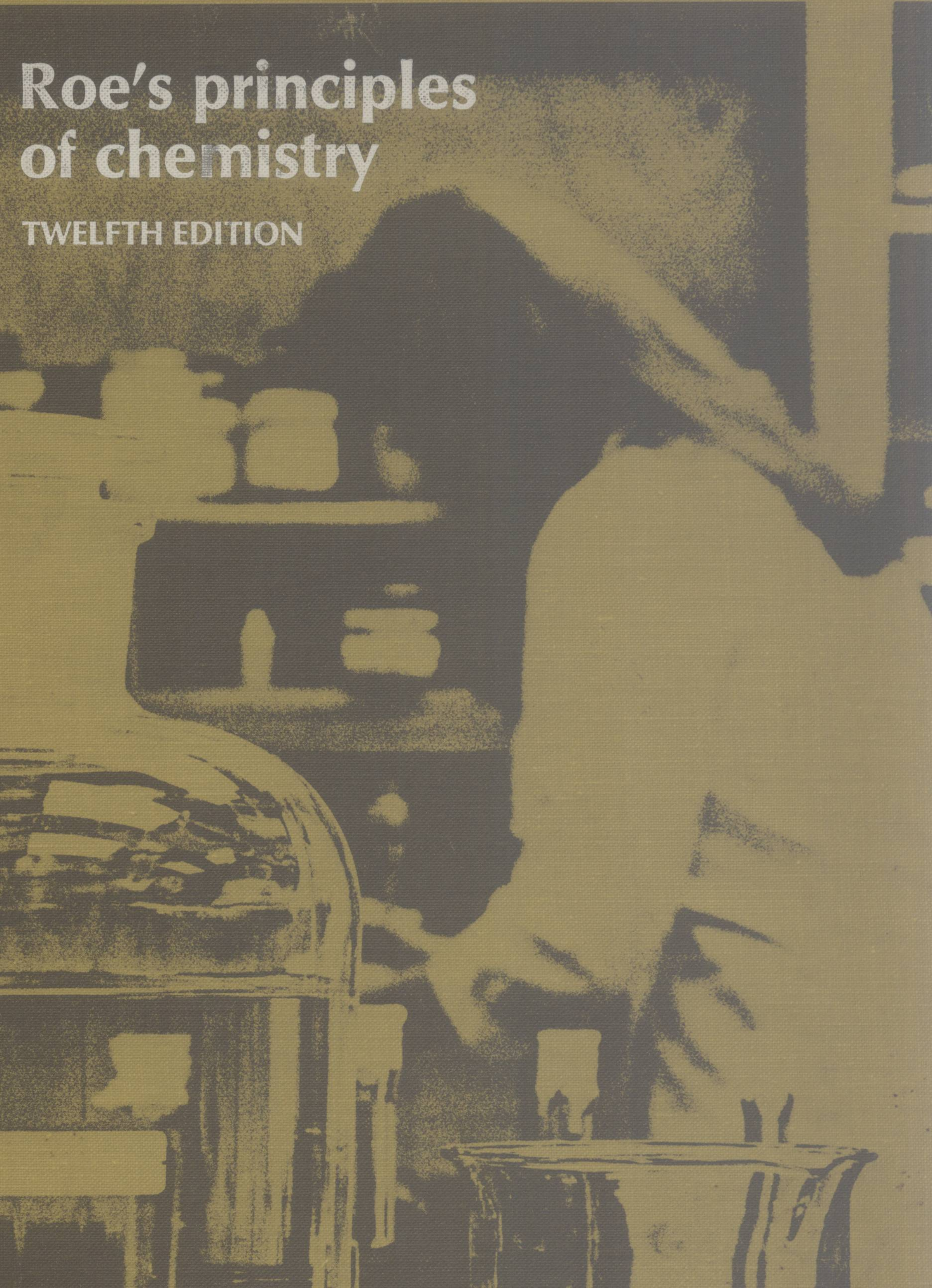
Alice Laughlin

Roe's principles of chemistry

TWELFTH EDITION



Roe's principles of chemistry

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Roe's principles of chemistry

An introductory textbook of inorganic, organic, and physiological chemistry for students in the allied health fields

Preface

For almost two generations, instructors and students of nursing, medical technology, and other allied health fields have found *Roe's Principles of Chemistry* to be a highly teachable and readable book. Its strengths have been its simple explanations, its ability to relate principles to practice, and its brief, but thorough, coverage of the essential areas of inorganic and organic chemistry and biochemistry.

In this new revision, although the basic forms and emphasis remain the same, new developments and new points of view have prompted many changes. Greater emphasis has been placed on the metric system, molecular and atomic structure, and recent discoveries in biochemistry.

Important additions are five new tables and 35 new illustrations by Robert Wiethop; a new appendix, containing a discussion of logarithms and a table of four-place logarithms; and a new chapter, "The Physical States of Matter." In all areas the material has been presented in as simple and uncomplicated manner as possible without distorting the true picture revealed through scientific investigation.

