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FOLDER Isotopes - Their Distribution and Use
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ISOTOPES—THEIR DISTRIBUTION AND USE

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From 1938 to 1942 Dr. Aebersold (Ph.D., California, 1938), under the direction of Dr. Ernest O. Lawrence, inventor of the cyclotron, was associated with physics and biophysics research at the Radiation Laboratory, University of California. During the war he worked on various phases of the atomic energy project in Berkeley, California, Oak Ridge, Tennessee, and Los Alamos, New Mexico. In 1946 he became chief of the Isotopes Branch of the Manhattan District and is now chief of the Isotopes Division of the Atomic Energy Commission, which supplies isotopes to hundreds of research institutions, universities, and hospitals all over the world.

IN THE first three years of the United States program of isotope distribution, from August 2, 1946, to June 30, 1949, more than 7,000 shipments of radioactive isotopes and 731 shipments of concentrated stable isotopes were made to government, private, and industrial laboratories for use in peacetime research. All the shipments were made from facilities now controlled by the U. S. Atomic Energy Commission. The isotopes were distributed for use in all the major fields of scientific investigation, as well as for applications in medicine, agriculture, and industry. The radioactive isotopes went to 549 departments in 305 institutions located in 39 states, the District of Columbia, and Hawaii, and to 150 institutions in 21 foreign countries. The concentrated stable isotopes went to 209 departments in 144 institutions within the continental United States.

Radioisotopes were distributed for use as tracer atoms and as sources of ionizing radiations. Tracer atoms are used in all fields of basic and applied study in which knowledge is desired on the movement, transformation, and chemical behavior of atoms and molecules. As sources of ionizing radiation, radioisotopes are used in medicine for detecting and treating certain diseases, and in industry for radiographic testing and process-control applications. The stable isotopes were distributed for use as tracer atoms and as objects of nuclear study. As tracer atoms the stable isotopes were also widely used in all major fields, and as objects of investigation per se they were mainly used by nuclear physicists and chemists.

What does a program, already grown to such magnitude and still growing rapidly, mean to the over-all advancement of modern science? Is government control of isotope distribution a handicap to their maximum usefulness? What precautionary steps have been taken with respect to the health-hazard aspects of radioisotope distribution? What are the security risks, if any, in making distribution to laboratories in foreign countries of these materials, many of which are direct by-products of atomic energy? Is the use of isotopes a passing "fad"? Presentation of this summary on the status of isotope distribution and utilization is intended to help provide an answer to these general questions, as well as a better over-all understanding of the program.

Development of distribution program. The use of naturally occurring radioisotopes, such as radiolead and radium, as radioactive indicators, or "tracer" atoms, dates back to the late 1910s. It was not until the middle 1930s, however, that the artificial induction of radioactivity permitted radioisotopes of the more common elements to come into usage as tracer atoms. Through the

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medium of the cyclotron it became possible to produce radioactive species, or radioisotopes, of all the elements. With a few exceptions, one or more radioisotopes, having radiation characteristics suitable for tracer or other applications, could be produced of each element. There was, however, one great drawback to the widespread use of cyclotron-produced isotopes—the expense and small-scale capacity of production. Although radioisotopes were used appreciably in laboratory-scale research investigations and in certain applications for medical treatment, this work was chiefly limited to a dozen or so institutions possessing cyclotrons.

Before World War II those scientists who had used radioisotopes had formed a keen appreciation of their usefulness. They had found, for instance, that radioisotopes could be used to label uniquely a specific batch of atoms, which could then be traced through a labyrinth of chemical or physical reactions. The labeled atoms could be traced independently even in the presence of other atoms or molecules of the same substance, and in spite of multiple reactions of numerous other kinds of atoms and molecules. It was also found that radioactivity detection instruments could reveal the presence of extremely minute quantities of radioelements—quantities millions and sometimes even billions of times smaller than those detectable by chemical means.

Thus, even before the war, science had in radioisotopes a research tool with the twofold power of extremely high sensitivity and unique specificity. It was a tool greatly in demand but small in availability.

During the war many of the scientists who were familiar with cyclotrons and the handling of radioactivity became associated with the development of the atomic energy project. They soon realized that the uranium chain reactor would be an excellent unit for large-scale production of a wide variety of useful radioisotopes. At the conclusion of the war these scientists, realizing the potential value of radioisotopes to peacetime research, proposed that reactor-produced radioisotopes be made generally available for scientific investigation. Working jointly with the Manhattan District, Corps of Engineers, U. S. Army, the original operators of the atomic energy project, they formulated a program based on this proposal. The present isotope distribution program is a direct outgrowth of that early planning. Although the spadework connected with establishing the program was mainly completed at that time, most of the responsibility for its administration has come under the jurisdiction of the Atomic Energy Commission.

