UNITED STATES ATOMIC ENERGY COMMISSION

# FOURTH SEMIANNUAL REPORT

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# LETTER OF SUBMITTAL

The honorable the PRESIDENT PRO TEMPORE OF THE SENATE OF THE UNITED STATES:

The honorable the SPEAKER OF THE HOUSE OF REPRESENTATIVES OF THE UNITED STATES:

SIRS: We have the honor to submit herewith the Fourth Semiannual Report of the United States Atomic Energy Commission, as required by the Atomic Energy Act of 1946.

Progress in atomic science and technology—which it is the purpose of the Commission to advance and to foster—brings with it many new and difficult questions of public policy for the consideration of the American Congress and the people as a whole. The intelligent and democratic consideration of these increasingly important policy questions requires that the Congress and the public be well informed concerning the Nation's extensive atomic energy enterprise, subject only to the prudent safeguarding of areas of information affecting the security of the Nation.

The extensive and detailed character of this report is one manifestation of this Commission's purpose to seek to further public knowledge about this enterprise, owned as it is by the people and so profoundly affecting their present and future security and well-being.

Respectfully,

UNITED STATES ATOMIC ENERGY COMMISSION.
ROBERT F. BACHER
SUMNER T. PIKE
LEWIS L. STRAUSS
WILLIAM W. WAYMACK
DAVID E. LILIENTHAL, *Chairman*

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# FOREWORD

In order to make its semiannual reports of maximum value to the Members of the Congress, the Commission has prepared this mid-year report as a specialized document giving a comprehensive account of several major phases of the atomic energy program. The complete and detailed record of this year's work will be contained in the January report.

The present report is given over largely to a résumé of the work being done with isotopes produced at Oak Ridge, Tennessee. Some of the work is being carried on in the research laboratories of the Commission, but the great bulk of it is being done in scores of medical, biological, agricultural, and industrial research centers, as well as in hospitals and in manufacturing plants. Attention is invited to the appendices of this report dealing with the work of the users of radioactive materials, who day by day are putting atomic energy at the service of man.

Of special importance, of course, is the publishable information dealing with Operation SANDSTONE, under which code name a program of tests of atomic weapons and observations of nuclear phenomena was carried out during the spring of this year. This project and certain other important phases of the atomic energy program are covered in the current report.

There is included in this report a statement to the Commission from the General Advisory Committee evaluating the prospects for useful power from nuclear fuels.

There are a number of important phases of the subjects covered by this report which for reasons of national security cannot be presented in a public report of this character. These are discussed with the Joint Committee on Atomic Energy which was authorized by the Congress to receive information on all activities of the Commission, and with appropriate advisory committees comprised of specially qualified individuals, such committees being authorized by the Atomic Energy Act of 1946.

The Commission's major responsibility in terms of plant investment, operating costs, and direct contribution to national defense, is in the production of fissionable materials, the development of reactors, and the development and manufacture of weapons. Radioactive materials distributed by the Commission are byproducts of these activities. They are of such far-reaching importance to the health, industry, agriculture, and welfare of the nation that the Commission is devoting the major portion of this report to the work being done by nongovernmental agencies with isotopes supplied by the Commission.

# FOURTH SEMIANNUAL REPORT TO THE CONGRESS BY THE UNITED STATES ATOMIC ENERGY COMMISSION

## I. PROVING GROUND OPERATIONS

On May 17, 1948, President Truman announced that three atomic weapons of new and improved design had been tested at the AEC Proving Ground on Eniwetok Atoll in the Marshall Islands. The announcement marked the completion of the first series of tests at the proving ground, which is being conditioned and placed in standby status for further use.

In its Second Semiannual Report to the Congress, transmitted July 22, 1947, the Commission stated that it was establishing proving grounds in the Pacific for routine experiments and tests of atomic weapons. In the Third Semiannual Report submitted in January of 1948, the Commission stated that its goal in the field of weapons development was the scientific and engineering perfection of improved designs, and that thorough testing of weapons and components is necessary to the attainment of this objective.

In any program designed to accomplish the effective development and production of weapons, the need for proof testing or the conduct of full scale experiments is a natural requirement. Failure to test developments would soon throttle the design of improved weapons. America's pre-eminence in the field of atomic weapons is not static. It depends upon achievement fully proved through tests and upon the observation by scientists of nuclear phenomena that can only adequately be studied by actual full scale test operations.

During the period of wartime development of atomic energy the one goal relentlessly pursued was the creation of an atomic bomb which would work—and work in time to be effective during World War II. It had only to work, it did not need to be too efficient; and the related problems of engineering and production were dealt with accordingly during the emergency of war.

The bomb did work. It worked during the war and also a year later at Bikini. But all of these weapons as far as their state of development was concerned were almost on a par. They were the wartime weapon—designed under extreme pressure and without regard for many problems which in the long run are of very great importance in the application of atomic energy.

With these considerations in mind, the Commission undertook the development of plans for the conduct of true field laboratory tests designed to determine whether the new designs under development by the Commission would work and to determine their efficiency and from the knowledge thus gained to proceed as rapidly as possible to further advances in design.

Initial planning for the tests began in the spring of 1947, when the necessity for such tests was apparent to the Los Alamos Scientific

Laboratory of the Commission. The Commission and its General Advisory Committee and a majority of the Military Liaison Committee approved the test recommendations. The President authorized the tests. Thereupon a site was selected, and the Commission asked the National Military Establishment to prepare the proving ground and to provide necessary logistic support. A number of agencies of the Military Establishment were also asked to participate in the operations, and to supply technical and other personnel. Among these were the Armed Forces Special Weapons Project, the Naval Research Laboratory, the Naval Ordnance Laboratory, the Army's Aberdeen Proving Ground, and the Navy's David Taylor Model Basin.

Through the cooperation of the Secretary of Defense, Joint Task Force Seven was created on October 18, 1947, for the purpose of readying the proving ground and aiding the AEC in certain of the scientific, technical, and administrative phases of the test program.

Joint Task Force Seven was an integrated effort on the part of the AEC, the Armed Forces, civilian scientists, and other specialized civilian elements. The Commission particularly desires to make known to the Congress the outstanding manner of performance of the Task Force organization. As the agency charged with responsibility for the proof-testing of weapons, the Commission was eminently satisfied with the conduct of the proving ground operations and was impressed with the efficiency of the combined Army-Navy-Air-AEC organization directed by Lieut. General John E. Hull, U. S. Army, Commander of the Task Force. In a public statement on the tests, given at a press conference at Fort Shafter, General Hull said, in part:

> "As a military organization, Joint Task Force Seven is unique. It was organized along the lines of our best wartime experience, but there was an additional element. As a part of the organization we had a Task Group which was essentially civilian in makeup. This was the Scientific Group, which conducted the actual tests and which recorded and is still analyzing the results. Captain James S. Russell, U. S. Navy, who is Deputy Director of the Division of Military Application of the AEC, headed this Task Group as Test Director, and Doctor Darol K. Froman, as Scientific Director for the Proving Ground, headed the Task Unit of scientists within the Task Group. Through Captain Russell, the scientific unit operated technically under the AEC. This Task Group, by common consent, did not work through my staff. The channels between Captain Russell, Dr. Froman, and myself were direct. Dr. Alvin C. Graves served as Deputy Director to Dr. Froman, and Mr. Robert W. Henderson and Dr. John C. Clark were Assistant Scientific Directors—all from the Los Alamos Laboratory.
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> "The operation of Joint Task Force Seven, thus organized, was the ultimate in integrated effort. . . . It is a tribute to the scientists who were members of the Task Force that the Operation was successful. . . . Much credit for this accomplishment is due Dr. Froman. . . .
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> "All of us have been equally impressed with the scientific competence, the technical skill, and the sound judgment of the civilian scientists and technicians assembled for these tests. Our close association has been valuable in many respects and, I am sure,

paves the way for a continuing and increasing cooperative effort to insure the common defense and security of the people of the United States.

"The military staff of Joint Task Force Seven included Rear Admiral William S. Parsons, USN, and Major General William E. Kepner, USAF, as Deputy Commanders. . . . Brigadier General Claude B. Ferenbaugh was Chief of Staff.

"Naval units of the Joint Task Force were commanded by Rear Admiral Francis E. Denebrink. Brigadier General David A. D. Ogden, USA, commanded Army units of the Task Force, and Major General Roger M. Ramey, USAF, was in command of Air Force units under the over-all direction of General Kepner.

"The major portion of the Joint Task Force sailed from Pearl Harbor on 8 March in ships of the Naval Task Group. Flagship of the force was the command ship USS MOUNT McKINLEY, veteran of the Pacific war and of the Bikini atomic tests. The four ships of the convoy had aboard the principal participants, both scientific and military. Construction of the proving ground had been commenced in late December 1947 by General Ogden's Army units, in accordance with plans developed in coordination with the Scientific Group. Some of our construction was performed by civilian contract.

"One of the most extensive construction projects was that of signal communication. . . . Nearly 1,000,000 feet of submarine cable was laid under direction of the U. S. Coast Guard.

"Within the Task Force in addition to the Scientific personnel . . . we had engaged at different periods during the preparation for and conduct of the tests personnel from the Army, Navy, including Marines, Air Force, Coast Guard, Public Health Service, Coast and Geodetic Survey, civilian employees from the different Services, and civilians working under contract. . . .

"During the period of construction and preparation for the tests some 50,000 measurement tons of material, supplies, and equipment were shipped from the mainland and from Oahu to the test area. . . .

"The over-all strength of the Joint Task Force was approximately 9,800 including civilian personnel.

"Observers of the tests were limited in the extreme, since it was the view of all agencies that only those who had actual need for the knowledge should attend. These observers included members of the Joint Congressional Committee for Atomic Energy and its staff, the AEC, and the Armed Forces. No other observers were permitted.

"To sum up, aside from the value of the tests themselves, the operation was one of great profit to the Armed Forces. Valuable training in joint operations was gained. . . . Such experience is invaluable in fostering integration within the Services."

The tests were carried out during the months of April and May of this year and involved three nuclear explosions carried out under conditions as close to laboratory control as possible, and with very extensive instrumentation.

Technical and experimental work was primarily designed to obtain answers to specific questions arising in connection with the instantaneous release of nuclear energy for its explosive effect. Subsidiary to the scientific aspects, there was a second group of observations carried out by several agencies of the Armed Forces, designed to fill in the gaps in the knowledge sought at Bikini with respect to the effects of atomic explosions on matériel and equipment.

It should be pointed out that investigative emphasis at Eniwetok was placed on the scientific aspects because new designs of weapons were being tested, whereas at Bikini the principal emphasis was placed on measurement of the effects of the nuclear explosion, rather than on the generation of nuclear explosion itself.

Much of the technical data recorded at Eniwetok is, of course, still being analyzed and evaluated. The results are generally clear, however, and the tests proved not only the effectiveness of the new designs of weapons but confirmed a great deal of the theoretical and experimental work performed at the Los Alamos Scientific Laboratory since the war. The experimental data gained at Eniwetok is important to future research and development, both for weapons and for non-military areas of knowledge and application.

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The Atomic Energy Commission, mindful of the Congressional direction that its paramount objective shall be to assure the common defense and security, reports to the Congress as follows:

> Operation SANDSTONE confirms the fact that the position of the United States in the field of atomic weapons has been substantially improved.

# II. ISOTOPES*

## INTRODUCTION

Isotopes for scientific, medical, agricultural, and industrial use constitute the first great contribution of the development of atomic energy to peacetime welfare. Industrial power from nuclear energy may be a decade or longer in the future (see discussion, page 43), and most other applications are still largely speculative. But isotopes produced in the Nation's atomic energy establishment at Oak Ridge, Tennessee, are already at work in more than 300 laboratories and hospitals in this country and abroad, adding to man's store of knowledge about himself and the world around him.

Isotopes assist science in two ways: as *sources of radiation* for many potentially important uses including the treatment of disease and as "*tracers*" of processes formerly difficult or impossible to observe. As tracers, they are proving themselves the most useful new research tool since the invention of the microscope in the 17th Century; in fact, they represent that rarest of all scientific advances, a new mode of perception.

Man's conquest of nature has generally followed the pattern of (*a*) observation, (*b*) understanding, and (*c*) control. The microscope and the X-ray machine have brought into view the cells and organs of living bodies, the molecules and crystalline structure of matter. But until recently man's vision has not penetrated into the details of growth and change in the living cell or the intricate chemistry of the molecule.

Now, using tracer isotopes, the scientist and engineer can observe atoms as they take part in basic organic and inorganic reactions, much as though the atoms were visibly tagged or labeled. For the first time, it becomes possible to follow in intimate detail nature's fundamental processes—such processes as:

*Photosynthesis*, in which green plants use energy from the sun to form sugar, starch, cellulose, and other energy-containing carbon compounds used by man;

*Metabolism*, in which some of these carbon compounds, taken into the body as food, give the sun's energy to the living cell;

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*There are differing kinds of atoms called *isotopes* in nearly all of the chemical elements (hydrogen, oxygen, carbon, iron, copper, etc.). The atoms of any chemical element are all alike in their chemical behavior—*the way they combine to make all material things*. Most elements, however, have atoms that are not alike in their nuclear properties. For example, every copper atom has 29 electrons whirling about its nucleus, and it is this number (the *atomic number*) that makes copper behave the way it does chemically. But the nucleus of some atoms of copper contains a total of 63 particles (29 protons and 34 neutrons), while the nucleus of other atoms of copper contains 65 particles (29 protons and 36 neutrons). Since these two kinds of copper atoms have different numbers of neutrons in their nuclei, they have different *atomic weights*. They are the two natural or "stable" isotopes of the element copper.

Copper atoms can be made, in nuclear reactors and in cyclotrons, which have nuclei containing some other number of neutrons than 34 or 36. These artificial nuclei are unstable. Any one of them sooner or later converts itself into a stable nucleus by giving off particles and energy rays. These artificial "unstable" copper atoms are called the *radioisotopes* of copper. The radiations from the radioisotopes of the various elements are all different, but they all are able to penetrate solid matter to a greater or less degree.

*The chemistry of hydrocarbons*, in which other carbon compounds—coal, oil, gas—that provide man with industrial fuel energy are processed into gasoline and other materials that serve his purposes.

New as it is, tracer research has already broadened our understanding of these and many other fundamental processes of nature. Already, medical men are profiting from a better understanding of the working of the human body. For the future, it is difficult to forecast the gains that isotopes will bring. They will speed the battle against disease. They will help man to make more efficient use of nature's materials, to grow more food, to produce better manufactured goods—in short, to adapt his environment to his needs.

## ISOTOPES IN RESEARCH

All told, the 96 known chemical elements have more than 800 isotopes, stable and radioactive. Carbon, for example, has five isotopes; that is to say, there are five different kinds of carbon atoms all chemically the same because their nuclei carry the same electrical charge. Where they differ is in their weight. The five kinds of carbon atoms weigh approximately 10, 11, 12, 13, and 14 times as much as the fundamental hydrogen nucleus. The variation in the numbers of neutrons in their nuclei, which causes these weight differences, is also responsible for differences in stability. Two of the carbon isotopes are natural and "stable", three are man-made and "radioactive".

### *Stable Isotopes*

The two natural isotopes occurring in ordinary carbon are carbon 12 and carbon 13 ("C 12" and "C 13"). Of each 100 carbon atoms found in nature, 99 will be C 12 and one will be C 13. This is true whether you find the carbon in the starch in a potato, the glycogen in the liver, or the coal underground; in the graphite in a pencil, the steel in a knife blade, or the diamond in a jeweler's window.

During the 1930s, physicists succeeded in processing a few of the lighter elements so as to "enrich" them in their rarer isotopes. They produced carbon, for example, that contained 20 percent and more of C 13, which was consequently slightly heavier than natural carbon, although chemically the same.

The physicist's success in producing "heavy hydrogen", "heavy oxygen", "heavy nitrogen", and "heavy carbon" was welcomed by the biologist. All of these elements enter importantly into life processes. Carbon compounds, for example, not only provide animals with energy but also enter into flesh, and blood and bone.

Yet investigators had always been baffled by such a basic problem as finding out how much of a given batch of carbon atoms taken into a living body went into fat, starch, protein, or intermediary compounds and how much went to build bone, flesh, or blood. By chemical analysis they could extract, purify, and weigh the quantities of carbon in a dissected rat, but all carbon was chemically alike, so the biologists could not say that this or that portion of the carbon had come from any particular batch of food. In other words, before tracers were available, the biologist found it impossible to observe and understand in detail how carbon or other food elements are used by the body.

Given carbon, however, that was enriched in C 13, he could perform a tracer experiment. Feeding to a rat a sample of sugar made with this heavy carbon, which behaves in the body exactly like any other carbon, he could dissect the rat after a measured interval, extract and purify such samples of carbon as he was able to handle, and learn how much of the sugar "tagged" with C 13 had gone into the make-up of each sample. In many parts of the animal the tagged carbon was too much diluted for analysis, and therefore the picture of its distribution was incomplete. But the availability of the isotope provided what had been totally lacking before: a method of identifying portions of a specific batch of atoms, even after they had gone through chemical changes, and learning something about where and how they had been used by the body at the end of a chosen interval of time.

*Radioactive Isotopes*

Also in the 1930s, while some physicists were learning to separate (or concentrate) the stable isotopes, others discovered how to manufacture radioactive isotopes that do not occur in nature. C 11 and C 14, for example, are man-made carbon atoms which are just as truly carbon in the chemical sense as C 12 and C 13. But the unnatural number of neutrons in their nuclei makes them unstable. They decay into stable elements (C 11 into boron; C 14 into nitrogen) and in so doing send out radiations from their nuclei.

The radioactive isotope puts nuclear energy at the service of the investigator and thus tremendously increases his power of perception. When tagged with C 14 the batch of carbon in the sugar fed to the rat can be detected in the dissected tissues no matter where it occurs in the body or what chemical form it takes. Minute amounts of the tagged carbon reveal their presence to electroscopes or Geiger counters by the radiation signals they emit. In the typical Oak Ridge shipment of C 14—a millicurie*—37 million atoms are distintegrating every second. This amount of C 14 is contained in a mere pinch (one three-hundredth of an ounce) of barium carbonate, the compound in which C 14 is usually supplied to users. Yet, if this quantity were distributed among a million rats, the radioactivity would still be detectable in each. The experimenter therefore may allow for extreme dilution of his tracer material in the processes he studies. In the terms of the scientist the radioisotope offers the same *specificity* as the stable isotope (the means of identifying a specific batch of material); and it adds to this an almost incredible *sensitivity*—a sensitivity millions of times greater than any analytical technique has ever before provided.

Furthermore, some radioisotopes have given the experimenter the additional advantage of *detection at a distance* of his tracer material. In qualitative observations he need not always end the experiment—dissect the rat or cut up the plant—to make his observations. Because many radiations penetrate solid matter to a practical degree, it is possible for the scientist to carry on continuous observation of life processes in plants or animals. Radioactive atoms have been called laboratory "spies," since they accompany groups of natural atoms through long series of chemical and biological adventures and report

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*A *curie* is arbitrarily taken as that amount of a radioactive material that disintegrates at a rate equal to that of one gram of radium, that is, about 37 billion disintegrations per second. A *millicurie* is one-thousandth (.001) of this amount; a *microcurie* is one-millionth (.000001).

all along the way the whereabouts and the size of the groups of which they are a part.

Generally speaking, the signals sent out by radioisotopes can be readily distinguished one from another. The radiation of C 11, for instance, is very penetrating or "hard", that of C 14 very "soft". The intensity of the radiation of a given element, depending upon the rate at which its atoms transform into the stable state, is directly related to its effective life or "half-life"*, to name the unit in which this rate of decay is measured. The half-lives of the elements are determined by their nuclear compositions, and nothing that man does can lengthen or shorten them by as much as an instant. C 11, with its intense radiation, has a 21-minute half-life. This naturally limits its usefulness for most investigations. C 14, on the other hand, has a half-life of 5,100 years. Most half-lives of the radioisotopes lie somewhere between these extremes, although a few, like that of C 10 (nine seconds), are so short as to rule the isotopes out as research tools.

Finally, in addition to *specificity*, *sensitivity*, and *detectability*, radioisotopes offer to scientists today the even greater benefit of unprecedented *availability*. Before the war, cyclotrons produced them in microcurie quantities—invisible to the eye; and some varieties, like C 11, must still be made in particle accelerating machines. But the war-created chain-reacting pile produces C 14 in quantities millions of times greater than had been possible before, and the same is true for most of the important radioisotopes used in research and the treatment of disease.

The scientific and medical work possible with radioisotopes today is limited primarily by the number of trained workers capable of using them.

## PROJECTS WITH ISOTOPES

Recently several hundred of the users of Atomic Energy Commission isotopes reported briefly to the Commission's Isotopes Division on the projects they now have under way. Excerpts from these accounts may be found in Appendix 1. For the most part, the excerpts are in the original wording of the scientists and technicians and are not easy for the layman to understand. However, even a glance through them will give an impression of the scope and variety of the work being done.

Projects with carbon 14 are illustrative. All told, those reporting tell of 72 different uses of carbon 14, which provide a representative sample of the more than 185 projects now under way throughout the world using this isotope.

Some of the reports tell of investigations of various phases of photosynthesis—of attempts to determine, for example, what compounds are first formed by green plants out of sunlight, water, and carbon dioxide; where these compounds are distributed in the plant; how they are built up into the more complex molecules of the food we eat; which plants tend to produce energy-rich compounds in their early stages of growth (a question of practical interest to cattle feeders); and so on.

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*The *half-life* of an isotope is that period in which the radioactivity decreases to one-half of its original value—the period in which one-half of the radioactive atoms will disintegrate. In the next similar period, one-half the remainder of the unstable atoms will disintegrate, leaving one-fourth. In a period equal to three times the half-life, the remaining radioactivity will be one-half times one-half times one-half, or one-eighth.

At least 40 of the reports recount studies of the way in which these compounds figure in the metabolism of living bodies. These studies are carried on by labeling with C 14 the sugars, starches, glucose, proteins, vitamins, and other substances eaten by men and animals. Seventeen of the studies are concerned with following the chemical transformations of carbon compounds in industrial processes, such as the "cracking" of petroleum, the processing of metals, and the use of the Fischer-Tropsch process for the manufacture of petroleum out of coal.

*A Thousand Projects*

Carbon 14 is only one of 100 varieties of radioisotopes now being distributed from the Oak Ridge atomic furnace and accounts for less than one out of ten of the total shipments. Many of the others are of equal or greater importance in particular fields—radioactive iodine and phosphorus, for instance, in medical therapy; radioactive phosphorus, calcium, sulfur, and iron in fertilizer studies; and radioactive phosphorus, sulfur, calcium, cobalt, zinc, and iodine in cancer research. All told, more than 1000 different isotope projects are being conducted today, and they deal, in one way or another, with every important aspect of the physical welfare of mankind.

## Production of Isotopes

### RADIOISOTOPES

The artificial production of radioisotopes for scientific use dates back only about 14 years. However, the radioactive elements that occur in nature were used as sources of radiation, and even as tracers, virtually from the time of their discovery during the early years of this century. In fact, Hevesy, the Danish investigator who, in 1912, demonstrated that radium-D was chemically the same as lead (thus helping to prove that isotopes exist) used the radiations of the radium-D lead isotope to learn about the chemical behavior of lead. This was the first tracer experiment.

Most of the naturally occurring radioactive isotopes belong to the heavy elements between thallium (number 81 in the table of the elements) and uranium (number 92). None of these enter much, if at all, into life processes. Therefore, few biological tracer experiments were performed with the natural radioisotopes. In the early years of the century, scientists used them primarily for treating diseases. The main use was of radium and its associated elements.

*Manufacture of Radioisotopes*

The modern era of the utilization of radioistotopes as scientific tools began less than 15 years ago. In 1934 the Joliot-Curies in France discovered that radioactive isotopes of the naturally stable elements could be produced by nuclear bombardment. Within a few years, cyclotrons and other particle accelerators had produced radioisotopes of all of the 83 stable elements. By 1940 some 370 varieties were known.

As soon as radioisotopes of carbon, phosphorus, sulfur, iron, iodine, and other elements entering into life processes became available, medical men and biologists put them to work. With the new tools, they

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went after previously insoluble mysteries of life and death, growth and disease, in plants and animals. It was tremendously costly, in both money and time, to produce isotopes in cyclotrons. But their power as research tools was unique, and the expense was justified by results.

Often only infinitesimal quantities were required. One series of experiments, for example, using radioactive hydrogen (tritium) consumed in a year's time less than a cubic centimeter—less than a thimbleful—of water containing the material, and the tritium in the water was only about one part in a million million.

*Wartime Development*

But the cost and scarcity of isotopes would long have prevented their use in most laboratories had it not been for the wartime development of the nuclear reactor, or atomic pile.

These can manufacture radioisotopes in hitherto undreamed-of quantities. For example, the Oak Ridge pile in a period of a few weeks has produced more than 200 millicuries of carbon 14—millions of times more than the amounts previously available. The operating cost was about ten thousand dollars. Theoretically, it would take one thousand cyclotrons to equal this output, and the operating cost would be well over a hundred million dollars.

The Manhattan Project began development work even before the war ended and in June 1946 announced that pile-produced radioisotopes would be available. The first shipment was made on August 2, 1946, almost exactly a year after the first use of atomic bombs in warfare. At first the radioisotopes were allotted only for research and medical use. Although the pile had sufficient capacity to manufacture isotopes for all purposes, time was needed to develop the strange new processes, skills, and apparatus required for their production.

*Pile Production of Radioisotopes*

Broadly speaking, there are three ways in which neutrons in the pile produce radioisotopes: (1) by splitting atoms of fissionable uranium into new atoms of entirely different elements—fission products, so-called—which are radioactive themselves; (2) by being captured in the nuclei of atoms of special "target material" inserted into the pile, turning them into heavier isotopes of the same element; (3) by altering the electrical charge of the nuclei of atoms of target material, thereby transmuting them into isotopes of a different element.

Uranium fission products removed from the pile contain a great variety of radioactive materials, which—in method (1) above—can be extracted and purified by chemical means. However, the radioisotopes obtained are all those of elements near the center of the atomic scale between zinc (number 30) and gadolinium (number 64). With the exception of iodine 131, these do not now enter significantly into medical, biological, agricultural, or most industrial processes. Therefore, most of the radioisotopes supplied by Oak Ridge must be prepared by methods (2) and (3). These call for the preparation and pile irradiation of special target materials. Phosphorus 32, a widely used radioisotope, can be produced by both methods and may be used to illustrate.