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Introduction Chemistry as a science

SCIENCE

For thousands of years man has made observations of the things about him and passed on to succeeding generations his thoughts regarding them. Man's early ideas concerning the universe and the substances of which it is composed were naturally very simple. These ideas appeared first as myths, which were often interwoven with religion, and later as theories proposed by the philosophers—all of which were imaginative and have literary charm to the present-day reader but were lacking in exactness because they were not based on man's greatest test of truth, that is, experimentation. As time passed, the earlier observations were found by experience to be inexact, and the old concepts gradually gave way to new ones that contained more of the truth because they were based on observation and the tests of experimentation. Thus a mass of ideas about matter and the universe has gradually accumulated and has been recorded in a systematic form.

This accumulation of knowledge of the universe constitutes the physical sciences. *A science is the systematic arrangement of observations and the conclusions derived from them.* The sciences of today contain much that is true because in them are observations that have been made thousands of times by thousands of different observers. When an occurrence happens many times in the same manner, the observation of this similarity of result establishes a fact that the observer can feel very sure is true. Out of such often repeated observations have developed the principles or laws that are the basis of the sciences. In science *a law is a statement of a fact that has been demonstrated to be true by often repeated tests or experiments* and that one believes would be verified at any future time one chooses to repeat these tests.

CHEMISTRY

Chemistry is a science that deals with the structure of matter and the changes that matter undergoes. Its purpose is to find out what are the simplest parts of matter; how these parts can be separated in a pure form from crude matter, put together, or rearranged to produce new forms of matter; and what energy is liberated or absorbed in making these rearrangements of matter. The energy changes of matter are considered more especially, however, by the science called *physics*. Physics and chemistry of necessity overlap in their treatment of material because both deal with the investigation of matter. *Biology* is a science that studies the structure and changes that take place in matter in living organisms. Chemistry and biology also have areas that overlap.

History of chemistry

The earliest recorded investigators in the field of chemistry were known as *alchemists*, and the principles that they developed and followed were called *alchemy*. The great purpose of the alchemists was to convert base metals, such as lead, into gold. In seeking a method to accomplish this dream, they produced little of value to the world, but as pioneer experimenters with matter, they initiated the science of chemistry, and in this respect they made a great contribution to civilization. The earliest records of alchemy date back to the beginning of the Christian Era. It probably originated with the Alexandrian Greeks and later spread to Egypt, Rome, and the nations of western Europe.

Just when the modern age of chemistry began is a somewhat indefinite date, but it can be conservatively said that practically all the chemistry known at the present time is a development of the past 200 years.

Divisions of chemistry

Chemistry is divided into two major branches—*inorganic* and *organic*. Inorganic chemistry deals especially with inanimate or lifeless matter; it includes a study of all the elementary substances, but the element carbon is treated only to a minor extent in this division of chemistry. Organic chemistry considers matter of which living things are composed or that is closely associated with living things; it is essentially a study of the compounds of carbon. Both these great divisions have many subdivisions, such as analytical, synthetical, physical, and physiological. The division of chemistry into inorganic and organic is not a clear-cut separation and is to be regarded as a convenience for purposes of study.

Importance of chemistry

Before the advent of chemistry, knowledge of the universe was clouded with mystery and superstition, and the human race lacked most of its present-day comforts. Chemistry has fulfilled a great mission in solving many of the mysteries of nature and revealing the wonderful properties of matter. Perhaps no other subject has contributed so much to the development of human knowledge, and certainly no other science has contributed so much to human happiness by utilizing the products and forces of nature and creating new products for human use. The significance of chemistry in the production of articles for human comfort and happiness can be seen readily by noting the articles surrounding us, wherever we may be. It is practically impossible in modern times to observe an article of commerce that has not been created, improved, or influenced in some manner by an application of the principles of chemistry. It will be an interesting and instructive exercise for the student to try to note an exception to this statement. Today chemists, along with others, recognize their responsibility to help combat the threat of pollution that may destroy our environment, to increase the production of food, to conserve energy, and to find new sources of energy.

Questions for study

1. Define science.
2. What is a law in science?
3. What is chemistry? What other sciences are closely related to chemistry?
4. State the two major divisions of chemistry. What is meant by inorganic chemistry? By organic chemistry?
5. Discuss the importance of chemistry.

1 Matter—introduction to chemical concepts

MATTER

Matter is anything that possesses inertia, has mass, and occupies space. It includes all the substances that we can see, feel, or otherwise perceive by means of our senses. The physical properties of matter are those characteristics that can be recognized by the senses, for example, color, size, taste, and odor. These properties of matter can be changed without greatly altering the chemical properties of the matter. The chemical properties of matter are those characteristics that have to do with the activity of the substance in a reaction, the ease or difficulty with which it enters into chemical change.

Inertia

Inertia is described by Newton's first law of motion, which states that matter possesses the ability to remain at rest until it is acted on by some outside force. *Force* is the cause of motion, or the cause of a change in motion, of matter. Newton's law goes on to state that, once set in motion, matter has the ability to remain in motion in a straight path at a constant momentum until it is acted on by an external force, or forces, to deflect its path, slow it down, or speed it up.

