THE LABORATORY AS A GUIDE IN PROBLEMS OF PEDIATRICS

USES OF RADIO-ISOTOPES. I—GENERAL CONSIDERATIONS*

B. S. Rau and R. P. Misra

Calcutta

When Dalton first put forward his atomic theory in the beginning of the nineteenth century, it was an accepted fact that all matter was composed of components called elements. The smallest fundamental particles of each element are its atoms. The atoms of a particular element are all exactly similar and are different from atoms of all other elements; they are indivisible and unalterable. With the discovery of radioactivity in 1896 by Henri Becquerel and of the electron in the following year by J. J. Thomson, it became evident that the atom must have a structure and even be capable of undergoing some sort of breakdown. As a result of the pioneering work carried out by Lord Rutherford and his co-workers in the early part of this century, it is now known that the atom, so long regarded as the ultimate particle of matter and incapable of further subdivision, is in itself composed of three distinct types of particles called the proton, the neutron and the electron. The atoms of every element are composed of these three fundamental particles in varying proportions. Basically, an atom is described as a miniature solar system. There is a central nucleus containing most of the atomic mass and carrying a positive electric charge. This is surrounded by a planetary system of one or more electrons. Although the positively charged nucleus (radius $10^{-12}$ cm.) comprises a very small fraction of the atomic volume (radius $10^{-3}$ cm.) it accounts for practically all the weight of the atom. Most of the atomic volume can be said to be relatively empty, being occupied by negatively charged electrons which are many thousand times lighter than the protons or neutrons.

The proton is a small massive particle of weight $1.6 \times 10^{-24}$ gm. and has a positive electric charge of the magnitude $4.8 \times 10^{-19}$ electrostatic units. The neutron has approximately the same mass as the proton but carries no electric charge. The electron is a particle of negligible mass compared with the proton or neutron, but carries a negative electric charge of the magnitude equal to that of the proton. The actual mass of the electron is $9.1 \times 10^{-28}$ gm. These figures are of little direct interest to anyone but the nuclear physicist.

The different nuclei are identified by symbols such as $^{53}_{11}^{131}$, $^{15}_{0}^{32}$, $^{55}_{0}^{137}$. The subscripts are the numbers of protons in the nucleus or the atomic number; the letters are chemical symbols; and the superscripts are the total numbers of particles in the nucleus—the mass number. The chemical properties of an element are determined by the number of electrons in the planetary system of its individual atom, i.e., by the atomic weight. From

* From the Institute of Child Health, Calcutta. Director: K. C. Chaudhuri. Received for publication on September 10, 1959.
this it follows that all atoms present in a sample of any one element will have the same atomic number but not necessarily the same atomic weight, i.e., all the atoms will have the same number of protons, but the number of neutrons in the nucleus may differ. These atoms, differing in the number of neutrons in their nuclei, are termed isotopes of the element; they have identical chemical reactions and, forgetting for the moment the phenomenon of radioactivity, the isotopes differ only in their atomic weights.

Practically all the known elements occur normally as a mixture of two or more isotopes. If the neutrons and protons in different numbers are arranged together to form the nuclei, most of the combinations would be unstable. They might decay by fission into two or more fragments by emission of gamma rays, an alpha particle, a positive electron, a negative electron or by some combination of these possibilities. Such unstable nuclei are called radioactive. Radioactivity is a spontaneous and self-disruptive phenomenon exhibited by several of the heavy elements of atomic weight greater than 206 occurring in nature. The activity consists in the emission of a complex type of powerful radiation composed of three distinct types of rays known as the alpha, beta and gamma rays. The result of the activity is the breaking down of the element itself for good, i.e., an irreversible self-disintegration. The activity is spontaneous in the sense that it arises solely from the intrinsic natural causes unaffected by any external agency, whether physical or chemical. Modern techniques of artificial transmutation of elements have been able to produce radioactivity in many other elements much lighter than those that occur in nature. This has necessitated a distinction between natural and artificial radioactivity. The atoms of radioactive elements undergo disintegration when they emit alpha and beta rays which are corpuscular in nature. These are also radioactive. The transformation goes on until an inactive or stable product is formed.

Radioactive isotopes can be detected with great sensitivity and can be used in large dilutions in biological experiments. They can also be detected in situ in the human body. These two advantages have led to their extensive use in medicine. One great advantage of the investigation using radioactive isotopes is that such small amounts are needed that there is little or no interference with the processes being studied. From a medical point of view, the unique feature of radio-isotopes is the emission of ionising radiation. Each emission has a particular energy expressed in terms of million electron volts (MEV). The different emissions have the ability to traverse distances and penetrate through matter. The term 'ionising' is applied because the profound effects produced on living tissues by these radiations are related largely to ionisation. The activity of any particular radioactive isotope decays with time. A measure of this rate of decay is its half-life, which is the time interval during which the amount of radioactivity halves in value. This may range from a fraction of a second to millions of years for different isotopes. In radioactivity, it is the number of radioactive atoms, which disintegrate in an unit of time, that is of real importance rather than