SAFE HANDLING
of
RADIOACTIVE ISOTOPES
in
MEDICAL PRACTICE

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To S. L. Q.

PREFACE

Radioactive isotopes were made readily available for medical use in 1946, when the Atomic Energy Commission decided to devote a part of its Oak Ridge facilities to their production. The clinical value of certain diagnostic and therapeutic procedures was quickly demonstrated, and isotope units began to be established in hospitals. The number of such units has increased rapidly; during the first year about 150 licenses for medical use were issued, whereas, at present there are several thousand (for hospitals and individuals), and the total is steadily increasing.

Because of the potential health hazards associated with the use of radioactive substances, the Atomic Energy Commission has been directed by Congress, in the various Atomic Energy Acts, to make sure that they are always employed safely. Although it had long been known that overexposure to x-rays or radium rays could produce serious damage, there had been no widespread concern. Radiologists and their associates had studied the problem and established permissible exposure rates designed to avoid such damage, and as isotopes came into use these rules were extended to them. In recent years, however, there has been so much publicity about radiation hazards in connection with uses of x-rays and of atomic energy that many people have become unduly concerned, not knowing really what the dangers were or how they could be avoided.

The dangers of radiation cannot be denied, and should not be ignored, but neither should they be exaggerated. Unbiased and nonpolitical national and international scientific groups have established, on the basis of all available information, so-called "permissible dose rates." Anyone continually being irradiated at these permissible rates or lower ones would never be expected to show any radiation injury whatever.

In order to fulfill its obligation regarding safe usage, the AEC has maintained as one criterion for licensure that for every radioisotope laboratory there should be a *radiation protection officer*, one of whose duties is to make certain that nobody under his supervision can ever receive more than the permitted dose of radiation. He must make sure that every procedure can be carried out without hazard, and must provide all necessary instructions for maintaining safety. All those working under the guidance of a competent radiation protection officer need not worry as long as they can follow his directions.

However, intelligent people are seldom satisfied to obey orders blindly; they want to know the reasons. Furthermore, in dealing with such potentially dangerous things as radioactive isotopes, there is always the possibility that an unforeseen situation will arise just when the radiation protection officer is not available.

I offer this book as a supplement to the work of the radiation protection officer; it cannot be a substitute for his judgment. It is written for technicians, nurses, doctors, or anyone else engaged in isotope work in a hospital or medical practice. In the first chapter, for purposes of background orientation, there is a brief presentation of the nature of radioactivity and the radiations from radioactive substances. This is followed by a section describing the various diagnostic and therapeutic uses of radioactive isotopes in medicine. Radiation hazards are then discussed, and a detailed statement given of levels of radiation exposure from which no damage of any sort would be expected. Methods for determining exposure rates under working conditions are presented.

Standard methods are outlined for maintaining low dose-rates in the laboratory and in the hospital. Instruction is given for patient care following administration of various quantities of commonly used isotopes. Procedures are set forth for dealing with possible emergencies, such as a spill of a quantity of isotope in the laboratory or unexpected incontinence or vomiting by a patient. If a radioactive patient should need emergency surgery, or should die, problems for the surgeon, the autopsy pathologist, or the funeral director are analyzed.

My aim in writing this book has not been to provide a complete manual on radiation safety, but rather to give basic information which will supply answers to questions as to the reasons for various procedures, supplement the instructions of the radiation protection officer, and give the radiation worker a feeling of assurance that he can meet nonroutine situations if they arise.

Obviously there is little original material in such a book as this; it is an attempt at collecting bits and pieces from many sources, and putting them together as a convenient compendium. Accordingly I have drawn freely upon published material, and in particular on the National Bureau of Standards Handbooks. I am indebted to Dr. Sergei Feitelberg and Dr. Robert Loevinger for their data on exposure due to patients who had received intra-abdominal radioactive gold. Dr. John Reeves and Dr. J. R. Dreyfuss generously put at my disposal their carefully worked out instructions to nurses; these I have modified for Appendices 3 and 4.

Several good friends read the manuscript and made valuable suggestions. I am particularly grateful to Dr. Otto Glasser, Dr. Sergei Feitelberg, Dr. Edgar Watts (Radiation Protection Officer to the College of Physicians and Surgeons), and Miss Betty Hiza (Chief Technician, Isotope Laboratory, College of Physicians and Surgeons). My very special thanks are due to my secretary, Mrs. Gerda Osborn, who has patiently coped with all the details involved in preparing a manuscript for publication. Miss Barbara Russell, of the Macmillan staff, edited the manuscript with great care; her aid was invaluable. Indeed, to the publisher, who initiated the writing of the book and maintained constant interest in its progress, must go a large share of the credit for its completion.

