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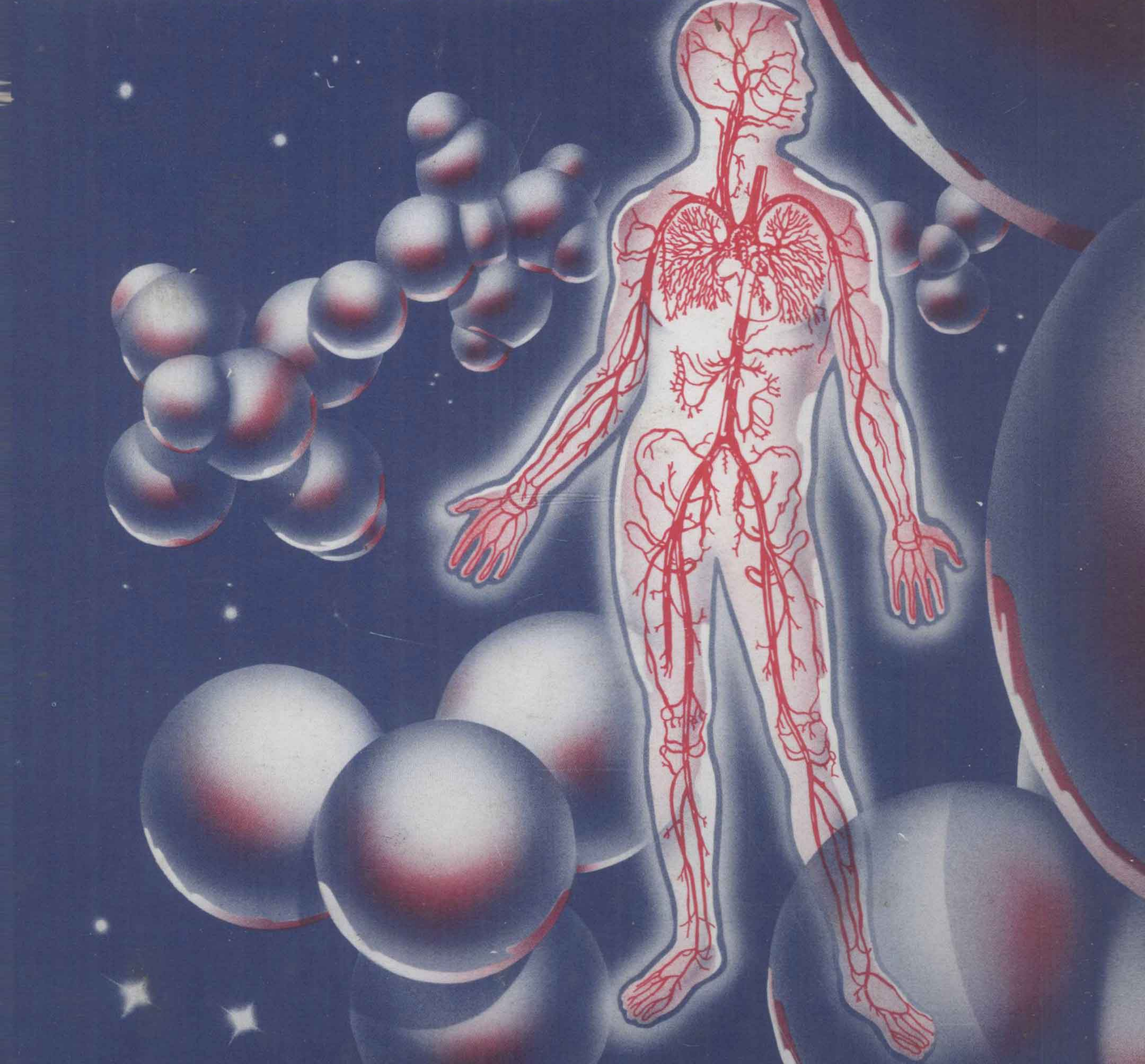

INTRODUCTION TO MEDICAL CHEMISTRY

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To Betty and Mari

Preface

Chemical reactions underlie all living processes. Recently molecular biologists have been unraveling the code that enables molecules to transmit genetic information from one generation to the next. This is an example of very complex biochemistry. But even a rudimentary understanding of chemistry can provide an insight into many living processes.

