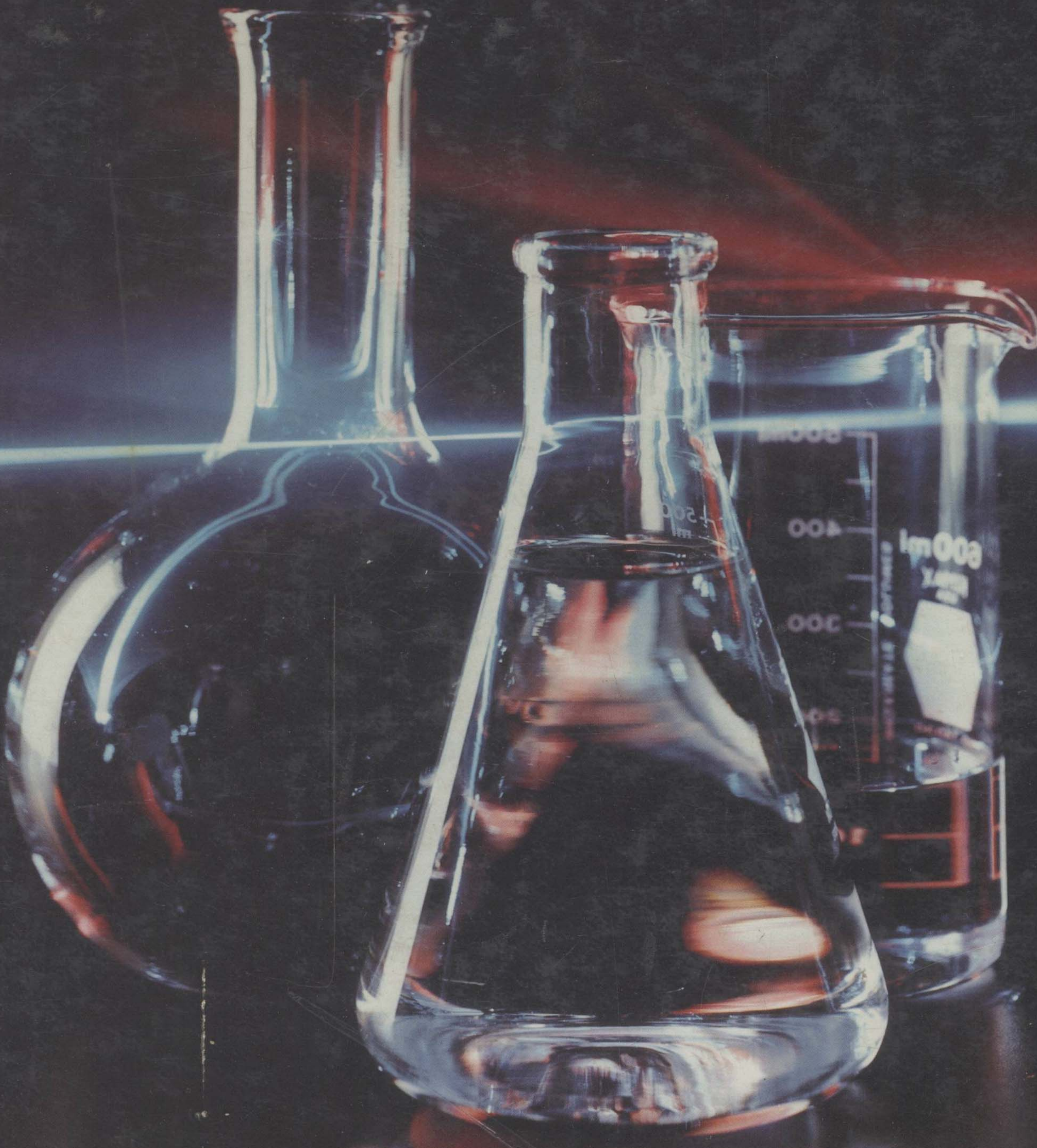
General Chemistry

Ebbing



General Chemistry

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Cover photograph by James Scherer.
Cover: Laser beams grazing the surface of laboratory glassware. The red beam (632.8 nm) is from a helium-neon laser; the blue-green beam (488.0) is from an argon ion laser.