In the production of phosphorus 32 by "neutron capture," method (2), phosphorus 31, contained in phosphate, is put into aluminum cans which are set in holes in a graphite block and pushed into the center of the pile. Each atom of the stable element phosphorus 31 that captures a neutron becomes phosphorus 32. But not enough neutrons are present in "low flux" piles to convert more than a small proportion of the phosphorus atoms to the radioactive state. Hence the phosphorus 32 is still much diluted with phosphorus 31, and the treated phosphate is not highly radioactive.

In practice, therefore, phosphorus 32 is usually produced by method (3), "transmutation." This process starts with a target element different from the element of which an isotope is desired. Sulfur is the target for the production of phosphorus 32. Bombardment by neutrons in the pile changes the electrical charge of the nuclei of some of the sulfur atoms, and thus transmutes them into phosphorus 32. When the sample has been removed from the pile, the radioactive phosphorus can be chemically separated from the target sulfur. Phosphorus 32 in a very pure form, high in radioactivity, can thus be obtained. Unfortunately many important radioisotopes—those of calcium, iron, and zinc, for instance—cannot effectively be made by transmutation. They can be produced only by neutron capture, and this, as stated above, gives a product low in radioactivity. When a pile of higher neutron flux becomes available, it will be possible to produce radioisotopes of greater usefulness for research.

From the preparation of the target material to the final shipment of the product, the production of radioisotopes demands skilled personnel and special equipment. When the pile is shut down for the removal of the irradiated samples, each member of the team of workers must know precisely his assignment in the operation and carry it out quickly and without error. Geiger counters and other radiation detection equipment must be used constantly to check the radiation present. In subsequent chemical treatment of materials, the work must be carried on behind lead shields, the workers using tongs and mirrors to avoid exposure. Many chemical operations are conducted inside a "hot lab," a room with thick concrete walls in which apparatus is manipulated from outside by remote control devices, the chemist viewing his work through periscopes. Each radioisotope, moreover, is a separate production problem, involving its own combination of requirements—for target material, irradiation time, chemical treatment, safety precautions, and the rigid time limits associated with its inflexible half-life.

*Routine Production*

By late 1947, the increased supply of radioisotopes permitted liberal allocations for research in all fields. This present situation is the result of an intensive development effort on the part of the contractors operating the Oak Ridge pile, the Monsanto Chemical Company from mid-1945 and the Carbide and Carbon Chemicals Corporation after January 1948. They have achieved the routine production of the regularly used radioisotopes. The processes of pile irradiation, chemical separation, testing, handling, and shipment have been taken over by trained laboratory workers, leaving the research scientists who developed the procedures free to concentrate on the harder-to-produce isotopes and the other problems associated with wider and safer utilization of radiomaterials.

The routine production of radioisotopes has been made possible by the rigorous training of the laboratory technicians who do the work and by the development of very precise operating procedures and much specialized equipment.

The demand for isotopes is increasing steadily. The experimental reactors already planned and under construction in the Commission's program assure adequate pile capacity. Increased production will call for expanded facilities for separation and processing and a larger staff of trained laboratory personnel.

*Shipment of Radioisotopes*

The half-life of sodium 24, a radioisotope widely used for medical research and diagnosis, is 14 hours 48 minutes; within that time, half of its atoms will have transmuted themselves into a stable isotope of magnesium and half of the radioactivity will have been dissipated; in 29 hours 36 minutes three-quarters of the radiosodium will be gone. Potassium 42, also widely used, has a similar half-life. Shipments of such isotopes must be scheduled in advance with airlines and other carriers and customers notified of the hour of delivery.

The penetrating radiation from many radioisotopes is the other important factor governing shipping procedures. Radioisotopes distributed from Oak Ridge are shipped by common carrier—by airline, railroad, and truck—in specially constructed containers, which range in weight from less than a pound to a ton, depending upon the thickness of lead shielding required to stop the radiation. Radioisotopes such as carbon 14, phosphorus 32, and sulfur 35, can be packed in light containers. Sodium 24, cobalt 60, and iodine 131, on the other hand, require heavy containers, the average weighing between 100 and 150 pounds. The latter type of radioisotope, in its glass or aluminum can, is placed in a steel container surrounded by a lead shield which is supported firmly inside a strong wooden box. After packing, the box is checked with a sensitive detection instrument, and if radiation reaching the outside is still above completely safe limits, the consignment is repacked with a thicker shield.

*Production of Isotope-Labeled Compounds*

Nearly all tracer research work starts with incorporating the radioisotopes into the chemical compounds which naturally take part in the processes being studied. Biologists studying the formation of proteins in the body, for example, need to be able to follow the transformations of glycine, one of the important body acids. They therefore need samples of glycine into which radiocarbon has been incorporated. Scientists in Commission laboratories have been developing methods of making such tagged compounds ever since pile-produced isotopes became available, and the Commission is now preparing to produce for distribution in the United States a large variety of compounds tagged with carbon 14 (see Appendix 2). These will speed tracer research in hundreds of laboratories, where workers would find it expensive and often impossible to make such compounds for themselves. The Commission will continue to supply tagged compounds until this service is developed by private firms. Some of these are already in production. As rapidly as commercial sources are expanded, the Commission will be able to withdraw from the field (see Business in Isotopes, page 35.)

## STABLE ISOTOPES

Although stable isotopes are not literally manufactured by man, but rather separated from their brother atoms in natural elements, the history of their production closely parallels that of the radioactive isotopes. Attempts to separate stable isotopes began shortly after the naturally occurring radioisotopes were first observed; in fact, these attempts were greatly stimulated by evidence offered by radioactivity that such things as isotopes existed. Identification and production of both types of isotopes proceeded over a period of nearly 40 years until the wartime development of atomic energy made its great contribution to the production and the utilization of both.

In 1912, the same year in which radium-D was shown to be a kind of lead, work with newly developed vacuum tubes furnished strong evidence that there existed two varieties of the stable element neon. But for many years scientists failed in their efforts to separate them, since the only difference between the two kinds of neon lay in their weight and amounted to less than 10 percent. In the meantime, however, the development of the instrument known as the mass spectrometer made it possible to observe isotopes, and by 1935 the important stable isotopes of all elements had been identified.

The first success obtained in the actual separation of stable isotopes—or more exactly the preparation of a sample of an element enriched in one of its isotopes—came in 1930 when "heavy water" (water containing hydrogen enriched in the rare hydrogen 2 isotope) was produced by distillation. Almost immediately this "tagged" water was put to use in biological and physical tracer experiments—as were the enriched samples of nitrogen, carbon, sulfur, oxygen, and chlorine also successfully prepared during the 1930s.

### *Electromagnetic Separation*

But prewar techniques for the concentration and separation of stable isotopes were impracticable for most elements, and the largest samples of pure separated isotopes obtained were in the range of a millionth of a gram. The war revolutionized this situation. One major effort in the manufacture of the atomic bomb was an isotope separation project, for the extraction from naturally occurring uranium of the fissionable isotope uranium 235, which is only about one part in 140 of the natural element. At one of the three plants built to do this job—the electromagnetic separation plant at Oak Ridge—a few of the giant magnets not now needed for uranium separation have been put to work manufacturing stable isotopes for research, in quantities millions of times greater than were ever obtainable before.

As a result of two years of developmental work by its contractors—the Tennessee Eastman Company and later the Carbide and Carbon Chemicals Corporation—the Commission was able to announce late in 1947 the availability of over 100 electromagnetically separated stable isotopes of 29 elements. Also, stable isotopes of five other elements produced by other methods are available, three from Commission facilities and two from commercial firms.

## Distribution of Isotopes

### RADIOISOTOPES

The program for the distribution of pile-produced isotopes was formulated with the assistance of the best scientific advice obtainable in the Nation. Early in 1946, at the request of the Manhattan Project, the president of the National Academy of Sciences nominated a panel of distinguished scientists from which an interim Advisory Committee on Isotope Distribution Policy was formed with two members experienced in each of the major fields of isotope application. This group was largely responsible for establishing the policies that have guided the distribution program since its inception. On January 1, 1948, the interim committee was replaced by a permanent Advisory Committee on Isotope Distribution.

*The Advisory Committee on Isotope Distribution*

Dr. G. Failla, of the Columbia University Medical School, is Chairman of the new committee. Other members are:

- Dr. H. A. Barker, University of California.
- Dr. Henry Borsook, California Institute of Technology.
- Dr. Robley D. Evans, Massachusetts Institute of Technology.
- Dr. Hymer L. Friedell, Lakeside Hospital, Western Reserve University.
- Dr. J. G. Hamilton, University of California.
- Dr. Joseph W. Kennedy, Washington University, St. Louis.
- Dr. Robert F. Mehl, Carnegie Institute of Technology.
- Dr. Paul C. Aebersold, Chief, Isotopes Division, AEC, Oak Ridge.
- Dr. Austin M. Brues, Argonne National Laboratory, AEC, Chicago.
- Dr. A. H. Holland, Jr., AEC, Oak Ridge.
- Dr. L. N. Nims, Brookhaven National Laboratory, AEC, Long Island.

Two subcommittees were formed: A Subcommittee on General Applications—Drs. Kennedy, Nims, Mehl, Brues, Evans, Barker, and Borsook—and a Subcommittee on Human Applications—Drs. Failla, Friedell, Hamilton, and Holland. Dr. Aebersold serves as secretary to the Committee and its Subcommittees and as liaison representative of the AEC.

Originally, radioisotopes were allocated in the following order of priority: (1) for publishable research in the fundamental sciences, including human tracer applications, requiring relatively small samples; (2) for therapeutic, diagnostic, and tracer applications in human beings and publishable research in the fundamental sciences requiring larger samples; (3) for training and education by accredited institutions in the techniques and applications of radioisotopes; and (4) for publishable research in the applied sciences, including industrial research. Now, however, production has increased to the point where it is not necessary to apply priorities to the distribution of the more important isotopes. Radioisotopes are made available to individuals only through institutions that have the personnel and equipment to handle them usefully and safely. Secondary distribution is not permitted without specific authorization.

*Procurement Procedure*

The prices charged for radioisotopes cover only direct production costs and not the cost of amortizing the investment in laboratory equipment and nuclear reactors, which have other important functions in the Commission's research and development program. Consequently, the present pricing policy results in a subsidy of the research in which radioisotopes are used. Furthermore, three radioisotopes—those of sodium, phosphorus, and iodine—are being distributed free for cancer research.

At present 100 kinds of available radioisotopes are listed and described in the AEC Catalogue and Price List issued by the Isotopes Division (see list, Appendix 2). New prospective purchasers submit an application describing the research they propose and their facilities for radiation measurement and health safety monitoring, and agree to publish the results of their investigations. Applications are reviewed by scientists in the Isotopes Division and if necessary by the Subcommittee on General Applications and by the Subcommittee on Human Applications when such use is contemplated. In the two years of the project's operation 1,742 applications have been received and 1,700 approved.

By the end of June 1948, 3,136 shipments of pile-produced radioisotopes had been sent from Oak Ridge to users outside the Commission in 33 states of the United States, the District of Columbia, and Hawaii (see Appendix 4). The recipients were 236 institutions: 54 medical organizations and hospitals, 111 educational institutions, 53 industrial organizations, and 18 public and private nonprofit research institutions. Within these institutions more than 385 different departments are using radioisotopes.

*Foreign Distribution*

In September 1947 the President announced the program of foreign distribution of isotopes by the Commission. Now, 29 radioisotopes of 20 elements important for general research, especially in biology and medicine, are available in limited quantities to foreign laboratories. The recipients agree to report semiannually to the Commission on results obtained and to publish their results; to use the isotopes only for purposes stated in the original requests; and to permit qualified scientists of all nations to visit their institutions and freely obtain information about the work. By the end of June 1948, 19 nations had qualified to receive radioisotopes: Argentina, Australia, Belgium, Canada, Cuba, Denmark, France, Ireland, Italy, Netherlands, New Zealand, Norway, Peru, Spain, Sweden, Switzerland, Turkey, Union of South Africa, and the United Kingdom; and 15 of these nations—all except Cuba, France, Ireland, and New Zealand—had already received 159 shipments.

### STABLE ISOTOPES

Five stable isotopes can now be produced by physico-chemical methods and therefore are available in relatively liberal supply. Hydrogen 2 (deuterium), boron 10, and oxygen 18 are obtainable through the AEC Isotopes Division at Oak Ridge. By the end of June 1948, 325 shipments had been made to 107 institutions. Carbon 13 and nitrogen 15 are available from the Eastman Kodak Co., Rochester, N. Y. The Sun Oil Company of Marcus Hook, Pa., has announced its intention of supplying carbon 13 and oxygen 18.

More than 100 varieties of stable isotopes of 29 elements that must be electromagnetically separated are also available, but in limited quantities, from the AEC Isotopes Division. The first shipment left Oak Ridge on January 21, 1948; and between that day and the end of June, 37 shipments were sent to 12 institutions in the United States. At present, these isotopes are furnished to laboratories only on a loan basis, to be returned when the investigator has completed his research. In this way a "pool" of stable isotopes will be built up at Oak Ridge to supply the increasing demands of the future.

## Uses of Isotopes

The services that isotopes are capable of performing for science, medicine, agriculture, and industry are so fundamental that no complete inventory will ever be made of their potential uses. As for their actual uses, the number of individual projects—most of which could not be undertaken in any other way—is more than 1,000. At least 600 papers on isotope utilization have been published in scientific journals since the war, and various aspects of the subject have been discussed in at least 20 symposia (see Bibliography, Appendix 5).

### FIELDS OF UTILIZATION

The types of problems being tackled with radioisotopes are as varied as the interests and imaginations of the investigators. A list of the fields in which they fall would include: agriculture, agronomy, animal husbandry, animal physiology and pathology, bacteriology, biochemistry, biology, chemistry, dentistry, entomology, horticulture, industrial engineering and hygiene, medicine, metallurgy, petroleum engineering, pharmacology, plant physiology and pathology, physics, radiology, soil science, surgery, toxicology, veterinary medicine, and zoology.

The uses of pile-produced radioisotopes which have been distributed from Oak Ridge are classified roughly into eight fields of investigation:

| *Field* | *Number of Projects June 1, 1946 to June 30, 1948* |
|---|---|
| Medical Therapy | 141 |
| Animal Physiology (including Human) | 305 |
| Plant Physiology | 77 |
| Bacteriology | 26 |
| Chemistry | 171 |
| Physics | 193 |
| Industrial Research | 83 |
| Metallurgy | 14 |
| Total | 1,010 |

Medical research (which is the bulk of the animal physiology group) and medical therapy account for more than 40 percent of all uses. The same proportion holds true in the representative reports of projects contained in Appendix 1. These reports have been arranged in five groups: Biological and Medical Research (116 reports), Medical Diagnosis and Therapy (42 reports), Agricultural Research (29 reports), Industrial Research and Metallurgy (22 reports), and Chemical and Physical Research (85 reports).

Beginning on page 18 there appear brief summations of the projects reported in these fields.

## PROBLEMS OF UTILIZATION

In the future tracer isotopes will become routine laboratory tools, and results obtained with them will no more be put into a separate category and discussed in special papers than are those using microscopes and spectroscopes today. For the time being, however, there is an acute need for wide discussion and dissemination of information about the isotope technique for its own sake. There is a severe shortage throughout the scientific world of the men able to use them effectively and safely.

### *Effective Results*

To get effective results with isotopes, the psysiologist or the chemist will use them to supplement his existing array of scientific methods. In any problem involving the transfer of atoms or the transformation of molecules, radioactive tracers can multiply the investigator's power of perception a thousand or even a million fold. But they are not usually shortcuts to results. Typically, they supplement rather than replace existing research methods and demand that laboratory workers acquire new skills and new knowledge. Whole notebooks full of useless data are not uncommon in pioneer isotope laboratories. Careful advance planning of experiments is essential if radiation instruments are to provide trustworthy results, and the correct interpretation of data demands some grounding in nuclear physics and electronics.

### *Safe Handling*

The safe handling of radioisotopes necessitates new laboratory designs and new work routines. Laboratories must be planned so as to avoid contamination of other areas; constructed with provisions for shielding, ventilation, and extreme cleanliness; and equipped with special implements for handling radioactive materials and with instruments for measuring contamination of equipment and exposure of workers. Laboratory personnel must develop new habits—for handling materials, surveying for contamination, changing of clothing, decontaminating equipment, and disposing of wastes. Safety, however, demands more than equipment and routine. Each operation and each experiment must be evaluated individually. Genuine understanding of the nature of radioactivity and its effects on living tissue is essential.

## SERVICES TO ISOTOPE USERS

A substantial body of knowledge concerning the handling of radioactivity is already in existence as the result of 50 years' use of radium and X-rays and the intensive wartime experience with nuclear energy. Experimental techniques with radioisotopes have been under development for a period of 15 years. Today, both the uses of isotopes and the effects of radioactivity on human bodies are being intensively studied (see page 32, Utilization of Isotopes in Commission Projects). The all-important instruments for the detection and measurement of radiation are becoming available in greater quantity and improved design as the result of the efforts of private industry (see page 35, Business in Isotopes). The effective and safe use of radioisotopes in a larger number of laboratories in the future calls, first, for wider use of the information and equipment already at hand.

The AEC Isotopes Division maintains an Advisory Field Service to assist prospective radioisotope users, particularly in the avoidance of radiation hazards. Members of this group are trained in the application of isotope techniques to chemistry, biology, biochemistry, and engineering. The Division also distributes information circulars dealing with the problems of instrumentation, shielding, radiochemistry techniques, and general safety precautions. The National Committee on Radiation Protection has recently sponsored preparation of a valuable pamphlet on "Safe Handling of Radioisotopes."

### EDUCATION AND TRAINING

But a radioisotope laboratory cannot be set up and operated on the basis of advice and pamphlets. At least one technician with general training in isotope applications and a grounding in nuclear physics and electronics is essential. To date, the most effective use of the new techniques has resulted from teamwork between physicists and other scientists. For the future, there is an acute need for scientific workers whose training enables them to bridge the gap between physics and other fields—whose breadth of knowledge equips them to act as the key men in the development of isotope laboratories.

Such workers are rare today; but training opportunities are rapidly being made available. Educational programs in nuclear physics are under way at all three of the AEC national laboratories—at Argonne in Chicago, Brookhaven on Long Island, and at Oak Ridge, Tennessee—with 58 associated educational institutions participating in this work. Recently the Commission announced the award of research fellowships in 24 institutions, where students already well grounded in biological and physical sciences will receive advanced training in fields related to atomic energy. The University of California; the University of Chicago; Iowa State College; Washington University, St. Louis; and the University of Wisconsin are already offering courses in radioactivity techniques as part of their regular curricula.

There is no shortage of scientific talent eager to take advantage of these opportunities. At the Oak Ridge Institute of Nuclear Studies, in which 19 southern universities cooperate, the recent announcement of a series of courses in radioisotope applications attracted three times as many qualified applicants as could be accepted.

The Nation has a double stake in the accelerated training of isotope technicians that is getting under way today. It will benefit not only from the resulting research contributions to the general health and welfare but also from the increased number of citizens prepared to deal with the problems of an atomic age.

## UTILIZATION—BIOLOGICAL AND MEDICAL RESEARCH

In a resolution adopted at a recent meeting, the Commission's Advisory Committee on Biology and Medicine stated that *the availability of radioisotopes is contributing more than any other factor today to the advancement of medicine and biology.*

The most fundamental contribution is a clearer picture of how the living body works. Physiologists once viewed the human body as being somewhat akin to a combustion engine. They thought of the body as a relatively inert structural system in which food was used to supply energy and repair worn or damaged parts. Recent generations of medical men have suspected that this view was false. But not until investigators were supplied with isotopes as a tool during the past two decades, did they learn how extremely far from fact it was.

### DYNAMIC LIFE PROCESSES

Tracing life processes by the use of stable and radioactive isotopes, we now have learned that all components of the body—the muscles, bones, and teeth as well as the blood, secretions, and food stores—are in a constant state of breaking down and renewal. The multitude of life compounds involved in this process go through continuous and rapid chemical reactions, many of them reversible. Those not serving at any given moment as part of the fixed structure, and not excreted from the body, are combined into a metabolic "pool" of life ingredients available for use anywhere in the body.

The most surprising fact revealed has been the extreme rapidity with which life processes take place. Experiments with radiosodium provide a measure of their speed. By "tagging" salt (sodium chloride) with sodium 24 and injecting it into the human body, investigators have found that salt is diffused through the walls of the veins, transported to the sweat glands, converted into sweat, and carried to the surface of the body, all in less than one minute's time. Again, it has been discovered that the transfer of fluid in and out of the human veins is so rapid and continuous that it carries back and forth with it 50 pounds of salt, on the average, every day.

Rapid as they are, however, the biochemical reactions which build up and break down living tissue are so delicately regulated that every part maintains its characteristic form and composition, every fluid its particular chemical make-up; and the total volume of all bodily ingredients remains constant. Although metabolic changes are continuous everywhere, the parts of the body, in health, always appear the same. Hence the classic concept of the body as a mechanical engine.

A modern tracer investigator has compared the body, instead, to a military regiment, which retains its size, form, and composition while the individuals of which it is composed are continually changing: joining up, being transferred from post to post, promoted, or demoted; acting as reserves; and finally departing after varying lengths of service.

Since the treatment of illness must be based upon an understanding of the normal functioning of the body, the medical implications of the new concept of the "dynamic state of body constituents" are nothing less than revolutionary. Fundamental changes in medical science are certain to result from research with isotopes. But isotopes assist the medical research scientist and the physician in more immediate ways as well. They are the most powerful and searching laboratory tools yet devised for the investigation of the functioning and malfunctioning of particular organs; for studying the action of vitamins, hormones, enzymes, and other biochemical substances; and for testing the efficiency of many kinds of treatments. Furthermore, they are of practical assistance in hospitals for diagnosis and therapy.

## KINDS OF TRACER RESEARCH

Virtually no observation was possible of the mechanisms, reactions, and pathways of elements and compounds in the body before isotopes were available to trace them. The hundreds of different life materials—those built into the structural parts and those in the metabolic "pool"—are indistinguishable as to origin. The almost limitless variations of the basic carbohydrates, fats, and proteins are formed out of relatively few source elements in the diet—carbon, nitrogen, hydrogen, oxygen, phosphorus, sulfur, and iodine. Long before isotopes were available, biologists had attempted to trace some of these elements by labeling them with benzine derivatives, dyes, and other identifiable materials, but the very abnormality of the substances used upset the delicate processes being studied and therefore produced confusing results.

Today isotopes provide labels for all the fundamental life elements—labels which the body cannot distinguish from the normal material. Biologists have already used them to trace such a variety of bodily ingredients as: alcohols, amino acids, antigens, bacteria, bile acids, blood cells, carbohydrates, carcinogens, enzymes, fats, fatty acids, hormones, insulin, nucleic acids, penicillin, pharmaceutical agents, proteins, starches, sulfa drugs, tissue fluids and salts, viruses, and vitamins.

So small are the quantities of radioisotopes required for tracer experiments that most of them can safely be employed in normal human bodies. Calcium 45 and strontium 89 and 90, because they have long half-lives and tend to remain in the body, are at present important exceptions.

Isotopic tracers permit two kinds of biological analysis: *qualitative*, in which a particular element introduced into an experimental animal, and sometimes a human subject, may be followed wherever it goes, whatever chemical form it takes, and *quantitative*, in which the amount of the tagged element in a tissue or fluid may be measured with unprecedented delicacy. When these two methods are combined, formerly insoluble biological problems, such as the rate of turnover of nutrient materials in different kinds of cells, may be successfully tackled.

## TRACER PROJECTS

Oak Ridge isotopes are being used in at least 450 separate biological and medical research projects in the United States. Appendix 1 contains excerpts from more than 100 reports of such projects and provides a good view of the character and scope of the work under way.

### *Qualitative Analysis*

It is difficult to envisage all the research possibilities that are opened up by the power to trace fundamental elements in living bodies. In the first place, biologists need to know much about the metabolic effects of the elements themselves. Thus, the University of Rochester, the Massachusetts Institute of Technology, and the Meharry Medical College of Nashville, Tenn., for example, report using radioiron to learn more about the mechanism of iron absorption in red blood cells in normal and anemic conditions. The Carnegie Institution of Washington, the Massachusetts Institute of Technology, Yale University, Harvard University, and a number of other institutions are using radiocalcium to study bone and tooth formation and the calcium content of muscles. Johns Hopkins University is comparing the phosphorus uptake of normal and damaged nerve tissues in muscles.

Being able to trace the elements, scientists now are able to trace the compounds of which these elements are a part, to follow them through the many changes wrought by the body processes, to discover changes of this sort previously unknown—in short, to learn the precise functions of compounds in the body. The University of Chicago, Harvard, and M. I. T. report such investigations with the fatty acids; the University of California, Cornell University, and the Massachusetts General Hospital, with proteins. New York University reports the discovery of a previously unknown kind of acid important in cell metabolism.

Isotopic labeling also permits observation of the action upon the body of foreign materials—anesthetics, artificial vitamins, toxic compounds, and drugs. The Mayo Clinic, for example, is using radiophosphorus to study the mechanism of the anesthetic, pentothal. Washington University, St. Louis, and the University of Cincinnati are using carbon 14 to observe the action of carcinogenic (cancer forming) compounds. The University of Chicago is preparing drugs containing radioactive carbon such as digitalis, morphine, codeine, nicotine, and atrophine for tracer research. The Chicago scientists accomplish this by feeding radioactive carbon dioxide gas to plants which produce these drugs, thus making the plants and their products radioactive.

By tracing elements and compounds, biologists are using radioisotopes to learn more about the functioning of every important bodily organ. The respiratory system is being studied at Harvard with radioargon; the flow of water from the eye, also at Harvard, with radioiodine; the utilization of glucose by diabetic animals at Presbyterian Hospital in Chicago with carbon 14; the functioning of nerves at the University of Illinois with radiopotassium; and the thyroid gland at a score of places with radioiodine. The Carnegie Institution of Washington reports using radioiron in experiments with guinea pigs to solve the problem of how red blood cells are transferred from the mother to the fetus.

A number of universities and medical institutions are using radioactive iodine, sulfur, and carbon to find compounds that have an affinity for different kinds of cancer tissue. If they are successful, they will have developed a powerful tool for diagnosis and treatment of cancer. Several researchers are using radioisotopes to find out what body substances are necessary to the growth of malignant tissues. If they can identify these, they may be able to starve cancers by withholding the essentials of their growth.

*Quantitative Analysis*

Tracer isotopes offer the biologist more than a method of following the movement of materials; they also help him to measure quantities of material that would be difficult or impossible to measure with any other tool.

When an investigator injects into the blood stream a sample of "heavy water" containing stable hydrogen 2 (deuterium) or a sample of radioactive sodium, the isotope will become evenly mixed with all of the aqueous fluids of the body. Then, if a single sample of fluid is removed, the investigator can easily calculate from the amount of dilution of the tracer the total volume of fluid with which it has been mixed. The amount of blood in the human body has been determined with new accuracy in recent years with deuterium.