Increased availablity of isotopes. To appreciate the capacity of a nuclear reactor for radioisotope production, one has only to compare it with a cyclotron. Production of the most widely useful isotopes in both units is based primarily on inducing radioactivity into stable target elements. In the reactor the target elements are bombarded only with the neutrons of the chain reaction, whereas in a cyclotron much more versatility is possible in the type and energy of the bombarding particles. In the nuclear reactor there is also a vast source of radioisotopes in the radioactive fragments resulting from fissioning, or splitting, of the uranium employed in the chain reaction. These are the so-called fission products.

Because of the extremely high density of neutrons (approximately 5×10^{11} neutrons/cm^2/sec.) available in the reactor for bombarding target elements, and because of the over-all size of the reactor, it is possible to produce thousands to many millions of times as much radioactivity as in a cyclotron. Also, because of the reactor size, it is possible simultaneously to induce radioactivity in hundreds of different target materials. Although there are a number of very useful radioisotopes that cannot be produced by neutron bombardment, thus requiring cyclotron production, most of the widely useful isotopes can be produced in a reactor.

With reactor production facilities, distribution would no longer have to be limited to a relatively small number of investigators, and research workers would not have to limit their investigations to those experiments requiring minimum quantities of tracer materials. Production would be sufficient for investigators to trace not only elements and simple inorganic compounds but also complex organic compounds and biological materials, even though the synthesis of such labeled materials would be inefficient in the use of active material.

The development of stable isotope separation and utilization has followed a similar pattern. Prior to the war, stable isotope separation was accomplished by electrolysis, exchange reactions, and fractional distillation on a very small scale. Deuterium, or hydrogen 2, carbon 13, and nitrogen 15 were the only stable isotopes, which were concentrated in quantities sufficient for significant tracer use. Stable isotopes of many elements can now be concentrated by large-scale electromagnetic separators similar to those used during the war for the mass-scale separation of fissionable uranium 235 from

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nonfissionable uranium 238. Approximately 130 different concentrated stable isotopes are now available to investigators in this country.

Stable isotopes are generally not as applicable as radioactive isotopes for tracer investigations because they can only be identified on the basis of differences in weight. This determination requires costly instrumentation and is much less sensitive than the methods used in radioactivity measurements. Stable isotopes have, however, proved very valuable as tracers in investigations where it is not permissible to introduce radioactivity, or where great sensitivity is not required. They are, of course, also invaluable for fundamental nuclear studies requiring isolated nuclear species.

Criteria of production and distribution. Before the isotopes distribution program could be initiated, certain criteria for both production and distribution had to be established. This was especially true for radioisotopes because of the variety of health-safety problems involved. In distributing stable isotopes, on the other hand, the principal problems were concerned with limited availability and cost. Answers had to be found for such questions as: What radioisotopes should be produced and in what quantity? In what chemical form should the isotopes be made available? To whom should isotopic materials be made available? What portion of the production costs should be borne by the prospective user? What, if any, limitations should be placed on the applicant?

A number of such questions were automatically answered by the Atomic Energy Act of 1946. Answers to others have been tentatively determined by the Atomic Energy Commission and its advisory groups in the best interest of the distributor and the isotope user. In some instances, such as in price scheduling and in procurement procedures, it has been necessary to make adjustments from time to time to meet changes in availability and demand.

To assist in the formulation of policies under which isotopes would be distributed, the Commission appointed a Committee on Isotope Distribution. This Committee, composed of twelve members, scientists and physicians who have had considerable experience in the handling and use of radioactivity, is subdivided into a Subcommittee on General Applications and a Subcommittee on Human Applications. Besides making recommendations to the Commission on basic policies governing allocation and distribution, the Subcommittee on Human Applications reviews all requests proposing to use radioisotopes in human beings, and the Subcommittee on General Applications reviews requests proposing to use large quantities of activity in experimentation outside the laboratory.

Because radioactive materials are potentially hazardous to health, it is necessary that the prospective user have adequate facilities, proper safety equipment, and specialized scientific background to insure their safe handling and use. It is also necessary to know what use will be made of the radioisotopes. These requirements are set forth in the Atomic Energy Act. The Atomic Energy Commission and its advisers have given these directives as liberal interpretations as was deemed feasible. The Commission has, for instance, adopted the philosophy that it is better to expend effort and money on educating isotope users in proper techniques than on attempting to police the health-safety aspects of isotope work. Although the policies may lean toward the conservative side, they have paid dividends in health safety. In more than three years of isotope distribution no case has been noted of injury to an individual using or handling radioisotopes.

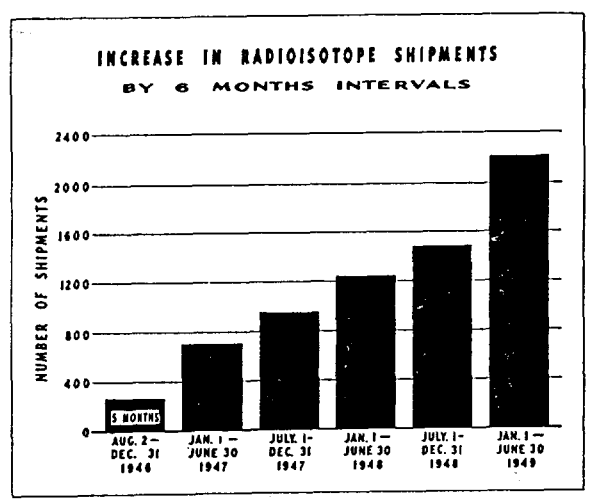

FIGURE 1.