Values for atomic weights listed in the periodic table on the inside front cover of this book are from the IUPAC report "Atomic Weights of the Elements 1981," *Pure and Applied Chemistry,* Vol. 55, No. 7 (July 1983), pp. 1107–1108.

Printed in the U.S.A.
Library of Congress Catalog Card Number: 81-83272
ISBN: 0-395-31489-5

BCDEFGHIJKLM-RM-8987654

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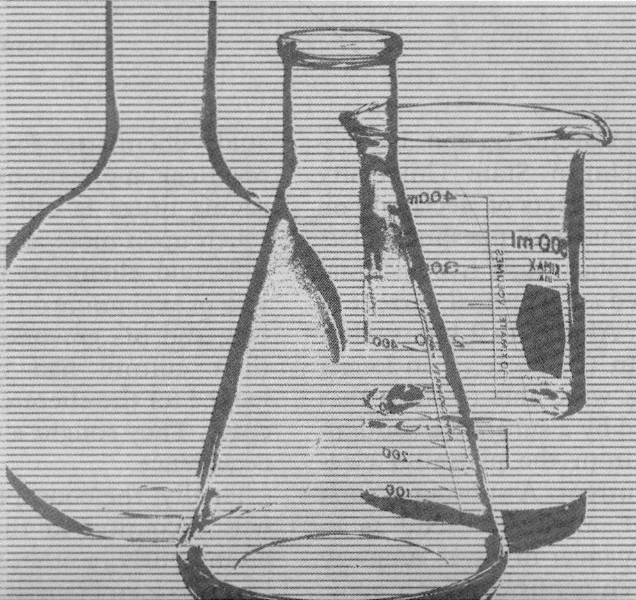

1. Chemistry and Measurement

In 1964 Barnett Rosenberg and his coworkers at Michigan State University were studying the effects of electricity on bacterial growth. They inserted platinum electrodes (electrical connections) into a live bacterial culture. Then they allowed an electrical current to pass through the culture. After 1 to 2 hours, they noted that cell division in the bacteria no longer occurred. The researchers were able to show that cell division was inhibited by a substance containing platinum, produced from the platinum electrodes by the electrical current. A substance such as this one, they thought, might be useful as an anticancer drug, because cancer involves runaway cell division. Later research confirmed their view, and in 1979 the Food and Drug Administration approved the marketing of *cisplatin,* a platinum-containing anticancer drug.

This story illustrates three significant reasons to study chemistry. First, chemistry has important practical applications. The development of life-saving drugs is one, and a complete list would touch upon most areas of modern technology.

Second, chemistry is an intellectual enterprise, a way of explaining our material world. When Rosenberg and his coworkers saw that cell division in their culture had ceased, they systematically looked for the chemical substance that caused it to cease. They sought a chemical explanation for the occurrence.

Finally, the concepts and thought processes you will encounter in the study of chemistry figure prominently in other fields. The above experiment began as a problem in biology; through the application of chemistry it led to an advance in medicine. Whatever your career plans, you will find that your knowledge of chemistry is a useful intellectual tool for making important decisions.

Chapter Overview

Chemistry, the science that studies materials, has a *quantitative aspect* that involves measurement and calculation. This quantitative aspect has been instrumental in the development of the science. Modern chemistry began with Lavoisier, who stressed the importance of measurements of mass (quantity of matter) in chemical research. Chemical research uses the scientific method, which depends on the interrelationship of *experiment* and *theory.* Because measurement and calculation are vital to chemistry, this chapter will concentrate on *units of measurement* and the calculation technique known as *dimensional analysis.*

Chemistry as a Quantitative Science

Chemistry is the science of the materials around us such as air, water, rocks, and plant and animal substances. Much of chemistry involves describing these materials and the changes they undergo. However, chemistry also has a quantitative side, which is concerned with measuring and calculating the characteristics of materials. This quantitative aspect has played, and continues to play, an important role in modern chemistry.