Today, work of this general kind is being done in many laboratories and hospitals. New York University reports progress on special problems concerning the connection between the volume of water in the body and deficiency of proteins for normal health and growth. Harvard is working with radioactive potassium to determine the total amount of potassium in the normal body, the amount lost in cancer and other diseases, and the amount necessary to restore health. At both the University of Virginia Medical College and Tulane University, radiophosphorus is being used for the measurement of the total volume of red blood cells, in a study of blood losses and blood needs of surgical patients.

*Combined Qualitative and Quantitative Analysis*

Combining the powers of radioisotopes both to trace the movement of materials in the living body and to measure their quantities, the biologist finds he has a new way of getting at the most subtle and fundamental facts about life processes. He can put simple tagged molecules into the body fluid and then by taking samples of tissue from various parts of the body find and compare the rates at which those molecules have been incorporated into the tissue. This is a rather complicated way of saying that he can find the rates at which the cells renew themselves. He can likewise determine accurately the rates of functioning of the body organs. Such observations, being made today by scores of scientific teams in the United States and abroad, are building up, bit by bit, a new understanding of the dynamic processes of life.

## UTILIZATION—MEDICAL DIAGNOSIS AND TREATMENT

Almost from the time of their discovery, radioactive materials have been used externally for treatment of disease. When experimenters found that radiation destroyed normal tissue, it was a logical step to use it to destroy cancerous and other abnormal tissue growths. The first case notes on the use of radium in medical treatment were published in 1904. The naturally radioactive isotopes of thorium, radium, and their decay products, plus the therapeutic X-ray machine, had been standard hospital equipment for a generation and longer, when the artificial production of the other radioisotopes began in 1934.

Investigators saw in the radioisotopes that enter into life processes, such as iodine and phosphorus, a new possibility: *that they might apply radiations much more precisely to diseased tissue in internal parts of the body that previously could not be reached.* Furthermore, as tracers, radioisotopes could be used to find out whether this actually was possible. By the late 1930s their usefulness had been demonstrated.

Today 80 hospitals and clinics have received shipments of pile-produced radioisotopes of iodine, phosphorus, and gold for therapy and of a wider variety for use in medical diagnosis.

### TRACER APPLICATIONS—DIAGNOSIS

In hospitals today, physicians are using radioisotopes to diagnose various circulatory disorders, to locate malignant tumors, to measure how sick thyroid glands are functioning, to find out how much iron the red blood cells of anemic patients can take up, and to diagnose various unhealthy internal body changes that they could not identify without the radioactive tracers to follow and report on the movement of materials in the body. For example, by injecting a tagged salt solution into a patient's leg the physician, equipped with his detection instrument, can quickly tell if circulation is abnormal by the rate at which radiosodium is concentrated in the foot. The University of California Medical School reports diagnosing in this way more than 200 cases of 19 different types of disorders in the circulation in the hands and feet. The diagnoses have been so reliable that they are used to determine whether or not it is necessary to amputate, and where to make the severance if it is necessary.

*Localizing Tumors*

Some malignant, abnormally growing tissues absorb certain elements in the body, such as phosphorus and iodine, faster than normal; others absorb certain elements more slowly than normal. Cancer specialists are taking advantage of this fact and using radioisotopes to help locate tumors. The University of California Medical School and the Cook County Hospital, Chicago, are using radiophosphorus to locate cancer in the breast; the radiations enable diagnosticians to distinguish between benign and malignant growths, since the latter take up phosphorus at a slightly greater rate. The University of Minnesota Medical School uses a radioiodine compound to determine the location of brain tumors as a preparation for operation and reports the tracer technique as being more accurate and reliable than other methods. Nine institutions note that they are using radioiodine in the diagnosis of thyroid cancer and the location of metastases—the deposits of the thyroid cancer tissue in various parts of the body, sometimes far removed from the parent growth. Often, when the physician needs a detailed examination, he resorts to autoradiography: a section of tissue is surgically removed and the concentrations of radioactive material in it are made to take their own pictures on photographic film.

Massachusetts Memorial Hospital, Meharry Medical College, and the University of Minnesota Hospitals all report the use of radioactive iron to determine how much of this element is taken up by red blood cells in cases of anemia.

*Thyroid Ailments*

Radioisotopes have been used longest and most widely to find whether the thyroid gland is more or less active than normal. Early diagnosis of thyroid diseases had always been difficult for physicians, but now radioiodine is solving the problem. The thyroid gland picks up and utilizes nearly all of the iodine in the human system: normally about 80 times as much as any other tissue (a fact established in the late 1930s with radioiodine as a tracer). The rate of iodine pick-up is above normal in hyperthyroidism (overactivity) and below normal in hypothyroidism (underactivity) and diagnosticians with radiation-counting instruments can easily determine this rate in any individual after administration of a small and harmless dose of radioiodine. Columbia University College of Physicians and Surgeons reports using the technique in about 350 cases to date (see Appendix 1). The Mayo Clinic is conducting extremely precise studies of the use of iodine in the body so as to set up standards for diagnosing over- and underactivity of the thyroid; Johns Hopkins Hospital is developing tracer methods for the early diagnosis of cretinism, the underactive thyroid condition in children; and Harvard's Beth Israel Hospital reports extensive diagnostic work with iodine. All told, 48 hospitals and clinics in the United States have received shipments of radioiodine from Oak Ridge.

### RADIATION APPLICATIONS—TREATMENT

Very often today, radioiodine plays two parts in the fight on thyroid diseases. It helps to diagnose the disorder. Then, if the trouble is overactivity, radioiodine is called upon as a source of radiation for treatment. A dose of it taken by mouth is rapidly concentrated in the thyroid which, when overactive, receives 100 and more times as much radiation as any other tissue. In a score of the Nation's leading medical institutions toxic goiter is being successfully treated with radioiodine. It appears to be of great value in treatment of patients who because of complicating factors are poor risks for surgical treatment. A dozen or more accounts in Appendix 1 testify to the effectiveness of this therapy. The Mayo Clinic, for instance, reports success in 80 percent of the cases treated.

It seems at first glance that cancerous growths in the thyroid and their metastases throughout the body could be treated with the same pin-point precision by radioiodine. Unfortunately, though, results here have been less satisfying. The malignant thyroid tissue often does not pick up as much of the radioactive iodine as does the normal thyroid tissue. Therefore thyroid cancers cannot always be selectively destroyed by the bombardment of the radioiodine. But a great deal of research is under way, and much of it is promising, particularly attempts to use radioiodine in organic compounds which will be selectively absorbed by cancerous tissue. In other studies, it has been discovered that by first using radioiodine or surgery to neutralize the activity of the thyroid gland it is possible to greatly increase the later absorption of radioiodine by the cancerous tissue.

Experimenters found years ago that phosphorus when first taken into the system concentrates in the blood-producing centers—in the bone marrow, the spleen, and the lymph glands—though not so heavily as does iodine in the thyroid gland. Nevertheless, this discovery has formed the basis for the treatment of certain blood abnormalities, notably polycythemia, in which there is an over-production of red corpuscles, and leukemia, with an excess of white corpuscles. Today, many medical centers report radiotherapy to be the most satisfactory treatment for polycythemia (see Appendix 1). In leukemia, however, which is a cancerous condition, the same treatment has proved useful thus far only as a palliative measure. Still, although results obtained are generally no better than with X-ray therapy, radiophosphorus is often favored as a treatment for leukemia because of the greater ease of administration and the absence of uncomfortable "radiation sickness" in the patient.

*Possibilities of Cancer Treatment*

It will be noted the two noncancerous conditions—hyperthyroidism and polycythemia—can be treated with radioiodine and radiophosphorus, respectively, but that the same isotopes are much less effective in treating two cancerous conditions: thyroid cancer and leukemia.

Radioisotopes will become a major weapon against cancer when dependable means are found to concentrate them in the malignant tissue and thus selectively to destroy it. A nation-wide research effort to solve this problem is now under way, and the Commission is distributing radioisotopes of iodine, phosphorus, and sodium without charge to institutions that are taking part. New lines of attack are opening up in this research—that taken by the Massachusetts General Hospital, for example, where radiocarbon is being incorporated into protein compounds that are rapidly absorbed by morbid tissue in experimental animals, or that of the Sloan-Kettering Institute for Cancer Research, in New York City, where nature's "antibodies" are being used as carriers of radiomaterials. Antibodies are substances in the tissues which act in opposition to certain harmful foreign materials such as toxins and bacteria. At the Sloan-Kettering Institute, antibodies are extracted from the livers and kidneys of rats and mice, tagged with radioiodine, and reinjected into other rats and mice. They return to the specific tissues which produced them, carrying with them strong doses of radioactivity. Other institutions are doing interesting work with radiogold and radiocobalt. Metallic cobalt, when irradiated in the Oak Ridge pile, emits radiations very similar to those of radium. Radiocobalt can be made inexpensively and fabricated into special applicators, but before it comes into general use for cancer treatment, problems of applicator design, handling, and dosage, now under study, must be solved.

Most of these investigations, however, are still within the area of fundamental research. Effective radiotherapy for cancer must wait upon a better understanding of basic bodily processes, and the same thing is true of all future applications of radiotherapy. Essentially the problem is to find molecules which will concentrate in specific diseased body tissues and then to tag these molecules with enough radioactive material to give effective radiations. Smaller quantities of radioisotopes serving as tracers can be used to test the ability of molecules to concentrate in malignant tissues. The attack by radioisotopes upon disease will usually follow the pattern already established in the cases of hyperthyroidism and polycythemia: tracer research will come first; then, possibly, radiotherapy.

## Agricultural Utilization—Plant and Animal Physiology

More than half of the two billion people in today's world do not get enough to eat, and population is growing at the rate of about 20 million a year. Food production is not increasing as fast as population. A prime need of mankind is a greater output of farm products. In bringing this about, man's oldest industry will be assisted by his newest: gains in agricultural production will result from the development of atomic energy.

True, research with isotopes has not as yet brought larger food yields; there has not been time. Before the war, isotopes were much too scarce and too expensive to be applied in any large way to farm problems. Today, however, the radioisotopes of a score of elements useful in plant and animal research, such as carbon, phosphorus, sulfur, calcium, and potassium, are plentiful and inexpensive. Radiophosphorus, the most widely used of these, is sold F. O. B. Oak Ridge at $1.10 per millicurie, and less than $100 worth is sufficient to supply an experiment station's program of fertilizer research for an entire growing season. Stable isotopes of hydrogen, carbon, nitrogen, and oxygen are also relatively plentiful; those of calcium, iron, zinc, and molybdenum are available for extensive research for the first time.

The agricultural research with radioisotopes in 1947 raised more questions that it answered, suggesting a multitude of new projects. This multiplication of questions from season to season will inevitably continue for many years. Today, in the middle of the second summer of isotope availability, more than 70 separate research projects are being conducted in 26 American laboratories and agricultural experiment stations.

## TRACER STUDIES

The fundamental question of agriculture is how plants grow: how green leaves, in the process of photosynthesis, manufacture carbohydrates out of sunlight and the carbon dioxide in the air; how roots pick up minerals and organic matter from the soil; how these many substances are distributed in and used by the plant in its growth. The majority of such questions have gone unanswered because scientists had no means of observing the intricate processes and the tiny quantities of materials. But the tracer technique has changed this. To illustrate: using radioisotopes, plant scientists have been able to follow through the soil, into the rootlets, and to their final disposition in the plant, minerals such as zinc, copper, and manganese, all of which are available to the plants in amounts of less than an ounce per acre.

### *Plant Growth*

In all, 18 tracer studies are being made of the photosynthesis of sugars, starches, and other carbon compounds and of the numerous subsequent biochemical transformations the plant makes in these compounds during the process of growth. Appendix 1 contains reports on such work from the University of California, the University of Chicago, the Hawaiian Sugar Planters Association, the University of Texas, and the University of Washington.

Such research in the life processes of plants is carried on for its own sake. But some of the discoveries of the pure scientists in this field will eventually find use in the development of plant strains which yield more heavily or produce more exactly the feed materials desired for better and faster growth of animals. For example, new knowledge about photosynthesis may enable scientists to develop plant strains that produce more energy-rich substances in their early stages of growth. This would be a boon to cattlemen.

The farmer has an obvious and vital interest in the 40 current studies on how plants use the minerals and organic compounds they draw from the soil. Appendix 1 gives some details of such investigations: with radiophosphorus by the Connecticut and Ohio Agricultural Experiment Stations, radioiodine by the U. S. Department of Agriculture, radiocalcium by Cornell University, radiosulfur by Purdue University, radiozinc by the Ohio Station, radiocobalt by the Hawaiian Sugar Planters Association, and radioactive molybdenum, vanadium, and columbium by the University of California. Radioactive iron, chlorine, arsenic, potassium, and rubidium are all being used in similar work.

The men carrying on such work are using varied and imaginative techniques. At the Connecticut Station, when radio-tagged phosphorus fed to corn plants was found concentrated in the young kernels, these radioactive kernels were then used in poultry-feeding tracer experiments. Radioautography is widely used; photographs made at the experiment station of the American Smelting and Refining Company, Salt Lake City, Utah, of the distribution of radiosulfur in a slice of tomato revealed not only the fact that the element was concentrated in the seeds but also its chief areas of concentration inside the seeds.

*Information About Fertilizers*

Such work is certain to reveal how to get more plant growth—more food and feed—from the 15 million tons of fertilizers upon which the American farmer spends half a billion dollars every year. Already, in field experiments conducted by the U. S. Department of Agriculture and State agricultural experiment stations and by the fertilizer industry in all parts of the nation, radioisotopes are answering very specific questions: such questions as where, when, and how plant foods are most effectively applied to different crops; what forms of fertilizer return the most in production; when and how the plant utilizes them; and how much expensive plant food is likely to go unused in today's fertilizing methods. For example, one study revealed that phosphorus is used by corn mainly in the early stages of growth; another study found that potatoes use phosphorus throughout the growing season; a third that the fertility of the soil influences phosphorus uptake by cotton; and still another that with certain crops the manner of applying phosphorus is of primary importance. The U. S. Department of Agriculture has found that phosphorus, when placed very close to seed potatoes, seems to slow up the growth of the plant, probably because of injury to the young roots.

*Diseases and Pests*

At least 12 current projects are aimed at better understanding of how plant diseases and pests develop and attack crops and, consequently, how they can best be defeated. Applications of radioactive iron, phosphorus, and sulfur to the investigation of chlorosis, tobacco leaf disease, fungus, and bacteriological problems, and the behavior and control of harmful insects are noted in Appendix 1. Also, the effects of insecticides and fungicides, such as sulfur (250,000 tons used annually in the U. S.) and DDT, are being studied with the new techniques.

*Livestock Studies*

Efficient production of meat, milk, and eggs may be advanced in many ways by the new facts about animal growth and development being supplied by isotopic tracers. Researches directed specifically toward livestock production problems are being conducted at several locations today. The University of Wisconsin, for example, reports studies with the radioisotope of molybdenum, an element injurious to the health of animals when present in high concentrations in the soil. The University of Florida is investigating the effect on the health of farm animals of this element and of soil-carried cobalt, copper, and phosphorus as well. Purdue University is employing radioiodine in an attempt to find out why iodinated casein apparently speeds the fattening of animals.

### RADIATION APPLICATIONS

Almost since the discovery of radioactivity at the turn of the century, its effect on plant and animal growth has been the subject of study. Investigators soon discovered the harmful effects of high levels of radiation. They have found less evidence of beneficial effects. Experiments have indicated that small amounts of radiation may stimulate growth in some plants, but results in the main have been conflicting. In March 1948, the Commission and the U. S. Department of Agriculture jointly undertook a program of research to investigate this question.

All of the effects of radiations upon living things—including the genetic effects—may some day be important to the farmer. As one of its major responsibilities, the Commission has under way today an extensive program for the investigation of these problems.

## Utilization—Industrial Research and Metallurgy

Industry stands to benefit from the use of isotopes in several fields of research, particularly in fundamental chemistry; and direct applications to its own problems are potentially as broad and varied as the industrial structure itself. In comparison with the possibilities, today's applications are few and far between. Extreme caution is called for in the development of many of the most promising services that radiations can perform, such as the treatment of materials or the automatic control of factory processes. However, more than 30 industrial organizations are already using radioisotopes in research and development programs. Some idea of the scope and variety of the work can be obtained from the reports in Appendix 1.

### TRACER APPLICATIONS

The powerful signals emitted by radioisotopes have been used to follow and measure a variety of industrially important substances otherwise untraceable, from the impurities in a batch of molten steel to the invisible coating on a wisp of thread. Manufacturers of steel, machinery, rubber, gasoline, oil, plastics, rayon, chemicals, drugs, and a rapidly growing list of other products are looking to these researches to bring better and more economical production.

*Metallurgy*

The entire field of metallurgy is certain to be greatly influenced by tracer investigations already under way on the structure, manufacture, alloying, durability, corrosion, and friction of metals. The Industrial Radiography Laboratory in Beaumont, Texas; Arthur D. Little, Inc.; Massachusetts Institute of Technology; Socony-Vacuum Oil Co.; Stevens Institute of Technology; and Westinghouse Electric Corporation—all report projects in this field; and the radioisotopes of more than a dozen elements are being used, including iron, calcium, carbon, sulfur, phosphorus, cobalt, silver, nickel, tungsten, copper, and zinc.

The power of these new investigative tools makes them extremely versatile. A tiny quantity of radiosulfur, for example, added to 24,198 pounds of mixed coal, enabled investigators to determine later what proportion of the sulfur impurities in the finished steel came from the coke and what proportion from the iron. Radiophosphorus, added to a molten batch of steel, joins with the phosphorus already present and thereafter, by its radiations, reveals the quantity of this impurity that still remains in the mix at various stages of processing. Radiocarbon, incorporated into iron during the coking process, provides investigators with a method of studying the diffusion of carbon in iron, a matter of great importance in the subsequent manufacture of steel. Radioiron, used in friction experiments, has been able to reveal the transfer of less than one hundred billionth of an ounce of metal from one moving surface to another. Piston rings and other motor parts have been made radioactive in the Oak Ridge pile for use in these latter studies.

Many of these metallurgical experiments take advantage of the technique of autoradiography, in which the precise distribution of the isotope-tagged material is photographed by the direct application of a film to the sample being analyzed.

*Petroleum Industry*

In the petroleum industry, the uses of isotopic tracers, both actual and potential, range all the way from the surveying of the location and quantities of raw materials underground to the testing of the final product in operating engines. Radiocarbon, of course, is the most important isotope here; the Shell Oil Company and the California Research Corporation use it to follow the changes through which crude oil goes in modern cracking processes, and the Texas Company, to study the process for manufacture of synthetic gasoline from coal and natural gas. A subsidiary of the Gulf Oil Corporation is using radiocobalt to determine the rate of settling of rust inhibitors and other substances added to lubricating oil; and the Socony-Vacuum Company reports that radioiron makes possible friction measurements with a sensitivity of one part in ten million.

In the study of oil fields, the availability of radioisotopes of such elements as iodine, chlorine, cobalt, and calcium is expected to result in new information about underground strata. Moreover, consideration is being given to tracer explorations of underground stores of fuel; radioisotopes in batches of oil or gas injected into a well, will be sought in samples from neighboring wells, and the resulting information about the underground routes in various parts of the field may make possible more efficient drilling procedures.

*Rubber and Rayon*

Similarly in other industries, tracer isotopes are throwing new light on fundamental problems. The way in which vulcanization and polymerization processes operate in the manufacture of rubber are being investigated—by the Goodyear Company, for instance—with the radioisotope of sulfur, the element that plays a primary but still largely mysterious role in these processes. The same isotope is solving a problem that has long made trouble in rayon manufacture, where sulfur must be added at one stage of the process and later removed because it lessens the strength and durability of the final product. Previously, it was impossible to determine at what stage of the process the sulfur had been eliminated; now a bit of the radioisotope mixed with the sulfur in a test batch gives this information with extreme accuracy. Also in the rayon industry, the isotopic technique demonstrated its incredible delicacy when radiosodium succeeded in measuring accurately the coating on a tiny fraction of an inch of thread so fine that it weighs less than an ounce to the mile.

## USES OF RADIATION

Availability of scores of radioisotopes, each offering its characteristic type and intensity of energy emission, will soon bring the power of radioactivity into the service of industry on a scale not equalled or even approached in the past. The possible uses are so varied and so unexplored that present speculation can only vaguely indicate them. There are two broad fields of such application.

First, radiations have powers—recognized but as yet little understood—to affect chemical reactions involving the hydrocarbons and other substances entering importantly into industrial processes. At the Massachusetts Institute of Technology, for example, chemists have been able, by the use of radiations, to convert certain fatty acids into paraffinic or straight-chain hydrocarbons, which compose a sizable part of petroleum. The future may see some manufacturing processes accelerated or produced at lower temperatures, and others rendered possible for the first time, when the chemists and engineers have learned to make radiation play its role in such reactions.

Second, radiations provide industry with a powerful and flexible measuring and analyzing tool. In the future, radioisotopes will be at work in factories doing a great variety of jobs that cannot be done at all today—measuring the thickness and size of objects to millionths of an inch or of a gram; revealing the internal condition of apparatus—the extent of corrosion inside a pipe, for instance; making photographs (radiographs) of opaque materials; analyzing the quality of products; and even controlling the operation of production machinery.

### *Radiation at Work*

A few beginnings have been made in the application of radiations to industrial processes. Probably the oldest application is in oil-well logging, where radiomaterials lowered along with detection apparatus into wells have provided valuable information by the manner in which they were reflected from the different materials lining the walls of the shaft. One of the newest applications is noted in Appendix 1: the use of radiations to dissipate hazardous and hampering static electricity which collects on belts, rolls of paper, and other moving materials in factories. Also in Appendix 1, the Goodyear Company reports the development of a gage in which radiocarbon measures the thickness of a sheet of Pliofilm on the production line accurately to a hundred thousandth of an inch. It is noted that the signal from this gage, amplified and hooked up with the production machinery, could actually be used to control the thickness of the film.

Such automatic process controls are an obvious extension of the measuring and analyzing function of radiation; but their application, like many of the most interesting applications of radiomaterials to industrial processes, must come gradually along with the development of technical understanding and safe procedures. Of first importance in industry today—as in medicine and agriculture—is the new fundamental knowledge that isotopes as tracers are revealing in the laboratories.

## Utilization—Chemical and Physical Research

It was the work of physicists and chemists that originally made isotopes available for research, and today their efforts in the field make a two-fold contribution to all the other sciences. First, by the application of isotopes to fundamental problems in their own subjects, they are daily uncovering basic facts that have profound effects on other fields of knowledge. Second, by their studies of the radiations of isotopes and of the instruments, equipment, and techniques required to put them to work, physicists and chemists are making possible the use of isotopes in other sciences.

### FUNDAMENTAL PHYSICS

The connection between the physicist's investigations of nuclear structure and the everyday life of mankind, although often remote, is appreciated today as never before. The entire development of atomic energy makes it plain. Generally speaking, however, the projects he undertakes—such as those described in Appendix 1—are understandable only to the scientist.

The reports tell of the use of both stable and radioactive isotopes of a number of elements—notably hydrogen, helium, carbon, oxygen, phosphorus, and zinc—to make new observations of nuclear particles and new deductions concerning the mysterious forces that hold the atomic nucleus together. For example, the "spin" of the fundamental nuclear particles, which is related to the force binding the nucleus together, has been measured in a number of isotopes—in carbon 14 at the University of California and in zinc 67 at the University of Wisconsin. (For some very fundamental results concerning these "magnetic moments," see the description of work with hydrogen and helium at the Commission's Argonne National Laboratory, Appendix 1, page 143.)

### FUNDAMENTAL CHEMISTRY

The chemist's fundamental studies of the combination of atoms into molecules are a step closer to the everyday world of practical application. A review of the projects described under "Chemical Research" in Appendix 1 makes apparent their close relationship with the work in all other fields of research. The University of Texas, for example, reports using radiochlorine to demonstrate that it is the chlorine atom in the salt molecule that destroys the "passivity," or chemical inertness, of chromium. This fact may some day provide the basis for the development of a more durable kind of chromium plating. In both the organic and the inorganic fields, chemists report using isotopes to study a great variety of processes that they could not previously observe—processes involved in molecular formations and exchanges; diffusion in liquids and solids; the interactions among gases, liquids, and solids; catalytic action; solubility of materials; complex biochemical reactions; and many other phenomena.

In the laboratories of physicists and chemists, isotopes function not only as tracers and as radiation sources but also as important objects of study in themselves. Especially is this the case in the laboratories of the Commission's contractors, where the products of nuclear fission are of primary importance to the work program. The consequence is that the Commission is able to offer considerable assistance to all users of isotopes. The contribution of physics and chemistry to isotope utilization in other fields, therefore, is discussed in the following section.

## Utilization of Isotopes in Commission Projects

From the start, the development of atomic energy has been a series of problems in the production and use of isotopes. The wartime production program at Oak Ridge employed tens of thousands of workers and hundreds of millions of dollars to separate from natural uranium a stock of the isotope uranium 235. At Hanford a comparable investment of labor and money went into the large-scale production, by nuclear transmutation, of the isotope plutonium 239. Fission-product isotopes are produced by the nuclear reactors which today manufacture plutonium and tomorrow may be a new source of industrial power.

A full description of the Commission's work with isotopes today would necessitate a description of its entire research and development program. An idea of the nature and scope of the work, however, can be obtained from the reports in Appendix 1 (page 139), in which nine of the Commission's contractors present brief accounts of the isotope projects in their laboratories.

### PHYSICAL AND CHEMICAL APPLICATIONS

In the Commission's three National Laboratories, Argonne in Chicago, Brookhaven on Long Island, and Oak Ridge; in the Los Alamos Scientific Laboratory; in the Radiation Laboratory at Berkeley; and in the Ames Laboratory at Iowa State College, physicists and chemists are depending heavily on isotopes to assist in probing into nuclear structure and nuclear and chemical forces and in studying the characteristics of certain rare earths and other elements now purified and isolated for the first time.

Isotopes used in such work sometimes act in their familiar roles as tracers and sources of radiation, but more often they are valuable as objects of study for their own sakes. It has been known for some years, for example, that there existed in nature a radioactive isotope of potassium (potassium 40)—one of the few known naturally radioactive materials among the common elements. But only since the Oak Ridge electromagnetic separators were devoted to the task has it been possible to isolate enough of the material for study. Studies of potassium 40 now under way at Argonne, Brookhaven, and at Columbia University under an AEC contract are expected to throw light on such diverse problems as the structure of the nucleus, the age and internal heat of the earth, and the natural radioactivity within plants and animals.