The isotope user is allowed to obtain safety equipment of his own choice and to design laboratory facilities that best suit his own needs. The requirement that the applicant indicate his proposed use of the material is primarily a safety measure. He is only required to show that proper use of the material will be made in a manner that is both feasible and safe. This assures maximum safety to both the investigator and all others likely to be exposed to the radiation. Disclosures of usage which the applicant desires to keep confidential are closely confined within the Commission. It is required, however, in the interests of accelerating

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the peacetime applications of atomic energy, that the user agree to publish the results of his use of isotopes within a reasonable time. The user is nevertheless at liberty to obtain patent rights in the usual manner to inventions resulting from his use of isotopes.

Production improvements. When the program first started, requests for isotopic materials warranted the immediate production of a wide variety of radioisotopes. The task of preparing approximately one hundred different varieties of radioisotopes made it necessary to limit their availability to the simplest and most generally adaptable chemical forms. But by placing the emphasis here, it was possible to make these "basic products" available cheaply and on a large scale. At first, production was limited because of the many new problems to be overcome. During the war the reactor laboratories were chiefly concerned with problems related to plutonium production. Little work had been done on developing production processes for those radioisotopes that would be most in demand for research, especially for use in biology and medicine. Initially, therefore, distribution of certain items had to be governed by a priority system outlined in the Atomic Energy Act. This provides that first priority be given to uses in fundamental research and medical therapy. In the past two years, however, the chief center of radioisotope production, the Oak Ridge National Laboratory, which is operated for the Commission by the Carbide and Carbon Chemicals Corporation, has markedly increased total production. Priority distribution is no longer necessary.

Improvements in quality production have also taken place as the program has grown. Considerable improvement has been made in the chemical processing procedures for separating radioisotopes which have been prepared by transmutation from the original target material. In this particular type of nuclear reaction the stable isotope of one element is converted into a radioactive form of another element, and the radioactive atoms may then be chemically separated from the stable atoms. Investigators receiving shipments of such separated radioisotopes can now be reasonably assured that the material will meet specifications of greater than 99 percent radiochemical purity. Although the production operators do not guarantee chemical and radiochemical purity, every effort is made to produce as high-quality material as possible. A continued effort has also been made to improve chemical specifications and the reliability of chemical analyses.

In at least one instance, quality improvement has been effected by entirely changing the method of production. Only within the past year has radioactive iodine 131 been extracted routinely as one of the products of uranium fission. Prior to that time this isotope was prepared by subjecting tellurium to neutron bombardment. The new production method not only gives better yields and permits the preparation of much greater quantities, but also guarantees higher quality. The chemical impurities in the stable tellurium are no longer a source of chemical contamination of the end product. More recently, the method of producing radioactive carbon 14 has been slightly altered. Although preparation is still based on the transmutation of stable nitrogen, the target material has been changed from calcium nitrate to beryllium nitride. This particular change has been made primarily in an effort to increase efficiency of production; the higher concentration of nitrogen in the nitride permits a better yield and a higher-activity product.

Closely associated with quality improvements are the advances that have been made in increasing the amount of radioactivity in the final product. Improvements in health-safety features of the production facilities now make it possible to prepare, handle, and ship much larger quantities of activity in a single radioisotope shipment. This is an important feature to investigators requiring larger quantities of activity either for large-scale tracer experiments or for high-intensity radiation sources.

Even more important than increased total activity is the recently announced availability of materials with increased specific activities, that is, with greater activity per unit weight of the element. Any radioisotope having a half life greater than sixty days can be appreciably increased in specific activity through extended time of irradiation in the nuclear reactor. Twenty radioisotopes with increased specific activities are now available. These include radioactive tantalum, whose specific activity has been increased from 105 millicuries to 1,000–3,000 millicuries per gram of tantalum; radioactive calcium 45, increased from 0.3 millicurie to 5–10 millicuries per gram; and radioactive cobalt 60, increased from 30 millicuries to 2,000–3,000 millicuries per gram. For radiocobalt, which has been suggested as a substitute for radium in certain applications in medical therapy and industrial radiography, the new material has a gamma ray output per unit weight approximately three times that of radium.