E. H. Q.

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CONTENTS

Chapter 1

RADIOACTIVITY AND RADIOACTIVE ISOTOPES

Structure of Matter

All matter is made of elements, of which there are 91 occurring in nature. The smallest part of any element is its atom, and until about 60 years ago it was believed that all atoms of any particular element were exactly alike, and that each one was solid and indivisible.

In 1896 Becquerel discovered the phenomenon of radioactivity, that is, he found that atoms of some elements were not unchanging and indivisible, but that they could undergo some sort of transformation, in the course of which they gave off radiation like x-rays. In a short time it was demonstrated that tiny particles of matter were also emitted during the radioactive transformations.

From studies of these substances during the next 20 years, a great deal was learned about atomic structure and stability. For atoms do have structure; they are not just little solid spheres. Each atom has a nucleus, which contains most of the weight of the atom, and has a positive electric charge. Around the nucleus electrons travel in orbits, as the planets travel around the sun; there are just as many negative orbital electrons as there are units of positive charge in the nucleus. Moreover the nucleus itself is not simple, but is built up out of two basic types of particles, the *proton,* which has unit mass (on the atomic scale) and a single positive charge, and the *neutron,* which has essentially the same mass but no charge. The orbital electrons, with their negative charges, have weights about 1/1800 that of the proton. The structure of some simple atoms is shown in Figure 1.

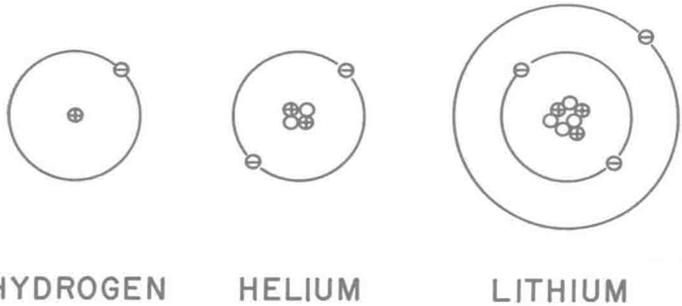

Figure 1. Structure of some simple atoms.

Isotopes

In addition to finding that atoms were not solid and indivisible it was also found that atoms of a particular element did not have to be all exactly alike. In such atoms the things that must be alike are the number of protons in the nucleus, or the nuclear charge, and the number of orbital electrons. But the number of neutrons in the nucleus, and hence the nuclear mass, may vary, although only over a relatively small range. Atoms of the same element, but with different numbers of nuclear neutrons, are called *isotopes*. Isotopes of some simple atoms are shown in Figure 2.

It is evident now that the simple chemical symbol for an element is not enough to define a particular isotope. The form generally accepted as correct is that used in Figure 2. The chemical symbol has a superscript at the upper right which is the *mass number*, that is, the sum of the neutrons and protons in the nucleus, and a subscript at the lower left which is the *atomic number*, the number of nuclear protons.* The atomic number defines the element; there is one element and only one

* Because of the inconvenience of writing or typing superscripts, isotopes are often indicated by the chemical symbol followed by a hyphen and the mass number, as I-131, Co-60.