1.1 Development of Modern Chemistry

The origins of chemistry are ancient, and probably began with the use of natural materials for practical purposes. Modern chemistry emerged in the eighteenth century when the balance began to be used systematically as a

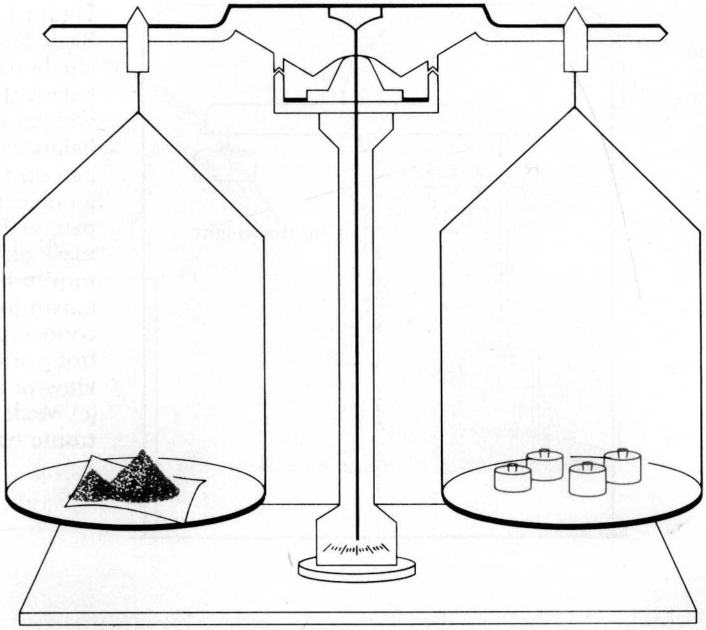

Figure 1.1
A simple pan balance. The material to be weighed is placed on the left pan and is balanced with weights placed on the right pan. When the masses on the two pans are equal, the forces due to gravity are equal and in balance, and the pointer rests at the center of the scale.

tool in research. Balances measure the **mass** or quantity of matter in a material (Figures 1.1 and 1.2). **Matter** is the general term for the material things around us and is often defined as whatever occupies space and can be perceived by our senses.

Antoine Lavoisier (1743–1794), a French chemist, insisted on the use of the balance in chemical research. His experiments demonstrated the **law of conservation of mass,** which states that mass remains constant during a chemical change (chemical reaction)■ A flash bulb gives a convenient illustration of this law. The flash from such a bulb accompanies a chemical reaction triggered by an electrical current. But a flash bulb that weighs 11.2 grams before it is flashed still weighs 11.2 grams afterward; the mass (11.2 grams) remains constant.

■ Heat or other forms of energy may be lost (or gained) during a chemical reaction. As Einstein's theory of relativity shows, mass and energy are equivalent: any substance having mass m has an energy mc^2, where c is the speed of light. Thus, when energy is lost as heat, mass is also lost. Changes of mass in chemical reactions (billionths of a gram) are too small to detect. Nuclear reactions, which are discussed in Chapter 22, however, involve enormous changes of energy and therefore detectable mass changes. In both kinds of reactions, any loss of mass that occurs in the reaction mixture is gained by the surrounding environment (from the energy released) so that the *total* mass always remains constant.

In a series of experiments, Lavoisier showed that when a metal or any other substance burns, something in the air chemically combines with it. He called this component of air *oxygen.* For example, Lavoisier found that the liquid metal mercury was transformed in air to a red-colored substance. The substance had greater mass than the original mercury. This was due, he said, to the chemical combination of mercury with oxygen. Furthermore, the new substance (a mercury oxide) could be heated to recover the original mass of mercury (see Figure 1.3). Lavoisier's explanation of burning, or combustion, can be written

$$\text{mercury} + \text{oxygen} \longrightarrow \text{a mercury oxide}$$

The following exercise illustrates how the law of conservation of mass can be used to investigate chemical changes such as combustion.*

*An exercise unaccompanied by a worked-out example can be solved by using the ideas just discussed in the text. The problems mentioned after the exercise appear at the end of the chapter and reinforce the skills associated with the exercise.