Continued improvements in the availability of the basic isotopic materials can be expected as a

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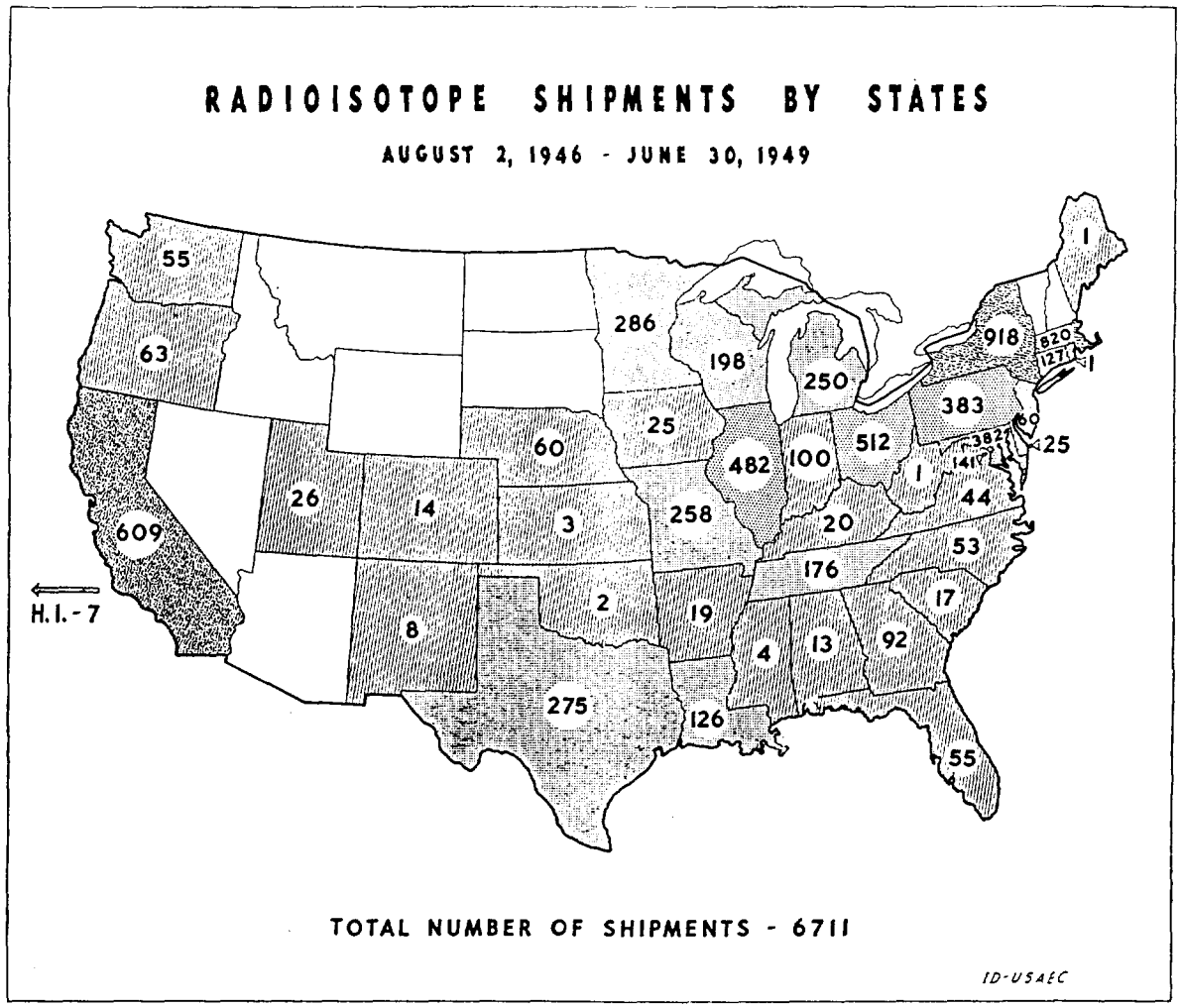

FIGURE 2.

result of recently improved facilities. Until quite recently almost all the radioisotopes made available through the distribution program had to be prepared and processed in temporary facilities originally built as a pilot-plant for plutonium production units at Hanford, Washington. The Commission has just completed, at the Oak Ridge National Laboratory, a new building for chemical processing of radioisotopes at a cost of almost $2,000,000. With these new facilities it is expected that much improvement will be made in production, processing, and shipping methods.

Improvements have likewise been made in the availability of concentrated stable isotopes as the distribution program has expanded. During the past year helium 3, boron 10 in elemental form, boron 11 in compound form, and 21 electromagnetically concentrated isotopes of sulfur, barium, cerium, tungsten, and mercury have been added to the list of more than 110 stable isotopes formerly available. Workers associated with the electromagnetic separation program will continue to build up a reserve, or "bank," of a wide variety of concentrated stable isotopes from which samples may be withdrawn and loaned as required for research purposes.

Cyclotron-produced isotopes. To extend further the availability of useful isotopes the Commission announced in June of this year that it would also make available certain long-lived radiomaterials which cannot be produced in a nuclear reactor but must be made in a cyclotron. To assist in this phase of the program, arrangements have been made with cyclotron laboratories of Massachusetts Institute of Technology, the University of Pittsburgh, the University of California, and Washington University. Target materials will be bombarded at these locations and then forwarded to

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the Oak Ridge National Laboratory for chemical extraction and distribution of the desired isotope to the users.