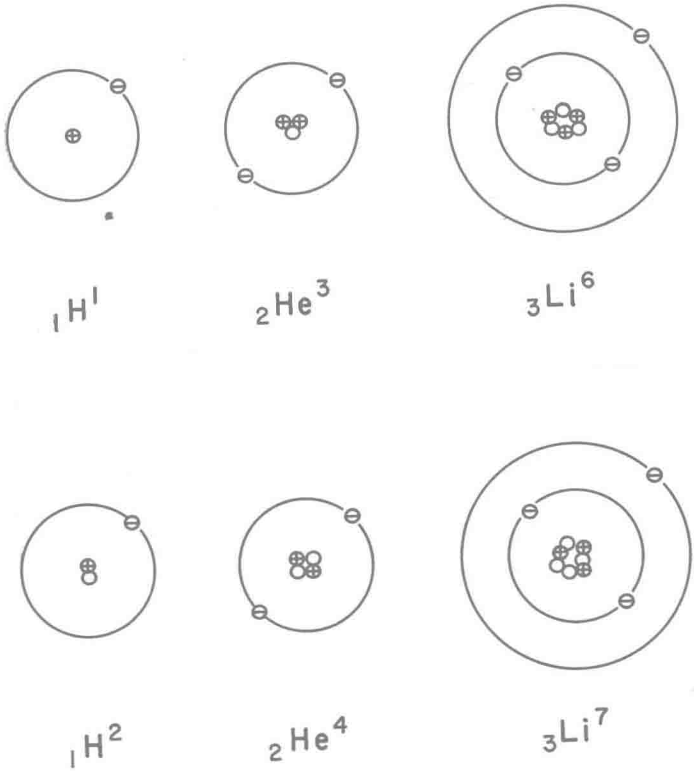

Figure 2. Structure of some simple isotopes.

for every number from 1 to 102.* The mass number defines the isotope. An element may have only one stable isotope, as is the case with iodine, or it may have several. Tin has 10, the largest number yet found.

Isobars

Since there is one element for every atomic number, and each one may have several isotopes, it is evident that isotopes of

* Elements found in nature have atomic numbers from 1 to 92. Those with higher numbers are man-made, by the use of "atom-smashers." These procedures are outside the scope of this book.

neighboring elements may have the same mass number. For instance, there are $_{28}$nickle^{64} and $_{30}$zinc^{64}. Such atoms, having the same mass numbers and different atomic numbers, are called *isobars.*

Radioactivity

Most atoms found in nature are stable and never change unless they are attacked from outside. But some of them, particularly among the heaviest ones, are inherently unstable, or *radioactive.* A nucleus of a radioactive atom at some time gets into an unstable state, and undergoes a change called *disintegration.* This disintegration, however, is not a complete falling to pieces. It is the ejection of a tiny charged particle, possibly accompanied by electromagnetic radiation. The rest of the material of the nucleus rearranges itself and becomes the nucleus of a different element.

Radioactive Disintegration

In naturally radioactive substances there are only two kinds of particles which can be ejected. One, the alpha (α) particle, is really the nucleus of a $_{2}$helium^{4} atom, as shown in Figure 1. It therefore carries away four mass particles and two positive charges. The new nucleus must have a mass number 4 less, and an atomic number 2 less than the original.

$$_{Z}X^{A} - {}_{2}\alpha^{4} = {}_{Z-2}X^{A-4}$$

The other, the beta (β) particle, is an electron. It does not, however, come from an orbit but from one of the nuclear neutrons, which under certain circumstances dissociates into a proton and an electron. The electron is not tolerated in the nucleus and is immediately ejected. Since it carries away essentially no mass, but has left an extra positive charge (neutron replaced by proton), the new atom has the same mass, but an atomic number one higher than the old.

$$_{Z}X^{A} - {}_{-1}\beta^{0} = {}_{Z+1}X^{A}$$

There are a considerable number of naturally radioactive substances, of which uranium, thorium, and radium are best known.

In 1934 it was discovered that it is possible to make artificially radioactive isotopes of normally stable elements, by bombarding the stable isotopes with high-energy sub-atomic particles. Now radioactive isotopes have been created of every element. In fact, every element has two or more, except for hydrogen and helium, which each have one. Iodine, with only one stable isotope, ${}_{53}I^{127}$, has 20 radioactive ones, from ${}_{53}I^{119}$ to ${}_{53}I^{139}$.

These artificially radioactive isotopes have the same α^+ and β^- radiations as the natural ones; some of them also emit positrons or positive electrons, β^+. These come from the dissociation of a nuclear proton into a neutron and a positron, and their ejection results in a new nucleus of the same mass number, and an atomic number one lower than the original.

$$ {}_{Z}X^{A} - {}_{+1}\beta^{0} = {}_{Z-1}X^{A} $$

Every radioactive disintegration results in the emission of one and only one of these particles, and possibly of radiation like x-rays, called gamma (γ) rays. Atoms of any particular radioisotope will always emit the same kinds of radiation when they disintegrate.

Radioactive Decay; Half Life

It is not possible to predict when any particular radioactive atom will disintegrate, but statistically, in dealing with the very large numbers of atoms which exist even in small quantities of radioactive material, it is possible to predict how many of them will disintegrate during a given time. That is, it is possible to predict this after an isotope has once been studied and its "disintegration constant" determined. Every sample of any particular radioactive isotope will always decay at the same rate. This rate is usually described by stating the *half life*, or