The opening chapters of this book provide a summary of basic chemical concepts; previous knowledge of chemistry is not essential. The chemical elements from which life is formed are then considered, with particular reference to their biological context. This is followed by a discussion of the organic substances, once believed to be produced only by living organisms but now known to obey the same laws as inorganic substances. From these we proceed to examine the way these substances are organized into biochemical pathways to provide the coherent pattern of living processes. The study of body fluids comes next; their very nature provides a kind of review of these processes. The book ends with two chapters on radiation chemistry and its growing importance in the medical field.

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Contents

1 Historical Introduction

Chemistry evolved out of man's need to make weapons, woman's desire for ornaments and their joint need of vessels, utensils, and embalming fluids. By 2000 B.C. the ancient Egyptians and Sumerians had already discovered how to extract gold, copper, silver, lead, and iron from deposits. They could also fix dyes to clothing materials with mordants of metallic salts and make coats of many colors.

By the beginning of the Christian era chemistry had become a recognized branch of learning in the city of Alexandria where it was known as the divine art. An early name for Egypt was Chemia, and when the Arabs invaded Egypt they adopted its divine art as 'al chemia' or alchemy.

The alchemists of the middle ages were mainly occupied in attempting to transmute base materials into gold. Paracelsus (1493–1541), a rebel physician and alchemist, hotly criticized medical practice of his day and founded a sect of medical chemists called Iatrochemists, who applied chemistry to the service of medicine. In particular, they tried to prepare the elixir of life, which would cure all diseases and also confer perpetual youth. Although unsuccessful in their main endeavors, they did incidentally discover many new substances such as alcohol, mineral acids and metallic salts.

Van Helmont (1577–1644) represents the transition from medieval alchemy to modern chemistry. Born of noble origin in Brussels, he qualified in medicine, married and then spent his life in careful chemical experimentation. He was the first to recognize clearly the production of gas in chemical processes. He derived the name gas from the Greek word "chaos" to represent the wild motion of its particles. He discovered that when he corked up limestone and acid in a bottle to produce carbon dioxide, it burst the bottle. So he called it gas sylvester—the wild untameable gas of the woods. He also concluded, wrongly, that a gas could not be contained in a vessel.

Robert Boyle (1627–1691) has been called the father of modern chemistry. He set up a laboratory at the back of his sister's house in Pall Mall, London, where he developed chemistry as a science in its own right and not just as a means of making gold or medicines. His chief contribution was the introduction of the scientific method, every theory being put to the test of carefully planned experiment.

Boyle developed the concept of chemical elements. He defined an element as a substance which cannot be split by any chemical means into simpler substances. The Greeks had originated the idea of elements almost 2000 years earlier, but believed them to be earth, water, air and fire. None of these is an element in the chemical sense. They can, however, be looked upon as a poetic representation of the three states of matter: solid (earth), liquid (water), and gas (air). Temperature (fire) is a major controling factor; heat converts ice (solid) into water (liquid) and then into steam (gas).

Once the nature of chemical elements had been understood, the stage was set for the rapid advances in chemistry which took place during the next 300 years.

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What Is Chemistry?

Chemistry is the study of substances, their properties and structures, and of the reactions by which they can be changed into other substances. By *structure*, we mean the arrangement of the minute particles of which a substance is composed.

MATTER IS TINY PARTICLES

Why do we believe that matter consists of tiny particles? We are all familiar with an important property common to all gases and vapors, the ability to spread or diffuse. Kitchen smells, unless we are careful, quickly pervade the whole house. The odor of disinfectant can be detected some distance from the place where it is used. If we think about it, the best explanation for this is that gases and vapors consist of tiny invisible particles that are constantly moving about in all directions.

Support for this idea is also given by the diffusion of liquids. If, for example, some bromine (a very dark red liquid) is placed under some water in a bottle we notice that after a day or two the bromine has spread evenly throughout the water giving it a uniform red color. We can explain this quite easily if we assume that the bromine and the water are made up of tiny particles which are continually moving about. Diffusion between solids is far less common than between liquids and gases. As a rule, the particles of a solid do not move about in all directions; they simply vibrate.