The cyclotron is the only source of at least 10

Preparation of isotope-labeled compounds is an activity which has been largely left to the resources of individual investigators and private enterprise. At present three private laboratories—Tracerlab,

mals and plants and to extract the labeled materials. Compounds scheduled for synthesis under this program include such materials as glucose, fructose, ascorbic acid, nicotine, opium, and morphine.

Results of use. Indication of the wide usefulness of isotopes is evidenced by the rapid expansion in isotope distribution. Figure 1, for example, shows that the number of isotope shipments made during the first six months of this year was nearly double that for the same period last year and more than triple the 1947 figure. An illustration of overall distribution within the United States is given in Figure 2. Further evidence and a more objective criterion of the value of isotopes are to be found in the nearly 1,900 publications that have already resulted from Commission-produced isotopes. These publications are listed in the report *Isotopes—A Three Year Summary of United States Distribution,* recently released by the Atomic Energy Commission.* Further illustrations of the many ways in which isotopes have been used are found in the *Fourth* and *Sixth Semiannual Reports of the Atomic Energy Commission* to Congress.* The *Fourth Report,* issued in July 1948, was devoted almost entirely to isotope utilization in peacetime research programs outside Commission laboratories. One of its appendices consists of progress reports from individual research men, in which they outline typical experimental investigations and findings. The *Sixth Report,* issued in July 1949, contains many examples of isotope utilization in biology and medicine.

In 1948 a report on the utilization of isotopes distributed by the Commission could be made only on the basis of individual progress reports. Now that there has been time for many of the investigations to be completed, it is possible to cover the field with a bibliography of published papers.

It would not be possible here to discuss in detail the hundreds of uses of isotopes. A summary of isotope utilization amounts to a representative cross section of all the research and investigation in the wide variety of fields in which isotopes are used. In view of the diverse interests of the readers of this journal, it seems desirable to present at least a brief summary of some of the major uses of isotopes.

Use in biology and medicine. In biology isotopes have been used to label and study a large number of body constituents and related substances. Materials which have been labeled and traced through complex body processes include phospholipids, sugars, proteins, nucleic acids, vitamins, hormones, antibodies, amino acids, drugs, dyes, organic acids, blood cells, and others. Isotopes have been used to develop an entirely new technique for studying metabolism and the synthesis, transport, utilization, and breakdown of various body compounds.

To date only a limited number of applications have been found for radioisotopes in medical diagnosis and therapy. Unfortunately, publicity in regard to such applications has usually surpassed actual achievements, especially in the diagnosis and treatment of cancer. Certain diagnostic applications have, however, proved valuable; for example, the use of radiosodium for the differentiation of normal and restricted blood flow and for radiocardiography; radiophosphorus for determining the exact extent of a tumor mass during brain surgery; and radioiodine for preoperative location of certain brain tumors, for detecting disorders of thyroid gland function, and for locating thyroid cancer metastases. Diagnostic uses of radioisotopes are expected to increase, however, for two reasons: only small nonhazardous quantities of radioactivity are usually required, and an increasingly larger number of isotope-labeled compounds will become available. The manner in which some of these compounds are selectively absorbed by certain tissues, or are differentially metabolized, will no doubt prove to be of diagnostic value.

In medical therapy, radioisotopes have proved useful in relieving, though not curing, a limited number of disorders. Radiophosphorus has been used for treating polycythemia vera and chronic leukemia; radioiodine for treating hyperthyroid-

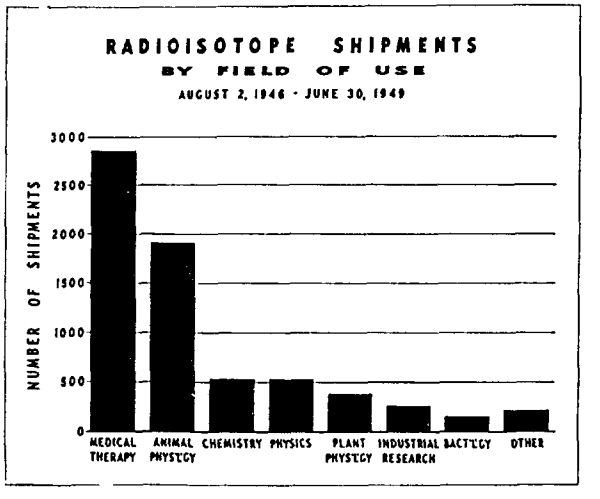

FIGURE 3.

* These publications may be obtained from the Superintendent of Documents, Government Printing Office, Washington 25, D. C.