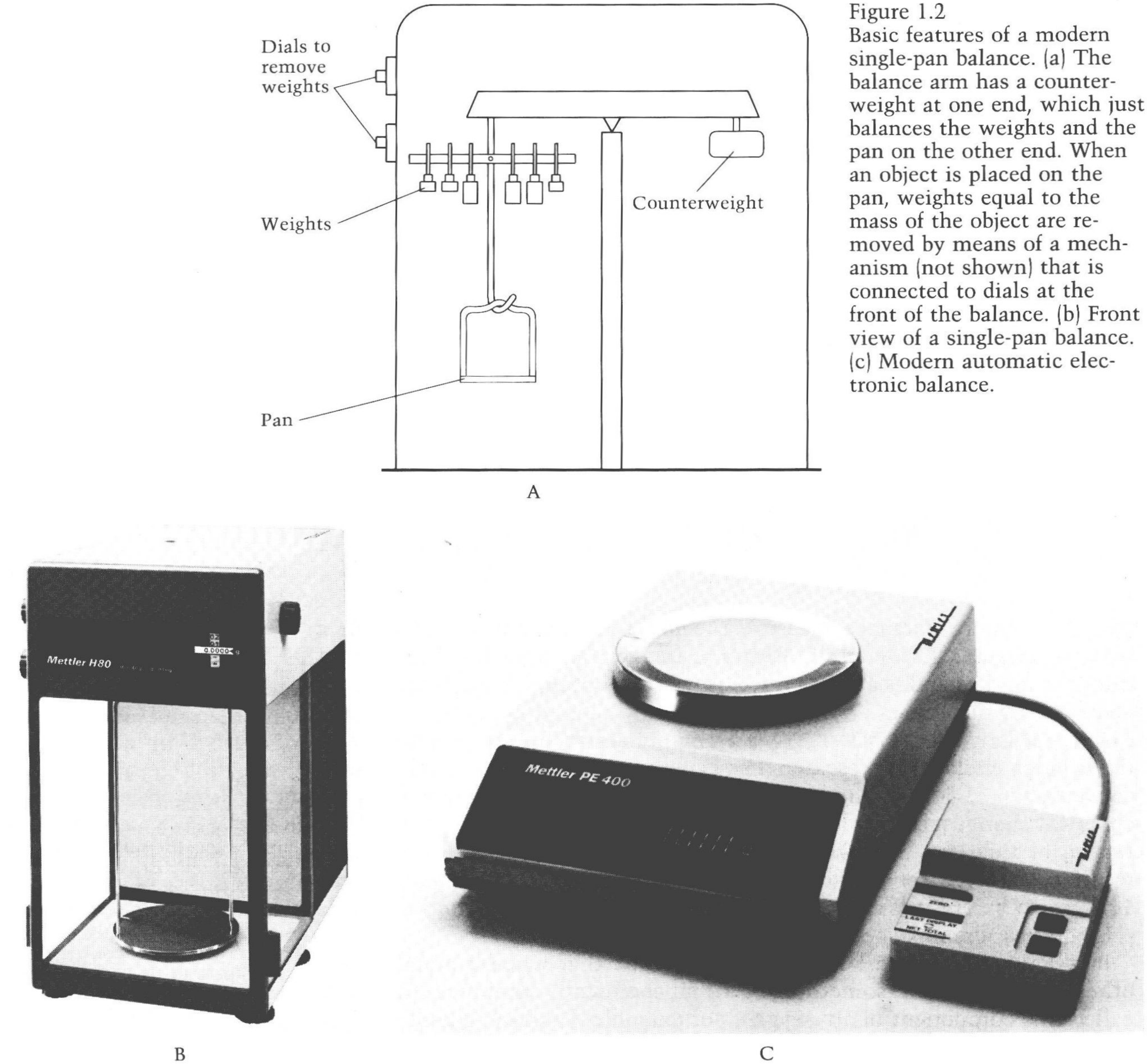

Figure 1.2
Basic features of a modern single-pan balance. (a) The balance arm has a counterweight at one end, which just balances the weights and the pan on the other end. When an object is placed on the pan, weights equal to the mass of the object are removed by means of a mechanism (not shown) that is connected to dials at the front of the balance. (b) Front view of a single-pan balance. (c) Modern automatic electronic balance.

Exercise 1.1

When 2.53 grams of metallic mercury are heated in air, they are converted to 2.73 grams of red-colored residue. Assuming that the chemical change is due to the reaction of the metal with oxygen from the air and using the law of conservation of mass, determine the mass of the oxygen that has reacted. When the residue is strongly heated, it decomposes back to mercury, a silvery liquid. What is the mass of the oxygen that is lost when the residue is heated?

(See Problems 1.7 and 1.8.)

Measurements of mass before and after the combustion of various substances were necessary to convince chemists that Lavoisier's views were