This theory of moving particles, which is supported by a great deal of other evidence, has proved extremely useful in explaining many properties of substances. It is one of the great theories of science and is known as the kinetic theory (Gr. *kineo*, I move).

TYPES OF PARTICLES

How many kinds of particles are there? Broadly speaking there are only three: atoms, molecules and ions. Before describing them we must first consider what is meant by elements.

Elements

These are different from all other substances in one very important respect: they cannot, apart from the radioactive elements, be broken down into simpler substances. Water is not an element because if we pass an electric current through it we split it up into hydrogen and oxygen. Similarly, common salt (sodium chloride) is decomposed by electricity into sodium and chlorine. Water and sodium chloride are called *compounds*.

There are at present 104 known elements; 89 of them occur naturally and the rest are man-made. A list of them is given in the Appendix.

Atoms

These are simply the smallest particles of an element. The Greek philosopher, Democritus, over 2000 years ago, originated the word atom, meaning a particle which could not be cut into any smaller pieces (Gr. *a*, not, +Gr. *tomos*, cut), but it was John Dalton from Lancashire, England, who first used the idea of atoms to explain chemical phenomena. His atomic theory, which he produced in 1807, is the cornerstone of modern chemistry.

Since Dalton's time, physicists have discovered that atoms are themselves built up of tiny particles of over thirty different kinds. However, only three need concern us. They are the proton, the neutron and the electron. We shall deal with them in Chapter 4.

Molecules

The atoms in many substances join together to form groups which we call *molecules*. Some molecules contain only two atoms; others, known as giant molecules or macromolecules, contain thousands of atoms. Chemists are able to determine by experiment and calculation not only the *number* but also the *arrangement* in space of the atoms in a molecule, in other words the shape of a molecule. The shapes of a few molecules are illustrated by the models pictured in Fig. 2.1.

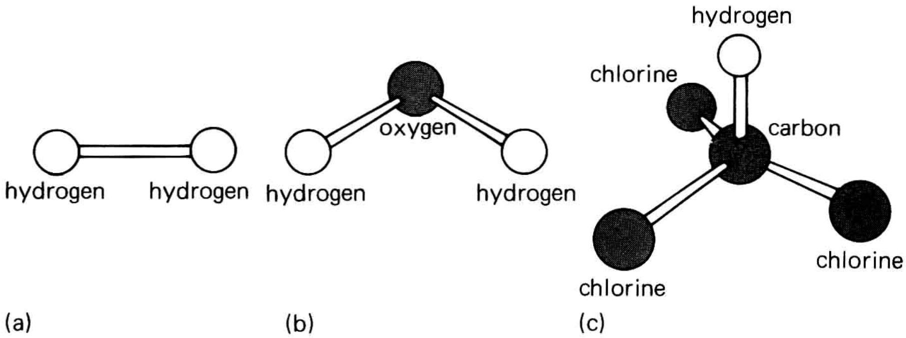

Figure 2.1
Models of molecules (a) hydrogen H_2; (b) water H_2O; (c) chloroform $CHCl_3$.

The rods joining the spheres represent the *chemical bonds* which hold the atoms together. We shall find out later what a chemical bond actually is. The properties of a substance are largely determined by the bonds between its atoms and by the way the atoms are arranged.

Representation of atoms and molecules

Undoubtedly, the best way of representing molecules is by the use of models or pictures of models. However, we often do not need to show the shape of a molecule, only the numbers and types of atoms it contains. We can do this quite easily using the molecular formula of the substance. H_2O is the molecular formula of water. The symbol H represents one atom of hydrogen and the symbol O one atom of oxygen. The number in a formula always refers to the symbol preceding it; the formula H_2O tells us that a molecule of water consists of 2 hydrogen atoms and 1 oxygen atom. The molecular formula of oxygen is O_2. This tells us that a molecule of oxygen contains 2 oxygen atoms. What does the molecular formula of glucose, $C_6H_{12}O_6$ tell you about the glucose molecule?

Ions

Atoms or groups of atoms which carry an electrical charge are called *ions*. Their nature will be described in the next chapter.