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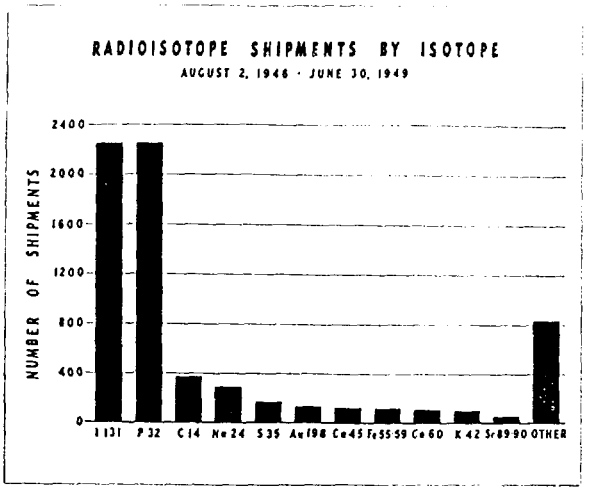

FIGURE 4.

ism and thyroid cancer metastases; radiogold for treating subsurface tumors of the lymphoid system and chronic leukemia; and radiocobalt as an interstitial source for treating accessible tumors. Also, very intense radiocobalt sources now available, equivalent in gamma ray output to over a pound of radium, should be valuable as teletherapy sources for treating deep-seated tumors.

It is possible also that isotope-labeled compounds may be used to a considerable extent to deliver radioisotopes and their accompanying ionizing radiation to specific tissues or organs. The use of such compounds will be limited to those into which the desired radioisotope can be incorporated and which will be selectively absorbed by the specific tissue or organ. Because of the much larger quantities of radioactivity needed in treatment, and the necessity for keeping total body irradiation at a minimum value, high selective absorption of the active material will be required.

As shown in Figure 3, a larger number of radioisotope shipments have been made for use in medical therapy (including diagnosis) than in any other field. The number of different projects utilizing radioisotopes in this field, however, is not as large as in some of the other fields. This is explained by the fact that the two isotopes most frequently used in medicine, radiophosphorus and radioiodine, have comparatively short half lives, and therefore several shipments may be made to complete a single investigation or case. A comparison of the number of radiophosphorus and radioiodine shipments with shipments of other radioisotopes is shown in Figure 4.

The potentialities of radioisotopes, together with their greatly increased availability, have stimulated an increasing interest in developing uses of these materials for the study, detection, and treatment of cancer. Because of this widespread interest, the Commission in April 1948 initiated a program for making available radiosodium, radiophosphorus, and radioiodine free of production costs to investigators proposing to use the materials in the study, diagnosis, or treatment of cancer and allied diseases. On February 25, 1949, this program was supplemented by making available free of production costs for use in cancer research all radioisotopes normally distributed from commission facilities. This phase of the distribution program has accounted for 2,059 shipments of isotopes of approximately 10 elements. Over 90 percent of these shipments have been of either radiophosphorus or radioiodine.

Use in plant physiology and agriculture. Isotope applications made thus far in the field of plant physiology fall largely into one of two categories, studies of photosynthesis and studies of phosphate fertilizer utilization. The first is a fundamental investigation into the mechanism of the process by which green plants, with the aid of sunlight, are able to convert water and carbon dioxide into complex sugars and other compounds. With radioactive carbon as a tracer, investigators have tried to determine the rate at which the process takes place and to identify the intermediate compounds formed. Although investigations are still incomplete, the tracer technique has enabled workers to identify some of the intermediates. Five compounds have been identified as having been formed within five seconds, and it also has been found that within ninety seconds at least 15 compounds are produced, including simple sugars containing 6 carbon atoms.

The studies on phosphate fertilizer uptake by various crops under different conditions of soil and climate are mostly being conducted by the United States Department of Agriculture in collaboration with state agricultural experiment stations. During the past growing season extensive field tests, using several different phosphate fertilizers labeled with radioactive phosphorus, have been carried out in more than 12 states on such crops as corn, potatoes, tobacco, sugar beets, alfalfa, oats, clover, rye grass, cotton, and peanuts.

Nutritional requirements and metabolism in plants of such elements as calcium, zinc, rubidium, and iron have also been studied with radiotracers. Metabolic disorders such as chlorosis and those caused by the parasitic action of fungi are readily studied by the tracer technique. Radioisotopes have also been used to study the action of plant growth regulators and the effects of radiation on plants.

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Also of agricultural interest are radioisotope tracer studies in the field of animal husbandry. The tracer technique has proved to be particularly valuable in metabolism studies concerned with mineral requirements and nutritional deficiencies. Tracers have also been used in applied problems of entomology and pest control.

Use in physics and chemistry. Isotope applications in chemistry, like those in physics, are primarily of a fundamental nature. Tracer techniques have been used to study the mechanism and kinetics of exchange reactions, diffusion coefficients, oxidation, crystallization, and solubility. Chemists have also used tracers to determine the mechanism of many organic and biochemical reactions.

Physicists have used radioisotopes for studying nuclear characteristics such as disintegration schemes, the absolute energies of both beta and gamma radiation, beta ray spectra, nuclear spins, magnetic moments, and radiation absorption coefficients. They have also used radiomaterials to study and improve methods of radiation detection and dosimetry measurement.

Isotope studies in both chemistry and physics will undoubtedly have considerable influence on the scope and ultimate usefulness of isotopes in other fields of research. In physics, for instance, new knowledge of atomic nuclei is not only essential to the advance of atomic science, but also basic to the utilization of isotopes in all fields of research.