Mass

Mass is a quantitative measure of the inertia of an object. The mass of an object determines how difficult it is to accelerate its motion. The rate at which movement occurs with respect to time is called *velocity* and is described by the distance an object moves in a given period of time, for example a car moving at the velocity of 50 miles per hour. *Acceleration* can be described as the rate at which the velocity changes with time. Force and mass are related through the equation, $F = ma$, where F is the force causing the acceleration (a) of the mass (m).

Weight

Weight is caused in an object because the mass of that object is being accelerated by the force of the gravitational attraction of a large object. In everyday experience that large object is the earth. From the beginning of time, mass and weight were almost synonymous because mankind was earthbound. Scientists theorized that an object in space could reach points in that space at which the gravitational attractions of stellar bodies would cancel each other and the object would have mass but would be weightless. They also realized that an object on another celestial body would weigh more or less than it did on earth, depending on the size of that celestial body with respect to the earth. The larger the body, the more gravitational force is associated with it. It was not until the dawn of the space age in the late 1950s that man could experience the truth of these theories.

Energy

Energy is the capacity to do work. *Kinetic energy* is that energy that matter exerts because of its motion and mass. When a force (F) operates on an object through a distance (d), work (W) is done, $W = Fd$. Kinetic energy is equal to one-half the mass of the object (m) times the square of its velocity (v), $E = \frac{1}{2} mv^2$.

Potential energy is the energy that an object possesses due to its position with respect to another object. A raised hammer has the ability to do work because of its position above the earth. Gravity will add to the muscular activity of the person wielding the hammer and increase the force of the blow. As the hammer falls, it does work, and the potential energy is converted to kinetic energy.

MEASUREMENT OF MATTER AND ENERGY

Length

Early in history, measurements were taken in a rather unscientific manner. A foot was the length of the foot of some leader in the community, the lord of the manor, or the tribal chief. It can be realized that the length of a foot varied from place to place. Soon it became clear that measurements needed to be standardized. Today we have the English measurements, inches, feet, and yards, and the metric measurements, millimeters, centimeters, and meters (Fig. 1-1). For many years the meter was standardized by a meter stick made of a platinum-iridium alloy kept at a constant temperature at the International Bureau of Weights and Measures in a suburb of Paris, France. This meter was one ten-millionth of the distance from the North Pole to the equator.

To make the standardization of the length of the meter more universally available, it was necessary to define the length as 1,650,763.73 times the wavelength of the orange-red line in the spectrum of the element krypton-86.* The metric system has an advantage over the English system in the fact that the metric system is based on units of ten.

1 kilometer (km) = 1000.0 m
1 meter (m) = 1.0 m
1 decimeter (dm) = 0.1 m
1 centimeter (cm) = 0.01 m
1 millimeter (mm) = 0.001 m
1 micron (μ) = 10^{-6} m
1 millimicron (mμ) (nanometer, nm) = 10^{-9} m
1 angstrom (Å) = 10^{-10} m

*An isotope of the element krypton.

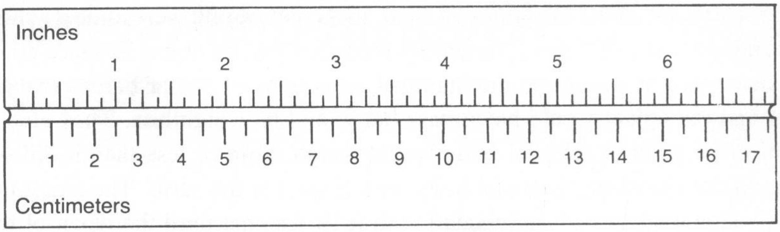

Fig. 1-1. Units of measurement.

Table 1-1. Some equivalent values

Metric system	*English system*
1 meter	39.37 inches
2.54 centimeters	1.0 inch
1 liter	1.0567 quarts
1 kilogram	2.205 pounds
453.6 grams	1 pound
28.35 grams	1 ounce
3.785 liters	1 gallon
1.60933 kilometers	1 mile

Volume

The English system of measuring volume uses the values of pints, quarts, and gallons, whereas the metric system uses the cubic millimeter, cubic centimeter, and the liter (l). The milliliter (ml) is 1/1000 of a liter.

Weight

The English system of weight consists of ounces, pounds, and tons. The metric system uses the gram (g) as the basic unit of weight. A gram is defined as the weight of 1 ml of water at 4° C. A kilogram (kg) is 1000 g, a milligram (mg) is 0.001 g, a microgram (μg) is 0.000001 g (10^{-6} g). The Greek letter μ is mu. The microgram is also called by the Greek letter γ, gamma.

Pressure

Air above the earth exerts a pressure on the surface of the earth. The higher areas of the earth have less atmosphere over them and, therefore, have less weight of atmospheric pressure than areas near sea level. It is usual to speak of air pressure at sea level as being 1 atmosphere of pressure. An instrument used to measure air pressure is the barometer. A barometer consists of a tube sealed at one end. A vacuum exists in the tube, and the open end of the tube rests in a well of mercury. The air pressure over the well of mercury forces the mercury into the tube to a level that corresponds to the amount of air pressure existing over the open well of mercury. It is usual to report barometric readings in either inches or millimeters, corresponding to the height of the mercury in the tube. One atmo-