Again, the man-made radioactive isotope hydrogen 3 (tritium), is now available for comprehensive study. Observations made at Argonne Laboratory of this simplest of all the radioactive isotopes have resulted in new accurate measurements of nuclear "magnetic moments" and "exchange forces" and have thus brought science a step closer to understanding the basic forces of the atom.

*Isotopes in Production and Development*

Isotopes are equally useful in the laboratories where the Commission's contractors are tackling the day-in-day-out problems of the production of fissionable materials and weapons and the construction of the many types of nuclear reactors upon which speedy development of atomic energy's peacetime uses depends. At Hanford, for example, purified isotopes are used in the study of the fission products produced in great quantities by the giant plutonium piles. At the Knolls Atomic Power Laboratory, Schenectady, N. Y., at the Ames Laboratory, Iowa State College, and at Argonne, Oak Ridge, and Los Alamos, they are probing into the nuclear, chemical, and metallurgical characteristics of materials that have suddenly become important to the national welfare and safety. Much of this applied research and development work is not publicly reportable, but in volume it is the major part of the Commission's research program.

## BIOLOGICAL AND MEDICAL APPLICATIONS

The vital problems of the effects of radiation upon human life—and of course, upon plant and animal life as well—are under intensive investigation in all of the Commission's major laboratories and also under contract by the University of California, Los Angeles; Columbia College of Physicians and Surgeons; University of Tennessee, Knoxville; Harvard University School of Public Health; the University of Rochester; Western Reserve University; the University of California, Berkeley; Washington University School of Medicine, St. Louis, and the University of Washington School of Applied Fisheries, Seattle. Since radioisotopes themselves are the sources of the radiations that are of chief concern, they are the standard investigative tools. Safety and health in a world where nuclear energy is being released must be based upon understanding of the changes that radiations bring about in living tissue, in life processes, and in the functioning of bodily organs. Yet the unknown areas of the subject are immense, and the workers capable of exploring them are very few. Therefore, although investigations with isotopes in this field are of very fundamental nature, they are pursued with an urgency that is more characteristic of applied science.

These investigations are of course essential to the protection of the tens of thousands of workers in the atomic energy program, and of others who might be affected by the failure to apply proper safety precautions. Not only the dangers of radiation but the toxic effects of uranium, thorium, plutonium, beryllium, and other newly important materials are being studied by the Commission's contractors, and reference to Appendix 1 will make clear the utility of isotopes in such work.

### SERVICES TO USERS OF ISOTOPES

A very important byproduct of the Commission's application of isotopes to the solution of its own problems is the service that it is able to provide to all other users of isotopes. In the field of physics, six of the Commission's contractors are studying the precise nature of the radiations emitted by various isotopes, and an equal number are engaged in the more exact calibration of radiation detection instruments. In the course of chemical and biochemical studies, the Commission's contractors have assisted in the improvement of the specifications for purity of distributed isotopes and have developed methods of making a large number of compounds containing isotopes, which will be offered to outside users (see Appendix 2). And in the field of biology and medicine, of course, nearly everything learned about radiations and their effects contributes to the usefulness of isotopes in private laboratories and hospitals. Columbia University College of Physicians and Surgeons, for example, as an essential preliminary to studies of radiation effects, has undertaken a thorough study of the dosage problem—the problem of determining accurately the quantities of radiation delivered to living tissues by various isotopes. In the course of this work, Columbia researchers have devised a new instrument to provide a standard of measurement. As a result, the College can now compare measured samples of the commonly used radioisotopes with those in use in other laboratories for the purpose of more accurately calibrating instruments for dosage determination.

The efforts made by the Commission's contractors to provide technical information to other users of isotopes are more than repaid in the new knowledge about radioactive materials that is flowing daily out of hundreds of laboratories where isotope research is in progress.

### FOREIGN UTILIZATION

Since the start of the program of foreign distribution of radioisotopes (see page 15), more than 100 research institutions and hospitals in 15 countries have begun to use them. Thus far, the great bulk of the work undertaken is in the biological fields, although a few projects in physical research are under way. The 159 foreign shipments from Oak Ridge up to June 30, 1948, included radioisotopes of 10 elements: calcium, carbon, cobalt, iodine, iron, mercury, phosphorus, strontium, sulfur, and zinc.

To date, only Australia and Great Britain have been receiving radioisotopes long enough to be able to report on projects under way. The Australian report shows that up to the end of February 1948 radiophosphorus had already been used with good results in 11 hospitals to treat 22 cases of polycythemia and two of leukemia. The therapeutic use of radioisotopes in Australia is regulated by a special committee of the National Health and Medical Research Council. During the period covered by the report, very little research work had gotten under way, but a variety of projects were being planned with radioactive carbon, cobalt, iodine, iron, and strontium.

The British report, dated June 17, 1948, shows a great variety of biological and medical research already under way in 21 institutions. Close to 50 different projects are listed, involving such problems as:

General body metabolism, normal and abnormal.

Blood formation, blood volume, and circulation in anemia and other diseases.

Bone formation and bone diseases.

Nerve and muscle metabolism and function.

Normal and abnormal functioning of the brain.

Fetal metabolism and circulation through the placenta.

Influence of pregnancy on metabolism.

Distribution of phosphorus in the teeth.

Flow of fluid into the eye.

Thyroid gland activity, normal and abnormal; thyroid cancer.

Growth and nutrition of tumors; differentiation between malignant and normal tissue.

Action in the body of immunization agents, antigens, etc.; of enzymes, hormones, and other secretions; of bacteria and virus infections; of penicillin and other drugs.

It is evident that British research with pile-produced isotopes is already branching widely in biology and medicine. As work in these fields and also in physical research gets under way in other nations, there will grow up abroad a new scientific activity paralleling that in the United States. All results in these foreign projects are to be published and will be read by Americans here, as are ours abroad. Isotopes for research and medical use will become a stimulus to human advancement on an international scale, as have the other great scientific discoveries of the past.

## Business in Isotopes

The businessman has reason to be interested in isotopes. Their utilization in scientific research has created a demand for new kinds of equipment and services which will continue to grow very rapidly in the years ahead. Their application to industrial problems opens an immense field for future development.

Today, two years after the first shipment of radioisotopes from Oak Ridge, 236 laboratories have been equipped for their use in universities, research institutions, hospitals, and industrial concerns in the United States. New laboratories are being established as rapidly as competent scientists and technicians become available, and a large number of educational institutions are already engaged in the training of these workers.

In the pioneer radiation laboratories now operating, research scientists have been forced to master many unfamiliar techniques and to improvise most of the equipment they use. They have had to double as mechanics in the design of special tools, as radiochemists in the preparation of radioactive compounds, and as electronics engineers in the operation of their instruments. Such laboratories today constitute a rapidly growing market for a great variety of equipment and services—new equipment for the assay of radiations, for protection against radiation hazards, and for the handling of radiomaterials; yet-to-be-provided services for the design of laboratories, the maintenance of complex instruments, and the preparation of organic and inorganic compounds labeled with radioisotopes. As rapidly as these present demands are supplied, new projects will get under way, new research will be possible.

The supplying of these growing demands is a job for business. With the Commission furnishing the basic pile-produced isotopes required for the manufacture of radioactive compounds, private industry is in a position to provide all of the equipment, materials, and services needed by isotope tracer laboratories today. Already, electronics firms have taken the lead in developing radiation detection instruments. Enterprising companies are beginning to offer prepared radioactive compounds. And some are thinking in terms of more complete services for research workers.

The firms going into this field are looking beyond today's market, in which 8 out of 10 isotope research projects are concerned with basic science, fewer than 1 out of 10 with industrial problems. Of course, the supplying of laboratories and hospitals can be a good-sized business in itself. But the potential application of isotopes to the work of industry—for the control of processes, the testing of products, and the development of entirely new processes and products—is an open field of opportunity. It is the kind of field that American competitive industry is uniquely fitted to develop.

### INSTRUMENTATION AND EQUIPMENT

Ever since World War II took radioactivity out of the physicist's laboratory and put it to work in gigantic production plants, the electronics industry has been multiplying its output of radiation measurement instruments and improving their performance. But much development remains to be done; eventually, the radiation counter may be as simple to operate for the biologist in a laboratory, or the materials inspector in a plant, as is the home radio for everybody today.

Essentially, the purpose of all radiation counting instruments is the same: to determine the average number of atomic disintegrations occurring in small units of time and hence to reveal the strength of the radiation source. But in actual experimental and technical work, this purpose must be accomplished under widely varying conditions; radiations from the various isotopes differ greatly in character and strength; the material in which they are measured may be gaseous, liquid, or solid—living or inanimate; the objective of the investigator may be the instantaneous determination of radiation strength or the charting of the gradual rate of increase or decrease over a period of time. With the increasing application of radioisotopes to new scientific and industrial problems, there are no foreseeable limits to the need for variation and elaboration of detection devices.

The protection of personnel, essential in every radioisotope project, calls for a separate catalogue of radiation detection instruments: survey meters for the handy monitoring of operations and checking of laboratory equipment and personnel for contamination; pocket ionization meters to determine the cumulative exposure of individual workers; and film badges and other specialized devices to meet specific needs.

There are now more than 30 firms in the business of supplying radiation detection instruments. An obvious complement to this business, already undertaken by at least one firm, is the supplying of other specialized equipment needed by radioisotope projects—the lead bricks and chests for shielding, the highspeed fans for ventilation; the extension-type tools for the remote-control handling of radiomaterials, and a host of other novel devices not obtainable in today's market.

### ISOTOPE-LABELED COMPOUNDS

Both the Commission and private industry are meeting the present urgent need of tracer laboratories for isotope-labeled compounds, (see page 12), but the supplying of this demand is ultimately a job for private industry.

While the Commission must necessarily continue to manufacture the basic pile-produced isotopes and also to pass upon the eligibility of applicants to receive radiomaterials, competitive commercial chemical firms, operating on a profit basis, will best achieve the rapid development and ready distribution of the radiocompounds that most tracer laboratories actually use.

Late in 1947, representatives of nine interested firms met with Commission officers at Oak Ridge to consider the new pattern of industry-Government cooperation required to achieve this end and to discuss such problems as prices, patent rights, and distribution procedures. This and subsequent studies of the problem have resulted in the Commission's establishment of a policy and procedure to meet the situation:—

> Commercial firms will be encouraged to manufacture and distribute for sale tagged compounds, with radioactive materials obtained from AEC. The Commission hopes that private firms will enter the field to such an extent that it will be able in time to withdraw from the manufacture of such compounds for general distribution.
>
> The price to be charged for isotope-labeled compounds produced by commercial firms will be established by the firm manufacturing the material in accordance with normal industrial practices. Inventions or discoveries made by persons using radioisotopes or using or manufacturing isotope-labeled compounds will be subject to patenting by the inventor in accordance with normal industrial practices. The Commission does not contemplate the reservation of patent rights to inventions and discoveries made by receivers of radioisotopes pursuant to the Commission's regular program of distribution.
>
> The users of radioactive isotope-labeled compounds will be required to meet the safety and health standards that are established from time to time by the Commission. They also will be required to publish or report the significant results of investigations using radioactive materials, but these reporting requirements will be applied so as not to interfere with an inventor's opportunity to obtain patent protection for his inventions and discoveries.

Already, one firm has started production of compounds; a second has completed the necessary arrangements with AEC; and three others are negotiating toward this end. AEC is assisting these firms by making available the results of its own experience in the making of compounds containing radioactive tracers.

### SERVICES

One commercial firm has already begun to offer certain services to the users of radiomaterials, such as the maintenance of electronic instruments, the regular inspection of the radiation-recording film badges worn by workers, the solution of problems of laboratory design, and even the instruction of laboratory personnel in the effective and safe utilization of radiomaterials. Furthermore, this firm is already exploring the possibilities of the application of radioisotope techniques to the problems of industry.

The section on industrial applications, page 28, describes some of the possibilities in this field. But so great are the potentialities that only a few of the applications can be foreseen. In the future it will be the radiation engineer—serving industry as other experts do today—who will develop the role of radioactive materials in the production of manufactured goods.

# III. PARTICLE ACCELERATORS*

The postwar assault of the physicists upon the citadel of the atomic nucleus is being mounted with new and heavier artillery. The number of particle accelerators—cyclotrons, synchrotrons, betatrons, linear accelerators, etc.—in operation in 50 U. S. laboratories and at least 10 abroad will be more than doubled by construction that is already scheduled. And at least two dozen of the new atom smashers will be capable of bombarding the nucleus with particles accelerated to more than 100 million electron volts—an energy produced by only a single machine today.

The Commission's particle accelerator program has been marked by two important events in 1948. The meson, a primary nuclear particle, was artificially produced and observed in the laboratory for the first time in the giant 184-inch synchrocyclotron operated with AEC funds in the Radiation Laboratory of the University of California at Berkeley; and plans were completed by the contractors and staff of the Commission for the construction of two new multibillion-electron-volt proton-synchrotrons, many times more powerful than the present Berkeley machine.

## THE MESON

On February 21, workers in the Berkeley Radiation Laboratory achieved one of the major objectives of modern research in nuclear physics: they recorded on photographic emulsion plates placed within the 184-inch cyclotron the presence of mesons, hitherto observed only in cosmic rays. The meson (also called the mesotron) is an evanescent high-energy particle intimately associated with those fundamental nuclear processes that are still largely mysterious to scientists. When available under controlled laboratory conditions, the meson is expected to be an important tool for studying the nature of the forces that hold the nucleus together. Since the development of atomic energy must depend upon man's understanding of these nuclear forces, the laboratory production of the meson is regarded by many nuclear physicists as the most important advance since the discovery of uranium fission in the late 1930s.

## MULTIBILLION-VOLT ACCELERATORS

Before the meson can be understood and exploited as a laboratory tool, however, more powerful atom smashers must be built. The 184-inch Berkeley machine—the world's greatest at this time—possesses barely enough power to produce low-energy mesons. During the past year, physicists in the Commission's laboratories have been studying the feasibility of constructing electronuclear machines powerful

*Cyclotrons, synchrotrons, and betatrons are particle accelerators employing large electromagnets to hold the paths of the particles being accelerated in closed or spiral orbits. These machines are to be contrasted with accelerators not employing electromagnets in which the paths are straight lines, e. g., linear accelerators and Van de Graaff generators.

enough to accelerate particles to energies of several billion electron volts. By the end of 1947, the Berkeley Radiation Laboratory and the AEC's Brookhaven National Laboratory on Long Island had completed the necessary theoretical work and submitted proposals to build such machines. After staff study, and upon the recommendation of its General Advisory Committee, the Commission approved, in April, the following specific plans for machine construction:

A 30-foot-radius proton-synchrotron to be constructed at Brookhaven; to yield protons with energies between two and three billion electron volts (BEV); to take about three years to build; and to cost approximately $3,000,000.

A 55-foot-radius proton-synchrotron to be constructed at Berkeley; to yield protons with energies between six and seven BEV; to take four or five years to build; and to cost approximately $9,000,000.

The Brookhaven machine, accelerating protons in a track almost four times the radius of that of the present Berkeley cyclotron, will develop energies about seven times as great—sufficient to produce mesons plentifully. The Berkeley proton-synchrotron is expected to accelerate particles with approximately 18 times as much energy as the 184-inch cyclotron. Not even its designers venture to predict the nuclear phenomena that it will reveal.

The ring-shaped magnet of the proposed Berkeley proton-synchrotron will require 10,000 tons of steel, approximately the quantity needed for a heavy cruiser. When it is considered that the proton, the nuclear particle to be controlled by this magnet, weighs only one in 17 million billion billion parts of an ounce, some conception of the forces applied to the particles may be obtained. In both machines, protons will be accelerated nearly to the speed of light—the maximum speed possible under the theory of relativity. In the Brookhaven proton-synchrotron, the particles while being accelerated will travel a distance of more than 150,000 miles—the equivalent of six times around the earth—in less than a second's time.

The synchrotron principle for the multibillion-volt acceleration of protons was conceived independently during the war by physicists in the United States, Great Britain, and Russia. Thus far the only known plans for such machines abroad have been made at the University of Birmingham, England, where construction is already under way.

Design of the American proton-synchrotrons is the achievement of two exceptionally competent teams of nuclear physicists. The Berkeley Radiation Laboratory has pioneered the entire development of high-energy nuclear bombardment. The Brookhaven Laboratory is a center of nuclear research for the great universities of the East. At these two locations the new machines will be ideally situated for maximum utilization of talent in the particle accelerator field.

## PARTICLE ACCELERATORS IN THE UNITED STATES

Today there are more than 50 particle accelerators operating in the United States in the high-energy (million electron volt) range. An almost equal number are now scheduled for construction. A few of these, notably the synchrocyclotrons under construction at Columbia

University, the University of Chicago, and the Carnegie Institute of Technology, are to be giant atom smashers with power in the range of that of the 184-inch cyclotron, designed to extend the frontiers of fundamental knowledge.

The great majority of them, however, are laboratory workhorses intended to operate, day in, day out, bombarding various target substances to get information and to produce materials obtainable in no other way. The information that they produce—about the nuclear characteristics of materials, for instance, or the behavior of nuclei under bombardment, or the fission and transmutation of elements—is basic to many kinds of scientific work and particularly to the development of atomic energy. The actual materials that they produce—isotopes not obtainable from atomic piles—are essential in today's laboratories and especially in the investigation of such problems as the effect of radiation and radioactive materials upon living things.

## THE COMMISSION'S ACCELERATOR PROGRAM

There are now seven particle accelerators of various types working in the Commission's program. Three more are under construction; and 10 others are planned.

### *Accelerators Now in Operation*

Accelerators now in operation in the Commission's program are located at the Radiation Laboratory in Berkeley and the Los Alamos Scientific Laboratory. In addition to the 184-inch cyclotron, Berkeley has a 60-inch cyclotron (a pioneer machine, in which plutonium was first produced), which has operated steadily for more than a year bombarding materials for the Commission's research projects, chiefly in the field of biology and medicine, at Berkeley and Oak Ridge. Also at Berkeley is a linear accelerator constructed on an experimental basis to determine the possibility of producing billion-volt protons by straight-line acceleration. Now that experience has shown the proton-synchrotron design to be more feasible for this purpose, the completed section of the linear accelerator has been put to work in physical investigations in the 20–40 million-electron-volt range. At Los Alamos are four accelerators working in the specialized physical research associated with the program of that laboratory: a 40-inch cyclotron, a 20-MEV betatron, a 2-MEV Van de Graaff generator. and a 200-KEV Cockcroft-Walton accelerator.

### *Now Under Construction*

Now under construction in Commission laboratories are:

*A Synchrotron* (virtually complete) at Berkeley which will for the first time accelerate electrons to energies of 300 million electron volts. The machine may prove capable of splitting nuclear particles: neutrons and protons.

*A Van de Graaff electrostatic generator* (4 MEV) at Argonne National Laboratory, chiefly for study of the nuclear characteristics of materials used in the reactor program.

*A Van de Graaff generator* (3.5 MEV) at Brookhaven National Laboratory, for general nuclear research.

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*To Be Constructed*

Scheduled for construction, in addition to the two previously described multibillion-volt machines at Brookhaven and Berkeley, are:

*Two 60-inch cyclotrons* (30 MEV) for Argonne and Brookhaven National Laboratories, to be used in both physical and medical research.

*Five betatrons* for various laboratories of the Commission and institutions in its program, to produce high-energy radiations for use mainly in medical research.

*A Van de Graaff generator* (12 MEV) for Los Alamos Laboratory, for special research in nuclear physics. This type of electrostatic generator makes possible a variation and precise control of particle energy not feasible with the multimillion-volt cyclotrons and synchrotrons, and the Los Alamos machine will provide data much needed for solution of the nuclear physics, chemistry, and engineering problems of that laboratory. It will be more than twice as powerful as any similar machine now in existence.

The Commission's joint support of a scientific program with the Office of Naval Research will include financial assistance for the operation of a number of other particle accelerators engaged in research associated with atomic energy in university laboratories throughout the country.

## IV. ATOMIC POWER

*There has been extensive discussion and speculation on the possibilities of atomic power and in some instances unwarranted optimism as to the character of the technical difficulties and the time required to surmount these difficulties. Following is a report to the Atomic Energy Commission by its General Advisory Committee* stating the Committee's evaluation of the prospects for useful power from nuclear energy.*

This paper proposes to discuss considerations that will determine the answers to the questions:

When shall we have heat and power from atomic energy?
On what scale will this be available?
How much will it cost?

Even if a full account of the events of the next decades were available to us, we would have to give a fairly complex answer to these questions. Thus, the first instances of the generation and uses of heat or power are likely to be on a small scale and be uneconomical. Further development may increase the scale without substantially improving the economy, and many steps surely lie between the present and the ultimate future in which atomic power is possible, economical, practical, and abundant.

At present, there already exist nuclear reactors which produce atomic power as a byproduct but not in a usable form. The large reactors at Hanford, made up of natural uranium and graphite and used in the production of plutanium for atomic bombs, generate great quantities of heat at low temperatures, and this heat is carried away in the water of the Columbia River. The much smaller uranium-graphite reactor at the Oak Ridge National Laboratory, used for research purposes and for the production of radioactive isotopes, generates heat which is dissipated in the air. A similar reactor is under construction at the Brookhaven National Laboratory. The uranium-graphite and the uranium-heavy-water reactors at the Argonne National Laboratory are used for research purposes and their small energy outputs are also wasted. The reactors at the Los Alamos Laboratory, made up of enriched uranium or plutonium and used for research in connection with atomic bombs, operate at a very low power and dissipate their heat into water or into the air. Thus, none of the reactors now in existence produce usable power. However, all of these reactors supply valuable information for the development of power reactors.

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*Members of the AEC General Advisory Committee are: Dr. J. Robert Oppenheimer, Director of the Institute for Advanced Study, Princeton, N. J., chairman; Dr. James B. Conant, President of Harvard University; Dr. Lee A. DuBridge, President of California Institute of Technology; Dr. Enrico Fermi, Professor of Physics at the Institute for Nuclear Studies, University of Chicago; Dr. I. I. Rabi, Chairman of the Department of Physics, Columbia University; Hartley Rowe, Vice President and Chief Engineer of the United Fruit Company; Dr. Glenn T. Seaborg, Professor of Chemistry at the University of California; Dr. Cyril S. Smith, Director of the Institute for the Study of Metals, University of Chicago; Hood Worthington, E. I. duPont de Nemours & Co., Inc.

There are numerous scientific and technical problems that must be solved before atomic power can become a practical reality. Some of these are connected with generating energy at high temperatures, for no other sound method of applying atomic energy usefully as energy has as yet been proposed. This problem of high-temperature energy generation is essentially one of finding suitable materials for use in a nuclear reactor, suitable forms for the fuel, for structural elements, for coolants, and for moderators. But even in a program focused primarily on high-temperature energy, novel considerations limit the kinds of material which can be used. Thus, any reactor must include one of the two fissionable elements, uranium and plutonium. Materials of the reactor must be able to withstand not only high temperature, but the high levels of radiation which are necessarily present if the power is not to be altogether trivial.

To these obvious and necessary requirements, further desirable but optional criteria must be added. For example, it is undesirable to use in a reactor materials which absorb many neutrons, since the investment in nuclear fuel would thereby be increased and its conservation impaired. It is undesirable to use materials or reactor designs which give a very short life without recharging, since this not only works against economy because of the cost and inevitable losses in reprocessing reactor components and fuels, but also limits the adaptability of the source of power. It is undesirable to build reactors in which the power per unit of fuel invested is very low, since this will clearly involve rather large capital fuel costs. It is desirable that the reactor design have as little net consumption of fuel per unit of power as possible, or even that it have a net gain of fuel, a so-called breeding, as power is generated. All of these considerations bear on increasing the possible scale and decreasing the probable cost of atomic power.

However, it is likely that in many early reactor designs these criteria will not be adequately satisfied. These reactors will involve relatively large charges of fuel, relatively low power per unit of fuel invested, frequent recycling, and a high net consumption of fuel per kilowatt obtained. They will also probably operate at moderate temperatures where the thermodynamic efficiency is low and where certain specialized applications may not be possible.

Two reactors are now authorized for construction which should produce atomic power and which should be completed within the next two or three years. Neither unit can conceivably rate as an economic producer of power. But, as a result of experience gained in these, and their successors, there will start a program of reaching higher temperatures and at the same time satisfying some of the criteria necessary for practicality and economy. Fairly practical reactors, that might be useful for special purposes, may then be available on an experimental basis within a decade.

The widespread use of atomic power will also depend on the availability of nuclear fuels. There are three possible nuclear fuels—uranium 235, uranium 233, and plutonium 239. Uranium 235 occurs to the extent of only 0.7 percent in natural uranium and can be used either in that highly dilute form, or after preliminary enrichment in isotope-separation plants. It is the natural source of all nuclear fuels. Plutonium and uranium 233 are artificial nuclear fuels obtained in the first instance by absorbing some of the extra neutrons from the fission of uranium 235 in either uranium 238 (the inert part of natural uranium) or in thorium. These elements, once formed, can be separated by chemical means from their parents, a simpler process than the physical separation of isotopes but fraught with great difficulties because of the enormously high radiation levels.

The selection between the various types of fuel will be, in the long run, a matter of economics and availability. If uranium ores should be found to be very plentiful even if low grade, it would probably be cheapest and best to use natural or, if needed, slightly enriched uranium as a fuel directly. The fuel might then be discarded without chemical treatment after, say, one percent had been utilized, which would give about 100,000 kilowatt-hours of heat per pound of the original material.

In anticipation of a rapidly growing shortage of uranium, great attention has been given to "breeding", a process in which plutonium or uranium 233 is produced by the power reactor at a rate greater than its consumption. It is theoretically possible—but in practice will be very difficult—to build an industrial reactor that will cause excess neutrons to be absorbed in a blanket of either U 238 or thorium, producing plutonium or U 233 which can serve as new fuel to continue the operation indefinitely as long as new natural uranium or thorium is supplied. This greatly increases the availability of fuel, for most of the uranium, not just the small 235 fraction of it, is consumable, and moreover the larger resources of thorium also can be used. It might even be possible by these means to build up fissionable material faster than it is consumed.

Nevertheless, the engineering difficulties associated with breeding are enormous. The conditions which have to be fulfilled to obtain high neutron economy are difficult to reconcile with those needed to obtain a high power output for a given material investment. There are acute chemical engineering problems associated with the repeated treatment of partly depleted fuel and the extraction of new fissionable material from the uranium or thorium blanket. Such procedures are complicated by the enormous radioactivity and have to be repeated many times before the fuel is completely consumed. The process must give virtually complete recovery at each stage if the physical reproduction is to be reflected in active material stocks.