Use in industry. Industry's use of isotopes has to date been limited mainly because of a lack of the necessary facilities and specially trained personnel in industrial laboratories. Nearly fifty industrial research laboratories, however, have initiated radioisotope research.

Tracer isotopes have, for instance, been used in studying the polymerization and vulcanization of rubber, the dehydrogenation and aromatization of petroleum, and the mechanism and catalysis of reactions such as those involved in the production of synthetic gasoline. Metallurgists have made extensive use of radioisotopes in studying steelmaking reactions such as determining the mechanism and kinetics of slag-metal reactions, oxidation and crystallization, the molecular constitution of slag and metal baths, the diffusion coefficients of metals, the metallurgical activity of one element as influenced by the presence of other elements, and the concentration gradients in solid solutions. One of the most straightforward industrial investigations with radioisotopes has been the study of lubrication and wear phenomena associated with friction.

Several applications of the "gadget" or control type, such as radioactive thickness and height gauges, have been developed where the radiomaterial is used only as a source of ionizing radiation. Radioactive thickness gauges have been devised for the automatic gauging of paper, rubber, plastic, glass, and steel sheets and are already available on the commercial market from two different sources.

International distribution. The international distribution of radioisotopes by the United States is in keeping with the traditions of science. It also stems from the realization that, to assist other nations to help themselves attain better standards of health and living, they must be assisted in developing a vigorous activity in basic and applied science. Further, it must be recalled that in all fields American scientists are greatly indebted to the scientific achievements of scientists in other countries. In the basic discoveries of atomic energy this indebtedness is especially great. It is even more pronounced in the fields of radioactivity, nuclear transmutation, and isotope tracer techniques, wherein most of the "firsts" took place abroad.

Since radioisotopes are direct by-products of atomic energy, some concern might arise over the security aspects of their international distribution. Before distribution was undertaken, however, all conceivable security problems were given thorough and lengthy consideration by the Atomic Energy Commission and its advisory groups. The fact that radioisotopes were released for distribution in the United States without security restrictions, actually with the requirement to publish results, indicates that security is not a significant factor in their utilization.

Radioactive materials available for export are limited to 20 radioisotopes, selected because of their primary value for medical and biological applications. The radioisotopes are furnished only for fundamental scientific investigations and for medical research and therapy. All isotopes distributed —in fact, all radioisotopes—can be made with a cyclotron. Inasmuch as the major countries of Europe and some minor countries possess cyclotrons, radioisotopes are already available abroad. In fact, most of the requests received from abroad have been from groups who have previously used cyclotron-produced isotopes. The supplying of reactor-produced isotopes permits use by the many countries not possessing cyclotrons and makes possible use of the much larger quantities required for many medical and biological purposes.

Each country receiving isotopes agrees to re-

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port semiannually to the U. S. Atomic Energy Commission on the progress of research done with the materials. In addition, each country agrees to permit qualified scientists, irrespective of nationality, to visit those laboratories where isotopes are being used. To date the following countries have made formal arrangements through diplomatic channels to the Department of State and have received radioisotope shipments: Argentina, Australia, Belgium, Brazil, Canada, Colombia, Denmark, Finland, France, Iceland, Italy, Netherlands, New Zealand, Norway, Peru, Spain, Sweden, Switzerland, Turkey, Union of South Africa, and the United Kingdom (Fig. 5). In addition, the following eight countries have completed the necessary arrangements, but have not placed orders: Chile, Cuba, Guatemala, India, Ireland, Lebanon, Mexico, and Uruguay. In the 22 recipient countries, the materials have been used in 150 institutions, many of which are world-renowned in the fields of research, education, and medicine. The impressive list of recipient institutions is published in the report *Isotopes—A Three Year Summary of United States Distribution*, referred to earlier.

It is expected that results obtained from foreign studies will provide valuable supplementary information to findings in the United States. For example, U. S. scientists investigating the possibility of using radioactive cobalt 60 as a substitute for radium in medical therapy have used the materials as interstitial needles and as teletherapy units. In Switzerland an investigator is making an entirely different approach. He first introduces a small rubber balloon by means of a catheter into the cavitary organ to be irradiated. The balloon is then filled *in situ* with the radioactive cobalt in solution. Upon completion of this work the advantages or disadvantages of the technique employed may be weighed against techniques being used in this country.

