converted into oxygen by bombarding nitrogen with high-speed particles from radium. However, for all ordinary purposes, the elements may be considered to be the simple substances that make up all matter regardless of how complex the substance may be.

The **elements** are conveniently divided into two subgroups, the **metals** and the **nonmetals**. Again returning to your familiarity with common substances, you are more or less familiar with such metals as lead, tin, aluminum, gold, zinc, copper, iron, and nickel. There is a less number of nonmetals, but a few of them are common, such as carbon, sulfur, phosphorus, and of course, all gases are *nonmetals*. For example, oxygen, nitrogen, hydrogen, helium, and neon are familiar gases. In regard to specific properties of these two subgroups, all metals possess a *metallic luster*, while the nonmetals do not. The latter cannot be characterized by a common appearance, but we must state that they do not have metallic properties. The transition from metals to nonmetals is marked by elements with intermediate properties—that is, having **physical properties** of *metals* and **chemical properties** of *nonmetals*. Elements that have *intermediate properties* are antimony, silicon, arsenic, germanium, boron, tellurium, and polonium.

ABUNDANCE OF THE ELEMENTS. Eight of the elements account for approximately 99 per cent of the solid portion of the earth, while ten elements make up about 99.3 per cent. Ten of the *most abundant elements* are listed in Table 2–2.

TABLE 2-2 Weight Percentages of Common Elements in the Earth's Crust, the Hydrosphere, and the Atmosphere

ELEMENT	PER CENT	ELEMENT	PER CENT
Oxygen	49.52	Sodium	2.64
Silicon	25.75	Potassium	2.40
Aluminum	7.51	Magnesium	1.94
Iron	4.70	Hydrogen	0.88
Calcium	3.39	Titanium	0.58

Spot Test 1

- Try to explain the necessity of changing the definition of "element" since the discovery of radioactivity.
- How would you classify ice—as an elementary substance or a compound?