Another very important factor in the possibility of widespread use of atomic power will be the cost of uranium. At the price of uranium compounds before the war, the cost of uranium fuel would compete with coal under almost any condition. However, the available supply came from fairly rich ores and was fairly limited. It may be assumed that the supply could be increased through intensive geological research and prospecting. Large use of uranium, however, will certainly drive the mining industry to the exploitation of poorer and poorer deposits. The cost will be determined by the cost of handling large amounts of rock, although it may conceivably be reduced by the sale of useful byproduct minerals.

If unfavorable assumptions are made about the cost of uranium and the technical practicability of breeding, the result is that atomic power would not compete with coal power in the United States except in regions where the cost of transportation of the fuel from the mine is the determining factor, or under other special conditions where the small bulk and weight of the uranium fuel are particularly valuable. On the other hand, if favorable assumptions are made about the cost of uranium and the technical practicability of breeding, the ultimate capacity may become comparable to and even larger than the present coal industry and will operate at a lower cost, at least as far as fuel expenditure is concerned. At the present time, sufficient knowledge does not exist to make a definite choice between these two alternative possibilities. It should be pointed out that, in either case, the cost of a nuclear-fuel power plant will be substantially greater than that of a coal-burning plant of similar capacity.

Even on the assumption of a most favorable and rapid technical development along these lines, a word of caution is needed as to the time scale. We do not see how it would be possible under the most favorable circumstances to have any considerable portion of the present power supply of the world replaced by nuclear fuel before the expiration of 20 years.

# V. CONSTRUCTION PROGRESS

In the spring of 1948, construction of new production plants, research laboratories, and housing and community facilities mounted to a high rate. Work accomplished during the 3 months of April, May, and June was about as great as the total for the entire year of 1947. As contractors began to translate blueprints into buildings, equipment, and utilities, construction expenditure reached a level where it accounted for about half of the total dollar outlay of the Commission.

Production facilities accounted for more than half of construction expenditure, research facilities for 12 percent, and housing and community facilities 32 percent.

## PRODUCTION AND RESEARCH FACILITIES

Plants for the processing of source materials and the manufacture of fissionable materials are being expanded in a major undertaking.

The bulk of this extensive construction job is at the Hanford plutonium works. There more than 15,000 construction workers are now employed on additions to plant, plus the construction of auxiliary facilities for transportation, utilities, storage, housing, and community needs.

A program of construction to replace and extend temporary wartime facilities is just getting started at Los Alamos, the Commission's weapon research and production center in New Mexico.

The building of major research facilities as of June 1948 was going on at several of the Commission's installations throughout the country. A site had been acquired in DuPage County, Ill., near Chicago, for the Argonne National Laboratory, and site work had begun. The new permanent plant of this laboratory, a major national center for atomic energy research, is estimated to cost about 57 million dollars and is scheduled for completion early in 1951. Temporary structures are now in place.

After delays caused by a severe winter, the construction program at the Brookhaven National Laboratory on Long Island, New York, is nearly on schedule again and is almost one-half complete. The target date for completion is early 1949. Building of the experimental nuclear reactor, which will help make Brookhaven a center of scientific work, is well under way.

Extensive new physics and chemistry laboratories were started at the Knolls Atomic Power Laboratory at Schenectady, N. Y., where the entire 17 million dollar project is now almost 20 percent complete.

At the Radiation Laboratory at the University of California at Berkeley, a new and unique particle accelerator, a synchrotron which will accelerate electrons to energies of 300 million electron volts, is virtually complete, and building of a new central research laboratory is about to begin.

### HOUSING AND COMMUNITY FACILITIES

Extensive new construction of housing and community facilities got under way during the first half of 1948 at all three of the Commission's town sites, in accordance with plans of development made during 1947. At Oak Ridge, the major effort is to replace substandard warbuilt housing and community facilities for a city of 36,000. By June, contracts had been let for about 500 new housing units, together with related community facilities and improvements.

The work programs at Los Alamos and Richland (Hanford) are still rapidly expanding; and the effort has been to provide proper shelter for people already in the program and prepare for scheduled growth of population. Work on about 600 new housing units has been started at Los Alamos. At Richland, one group of 450 houses was complete. The new housing being built also includes a group of 397 houses and apartments, virtually complete, and another group of 1,000 houses, well started. At the Richland construction camp, barracks, portable houses, trailer spaces, utilities, stores, and recreational facilities to provide for 13,300 workers and some 6,000 of their dependents were largely completed.

### THE PROGRAM AHEAD

The construction program on which the Commission has embarked will extend over several years and is expected to cost about one and a quarter billion dollars. Up to June 30, 1948, only about 20 percent of this expenditure had been made, and the peak of construction activity is not expected to be reached until 1949 or later.

# VI. RAW MATERIALS PROGRAM

During the first quarter of 1948 the Commission's staff made a detailed study of the sources of uranium available to the United States. One result of the study is an intensive program now under way for increasing supplies of uranium available to the United States atomic energy program from both foreign and domestic sources.

A substantial part of the uranium used in the American atomic energy program has come from the high-grade ore deposits of the Belgian Congo and Canada, with the greater amount from the Belgian Congo.

The Commission's program for foreign procurement of uranium is directed toward increasing the supplies available through expansion of production from existing sources and development of new production which may be available to this country.

To enlarge the available uranium supplies to the maximum, the Commission has also embarked upon a program of expanding domestic uranium production. The Colorado plateau area is an important domestic source. The deposits here, however, are quite low-grade compared with the deposits in the Belgian Congo and with some in Canada and Europe.

The aim of the domestic program is to stimulate the discovery and production of domestic uranium by private competitive enterprise. The major elements of the program are:

1. Government-guaranteed 10-year minimum prices for domestic refined uranium, high-grade uranium ores, and mechanical concentrates.
2. A bonus of $10,000 for the discovery and production of high-grade uranium ores from new domestic deposits.
3. Government-guaranteed three-year minimum prices for the low-grade carnotite and roscoelite-type uranium-vanadium ores of the Colorado plateau area and Government operation of two vanadium-uranium plants in that area.

Preliminary plans for the Colorado plateau area have been completed and the ore purchase program is under way. The Commission has purchased two plants for processing the ores—one from War Assets Administration and one from the U. S. Vanadium Corporation—and negotiations are in progress for the operation of a third plant. These three plants have been idle since the war and approximately one year will be required to rehabilitate and modernize them for efficient operation. During the construction period, stockpiles will be accumulated to assure a continuous ore supply when operations commence. Two privately-operated plants will continue to supply finished products under contracts with the Commission.

The announcement of the domestic uranium program has created widespread interest in searching for uranium deposits in the continental United States and Alaska. Several hundred inquiries are received by the Commission each week and many others are received by the U. S. Geological Survey and the Bureau of Mines. Mining activity in the Colorado plateau area has rapidly increased and plans are under way for large-scale production by mining companies and individual operators. It is expected that production will equal or exceed that of the war period when the ores were mined for vanadium under a government buying program. In addition to mining, private interests are planning extensive development and exploration programs. This work has been encouraged by a provision in the Commission's price schedule which includes a development allowance. The Commission recognizes that, in line with the policies expressed in the Atomic Energy Act of 1946, development and production of uranium ores can be stimulated most effectively by the type of private operations responsible for the growth and efficiency of the American mining industry.

The Commission is also expanding its own domestic exploration, development and research relating to raw materials. This work is designed to aid rather than limit the operations of private enterprise in prospecting, ore production, and ore beneficiation. In general, deposits of uranium discovered by the Commission on public lands are expected to be made available for development by private operators on an equitable basis.

Research activities in the field of raw materials include programs for improving existing processes for treatment of Colorado carnotite ores and for the development of new processes which may make available other low-grade sources of uranium. These research programs are being carried out by a number of industrial, educational, and governmental research organizations.

Attention is also being given to other mineral products, which have, or may have, special applications in the field of atomic energy.

# VII. ADMINISTRATION

## Personnel Security Program

One of the most important and difficult responsibilities of the Commission is the administration of the personnel security program. Pursuant to section 10 of the Atomic Energy Act of 1946, the Federal Bureau of Investigation makes a "full background" investigation of the character, associations, and loyalty of each employee of the Commission, and also of each employee of a contractor whose work involves access to restricted data. After receiving the information developed by such investigation, the Commission must determine whether the common defense and security of the United States will be adversely affected by permitting the individual to have access to restricted data. The Atomic Energy Act requires that such an investigation and determination be made not only for new applicants for employment but also for the very large group of persons who were already employed on atomic energy work and had been given access by the Manhattan Engineer District to atomic energy information.

In compliance with the requirements of the Act, it has been necessary to examine the records of FBI investigations of the thousands of employees already on the job and of additional thousands of applicants. Only a small percentage of the investigations bring forward considerations that may be substantially adverse to the character, loyalty, and associations of employees or applicants. However, owing to the novelty and the gravity of the questions presented in evaluating such cases, each of them consumes much time of considerable numbers of officials. For these reasons, the personnel security program has proved to be a significant part of the work load of the Commission and its staff, and a substantial amount of administrative expense is accounted for by this requirement.

To assist it in meeting the complex problems in this field the Commission has appointed, as was stated in the Third Semiannual Report to the Congress, a five-member Personnel Security Review Board composed of prominent citizens with a wide range of experience. Members of this Board are:

Owen J. Roberts, former Associate Justice of the United States Supreme Court, Chairman.

Dr. Karl T. Compton, president, Massachusetts Institute of Technology.

Hon. Joseph C. Grew, former Under Secretary of State.

George M. Humphrey, president, M. A. Hanna Co.

H. W. Prentis, Jr., president, Armstrong Cork Co.

This Board serves in an advisory capacity to make recommendations as to the appropriate disposition of specific cases, and also to make general recommendations with respect to personnel security standards and practices.

The Commission recognizes that it is essential that the procedures established and the practices adopted in this field should be effective in safeguarding the security of the atomic energy program and at the same time fair and just in their treatment of the individual. The Commission is convinced that a hearing procedure should be in effect to give the fairest possible hearing to employees whose eligibility for security clearance has been drawn into question by information developed in the course of the investigation of their character, loyalty, and associations. On April 15, 1948, the Commission issued an Interim Procedure pursuant to which employees would have the opportunity to appear before an impartial local personnel security board, which would make recommendations as to security clearance after sifting all available evidence. This Interim Procedure, which the Commission intends to revise in the light of further experience in the handling of the cases, may be outlined as follows:

(*a*) The employee is notified of the basis for the question concerning his eligibility for security clearance, in as much detail as security considerations permit.

(*b*) The employee is given an opportunity to answer the questions concerning the security clearance, both in writing and in a hearing before a local personnel security board appointed by the Manager of Directed Operations for the area in which he is employed.

(*c*) In his appearance before the local board the employee may be represented by counsel of his own choosing and may present evidence in his behalf in person and through witnesses.

(*d*) On the basis of all of the evidence before it, including the employee's written explanation and information submitted by the employee during his appearance before the local board, the local board makes a recommendation to the Manager of Directed Operations as to whether security clearance should be granted. It is the practice for this recommendation to be accompanied by a memorandum in which the local board analyzes the case.

(*e*) The local Manager then reviews the entire record in the case, including the local board's recommendation, and in turn makes a recommendation to the General Manager of the Commission as to whether security clearance should be granted.

(*f*) If the Manager of Directed Operations recommends that clearance be denied, the employee is so notified and has an opportunity to request that the Personnel Security Review Board review this adverse recommendation. Provision is also made for the General Manager to submit a case to the Personnel Security Review Board on his own initiative, with appropriate notice to the employee. On the basis of its review, the Personnel Security Review Board makes a recommendation to the General Manager to assist him in his final determination as to security clearance.

These hearings are not confined solely to the question of loyalty. Under the Atomic Energy Act, consideration must be given to "character and associations" as well, and a determination made whether, in view of all the factors, the common defense and security will be adversely affected by permitting the individual to have access to restricted data. Without minimizing the importance of loyalty, it should be stated that loyalty constitutes but one of the factors that must be examined to determine eligibility for access to restricted data, and the issues most often presented before the Commission's local boards have involved questions of character and associations and not loyalty.

Whether hearings should be granted to applicants for employment, as they are for persons already employed on atomic energy work, is a matter currently under consideration by the Commission.

In any hearing procedure based on information contained in investigative reports, one of the principal difficulties encountered is that of attempting to afford employees an opportunity to confront and cross-examine persons who have furnished information unfavorable to them. In the interest of the common defense and security of the United States, it is the Commission's duty to give appropriate consideration to all information which may be relevant to the security clearance of the person concerned. Under the Atomic Energy Act, the FBI report is the primary source of such information. There will be some cases in which important information comes from a source which the FBI has designated as confidential and which therefore the Commission may not properly disclose. In such a case the employee will not have an opportunity to confront and cross-examine the person who supplied the information. It is hoped that it will be possible to keep these situations to a minimum, and that the sources of significant information bearing on the case can be available at a local board hearing.

The Commission recognizes that where full confrontation is not possible it is extremely important that the employee be protected against statements activated by bias or prejudice, or statements which result from simple lack of information, and that care be taken to check the accuracy of the information furnished. The Commission considers that one of the primary functions of the local board is to serve as an impartial body to do its best to evaluate all sources of information, and to elicit from the employee and others all information necessary to clear up any misunderstanding which might otherwise result from lack of complete confrontation.

As of July 15, 1948 there have been 15 hearings conducted before local personnel security boards, including one which occurred prior to the issuance of Interim Procedure of April 15th. While most of these cases are still in process, six have been finally disposed of; and of these six, security clearance has been granted in five instances and denied in one.

## Labor Relations

The Third Semiannual Report by the Commission to the Congress described certain developments in the field of labor relations that had a bearing on continuity of atomic energy operations and noted that the Commission and the Joint Committee on Atomic Energy had under consideration how best to insure that work stoppages would not occur at major AEC facilities.

As described in the Third Semiannual Report, labor negotiations at the Oak Ridge gaseous diffusion plant (K–25) resulted in the signing of the new contract, without any work stoppage, although a vote of the local union membership authorized the union officers to call a strike in the event negotiations were unsuccessful. A report of these negotiations was prepared by the Commission and transmitted to the Joint Committee on Atomic Energy on January 6, 1948. The text of the report, titled "History of Union-Management Relations at K–25 Plant", may be found in Hearings before the Joint Committee on Atomic Energy (80th Congress, 2nd Session) on Labor Policy in Atomic Energy Plants (hereafter referred to as "Hearings"), Part I, pages 6 through 10.

The Commission also transmitted to the Joint Committee on Atomic Energy, on January 16, 1948, a "Report on Labor Problems Relating to Continuity of Production in the Atomic Energy Commission Program." The broad ramifications of the problem of assuring continuity of operations are described in this report, which may be found as Exhibit I to the Hearings, Part I, pages 117 through 136.

The Joint Committee on Atomic Energy held hearings on the subject of labor policy in atomic energy plants on March 9, 10, 12, 15, and 16, 1948. At the outset Senator Hickenlooper stated that the Joint Committee desired to acquire as complete an understanding as possible of all the facts involved.

The first witness was the Chairman of the Commission, who presented the views of the Commission and submitted for insertion in the record the two reports previously furnished to the Joint Committee, as well as a report prepared by the staff of the Commission with respect to the then current labor dispute at the Oak Ridge National Laboratory (X–10), the parties being the Commission's contractor, the Carbide & Carbon Chemicals Corporation and the Atomic Trades and Labor Council, A. F. of L.

Other witnesses before the Joint Committee were James A. Brownlow, Secretary-Treasurer, Metal Trades Department, A. F. of L.; Cyrus S. Ching, Director, Federal Mediation and Conciliation Service; Silas W. Pickering II, Director of Industrial Relations, Carbide & Carbon Chemicals Corporation; and Benjamin C. Sigal, Counsel, Gas, Coke & Chemical Workers of America (CIO). The testimony of all the witnesses is set forth in the Hearings.

### SETTLEMENT OF OAK RIDGE LABORATORY DISPUTE

The labor dispute at Oak Ridge National Laboratory (X–10) was settled on June 15 without any stoppage of work. During the course of negotiations, however, the employees involved in the dispute voted to strike unless a settlement was reached on March 5. Accordingly, on March 5, the President issued Executive Order No. 9934, creating a Board of Inquiry pursuant to the Labor Management Relations Act, 1947. At the President's request, both parties agreed to maintain the status quo until March 19.

On March 15, the Board of Inquiry submitted its first report. Thereupon, at the request of the President, the Attorney General, on March 19, instituted action and obtained an injunction in the United States District Court for the Eastern District of Tennessee, pursuant to the Labor Management Relations Act.

At an election conducted by the National Labor Relations Board, on June 1 and 2, the employees, by a vote of 771 to 26, voted not to accept the final offer of settlement as made by the employer. Consequently, on June 11, pursuant to Section 210 of the Labor Management Relations Act, the injunction was discharged on motion of the Attorney General. The parties continued negotiations, with the assistance of the Federal Mediation and Conciliation Service, and on June 15 reached agreement on the terms of a new contract.

The facts concerning this labor dispute are set forth in detail in the first and second reports of the Board of Inquiry which were transmitted with the message of the President to the Congress (House Document 726, 80th Congress, 2nd Session). The position of the Commission with respect to labor relations in the atomic energy program has been set forth in its reports and testimony to the Joint Committee on Atomic Energy and in its statements submitted to the Board of Inquiry appointed by the President under Executive Order 9934. This position may be summarized in brief as follows:

The Commission decided at the outset of its tenure that the necessary pace and level of progress of the atomic energy program could be obtained only through the enthusiastic support and drive of broad sectors of the American economy. Accordingly the Commission decided that major operations should be carried forward by nongovernmental contractors, both industrial and academic, with responsibility and commensurate authority for managerial decisions comparable to those exercised in their private activities. A year and a half of experience has strengthened the Commission's belief that this is by all odds the best way to advance this new technology.

By carrying forward major operations through private contractors, with deep roots and a firm base in the American economy, the atomic energy program not only benefits from accumulated experience and established resources, but also enlists the interest and support of industries and universities for future private development. Correspondingly, the Government machinery for supervising the enterprise is kept at a minimum.

The Commission has sought actively to obtain voluntary agreement by its contractors and by the labor organizations representing their employees on an over-all labor relations program that would include positive assurance against work stoppages.

If accepted voluntarily, such a program would have much to recommend it. But it is the Commission's view that imposition by the Commission of a labor relations program, not accepted voluntarily would seriously impede the support and drive required to push ahead rapidly in this enterprise.

Consequently the Commission feels that legislation directed toward a special labor policy for the atomic energy enterprise would not be desirable at this time.

In his recent message to the Congress (H. Doc. No. 326, 80th Cong., 2d Sess.) the President stated his intention to establish a commission to concern itself with the broad code of conduct which should be observed by management and labor in their relations with each other in this vital program. The message further stated that the President would request the advice of the Atomic Energy Commission and the Joint Committee on Atomic Energy, both as to the membership of the commission and the specific questions to be studied.

## Community Management

For obvious reasons, the great plants at Oak Ridge and Hanford for manufacturing fissionable material and the laboratories at Los Alamos for fabrication of these materials into weapons were in wartime built in locations remote from towns and cities. It was necessary to establish at each of these centers living quarters, supply stores, and community facilities for the people who carried on the work in the plants and the laboratories.

Hence, the Commission took over, as part of the atomic energy production and research enterprise, the management of three towns—Oak Ridge, Tenn. (population now some 36,000) Richland, Wash. (30,000), and Los Alamos, N. Mex. (8,000).

The Commission believes that it is important that the affairs of these towns be carried on and their development pointed in such a way as to give the people who live there—and whose work makes the production program possible—a growing opportunity to live as nearly the normal life of Americans in an American community as the special circumstances will permit. It is also important that the costs to the Federal Treasury of town operation be known and be not excessive.

During the past 6 months the Commission has examined the operations of these three towns. Each developed separately during the war, and the policies of operation differed. In each, in order to attract and hold the qualified people for the plants at remote localities there was a heavy element of subsidy of costs of housing and community services. The Commission's analyses have been made with the objectives of finding ways of (1) reducing subsidies and eliminating excess costs and services; (2) getting precise and comparable fiscal information for all three communities through uniform accounting systems and policies; (3) separating from governmental services the real estate and commercial operations.

On April 15 the Commission authorized the employment of independent public accountants to develop and install suitable accounting and reporting systems for the town management functions carried on by contractors at the three AEC towns. These new procedures will make it possible to have financial statements for the town management operations prepared on a comparable basis for the three installations, and will provide the Commission with accurate information concerning the allocation of costs between housing, commercial facilities, utilities, and other services. The work has been substantially completed at Oak Ridge and is under way at Los Alamos and Richland.

## RICHLAND

A program is being worked out at Richland to enable private businesses, at their own expense, to construct buildings on Government land for the additional commercial operations required for the expanding permanent town of Richland. Long term leases or licenses will be entered into with the persons erecting the buildings and operating the commercial establishments.

## OAK RIDGE

The Commission announced in June the decision to remove the town of Oak Ridge from the controlled area near the end of 1948. When this is done, Oak Ridge will be in the same status as Richland, where many of the persons employed at the Hanford Works live. Richland has been an unfenced town ever since it was built during the war. The production plants at Oak Ridge, as at Hanford, will of course, continue to be in controlled areas.

## LOS ALAMOS

At Los Alamos, to speed progress towards more nearly normal community life, it is necessary to remove present doubt over whether part of the Project area is under exclusive Federal jurisdiction.

Of the 69,000 acres in the Project area, some 65,400 were transferred from the United States Forest Service, either directly or through the Manhattan District, to the Commission. It appears that this land remains under the jurisdiction of the State of New Mexico. The remaining 3,600 acres were bought in fee by the Manhattan District from private owners, and were later transferred to the Commission. The small parcels of land comprising this 3,600 acres are scattered throughout the Project. Although the matter has not been decided in the courts, it appears that, owing to the manner of acquisition, these parcels fall under Federal rather than State jurisdiction.

Since much of the land in the residential section of Los Alamos is in this doubtful jurisdictional status, many residents may not have access to the normal judicial processes of county and State. This uncertainty hinders growth of effective community government, a uniform system of law enforcement, and the setting up of adequate safeguards for private rights.

To clear the way to these desirable ends, the Commission has decided to request Federal legislation returning to the State of New Mexico jurisdiction over those 3,600 acres which now appear to be under exclusive Federal jurisdiction.

## PATENT COMPENSATION BOARD

Section 11 of the Atomic Energy Act provides for the designation of a Patent Compensation Board. This Board is to have the responsibility for considering, pursuant to procedures which the Commission establishes by regulation, applications for the determination of reasonable royalty fee, just compensation, or the grant of an award for patents, inventions, and discoveries, as specified by the Act. Upon the recommendation of the Commission's Patent Advisory Panel, the Commission has now adopted general rules of procedure to govern such proceedings. These regulations were published in the Federal Register for June 24, 1948, after revisions which had been made in the light of comments submitted by interested persons in response to the earlier publication of the regulations in draft form. The members of the Patent Compensation Board have not yet been designated.

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# APPENDIX 1

## REPORTS OF USERS OF ISOTOPES

(A) IN UNIVERSITIES, PRIVATE RESEARCH INSTITUTIONS, HOSPITALS, AND GOVERNMENT LABORATORIES OTHER THAN AEC

(B) IN AEC PROJECTS

*Reproduced here in part are several hundred reports on work done by users of isotopes in 136 institutions in the United States and Hawaii and by nine of the Commission's contractors. They are presented in the language of the scientists who submitted them, without translation of technical terms. To the layman, they indicate the significance and scope of the work being done with isotopes and the expansion of American scientific effort that is resulting from the liberal availability of the new research tools.*

*It will be noted that a majority of the users of isotopes are not now prepared to interpret or evaluate the results of their work. Within the next few years, however, most of these research projects will have been reported upon and added to the Nation's scientific literature, along with the more than 600 scientific papers listed in Appendix 5. Although the fundamental nature of most of the work makes its popular presentation difficult, the daily and periodical press and the radio broadcast industry may be expected to continue and expand their presentation of developments related to atomic energy in a form adapted to public needs.*

## (A) USES OF ISOTOPES IN UNIVERSITIES, PRIVATE RESEARCH INSTITUTIONS, HOSPITALS, AND GOVERNMENT LABORATORIES OTHER THAN AEC

### Biological and Medical Research

(ANIMAL PHYSIOLOGY)

*American Cyanamid Company, Stamford, Conn.*—We have been concerned with incorporating radiocarbon (C 14) into folic acid, a vitamin. In another phase of our work we have used radiostrontium (Sr 89, 90) in the study of oxytocic properties of strontium. We were able to show with pregnant rats that the amounts of strontium in the fetus are sufficiently large to make it inadvisable to use strontium as an oxytocic agent.

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*Biochemical Research Foundation, Newark, Del.*—Radiosulfur (S 35) has been used for the biological synthesis of glutathione containing S 35 by feeding it to the yeast in a culture medium in which the only source of sulfur was the S 35 as sulfate. The radioactive glutathione is being used for tracer studies in rats in different states of nutrition. Glutathione is a naturally occurring body substance, and it is hoped by these studies to find out something about its function in the body. Animal experiments have just been started in which the object is to produce radioactive glutathione synthetically as a prelude to the production of radioactive insulin, the mechanism of which in the treatment of diabetes is unknown.

In another investigation radioactive sulfur has been used for the chemical synthesis of cysteine, a sulfur containing amino acid. The cysteine has a radioactivity of about 1.5 millicuries per gram after the time required for its synthesis and is being used for tracer studies in rats.

Radiophosphorus (P 32) treatment of animals has been carried out in order to compare the cellular effects of a radio compound with direct neutron effects which we had previously observed.

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*Bowman Gray School of Medicine, Winston-Salem, N. C.*—We have been using radioactive phosphorus (P 32) to study the formation of phospholipids in animal tissues. Phospholipids are fatty-like substances containing phosphorus which are present in all living cells and which are probably very important for the well-being and the proper functioning of the organism. In the present investigation, it has been shown that the formation of phospholipids in the liver and intestine is stimulated by a number of substances, some of which are components of the diet. These results may be of interest in relation to the symptoms and treatment of certain diseases of the liver in humans.

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*University of California, Berkeley, Calif.*—Radiosulfur (S 35) and radiocarbon (C 14) have been used to study the persistence of protein formation and breakdown in the whole animal and its isolated tissues. In the whole animal it is possible to obtain indications of this formation and breakdown, but in its isolated tissues isotopic amino acids provide the only reliable indication of such processes. Consequently, complete reliance is placed on the isotopic technique. After studying the normal picture, we are becoming more concerned with the effects of deviations from the normal resulting from effects of other amino acids, starvation, hormones, etc., on the system. When the picture is more complete we hope to have attained a better conception of protein metabolism.