In Nigeria, British West Africa, radiostrontium has been used to tag the mosquitoes that are

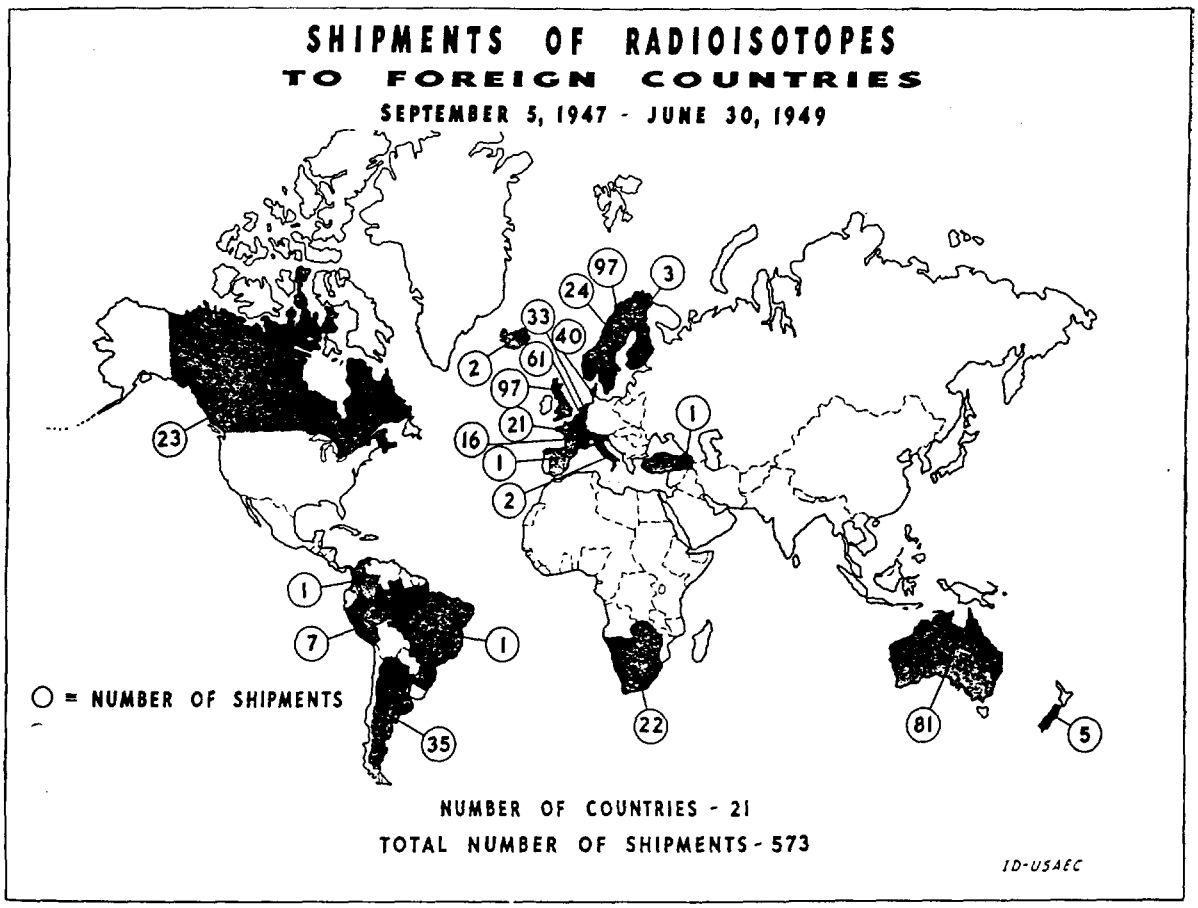

FIGURE 5.

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carriers of yellow fever. The tagged mosquitoes are then used in studies designed to permit an estimation of the spread of yellow fever from a source of infection. In Australia, radiocobalt, radioiron, and radiozinc are being used to study the parasitic action of mistletoe on eucalyptus trees. Although the spread of yellow fever and the growth of eucalyptus trees are not serious problems in this country, the techniques used and the results obtained will certainly give valuable information to U. S. investigators using radiotracers in allied problems.

Compliance with the terms for obtaining isotopes has been excellent. Progress reports are submitted regularly, and the laboratories receive foreign visitors, including many from the United States. Good will and understanding have been evidenced by all foreign representatives dealt with in carrying out the program, and great appreciation has been shown by scientists and medical men who receive the isotopes. Although it is too early to expect extensive publication arising from the isotopes distributed, the results already reported are of high caliber and indicate that much value is certain to come from the researches conducted abroad.

Conclusions. The rapid growth in the isotopes distribution program may be attributed to a number of factors, including: (1) wider appreciation of the number and variety of potential isotope applications; (2) increased availability of isotopes and isotope-labeled compounds; (3) increased numbers of persons trained to handle and use radioactive materials; and (4) the AEC-sponsored program for supplying radioisotopes free of production costs for cancer research.

On the same bases, isotope utilization can be expected to increase in the future. A steady increase is expected as a result of both new types of research applications and new groups undertaking research with isotopes. A marked acceleration may take place if new wide-scale applications are developed for use in medical practice or industry. Future isotope utilization will also depend on the participation by private industry in various phases of the distribution program, for it is expected that the areas in which private enterprise can make valuable contributions will further expand.

The Commission will continue to encourage wider use of isotopes through its policies of extending the availability and usefulness of isotopes and isotopic materials, supporting educational programs in isotope techniques, and making available information on the feasibility and health-safety aspects of isotope utilization.

As tools of science and technology, isotopes will take their place with other long-established scientific instruments, and there should be no end to their growth in usefulness.

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