Amino acids in the body proteins can be formed from the transformation of other amino acids and even from non-amino acid compounds such as carbohydrate and fatty acid. The problem of the mechanism of protein synthesis can only be adequately studied by the labeling techniques with isotopes.

The following results of outstanding interest have been secured:

1. Amino acids can be incorporated by enzymatic reaction into the fragments of disintegrated cells as long as these fragments can utilize oxygen. This discovery gives hope of determining and purifying the enzymatic components necessary for the synthesis of proteins.

2. Rapidly growing cancerous tissue is able to secure a disproportionate share of the available nutriments and thus tends to starve the normal tissues of the body.

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Radioiodine (I 131) is being used in studies of thyroxine synthesis by the thyroid gland and, in general, the mechanism of action of the thyroid gland in health and disease.

Radiophosphorus (P 32) is being used in studies of phospholipid metabolism, namely to determine the site of origin of this lipid in plasma, its fate in tissue, etc.

Radiocarbon (C 14) is being used in the synthesis of palmitic acid and glucose; the metabolism of both are being followed in the normal and diabetic animal.

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Radioactive isotopes of yttrium, columbium, and zirconium have been used in the study of the localization of radioactive isotopes in certain specific animal tissues and organs, both for the purpose of studying the biological effects of special tissue irradiation and for the therapeutic value of such localized irradiation with such isotopes.

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Radioarsenic (As 74) has been used in distribution studies in animals that have developed an immunity to arsenic and to determine paths of excretion in the dog.

Radiocarbon (C 14) has been used to study the distribution and excretion of methadon and other morphine substitutes in mice and rats and the relationship of tissue levels to pharmacologic activity.

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*California Institute of Technology, Pasadena, Calif.*—As part of a study of protein and peptide metabolism, lysine was synthesized with radiocarbon (C 14). It has been found that one thousandth of a milligram of lysine is converted to alpha-aminoadipic acid per 10 milligrams (dry weight) of guinea pig liver homogenate per hour.

In another investigation it had been shown that arginine may be synthesized by the transfer of the amino group of glutamic or aspartic acid to citrulline. Since lysine was also active, it was suggested at the time that it was first converted to glutamic acid which then aminated citrulline. However, experiments in liver homogenate with lysine labeled with C 14 showed that a radioactive dicarboxylic acid was formed. This excluded glutamic acid formation by oxidative removal of the radioactive carbon. Alpha-aminoadipic acid has now been shown to be very probably the product of the reaction.

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We are using radiocarbon (C 14) as a tracer in studying the mechanism of protein synthesis in biological materials. This work would be impossible without some such tracer as C 14. As protein is one of the major components of all its catalysts and many of its hormones, as well as in structural tissues, the value of getting some information on the mechanism of its production in the tissue is obvious.

We have so far been able to work out the major steps in the metabolism of the essential amino acid, lysine, and have also isolated a number of peptides which appear to be intermediate in both the synthesis and degradation of proteins in tissues.

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The present program involves the study of exchange reactions between carbon 14 labeled leucine and antibody globulins. It has been found that such proteins will incorporate the labeled leucine in the body and also in the test tube providing a suitable enzyme system is present. Such studies have also given information as to the rate of antibody formation and the amount of stored or reserve antibody. The *in vivo* exchange reactions do not take place with foreign proteins, e. g., horse globulins injected into rabbits containing labeled leucine.

Such studies of the formation, destruction and state of serum proteins in the body would of course be impossible without the aid of isotopes for tagging definite molecular structures. The C 14 isotope is one of the most valuable for this work.

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*University of Southern California, Los Angeles, Calif.*—Radiophosphorus (P 32) is being used to study nucleoprotein turnover rates in tissues *in vitro* and the correlation of this process with cellular metabolism. Radioiodine (I 131) is being used in studies to determine the nature of blood and tissue iodine containing compounds and the metabolism of thyroxine.

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Attempts are being made to study cholesterol turnover as related to the development of arteriosclerosis, by means of using deuterium as a tracer. No results have been obtained as yet.

Deuterium is being used to label the fatty acids of linseed oil in tracing their incorporation in phospholipids of the gastrointestinal tract and liver. The amounts which are incorporated and the speed of incorporation are being studied.

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*Carnegie Institution of Washington, Washington, D. C.*—Radioisotopes are particularly valuable in permitting study of important mechanisms of living matter. Results of research are as follows:

Radioiron (Fe 59) has permitted discovery of a method by which fetal iron is derived from maternal plasma. In contrast to the classical conception of the destruction of the red blood cell, it has been learned that ferric beta globulinate of the plasma is a sufficient source of fetal iron for growth.

Use of Fe 59 has led to the elaboration of a method permitting accurate and precise biological assay of extremely small quantities of this substance.

The rate of escape from the plasma of Fe 59 in the form of ferric beta globulinate has been determined in an effort to elucidate the mechanism of transport of proteins across the capillary wall.

Studies have been made of the mechanism of bone and tooth formation using radiocalcium (Ca 45). The work has demonstrated the key role of the interaction of thyroid in calcium deposition.

A study has been made of phosphorus uptake of the dividing cells. The work indicates an important correlation between cellular activity as evidenced by cell division and radiophosphorus (P 32) uptake.

*Cedars of Lebanon Hospital, Los Angeles, Calif.*—Radioactive sodium (Na 24) is an excellent vehicle for studying the flow of blood in the body. Radiocardiography has been developed here as a rapid, accurate method of tracing the blood flow through the chambers of the human heart. The tracing reveals graphically the condition of the pumping action of the heart within one minute after injection so that enlargement, failure, or normalcy are easily seen. The diagnosis of particular types of congenital defects in children's hearts is still in the process of development.

Other aspects of the circulation are also being analyzed with regard to return of venous blood from the feet to the heart, factors usually causing error in the older forms of circulation time studies, and the rates of absorption into the general circulation of substances injected intramuscularly or just under the skin.

Radioactive phosphorus (P 32) has been used to label red blood cells in additional research on the coronary circulation (of the heart). This type of investigation traces the specific distribution and collection of the blood in the heart muscle after coronary occlusion and in shock.

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*Cedars of Lebanon Research Institute, Los Angeles, Calif.*—An investigator who has been using radioactive phosphorus (P 32) and iodine (I 131) to study the effect of radioactive isotopes on bacterial growth reports the following:

The study was instituted because of the failure of growth of steptococcus viridans cultures which had apparently been accidentally exposed to P 32 and I 131. A large variety of organisms were inoculated into media containing varying concentrations of the isotopes, The early studies indicated that there was a selective sensitivity of the viridans streptococcus to the isotopes. However, later studies using a variety of methods indicated that this specific sensitivity did not exist. Various organisms studied such as staphylococcus albus and aureus, streptococcus viridans and hemolyticus, B.coli, B.sublilis, diphtheria and pneumococcus were all quite resistant to the isotopes and in the concentrations used there was no inhibition of growth.

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*Chemical Corps Technical Command, Army Chemical Center, Md.*—Investigators state that di-isopropyl fluorophosphate has been shown to have a specific action on the enzyme cholinesterase. In order to investigate the mode of action of the compound in the body, it has been synthesized on a millimole scale using radiophosphorus (P 32) as part of the molecule.

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*University of Chicago, Chicago, Ill.*—We are using radioactive phosphorus (P 32) as a tracer element to study the metabolism of essential phosphate compounds in the nervous system. In particular we are interested in the problem of nerve fiber degeneration and regeneration and are testing the hypothesis that the nerve cell body (spinal cord) is continually sending out an essential nucleoprotein to the rest of the nerve. Since nucleoproteins contain phosphorus, it should be possible to trace the migration of nucleoproteins by tagging them with P 32. The importance of understanding the nutrition of the nerve fiber, not only for basic physiological but also for medical problems of nerve injury and regeneration, is obvious.

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It has previously been found that the addition of ordinary iodine to the diet of rats afforded them resistance against the acute toxic action of the rodenticide (alpha-naphthylthiourea (ANTU). It was, therefore, of interest to examine the effects of ANTU on the iodine metabolism of the rat. Radioiodine (I 131) studies were made to supplement those previously made with ordinary iodine. It was found that ANTU markedly depressed the uptake of iodine by the thyroid gland which is consistent with the previous findings with other thiourea derivatives. Studies on the rate of uptake of radioactive iodine by the thyroid tissue of normal rats demonstrated that the uptake of iodine is greatly influenced by the quantity of iodine in the diet and is only constant among different animals when they are fed an iodine-deficient diet. Research on iodine metabolism in the normal and ANTU-poisoned animals is being continued and completion of the project is necessary before definite conclusions can be drawn.

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Radiophosphorus (P 32) has been used as a tracer to study the transformation of energy released on biological oxidation into a form of energy useful to the cell. Although it has been known for some time that phosphate is involved in this transformation, the details of the mechanism have been obscure because of analytical difficulties. For instance, by using P 32 as a tracer it has been found possible to demonstrate in cell-free extracts of liver that the synthesis of at least part of the molecular structure of nucleic acids is dependent on oxidations for energy.

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We are using radiocarbon (C 14) and the stable isotopes C 13 and N 15 in our investigation. It has been found that pyruvic acid amide, in contrast to other amides, is not appreciably hydrolysed in the animal but undergoes "splitting" to acetic acid and an unknown component. The extent of incorporation of isotopic carbon from pyruvic acid into fatty acids, cholesterol etc., has been determined. This made possible calculation of the role of carbohydrate as precursor for other body constituents. Preliminary results suggest that pyruvic acid together with acetic acid is the main precursor of lipids in the animal body.

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Radioactive phosphorus (P 32) is being used to study the metabolism of phosphorus compounds in the body and in micro-organisms in order to determine the mechanisms of action of drugs both from the standpoint of their toxicity and their therapeutic action.

Radioactive carbon (C 14) is being used in the biosynthesis of a number of important drugs. The medicinal plants are grown under sealed conditions and radioactive carbon dioxide is introduced into the system thus becoming incorporated in all of the substances of the plant. After a suitable interval the plant is harvested and the drug extracted from it. The medicinal plants being used in this program include digitalis (digitoxin), the opium poppy (morphine, codeine, etc.), tobacco (nicotine), the autumn crocus (colchium) and the atropa belladonna (atropine). In most cases the production of radioactive drugs in this manner will make possible certain investigations which could not otherwise be carried out due to the lack of sufficiently sensitive methods of chemical analysis.

It is also necessary to use the isotope tracer technique to study the metabolic fate of these drugs in the body since the amounts used to produce profound pharmacological effects are very small. The present state of knowledge concerning the metabolism of these important drugs and the mechanism of their action is very incomplete. It is not known, for example, if certain drugs exert their effect as such or whether the effect is a property of one of the metabolic derivatives of the drug which is formed by the action of the body. With reference to the latter case, researches designed to uncover synthetic substitutes are made much more difficult because the chemical nature of the active agent is not known. Possibly the most dramatic example of the value of such studies is the history of the sulfonamide drugs with the recognition that the activities of the original complex molecule resided in a small fraction of the total molecule. Similar phenomena are almost certain to exist with a large number of the more complex drugs currently used in medicine, and investigations designed to uncover these situations are of the utmost importance.

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This work is concerned with the determination of the uptake and intracellular distribution of C 14 using protozoa. If successful, this work should indicate the mode of origin and constitution of certain structures in cells which heretofore have not been possible to resolve.

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*University of Cincinnati, Cincinnati, Ohio*—A group of investigators has been using radioactive iodine (I 131) in the study of cancer of the stomach in man, and other types of cancer in animals.

Isotopes are essential to continuation of this work.

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Investigators have been using radioactive iodine (I 131), carbon (C 14) and sulfur (S 35).

It has been known since 1941 that 2-acetylaminofluorene causes cancer in experimental animals that resembles spontaneous cancer.

We are also making other compounds which, it is hoped, will localize or concentrate selectively in cancer tissue. This technique should enable cancer to be diagnosed more readily and treated from within the diseased tissue. Partial success has been achieved with localization and diagnosis in animals but much further work must be carried out before the technique can be applied to human cancer.

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*Columbia University, Barnard College, New York, N. Y.*—We have used radioactive iodine (I 131) in the following two ways:

1. To determine dosages of radioactive iodine which will destroy normal thyroid and neighboring tissues.

2. To determine the uptake of iodine by the tissues of invertebrate animals which have no thyroid gland, but which may possibly have a thyroid-like function.

In the first investigation it was found that in mice doses of over 15 to 20 millicuries of radioactivity per kilogram of body weight destroy not only the thyroid gland, but also the parathyroid, and produce extensive loss of the mucus lining of the nearby trachea. Doses in the neighborhood of 5 millicuries per kilogram, though they may destroy most of the thyroid, permit its survival and eventual regeneration. The parathyroids, however, are irreversibly injured and the tracheal epithelium is lost. One of the suggestions arising from this work is the usefulness of radioactive iodine, properly administered, for nonsurgical removal of the thyroid gland. The quantitative data may be of use to physicians in understanding the limits and hazards of clinical use of radioactive iodine.

In the second investigation small amounts of radioactive iodine were given to a number of invertebrates including protozoa, hydra, flatworms, annelid worms, clams, snails, lobsters, daphnia and ostracods. By use of the Geiger counter and radioautography it was determined that almost all forms are able to concentrate iodine in some part of the body to a degree almost equal to the thyroid gland of vertebrates.

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*Columbia University, New York, N. Y.*—Our investigation is designed to determine the metabolic fate of representative barbiturates labeled with radiocarbon (C 14). These drugs are extensively employed in medicine as hypnotics, for preanesthetic medication and for psychiatric examination or "narcoanalysis". Thus far the metabolic products of these widely-used drugs have resisted isolation and identification by traditional methods. It is our belief that the use of isotopes will make possible the elucidation of the structural changes which the barbiturates undergo in the organism.

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An investigator who has been using radioactive ions to study the exchange of ions across nerve membranes states, "The use of radioactive material may become a turning point in the development of research on the mechanism of nerve activity." For half a century, neurophysiologists have assumed that ion movements across the nerve membranes play an essential role in the electrical manifestations observed during nerve activity, but there has been no way of studying such movements. The availability and use of radioactive ions for the study of this problem has changed the situation fundamentally. Significant results have already been obtained. In continuation of these investigations, a project has been worked out which may become of great importance for the understanding of the basic mechanism of nerve activity and eventually for the pharmacology and the treatment of nerve disorders.

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*Cornell University Medical College, New York, N. Y.*—The amino acid methionine is of unusual strategic importance in the maintenance of health because of its multiple functions in the animal body. It is an essential building block in the structure of living tissues, it supplies the sulfur for the formation of another essential building block, cystine, and it serves as a source of the methyl groups used in the formation of a variety of indispensable compounds. Full understanding of the detailed reactions whereby methionine fulfills its functions, and hence the intelligent understanding and management of diseases that can result from a disturbance of these functions, such as cirrhosis of the liver, can only be achieved through the use of isotopically labeled methionine. The same may be said with respect to the exceptionally potent vitamin, biotin, which is also under investigation in our laboratory.

Methionine containing radiosulfur (S 35) has been synthesized in our laboratory and is being used to study the basic defect in the animal body responsible for the symptoms of the hereditary disease cystinuria. It is also being used to extend our earlier studies on cystine formation conducted with methionine containing both S 34 and C 13.

Methionine containing radiocarbon (C 14) in the methyl group has been synthesized and used to demonstrate that a considerable portion of the essential methyl group is rapidly destroyed in the animal body.

As an adjunct to this problem, it has been shown, through the use of C 14 that the source of carbon used in the formation of urea, the main nitrogenous product of the body is carbon dioxide.

Biotin containing C 14 has been synthesized and is being employed to track down the nature of the essential chemical reactions for which this vitamin is responsible. It is also being used to study the distribution and stability of the vitamin in the body and the rate of its excretion.

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*Department of the Army, Medical Department Field Research Laboratory, Fort Knox, Ky.*—While it is generally believed that thyroid function is increased in cold environments, the evidence on which this view is based is far from clear-cut.

The most recent studies on this subject showed by an indirect method that thyroxine release from the thyroid gland is increased in a cold environment. Radioactive iodine (I 131) was used to estimate the activity of the thyroid gland and the conclusion was reached that exposure of rats to cold (0°–2° C) for various periods of time produces a thyroid stimulation which is doubtful after 1 to 3 days, definite after seven days, maximal at 26 days but absent after exposure for 40 days.

These conclusions were based on a study of the uptake of radioactive iodine by the thyroid gland and its conversion to diiodotyrosin and thyroxine.

In most experiments a moderately large amount of carrier iodide was used (5 micrograms) and it was shown that after exposure to cold the uptake of radioactive iodine and/or its conversion to diiodotyrosin and thyroxine was increased at first, but returned to normal after 40 days. With smaller amounts of carrier (0.2 micrograms), however, a decreased uptake of radioactive iodine was obtained during the first seven days of exposure to cold. No longer time intervals were studied and no explanation given for the observation.

The experimental evidence on which these early workers based their conclusions appear far from convincing and thus a reinvestigation of thyroid function after exposure to cold seemed necessary. The supposed absence of thyroid stimulation after exposure to cold for forty days or longer is a point especially in need of either confirmation or correction.

It is intended to expose rats to a temperature of 0°–2° C for periods up to 50 days and to study their thyroid function by measuring the uptake of true tracer doses of radioiodine (no carrier added) and also of large doses of iodide.

The first procedure will serve as a true label of the course of endogenous iodine while the second one will measure the thyroid's capacity to take up exogenous iodine.

A third procedure which is contemplated for use as a measure of thyroid function is the determination of protein bound radioactive iodine of the plasma.

These experiments should furnish good evidence as to whether or not thyroid function is really stimulated by the cold and whether or not this stimulation persists.

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*Detroit Institute of Cancer Research, Detroit, Mich.*—Radiocarbon (C 14) has made possible for the first time a detailed study of the distribution and metabolic alterations of carcinogenic hydrocarbons beyond the point where the characteristic fluorescence of such compounds is lost. By means of these experiments we believe it will be possible to study the changes involved in the production of cancer in experimental animals on a more fundamental basis than has heretofore been undertaken.

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*Distillation Products, Inc., Rochester, N. Y.*—Radioactive carbon (C 14) has been used in this laboratory for synthesizing radioactive alpha-tocopherol (vitamin E). Studies are now under way to determine the distribution, utilization, and metabolism of this compound in the animal body. The use of such a labeled compound enables us to detect smaller amounts than can be detected by chemical means and also enables us to determine the fate of a given dose of this compound despite the large amounts of this vitamin normally present in the non-radioactive form.

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*Emory University, Emory University, Ga.*—Radiosodium (Na 24) has been used to investigate the status of the circulation of blood in the extremities. The method used has consisted of injecting radioactive salt solution, sodium chloride, into the muscle and measuring the rate of its disappearance by the circulation. In this manner a diagnosis of the degree of impairment of the circulation can be made. Critical evaluation of drugs and procedures which are generally believed to improve the circulation can be objectively studied.

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*General Foods Corporation, Hoboken, N. J.*—A great many iron compounds have been used in mineral supplements for livestock. In order to obtain more information on the physiological availability of these compounds, several of them, both soluble and insoluble, were prepared from radioactive iron (Fe 55, 59), fed to both white rats and to cattle, and traced through the animal system by means of a Geiger counter. In general, the soluble iron compounds were more readily absorbed by animals than the insoluble compounds but differences were observed in the availability of the water-insoluble compounds. For example, iron sulfate was more readily absorbed than iron phosphate which in turn seemed to be a better source of iron than iron oxide. Such studies will serve as a guide in the selection of iron compounds to be incorporated in mineral supplements for livestock feeding.

A study has been made of the comparative physiological availability of water soluble and insoluble zinc compounds. Zinc carbonate and zinc chloride made from radioactive zinc (Zn 65) have been fed to white rats and to cattle. From an examination of the blood, urine and feces of these animals, it seems that both are suitable sources of dietary zinc. Such findings serve as a guide in the selection of the most suitable zinc compound for mineral supplements.

Although requirements are very low, copper is an essential dietary constituent for livestock. The physiological availability of copper in copper carbonate has been determined by the use of radioactive copper (Cu 64). This water-insoluble compound was shown to be effective in supplying copper which appeared rapidly in the plasma soon after feeding of the compound. By such tracer studies, the value of the specified compound as a mineral supplement for cattle may be determined readily.

When salt blocks for cattle are iodized with soluble iodine compounds, much iodine is lost upon exposure to atmospheric moisture. This difficulty is avoided by using water-insoluble iodine compounds, but it remained to be shown whether such compounds were effective in supplying iodine to the animal system. Radioactive iodine (I 131) was used to synthesize dithymol diiodide which was fed to white rats and to heifers. The iodine in this water-soluble compound was shown to be physiologically available for use by the thyroid.

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*Georgetown University Medical School, Washington, D. C.*—Radioactive calcium (Ca 45) has been used in animals to determine whether the distribution of compounds of calcium which are water-soluble differ in their behavior and distribution in the body from compounds of calcium which are oil-soluble. This isotope has also been used to determine the utilization of calcium ions by various forms of animal and human tumors.

These studies have shown that the oil-soluble forms of calcium are retained in the body for longer periods of time than the water-soluble form and are more apt to be distributed to the soft parts and bones than the water-soluble form. They show that several forms of cancer concentrate the calcium ions.

This line of investigation has proved important in the study of the metabolism of calcium in both normal and malignant tissues.

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*Harvard School of Dental Medicine, Boston, Mass.*—Our studies have been designed to test and improve various available methods for determining the quantities and distribution of radioactive phosphorus

(P 32) in the enamel and dentin after the radioactive material has been injected intravenously. The best method for separating enamel and dentin in relatively large quantities consists of powdering the crowns of teeth and centrifuging the resultant mixture in bromoform. The heavier enamel particles collect at the bottom while the dentin particles and particles from the dentine-enamel junction float on the surface. Thus the radioactivity of these two samples can be independently determined. Our tests have shown that the radioactivity of the enamel thus prepared is a true value characteristic of the overall activity of the enamel, that no radioactivity is present in the bromoform used, and that no radioactive dentin particles are contaminants of the enamel. The samples of dentin and enamel prepared by this method represent an average value since all regions of the dentin and of the enamel are represented in the final samples.

More accurate methods for the localization of the radioactivity in each of these tissues has been possible through the use of the radioautograph. Ground sections of teeth or of sections through the jaws were made by a rapid plastic embedding method; these were applied against selected types of photographic film to allow the radioactivity of the sections to produce images roughly characteristic of the amount and distribution of the active materials.

At best radioautographs were useful to demonstrate relative distributions of the radioactive materials without presenting accurate determinations of the exact activity of a unit weight of any region in a unit time. To achieve this result it was found possible to remove small samples of enamel and dentin by diamond drills from carefully selected and representative regions of the enamel and dentin at various distances from the surface of the teeth or from the pulp. The activity of the various regions of the teeth prepared in these studies was sufficiently great that samples as small as 2 and 3 milligrams could be collected with satisfactory accuracy.

The results of these three methods have been demonstrated to be sufficiently satisfactory in repeated tests to merit their use in extensive experiments on the metabolism of the hard dental structures. It is obvious from these experiments that the surface enamel and the secondary dentin of erupted teeth have become highly radioactive and that the external dentin and the internal enamel have but slight activity in comparison. At present sufficient experiments have not been performed to merit the interpretation of what the results mean in terms of the relative routes of metabolism in enamel and dentin.

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*Harvard Medical School, Boston, Mass.*—We have been using radiophosphorus (P 32) to study the phosphorus turnover in carcinoma of the human stomach. In connection with this investigation we are developing an intragastric counter. We are carrying on spectrographic studies of gastric tissues and gastric tumors and other types of biological tissue. Methods of determining and measuring small amounts of chromium in tissue are being perfected. We are also carrying on partition studies with P 32 on the blood of cancer patients.

In another program we are studying the metabolism of di-hydroxyproline, ornithine, methylene-labeled succinic acid, sorbitol and gluconic acid, the latter two being in the diabetic rat. As a part of the same program we are studying the fate and turnover of injected uric acid in the normal human, the gouty and hyperuricemic human, the rat and the Dalmatian coachhound. We are also studying the mechanism which causes obesity in rats subjected to hypothalmic injury.

In still another phase of the work we have been making studies related to the formation of cerebrospinal fluid using radiosodium (Na 24) and other radioactive isotopes. We are also determining the the uptake of radioactive phosphorus in normal brain as compared with brain tumor. In another study we are investigating the turnover of radiocalcium (Ca 45) in lobster nerve.

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We have been using deuterium as a tracer in the study of carbohydrate and fatty acid metabolism of heart muscle, in intact animals and in heart-lung preparations. The method has involved enrichment of the body water with deuterium oxide, isolation of glycogen and fatty acid from the heart muscle at intervals after such enrichment, and determination of the deuterium concentration in the samples isolated. From the rate of incorporation of deuterium into these substances from the body water it is possible to calculate the rate of synthesis of the substance. The influence of certain vitamin and hormonal deficiencies upon these rates of synthesis is under study.

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We have been using radiocarbon (C 14) in our investigations. One investigation has been concerned with making a comparison of the rate of oxidation of carboxyl-labeled succinate in the normal and adrenalectomized rat. Another problem pertains to a comparison of the rate of incorporation of radiobicarbonate into the liver slice protein of the normal and adrenalectomized rat. A study is also being made to determine the utilization of C 14-labeled glucose by isolated muscle from hypophysectomized rats.

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An investigator who has been using radioactive sodium (Na 24) to study the rate of formation of cerebrospinal fluid in man states that the results thus far are throwing light on the cause of a number of obscure disorders affecting the brain. The patients are those in whom an increased pressure has developed inside the head. This pressure has been caused by an imbalance in the formation and absorption of the cerebrospinal fluid within and outside the brain with accumulation of an excess of fluid.

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An investigator has been using radioactive iodine (I 131) to study the rate at which aqueous humor flows out of the eye. It was found that the aqueous humor is secreted into the eye from the blood and that most of it leaves the eye by a simple flow process. This study is important from the standpoint of devising treatment for glaucoma.

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It is our purpose to study the kinetics of respiration and circulatory function in normal subjects and in patients with various types of pulmonary or cardiac and circulatory failure. This involves a long preliminary period of study (a) to perfect physical methods of measurement and technique and (b) to establish the normal absorption curve for radioactive argon (A 37) to other gases.

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*Harvard University, Cambridge, Mass.*—Radioactive silver will be used shortly to investigate the addition of inorganic ions to a protein urease and the effect of such addition on the enzymatic activity of urease. If successful, the results of this investigation will contribute to the understanding of enzymatic reactions which play a very important role in almost all biological processes.

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Interest concerning tellurium compounds has arisen from time to time, with their application as a therapeutic agent to stop the night sweating of tuberculosis patients, in the treatment and cure of syphilis and more recently with their increased industrial use.

Most previous investigations concerning distribution and excretion of tellurium dealt with the administration of rather large amounts, because no suitable method was available for the detection and quantitative determination of tellurium in minute quantities. By using radioactive tellurium, we have been able to study the fate of this element after administration of much smaller doses (0.1 to 0.5 milligram per kilogram of body weight) and to determine the main storage sites and excretion data.

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Our work which will utilize radiocarbon (C 14) is still in the synthetic stage, i. e., the production of compounds containing C 14. These will include fatty acids, fats and glycocyamine. When available they will be used to study the problems related to fat metabolism as well as to the general problems of intravenous feeding.

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*Harvard Medical School—Massachusetts General Hospital, Boston, Mass.*—The radioactive potassium (K 42) employed in our investigation has permitted us to measure the total amount of potassium in the body, a measurement not previously obtainable in the living patient. By this method we have been able to determine the amount of potassium lost by disease and the amount needed for replacement to restore the patient's health.

We have used deuterium (heavy water) for the same purpose; we are developing methods for the measurement of total body water in the human patient in the hope of learning more about surgical disease.

The results of our research indicate that in the presence of cancer intestinal obstruction, peritonitis, and other depleting diseases the human body may lose one-eighth to one-fourth of all its potassium. Potassium is the most important alkali substance in body cells, and its replacement is essential to the building of new tissues, the healing of wounds, and the restoration of sick people to health.

*Howard University, Washington, D. C.*—We are using radiophosphorus (P 32) to study the effects of vitamins on phosphorus metabolism in the chick embryo. We are using radiocobalt (Co 60) in metabolism studies in the rat and radioiodine (I 131) in metabolism studies in the mouse.

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*Illinois State Water Survey, Champaign, Ill.*—Radiocarbon (C 14) has been used in studying the mechanism of anaerobic decomposition of acetic acid. This reaction is of general interest, since acetic acid is a very common metabolic product in many biological processes. It is of particular interest, since acetic acid is a very common intermediate in the processes by which organic matter is reduced to stable inert humus. The reaction has been of wide use in the field of sanitation.

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*University of Illinois, Urbana, Ill.*—Radioactive potassium (K 42) is being used in the investigation of nerve function. It has been found that nervous tissue concentrates potassium much more than any other tissue. Nerves of animals are being subjected to radioactive potassium. Following the introduction of this material the nerves are stimulated and the perfusion fluid counted for radioactivity. It is hoped to learn whether potassium moves outward across nerve membranes when nerve impulses are propagated.

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The exact biochemical function of ascorbic acid is not known. However, it has been known for several years that the absence of this material from the diet leads to a failure of certain cells in the body to form collagen (needed in the repair of wounds). The question has arisen as to whether ascorbic acid is used in the actual structure of collagen or is necessary for the cell processes which lead to the formation of this substance.

We are in process of synthesizing ascorbic acid containing radiocarbon (C 14). The availability of such a radioactive ascorbic acid will make it possible for the first time to define more closely the part played by this essential nutrient in the process of healing.

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*Johns Hopkins University, Baltimore, Md.*—Radioiodine (I 131) has been synthesized into paraiodoaniline, subsequently diazotized to dysentery toxin and the distribution of the toxin followed after various modes of administration in the rat. This investigation is part of a program aimed to define the effects of bacterial toxin in the mammalian body. It is also part of a program to investigate the specific inter-relations of a natural toxin and its physiological target in an effort to learn something of the specific mechanism of immunity and of protein synthesis.

These studies have given definite concentration values for dysentery toxin in all organs of the body and have shown that most of the toxin is taken up by the liver.

Radiocarbon (C 14) has been successfully synthesized into the amidine group of arginine and will soon be fed to mice to label preformed

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serum protein. The mice will then be immunized and it is hoped that the C 14 content of the specific antibodies isolated will throw light on the question of whether or not antibodies are composed of newly synthesized protein or of preformed protein which has undergone a rearrangement.

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Radiophosphorus (P 32) was used as a tag to determine the uptake of phosphorus after intravenous administration of disodium phosphate, by different phosphorus fractions of normal nerve and crushed nerve of the Rhesus monkey. In this study eleven (11) monkeys were used. Five of the monkeys had the left brachial nerve crushed 6 to 8 days previously; six of the monkeys had the left brachial nerve crushed 23–28 days previously. The right brachial nerve in each animal served as a control. Five of the animals were sacrificed 12 hours after administration of the salt containing the isotope; the remainder at 48 hours.

The data indicates a markedly higher concentration of the P 32 in all the fractions analyzed from the crushed nerve at all sampling times, except in the "nucleoprotein" fraction of the monkeys operated on 23–28 days previous to isotope administration. No marked differences were determined by simple chemical analysis.

Radiosulfur (S 35) is being used as a tag to determine the uptake and disappearance of sulfate sulfur in different tissues of the adult rat. It appears that S 35, given as sulfate, is rapidly eliminated by the rat, as inorganic sulfate. It can, however, be bound to phenolic compounds and excreted as ethereal sulfate to some extent.

In the very young rat, sulfate, labeled with S 35, is taken up rapidly by cartilage and kept therein as chondroitin sulfate for some time.

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*Louisiana State University School of Medicine, New Orleans, La.*—Attention has been paid primarily to hexaethyltetraphosphate, a compound which is closely related to the war gas diisopropyl fluorophosphate, and which is itself a highly poisonous insecticide. By incorporating radiophosphorus (P 32) into the molecule it was hoped to learn which part of the molecule partakes in the interaction of this material with the enzyme cholinesterase. (It is the inactivation of that enzyme which is chiefly responsible for the compound's lethal action.) This work has shown that the phosphorus containing portion of the molecule is not fixed on the enzyme. Supplementary studies using radiocarbon (C 14) tagged hexaethyltetraphosphate are under way.

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*Loyola University, Chicago, Ill.*—It is definitely known that calcium and phosphorus metabolism are interrelated, and that changes occur in both calcium and phosphorus metabolism when there is an impairment or total loss of the activity of the parathyroid glands. Through the use of radiocalcium (Ca 45) and radiophosphorus (P 32) a clearer insight into the role which the parathyroid glands play in the metabolism of calcium and phosphorus is being sought.

*Massachusetts General Hospital, Boston, Mass.*—Radiocarbon (C 14) has been used to study the effect of dinitrophenol on the incorporation of labeled alanine into the proteins of slices of normal and malignant rat liver. Studies have also been made on the incorporation *in vitro* of C 14 from carboxyl-labeled dl-alanine and glycine into proteins of normal and malignant rat livers.

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We have used radiocarbon (C 14) to study the protein metabolism of normal and malignant tissues. The C 14 was built into amino acids and the rate at which these amino acids were incorporated into proteins was followed. The rate of protein synthesis of the rat hepatoma was found to be six times as rapid as that of the normal rat liver.

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*Massachusetts Institute of Technology, Cambridge, Mass.*—It is inconceivable that the research we have undertaken could have been attacked without the use of radioisotope tracers. Even the use of stable isotopes could not have served as only the radioisotopes such as radiocarbon (C 14) are capable of surviving the dilutions necessary in our work.

Aside from developing more reliable methods of assaying carbon radioactivity and of preparing organic compounds containing radioactive carbon our efforts have been directed towards the study of the differences in the living processes of healthy and cancerous cells. So far, we know that some substances which inhibit growth in normal tissue cause cancer and then cannot inhibit the growth of the tumor. Further, we have observed that a cancerous tissue will incorporate 5 to 7 times as much tagged amino acid as will healthy tissue. This phenomenon may lead to a technique of therapy.

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We are using deuterium as a tracer element to study the metabolism of fatty acids. The isotope is incorporated into a fatty acid by replacing some of the hydrogen atoms originally present in the acid. The acid then becomes "tagged" or labeled; its metabolic fate in the body can then be readily followed.

Using this tracer technique, we are endeavoring to learn more about the metabolic pathways taken by four saturated fatty acids after they have been ingested. The deuterium tracer affords us the only way to distinguish between dietary fat and fat originally present in the body. In this way, we can trace the steps taken by fatty acids during their catabolism as well as identify the tissues where they are deposited.

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Phytates are present in many foods especially cereals, and have been reported to interfere with the absorption of minerals from the gastrointestinal tract.

We are using radiocalcium (Ca 45) to study the effect of phytates on the absorption and metabolism of calcium. In order to determine the amount of calcium absorbed it is necessary to differentiate between the calcium from the test meal and that already present, hence the use of the isotope is of great value. Since phytic acid is a fairly common constituent of the diet, it is of importance to determine to what extent, if any, it interferes with the absorption of calcium and thus interferes with the formation of bones and teeth, in animals and human beings.

In an earlier study we used radioiron (Fe 55 and Fe 59) to study the effects of food phytates upon the absorption of iron. Phytates do interfere with iron absorption, but this interference seemed to be no greater than the interference due to the bulk of the diet. As the solids content of the meal was increased, the iron absorption decreased proportionately. The absorption of radioiron from a breakfast was only 1/5th that observed when the same amount of iron was given with a glass of water. Radioiron is very useful in studying those factors which interfere with, or assist, the normal metabolism of iron.

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*Massachusetts Memorial Hospital, Boston, Mass.*—Radioactive iron (Fe 59) has made possible the "labeling" of red blood cells for studies on the preservation of red blood cells in blood banks.

Radioactive iron is also being used for studies of various serious, and as yet incurable, types of anemia. Information is being obtained which may aid in developing a satisfactory treatment for such anemias.

Radioactive zinc (Zn 65) is being used to study the growth and function of red blood cells and white blood cells in patients with various types of anemia and leukemia. Such studies have already indicated that zinc is of fundamental importance in the function of these cells. Its exact role is yet to be determined and the radioactive isotope will make possible studies which otherwise could not be performed.

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*Mayo Clinic, Rochester, Minn.*—The use of radioactive phosphorus (P 32) has enabled us to determine the rate of formation in the body (animals) of many organic compounds i. e., those normally present in tissue in constant amount due to continuous formation and destruction. With the labeling by P 32 of the newly formed compounds the rate of formation and destruction can be determined. The functions of these organic compounds is thus determined and the alterations produced by pathologic processes may be evaluated.

Phosphoric acid is liberated from organic compounds in the muscles during work. With P 32 we found that this acid is held in the muscle and recombines in its original organic form immediately after working ceases.

Fat absorption from the intestine and the mobilization of fat from body tissues is somewhat related to the metabolism of phospholipids. With P 32 we found that about 5 percent of the phospholipid of the liver of rats is newly formed each hour. If part of the liver is injured or removed the remaining liver makes more new phospholipid so that the total production for the body is not diminished. If the body metabolism is increased or decreased by excess or lack of thyroid hormone the phospholipid production by the liver is correspondingly increased or decreased. The amount of fat in the diet does not alter the phospholipid formation of the liver. Certain vitamin deficiencies which produce a very fatty liver do not alter the formation of new phospholipids although their concentration in the liver is markedly diminished.

Pentothal labeled with radiosulfur (S 35) indicates that its anesthetic effects are due to the presence of pentothal and not its degradation products in the brain. The distribution of injected pentothal in the blood, brain, liver, kidney, muscle, etc. can be somewhat more accurately determined with S 35 than by ordinary chemical means.

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*Meharry Medical College, Nashville, Tenn.*—We are using radioiron (Fe 55, 59) as a tracer in a study of iron absorption in 1,000 hospital admissions. At the present time only very limited data on iron absorption in pathological cases exists. This investigation could be carried out using ordinary iron, feeding it to patients, and then examining the excreta for unabsorbed iron. Such a procedure is fraught with difficulty because of the presence of substances in the intestine which interfere with iron determinations, is likely to be time-consuming, and at best is only semi-quantitative. If one attempts to follow a given dose of ordinary iron through blood sampling it would not be possible, since there is no way to distinguish the molecules of ordinary iron compounds from those already present in blood. If, however, the iron sample administered contains tracer amounts of radioiron the latter can be distinguished from ordinary iron by radio assay of blood while the chemical and metabolic reactions would not differ materially from those of ordinary iron.

The results obtained so far in this study, which at completion will be the largest survey of this type done up to the present time, in general, confirm the meager data on humans to be found in the literature and similar experiments carried out with animals. Large uptakes are observed in pregnancies particularly in the latter stages. No uptakes are observed in cases where the blood picture is essentially normal and where no need for iron absorption exists. This is in line with the newer concept of iron absorption which indicates the presence of a mucosal block in animals plethoric with respect to their iron stores. In infections and inflammatory conditions, little or no iron is absorbed even when the blood picture indicates the need for iron, a finding in line with experiments already reported for dogs. Anomalous results in certain types of heart disease with normal or nearly normal blood pictures have been found in the form of significant iron uptakes. Evidently, the need for iron exists possibly as a compensatory mechanism in such cases. In severe anemias of long standing significant amounts of iron are absorbed, as would be expected from the well-known experiments carried out on anemic dogs.

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*Memorial Hospital, New York, N. Y.*—Investigators who have been using radioactive iodine (I 131) to study metastatic thyroid cancer, state that the isotope has been invaluable in studying many physiological properties of different thyroid tumors and in evaluating the possibility of therapy by means of that isotope.

Investigators are making a fundamental study of the metabolism of nucleic acid-containing compounds in the various cells of the body. Nucleic acid is a constituent of important parts of the cell which are concerned with reproduction and vital processes. It is probable that nucleic acid or substances containing it are concerned in an important way with virus infection and cancer. This material is also a constituent of those cellular structures which are affected by radiation. For these reasons a thorough understanding of the anabolism and catabolism of nucleic acid is considered to be one of the most fundamental and desirable studies at the present time.

We are engaged in the synthesis of nucleic acid precursors, purines and pyrimidines, containing stable nitrogen (N 15) and radiocarbon (C 14). These precursors are fed to experimental animals, both normal and with various types of injury, in order to establish their normal and pathological metabolic routes. A new and fundamental observation has been made by this procedure, namely, that adenine alone, of all the materials tested, is deposited in the cell. Moreover, it appears to be deposited principally in the cytoplasm. It is hoped by an extension of this study to work out a complete pattern of nucleic acid formation, particularly under conditions involving radiation injury. Other investigators are developing methods for separating the various morphologic constituents of different types in cells, normal and affected by radiation. When these methods have been perfected, it is expected that they will be applied to a study of the uptake of nucleic acid precursors marked by radioactive and heavy isotopes.

In another department C 14 has been used for the synthesis of three steroids, namely, methyl testosterone, progestin and testosterone. We are just beginning biological experiments with these substances. It is hoped to define by their use the amount of hormone localized in target tissue, particularly the genital tissue. It is also expected to obtain more detailed knowledge of the metabolic pathways followed in the synthesis and metabolism of steroid hormones.

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*Merck and Company, Rahway, N. J.*—The isotope tracer method is being applied to benzylpenicillin as a means for its specific determination in the presence of other penicillins, such as penicillin K, F, etc., as well as in the presence of their degradation products and many other substances as occur, for instance, in penicillin fermentation liquors. Such a completely specific assay for benzylpenicillin is not now available and would be of inestimable value in production, research, and control.

We are also using deuterium as a tracer in connection with the fate of the analgesic isoamidine in the animal economy. The results of this use of an isotopic tracer should prove of considerable value in the elucidation of the chemistry of this drug in the living organism and thus should be a contribution to a more detailed medical understanding of its action.

In another assay problem we are concerned with the specific determination of morphine in opium. No reliable assay for morphine in opium appears to have been developed and since a reliable assay is essential in commercial processing, we propose to attempt the development of an isotope tracer method.

*University of Minnesota, Minneapolis, Minn.*—Deuterium oxide will be used to study the chemical reactions by which those species which do not require a dietary source of vitamin C can synthesize this compound within their own bodies. An understanding of these reactions is of fundamental importance because they may tell us in part how species such as man, the guinea pig, and the monkey differ chemically from such other species as the rat, swine, and cattle, which can synthesize vitamin C.

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By the use of the stable isotope of oxygen (O 18) we are studying the fate of the oxygen taken into the body via the respired air and the source of the oxygen which appears in the respiratory carbon dioxide. Without tracer oxygen it would be impossible to carry out such a study.

Thus far, preliminary experiments point to the conclusion that either the oxygen of the respiratory carbon dioxide does not come from the respired oxygen in appreciable amounts or the oxygen of the carbon dioxide comes into isotope equilibrium with the oxygen of the body water.

The rat has been found to utilize carbon given as inorganic carbon in its bodily processes. This carbon, tagged with radiocarbon (C 14), has been found to enter the fats and proteins of the body and the bones and teeth. Information as to the rate at which the bones and certain proteins are regenerated has been obtained. Data as to the excretion of C 14 has been obtained which is of value in considerations of the health hazards associated in working with C 14.

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*National Institute of Health, Bethesda, Md.*—We have been using an irradiated unit of antimony for (1) radioautography of parasites and host tissues after injection of host with tarter emetic prepared with radioactive antimony and (2) studies on antimony distribution in mammalian tissue fractions.

The experiment performed by autoradiography did not give unequivocal evidence of antimony distribution because of lack of definition of parasite tissues on emulsion.

The experiments on tissue fractions have given valuable clues as to the nature of the antimony compounds formed in the mammalian tissues.

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Our research program is considered the first step toward production of labeled antibiotics which may be used to gain a better understanding of their action. The assay of radioactive sulfur incorporated in the penicillin molecule is superior to the usual chemical assay because of the minute quantities detectable in the former compared to the latter.

Radioactive sulfur (S 35) can be incorporated into the penicillin molecule by growing the penicillin producing mold on a medium containing radioactive sulfur. It has also been found that the radioactive assay for sulfur can be made more accurate than the usual chemical assay.

Radioactive potassium (K 42) has been used to study qualitatively the efficiency of the ventilating system in a building to be used for the study of infectious diseases. This use of the isotope gave the needed information in a much shorter time and was open to less criticism than the standard methods of dust sampling.

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*New England Deaconess Hospital, Boston, Mass.*—Work on radioactive antigens in anaphylaxis is being carried out using bovine albumen and radioactive iodine (I 131). Radiophosphorus (P 32) is being used to determine its uptake from the egg yolk and its effect on the developing chick. The uptake of P 32 as well as that of radiosodium (Na 24) by the tissues in cases of disturbance of the peripheral circulation, particularly cases of diabetic gangrene is being determined. P 32 is also being used to study its therapeutic value in leukemia, plasma cell myeloma, and polycythemia vera.

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*New York University, College of Medicine, New York, N. Y.*—Only two nucleic acids have hitherto been known. By the use of radiophosphorus (P 32) the presence of another nucleic acid in the cell nucleus has been demonstrated and shown to be the precursor of the two previously known. It is very much more active in the phosphorus metabolism of the cell than the ones previously known. Confirmation of the existence of this precursor nucleic acid has been obtained with the aid of radioactive iodine (I 131).

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We are using deuterium oxide (heavy water) to determine total body water. This determination has permitted us to arrive at the total amount of body solids in protein depletion and the rise of these solids in the process of repletion.

We are using isotopes in a study of the effect of adrenal cortical hormones on kidney function and water and salt distribution in the dog. Deuterium oxide ($D_2O$) is being used for determination of total body water since it is the only accurate method now available. We plan to use radioactive sodium (Na 24) in a study of the comparison of sodium space and the mechanism of sodium excretion in control animals, in animals treated with adrenal cortical hormones, and in adrenalectomized animals at various levels of substitution therapy.

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Our research program is designed to study the correlation of phospholipid turnover to levels of cholesterol.

A study in phospholipid turnover was undertaken in a very small number of subjects of various ages and on high cholesterol diets. Radioactive phosphorus (P 32) was administered to six subjects, 7 microcuries per kilogram. Blood samples were drawn at 1, 3, 5, 9, 12, 24, 29, 48, 72, 96, 168, and 216 hours after the initial administration of P 32. The specific activity of the organic phosphorus (phospholipid) was determined in all samples and results were expressed as percentage of original dose administered.

The turnover in six patients did not differ significantly from one another (age range 40 to 82). The feeding of cholesterol did not significantly alter the turnover of phospholipid. Recent publications have not shown significant change in phospholipid turnover in cirrhotic, as opposed to normal, individuals. This fact was confirmed in three patients with cirrhosis of the liver. Our figures for turnover appear to be in the range of those found in the literature. Maximum turnover was found to occur between 48 and 72 hours; the maximal percentages varied from 0.01 to 0.15.

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*Northwestern University, Evanston, Ill.*—Radioactive sulfur (S 35) has been used in connection with two problems of biochemical interest.

In one we have studied the uptake of amino acids (labeled with S 35) by bacteria under conditions where no net growth is obtained. In this manner it has been found that these building blocks are in a constant state of flux in the proteins of the bacteria, breakdown and synthesis going on simultaneously. The use of isotopes has enabled us to study the effect of drugs on the synthetic process even though no net growth is observed. Without isotopes this could not be done.

In a second problem we have made sulfanilamide with a radioactive atom in it and are following its course in bacterial suspensions in order to gain some insight into the mode of action of sulfa drugs.

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*Parke, Davis & Company, Detroit, Mich.*—Investigations of a series of drugs having inhibitory effects on the thyroid gland have been greatly facilitated by use of radioiodine (I 131) as a tool for measuring normal and altered thyroid function. As a result of this work carried out on animals, earlier application of certain selected compounds to clinical trial in human patients has been possible. Radiocarbon (C 14) has been used as a means of labeling benadryl, an antihistaminic drug. Radioactive iron (Fe 59) has been employed by investigators to study the effect of radiation on malarial infections in animals.

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*University of Pennsylvania, Philadelphia, Penna.*—In order to learn how the body utilizes food materials for various purposes, it is necessary for us to look inside the body and see where the various molecules go and what chemical changes they are caused to undergo until they are changed into body structure or are excreted. Obviously it is impossible to follow ingested ordinary molecules because they cannot be seen. If, however, such molecules are tagged in some characteristic way and later a tagged compound is found in the body we know that the tagged material introduced must have been changed into the tagged compound which was isolated. Stated in another way, if we could see a carbon atom we might stain some of them red and then follow them through the organism.

Investigators using radioactive carbon (C 14) to study the metabolism of protein, fats and carbohydrates, state: (1) When lactate (which is related to carbohydrate), containing radioactive carbon is fed to a glycosuric animal, some of the radioactive carbon appears in urinary glucose, some in urinary ketone bodies (which are related to fat metabolism) and some in body fat. This demonstrates that lactate when ingested may be changed into sugar or fat. (2) Radioactive adrenalin is formed when radioactive phenylalanine is administered.

This experiment shows that adrenalin may be formed from phenylalanine in the body. It is interesting to note that the structure of phenylalanine is such that one may show theoretically how it can be transformed into adrenalin.

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*Peter Bent Brigham Hospital, Boston, Mass.*—The radioisotopes of iron (Fe 55, 59) have been of particular importance in the study of iron metabolism in relation to turnover rates of various fractions of body iron and to absorption of small amounts of iron by the intestinal tract.

With isotopes it has been possible to estimate size of iron stores in man, the turnover rate of iron through the serum compartment, the synthesis of hemoglobin by bone marrow cells *in vitro*, the life span of the red cell, and the pathway of red cell breakdown.

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*Pratt Diagnostic Hospital, Boston, Mass.*—We have been using radioiodine (I 131) to study thyroid function in animals and in man. The method has permitted a development of new drugs for the treatment of hyperthyroidism. It has yielded considerable new information regarding the details of thyroid hormone synthesis, and three new tests have been devised for the clinical diagnosis of thyroid disease. It is quite clear that this isotope will have continued usefulness for diagnostic methods.

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*Presbyterian Hospital, Chicago, Ill.*—Very little is known of the way in which radiations produce their profound and subtle effects on living substance. By use of such a powerful tool as a radioactive tag it seems possible that problems can be answered such as the size and identity of the sensitive molecule; action by direct collision of the molecule with radiation, or the alternative indirect effect of other substances on the sensitive molecule; and the reason for the great variation of sensitivity from one living substance to another.

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The objectives of our research projects are:

1. To determine how much radiocarbon (C 14) is retained by animals under various conditions of exposure and thus to contribute to our knowledge of the hazards involved in the use of this isotope.
2. To measure the ability of diabetic animals to utilize glucose, a question fundamental to the understanding of diabetes and one which has not been solved by non-isotopic methods.

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*Purdue University School of Pharmacy, Lafayette, Ind.*—An enteric coating is the covering that protects a substance from the gastric fluids and releases the contents into the intestinal fluids. This study is directed toward the development of a test which will disclose not only the location but also the time required after administration for the drug to be released into the intestinal fluids.

There is a need for such coatings for several types of drugs:

1. Drugs that irritate the stomach lining;
2. Drugs that react with the stomach secretions to inactivate the digestive enzymes;
3. Drugs that are inactivated by the stomach secretions;
4. Drugs that should be in high concentration in the intestines to exert their therapeutic activity; and
5. Drugs desired to be delayed somewhat before absorption.

Among the various substances used to coat such drugs are those that are made to be insoluble in the acidic secretions of the stomach and to be soluble in the more alkaline secretions of the intestines. If this were entirely the case, the conditions could be simulated outside the animal body. Actually there is a gradual change from the distinctly acid secretions of the stomach to neutrality and subsequently to alkalinity because the secretions of the intestinal glands dominate. The problem is to find a substance (or a combination of compounds) that will be sensitive to these slight changes in the medium. Before this type of compound can be intelligently sought, one should have an accurate method of determining solubility as a function of the pH of the medium.

The radioactive material used to develop this test is radiosodium (Na 24), whose radiations have sufficient energy to be detected readily and which has a short half-life. This lessens the danger of permanent contamination. The radioactive material is enclosed in an enteric coat and the pill is given to a rat. The body of the rat is shielded and the tail is continuously measured for radioactivity. Upon release of the material by the rupture of the coat, there is a sudden increase in radioactivity of the tail due to the absorption into the blood of the enclosed compound. The rat is sacrificed and site of the disintegration can be found by examination of the tract.

Radiosodium is used for the testing of absorption rates of sodium in the form of sodium chloride from the alimentary tract.

Radiophosphorus (P 32) is used for the testing of phosphorus depletion of teeth by various solutions.

Radioiodine (I 131) is used for testing the rates of absorption of iodine from various ointment bases.

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*University of Rochester, Rochester, N. Y.*—Radioiodine (I 131) analogues of the preparations employed clinically for cholecystography and intravenous pyelography are being utilized to study the absorption, distribution, and excretion of these widely used contrast media. Preliminary work in dogs indicates that this approach will be particularly instructive as to the behavior of these contrast media at the several blood organ tissue barriers.

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We have been using radioactive iron (Fe 59) to investigate the mechanism of iron absorption in normal and anemic animals.

Radioactive iodine (I 131) is being used in the investigation and treatment of thyroid disease. Several patients with hyperthyroidism who had become resistant to more traditional therapeutic methods have responded favorably to therapeutic treatment with radioiodine.

One patient with malignant thyroid disease has shown no recurrence for two years following treatment.

Work is under way using radiocarbon (C 14) synthesized into the amino acid, lysine, as a tracer to study the metabolism of the blood plasma and erythrocyte proteins. It has proved possible to obtain labeled plasma proteins by feeding an experimental animal lysine labeled with C 14. Such labeled plasma proteins are used to study the fate of plasma transfused to other animals.

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*Rockefeller Foundation, New York, N. Y.*—The radioactive isotope, phosphorus 32, is being used to study the metabolism of the malaria parasite. It has been shown that the avian erythrocyte parasitized with *plasmodium gallinaceum* takes up labeled phosphorus at a considerably more rapid rate than does the normal cell both *in vivo* and *in vitro*. In the course of studies on the factors essential for parasite growth, this isotope is being employed as a means of following the rate of nucleoprotein synthesis by the parasite, both *in vivo* and *in vitro*. In addition, by administration of this isotope to normal animals, body fluids and tissue extracts are being prepared containing a variety of labeled components. Those fluids and extracts known to be effective in maintaining parasite metabolism are being studied with the aim of determining the nature of their active components. If it seems feasible, such studies will be extended to include isotopes of other elements. The above studies are not yet sufficiently advanced to permit any definite conclusions to be drawn.

In addition to the above experiments we have also been using P 32 for tracing the dispersion of inocula introduced by various routes into embryonated eggs. Bland inocula containing approximately 100,000 count per minute of P 32 have been introduced into the allantoic sac, the amniotic sac, the yolk sac and into the blood stream of normal embryos. It has been found that when P 32 is inoculated into the allantoic sac, it tends to remain largely in this location, but when introduced into the amniotic and yolk sacs, it finds its way rather rapidly into the blood stream as well as into the allantoic sac. (Entrance into the allantoic sac may be effected by the necessity of passing through this sac in entering the amniotic sac as well as in entering the yolk sac in older embryos.) P 32 inoculated into the blood stream is detectable after short periods within the allantoic fluid but is not found in the amniotic fluid.

Utilizing these data as a base line, the effect of dispersion of P 32 on influenza virus has been studied. It was found that when the inoculum containing P 32 and influenza virus was introduced into the allantoic sac, it tended to disperse more rapidly than in noninfected eggs.

Experiments are now under way to study the effect of P 32 in more concentrated amounts upon influenza viruses. It is hoped to ascertain if radioactive isotopes tend to enhance mutation of these viruses.

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*Rockefeller Institute, New York, N. Y.*—Mustard gas in low concentration has the unique property of inducing mutations in cells and organisms. Chemical determinations of mustard gas although capable of measuring as little as 5 micrograms are not sensitive enough to detect the amounts involved in the inducing processes. By substituting radiosulfur (S 35) in mustard gas in place of stable sulfur (S 32), 0.01 microgram of mustard gas can be determined with comparative ease.

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*Rockefeller Institute, Princeton, N. J.*—An investigator who has been using radioactive sulfur (S 35) to study the composition of the infectious agents called viruses states, "Complete chemical analysis of viruses is believed to provide a basis for understanding and controlling these disease agents. It was not possible to establish conclusively the presence or absence of sulfur in a particular virus by customary chemical methods, but this has been readily accomplished by use of radioactive sulfur, owing to the great accuracy with which small amounts of this material can be detected."

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*Sloan-Kettering Institute, New York, N. Y.*—We are using radioiodine (I 131) to label antibodies which are prepared against various tissues, normal and tumorous. By the use of these tracers we can tell whether antibodies are formed which go to the specific tissue. So far, we have been able to trace antibodies prepared against rat kidney tissue and mouse kidney tissue to the kidney of the specific antibody.

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*Southern Research Institute, Birmingham, Ala.*—Because of the striking effect of ethyl carbamate (urethan) on leukemic cells and the similarity of its action to that of X-rays, a study of the *in vivo* degradation of this agent was undertaken, employing material labeled with radioactive carbon (C 14).

Upon intraperitoneal injection into mice, urethan begins to break down almost immediately. The labeled (carbonyl) carbon is excreted largely as carbon dioxide, about 90 percent being accounted for by this route within 24 hours. Another 5–10 percent is eliminated in the urine. A small fraction of the active carbon is present in all tissues after 24 and 48 hours. Preliminary experiments indicate that after 24 hours, animals with advanced spontaneous lymphoid leukemia retain several times as much active carbon from labeled urethan in all tissues as normal animals.

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*St. Louis University School of Medicine, St. Louis, Mo.*—Radiocarbon (C 14) is being incorporated into vitamin K in order to follow this vitamin in the animal body and thus gain an insight into the mechanism of blood clot formation and certain deficiency syndromes.

This isotope is also being incorporated into molecules related to the female sex hormones to study their metabolism. A successful attack on these fundamental problems has awaited the availability of this isotope.

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*Temple University, Philadelphia, Penna.*—We have been engaged in the study of metabolism, using the stable isotope, carbon 13, as a tracer. This work is of particular importance in supplying a background of information on bodily processes necessary for more effective treatment or prevention of disease. The availability of radiocarbon (C 14) will aid and simplify our work tremendously and will allow us to study problems not possible with carbon 13.

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*The University of Tennessee, Memphis, Tenn.*—By labeling thiocyanate with radioactive sulfur (S 35), it has been possible to measure the amount of the ion in biological tissues with an accuracy, sensitivity, and specificity much greater than by any other method available. Our present program on problems related to hypertension and cancer would be prohibitive in cost if the cyclotron were still the only source of S 35.

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*University of Texas, Galveston, Tex.*—We have used radioiodine (I 131) for studying the passage of iodides through the intact unbroken skin of experimental animals. This isotope has proven extremely valuable in indicating the manner in which iodine is absorbed from the skin and has contributed to the physiology of this element as it was shown that much of the iodine is secreted by the gastric mucosa, as are the chlorides.

We are planning to use some of the isotopes of the rare earths in cancer research.

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*University of Texas Medical School, Galveston, Tex.*—With a view to improving methods of resuscitating and of treating the almost-drowned, we are investigating what happens during experimental drowning. The water which is "breathed in" during drowning enters the blood in large quantities. By employing isotopic hydrogen (deuterium) in heavy water, we will investigate how much and how rapidly this water enters the blood.

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*Thorndike Memorial Laboratory, Boston, Mass.*—We have been using radioiodine (I 131) as a tracer and therapeutic agent in thyroid disease and malignancies of the thyroid gland.

All patients treated with radioactive iodine were ambulatory and consequently no possibility of close contamination between the patients or piling up of radioactivity in the excreta was possible. When normal subjects were investigated, the injections of radioactive isotope were never greater than 200 microcuries and were repeated at such time intervals (one month) that the concentration of isotope in their blood never exceeded a safe tracer level. No normal subject or patient was treated with more than three injections at this level.

We are now conducting studies of phosphorus exchange in man, *in vivo*, following the administration of insulin, adrenalin and glucose.

Later we shall proceed to study diabetic individuals, using these tested substances, and in suitable cases additional substances, particularly estrogenic and androgenic hormones, in an attempt to study the basic metapathy of the diabetic syndrome. Parallel studies will be made on individuals suffering from abnormalities of creatine and creatinine metabolism, such as pseudo-hypertropic muscle distrophy. It is hoped in the latter instance to obtain some clue to the etiology and possible treatment of this, at present, untreatable and often fatal condition.

We have also carried on some basic physiological work of an *in vivo* and *in vitro* nature with radioactive iodine in the exploitation of the antigen-antibody response in man in the hope that we may be able to answer some of the questions regarding the defense of man against infection, particularly those problems concerning the place where antibodies are formed and the nature of the antibody-antigen reaction. Techniques are now at hand for iodinizing proteins, particularly without the use of ammonia, and preliminary work on animals has shown a close parallel barrier between radioactive isotope exchange and the well-known histological changes in lymph nodes following antigen-antibody response.

Iodine is also being used to tag albumin for purposes of establishing the time from injection or ingestion of the protein to its time of entrance into the metabolic pool. This problem has become, in this laboratory, an important question in the treatment with albumin of patients for the relief of edema caused by various kidney disorders and starvation. It will also be used for the purpose of the general study of albumin metabolism in man.

Radioactive iron (Fe 55, 59) will be used not only for the purpose of determining blood volume and iron metabolism in the manner which has now become routine in this country, but also in the solution of other problems. We are anxious to study the rate of uptake of iron from the intestinal tract under the influence of certain environmental conditions, including specific accessory food materials, changes in pH, the presence of oxidizing and reducing agents, and the form of iron administered.

We are also anxious to pursue problems relating to the age of cells in given blood samples, and by this technique determine the relation of cell age to the reaction of blood cells under various pathological conditions encountered in our patient population.

Phosphorylation has been related in several ways to the problem of anemia and certain aspects of this are planned for the coming year, particularly in relation to the reaction of substances increasing bone marrow activity. During the war we reported marked metabolic changes in man following injuries due to flame, crush wounds and penetrating wounds. While several therapeutic suggestions were offered as a result of this work, there were many aspects of the problem of injury and convalescence left pending because of the lack of an adequate investigational tool. These are being followed up by the use of radiophosphorus (P 32) in the hope that during the period of peace some definite therapeutic measures for the routine handling of large numbers of wounded and injured individuals may be resolved.

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*Tufts Dental School, Boston, Mass.*—We are at present engaged in using radiophosphorus (P 32) and contemplate studies using radioiodine (I 131) and radiocalcium (Ca 45). Since the teeth have the greatest percentage of inorganic material of any of the body tissues and since the rate of exchange of the mineral components is extremely low, the use of radioactive isotopes tends to greatly extend our knowledge of the vitality of the teeth.

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*Tulane University, New Orleans, La.*—We are using radioactive isotopes to investigate the formation of hemoglobin in subjects depleted of this material by long illness or by trauma. An important aspect of this problem is the accurate measurement of total blood volume and of total circulating red cell volume. It is desirable that some method for measuring blood volume be devised which can be repeated daily if necessary and which can be executed with little advance warning, thereby requiring no previously tagged donor blood. It is also desirable that the method require no injection of foreign substances the physiology or toxicity of which would need to be investigated.

For such a purpose radioactive phosphorus (P 32) works out very well. If a sample of the patient's own blood is properly mixed with radioactive phosphorus, some of the radioactive phosphorus exchanges for normal phosphorus in the patient's blood cells. The dilution of the labeled cells, when reintroduced into the patient's circulation, enables an accurate calculation of the red cell volume.

From this determination of red cell volume and a determination of the concentration of red cells in an aliquot of the whole blood of the patient, the whole blood volume of the patient can likewise be calculated.

In addition to the phosphorus method which measures the red cell volume directly but which depends upon the determination of a hematocrit to give a value for whole blood volume, the use of radioactive iodine (I 131) adsorbed to serum protein is being exploited. The method looks directly feasible and if it proves successful, it provides a direct means of measuring the plasma volume. Independent determinations could thus be made of plasma volume directly and of red cell volume directly, and the value for total volume could be obtained by adding the two.

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We have been using radiosodium (Na 24) to study some aspects of renal excretion of sodium by normal subjects and by patients with congestive heart failure.

Excretion of radiosodium, following intravenous administration of the isotope, was studied in 12 normal subjects, 10 patients with chronic congestive heart failure, and 7 patients with miscellaneous diseases. The Na 24 required about three times as long to appear in the urine of the patients with congestive heart failure as in the normal subjects. In no instance did the concentration of Na 24 in the urine of patients with congestive heart failure exceed that in the serum; in the normal subjects it varied over a wider range than in the patients with heart failure, and exceeded, equaled or was less than that in the serum. The Na 24 clearance in the patients with congestive heart failure was definitely less than that in the normal subjects.

An investigator who has been using radioactive phosphorus to study blood volume states, "The use of red blood cells tagged with P 32 has made it possible to measure the total circulating volume of red blood cells."

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*U. S. Public Health Service, Bethesda, Md.*—We have used radioactive carbon (C 14), phosphorus (P 32), and arsenic in preparing radioactive antigens for studies in immunity. We are using radioactive iron (Fe 55, 59) for studies in iron metabolism.

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*University of Virginia, Charlottesville, Va.*—An investigator has been using radioactive phosphorus (P 32) to study the transfer of this material into red blood cells under the influence of various anesthetic agents. It has been found that several anesthetics block the entry of radioactive phosphorus into the red blood cell. This work points to a possible general action of anesthetics and may aid in explaining the action of sleep-producing drugs.

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*Medical College of Virginia, Richmond, Va.*—Our research is concerned with the evaluation of blood loss and blood needs in surgical patients. We have had a great deal of experience with dye techniques for the estimation of whole blood volume but have had considerable difficulty in getting check results. There has been a great need for an accurate method of determining red cell volume in clinical surgery. Early results obtained with the use of radioactive phosphorus (P 32) are very encouraging. The studies have not progressed sufficiently to be absolutely certain, but we feel that this technique will be very valuable in clinical investigations of many sorts. We intend shortly to utilize radioactive sodium (Na 24) in the study of certain shock states but this work cannot proceed until certain technical problems are ironed out.

We are also engaged in a large research program for the Army in connection with radiation sickness. The red cell volume technique with radioactive phosphorus will prove exceedingly valuable in this research. Further, we could not carry out many of the proposed problems in this field without radioactive material. The nutrition studies which are planned with carbon 14 and stable nitrogen (N 15) could not even be contemplated without the aid of radioactive isotopes.

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*Washington University, St. Louis, Mo.*—The cancer research program of the Barnard Free Skin and Cancer Hospital has been making extensive use of isotopes in a study of epidermal carcinogenesis. Radiocarbon (C 14) has been used in an effort to trace methylcholanthrene in cells during carcinogenesis.

Radiocalcium (Ca 45) has been employed in a comprehensive program of the study of calcium-binding mechanisms in epidermal carcinogenesis and in aging of various mouse tissues. It has been sug-

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gested that a growth regulatory mechanism probably protein in nature and located at the cell surfaces is altered in diverse fashion in both aging and in cancer. Alterations in this protein complex are indicated by changes in calcium binding properties. Much of these data have been procured through the application of the isotope method of tracing and estimating calcium changes.

Study on epidermal carcinogenesis indicates that unlike the normal epidermal cell the squamous cell carcinoma is unable to take up and retain Ca 45. This isotope study is consistent with previous observations that the calcium content of cancer cells is very low and that the ratio of free and bound calcium in cancer cells is radically different from normal.

Age changes in mouse liver as measured by radiocalcium uptake and exchange have been determined. It indicated that the old liver cell contains a high level of calcium, but has a very low exchange rate of calcium ions. This observation is consistent with the fact that there is a higher level of calcium binding in old cells than in the young.

Both of the isotope studies on aging and cancer are being continued largely with the aid of cell fractionation and ultrafiltration with a view towards gaining an understanding of the protein changes at the cell surface. The radioactive isotope of calcium has been of singular value in facilitating these investigations.

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In our investigation with radioisotopes we have demonstrated the following:

Iron injected into the body in small amounts is quantitatively and promptly synthesized into hemoglobin providing the bone marrow is capable of making red blood cells at a normal rate. When, however, the marrow manufacture of red blood cells is decreased, there is a corresponding decrease in the rate at which iron is utilized. These results provide information as to the rate of hemoglobin synthesis in the body but demonstrate that radioiron (Fe 55, 59) cannot be used in the ordinary manner for measuring iron absorption unless the bone marrow is functioning normally.

Iron absorption with radioiron has ordinarily been measured by determining what percent of a given oral test dose appears in the circulating blood as hemoglobin. Because of the previous considerations the method for measuring absorption has been augmented to include determination of unabsorbed radioiron eliminated in the feces. With this technique we have shown that iron deficient persons absorb more iron than do normal subjects. However, patients with various types of anemia may absorb relatively large amounts of iron in spite of adequate iron stores. These results have caused workers to question the currently held theory that the intestinal mucosa, influenced by iron stores in the body, acts as a major regulator of iron metabolism by accepting or rejecting iron according to body needs.

Small but definite amounts of iron are regularly excreted by the intestinal tract. The statements often made to the effect that the mammalian organism has no capacity to excrete iron except by hemorrhage is thus shown to be an oversimplification.

*University of Washington, Seattle, Wash.*—Two problems are under investigation here which involve the use of radioactive isotopes. The one is concerned with the synthesis of radiocarbon (C 14) labeled stilbestrol and investigation of its behavior in body processes, particularly its possible bioconversion to natural sex hormones. The other is the synthesis of C 14 labeled xanthopterin which will be used in the investigation of the action and interconversion of pterias, including folic acid and vitamin B 12.

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*University of Washington Medical School, Seattle, Wash.*—Through the use of radioactive iron (Fe 59) in tagging red blood cells it has been possible to approach in a logical manner the problem of transfer of blood cells from fetus to mother. Preliminary experiments with rats indicate that some blood cells cross the placental barrier.

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*Western Reserve University, Cleveland, Ohio.*—In order to elucidate reactions which occur in the formation and metabolism of the hormones of the adrenal and of the sex glands, studies are being conducted using hormones (and their suspected precursors) containing the stable isotope of hydrogen (deuterium).

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Radioiodine (I 131), radiosodium (Na 24), and radiopotassium (K 42) have been of extreme value in our work on the detection of minute amounts of hormones. The development of these new micro methods gives us new tools to study the mechanism of action of hormones in normal as well as diseased individuals.

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The research being carried out with isotopes has as its ultimate purpose the elucidation of the chemical processes whereby the body obtains energy from foods. For this type of investigation isotopes are indispensable. They permit tagging the carbon of the food and tracing it through its myriad reactions in the body. Among the research problems being investigated is the conversion of fatty acids to glycogen, the ready source of energy to the body. By labeling the individual carbons in the fatty acids and determining the position of the isotope in the resulting glycogen, it is possible to make certain deductions concerning the reactions which the fatty acid undergoes in its conversion to glycogen.

In the oxidation of pyruvate, acetylphosphate and formate have been suggested as components of the system. It has been possible, by labeling the acetylphosphate and formate to show that only formate is a component. These are representative examples of the type of work being carried out. Investigations are also being carried out on the study of purine metabolism and on the conversion of other compounds to glycogen.

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*University of Wisconsin, Madison, Wis.*—In our research program radiophosphorus (P 32) is being used to study rickets and the mode of action of vitamin D.

Our progress to date consists primarily of establishing the reliability of our technique of producing rickets of the desired degree of severity and uniformity, of analyzing various tissues for their organic phosphorus compounds and of tracing radiophosphorus in the animal body by the analysis of various tissues and through external counts in the living animal.

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*Worcester Foundation for Experimental Biology, Shrewsbury, Mass.*—Radioactive carbon (C 14) will be used in studies of the metabolism of steroid hormones in cancerous and non-cancerous processes. By the use of labeled hormones we hope to determine more exactly the part they play in the control of cancer as well as their role in numerous normal body processes.

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*Yale University Medical School, New Haven, Conn.*—An investigator who has been using the radioisotopes of iodine (I 131), sulfur (S 35), and carbon (C 14) to study the action of drugs and glandular secretions in disease states that through the use of tracer isotopes it has been possible to unravel problems concerning the cause of sickness. Furthermore, the action of poisons like mustard gas has been elucidated in part by this method and the same technique is being applied to the development of agents for anesthesia.

Certain hormones (chemical substances made by certain glands in the body) are essential for life; many are essential for health. The manner in which certain hormones originate is not known. The isotopic labeling of substances which might give rise to steroid hormones will provide the only direct means of ascertaining the origin of these essential compounds. No other method will give this important information.

Radiocalcium (Ca 45) has been used in studies of denervated muscles. A pilot experiment was carried out to determine possible changes in calcium distribution in the denervated muscle as compared with the control. Radioautographs were made in order to detect such changes. Results on one experiment are inconclusive.

## Medical Diagnosis and Therapy

*Beth Israel Hospital, Boston, Mass.*—Investigators have been using radioactive iodine (I 131) to study and treat diseases of the thyroid gland and also certain patients with advanced heart disease and angina pectoris. Many patients in whom other forms of treatment have failed have been found to respond satisfactorily to radioactive iodine. The optimum schedules of treatment are being ascertained on the basis of radioactive tracer studies and clinical observations which are now in progress.

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*Biochemical Research Foundation, Newark, Del.*—Radioactive iodine (I 131) has been given orally to a patient with angio-invasive adenoma of the thyroid metastasizing to the bones of the pelvis, the lower spine and one of the ribs. The iodine has been given in doses of about 30 millicuries every two weeks and the results followed by

Geiger counter surveys. Although there seemed to be some concentration of the radioactive iodine by the tumors, X-ray film indicated gradual progress of the tumor. It was finally concluded that the radioactive iodine was accomplishing nothing and its use was therefore abandoned. The object of the study was to find the effects upon a cancer of the thyroid which has produced metastases, or tumors, in other parts of the body.

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*Birmingham Veterans' Administration Hospital, Van Nuys, Calif.*—Radioactive iodine (I 131) is being used in this laboratory for the following:

(1) As an aid in the diagnosis of thyroid diseases;

(2) For the treatment of thyroid cancer in carefully selected cases;

(3) In a basic study of the biochemistry of the thyroid gland, (where its use has resulted in the detection of hitherto unsuspected iodine-containing chemical compounds in the thyroid); and

(4) As a chemical reagent essential in carrying out chemical analyses for certain trace substances present in quantities very much less than those required for measurement by usual micro-chemical techniques.

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*Brooklyn Cancer Institute, Brooklyn, N. Y.*—Isotopes have opened up a new field for research of carcinoma of the thyroid as well as opening up new vistas in the study of leukemia, polycythemia and hyperactivity of the thyroid gland.

Polycythemia cases treated with radioactive phosphorus (P 32) have also had most encouraging results.

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*University of California Hospital, San Francisco, Calif.*—Radioiodine (I 131) has proved to be useful in studying diseases of the thyroid, normal action of the thyroid, and the fate of iodine in the body. It has also been useful in treating certain diseases of the thyroid such as toxic goiter.

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Radiophosphorus (P 32) and radioiodine (I 131) are proving very useful both for diagnostic and therapeutic work in a limited number of patients.

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*Cedars of Lebanon Hospital, Los Angeles, Calif.*—Radioactive iodine (I 131) is being used to treat and diagnose thyrotoxicosis (goiter, Grave's Disease) and to treat carcinoma of the thyroid. We have been able to treat many cases which were inoperable or which had not responded to other forms of thyroid therapy, without the surgical risk which usually accompanies this condition. A total of 44 patients adequately treated were cured. However, as far as the details of the treatment are concerned, such as dosage and total time necessary for therapy, the use of radioiodine remains in the research stage.

*University of Chicago, Chicago, Ill.*—We are using radioactive iodine (I 131) for the treatment of carcinoma of the thyroid and hyperthyroidism. Although our series on both is small we are having some very gratifying results. We are also using radioiodine clinically as an aid in diagnosing hyperthyroidism and estimating thyroid function. We are also using it in experimental animals to study thyroid physiology and in one case to see if there is any relationship between the thyroid and tumor formation.

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*Cleveland Clinic Foundation, Cleveland, Ohio*—The following investigations have been carried out:

(1) Twenty cases of hyperthyroidism were treated with radioiodine (I 131);

(2) Five cases with tumor in the neck were studied with radioiodine tracer doses before operation or biopsy. Radioautographs of removed tumor tissues were made;

(3) Nine cases of suspected hyperthyroidism were studied with radioiodine tracer doses and sufficient evidence obtained to make a definite diagnosis; and

(4) One case of adenocarcinoma of the thyroid was studied with radioiodine tracer after removal of the tumor and metastases were found in the lower part of the lungs. This patient is being treated with large doses of I 131.

A considerable number of patients have been scheduled for the tracer studies and treatments with I 131 in the near future.

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*Columbia University, College of Physicians and Surgeons, New York, N. Y.*—Radioactive iodine (I 131) has proved invaluable in the estimation of thyroid function in various clinical conditions by means of the tracer dose technique.

It has also proved of great value in the differentiation between toxic goiter and the anxiety state. It has been surprisingly effective in larger doses in the treatment of toxic goiter. The success rate averages about 88 percent in 57 cases of primary and recurrent toxic goiter.

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Radioactive iodine (I 131) has been used to study thyroid function in about 350 cases, to treat hyperthyroidism in about 65 patients, to prepare radioautographs in 73 cases of known or suspected thyroid cancer, and to treat three suitable cases of thyroid cancer with functioning metastases.

The tracers are valuable as a diagnostic aid in determining whether the patient has a thyroid disorder. This technique is particularly valuable in children, where other methods are not very satisfactory. The treatment of hyperthyroidism has been very successful; about 85 percent of the treated patients have responded favorably. The method is of particular value in cases recurrent after surgical treatment.

Radioautogoraphic studies of primary thyroid cancer give information as to the probable uptake in metastases already present or which may occur later. Such studies point the way to possible therapy. Therapy itself is too recent to evaluate.

*Cook County Hospital, Chicago, Ill.*—We have used radioactive phosphorus (P 32) in the treatment of polycythemia rubra vera and chronic leukemias. The therapeutic results obtained have been gratifying and similar to those previously reported by other investigators.

Radiophosphorus, given in tracer doses, has been shown to be of definite value in the differential diagnosis and prognosis of peripheral vascular diseases. This radioisotope has also been used in the differential diagnosis of breast tumors.

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*Emory University Hospital, Emory University, Ga.*—We have given tracer doses of radioiodine (I 131) to several patients with carcinoma of the thyroid and have given a therapeutic dose to one patient with apparent clinical improvement.

Radiophosphorus (P 32) has been used in several cases of polycythemia vera with good results. Our impression is that it is a valuble therapeutic agent.

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*Jefferson Hospital, Philadelphia, Penna.*—Using radioactive phosphorus (P 32) and radioactive iodine (I 131) to study the therapeutic and clinical effect on patients with polycythemia, leukemia, hyperthyroidism and cancer of the thyroid. At the present time radioactive phosphorus is the treatment of choice in patients with primary polycythemia (vera). It is a satisfactory therapeutic agent for chronic leukemia. Radioactive iodine is a very satisfactory therapeutic agent in hyperthyroidism, particularly in those patients who cannot undergo surgical procedures or who are sensitive to anti-thyroid medications. Radioiodine is satisfactory in those cases of thyroid cancer the cells of which concentrate iodine.

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*Jewish Hospital, Philadelphia, Penna.*—We have used radioactive phosphorus (P 32) in treating a case of myeloid metaplasia exhibiting a leukemoid response. Satisfactory improvement of the treated patient has been observed.

We plan to use radioactive iodine (I 131) in an investigation of fungus infection. We plan to experimentally produce sporotrichosis in guinea pigs and to evaluate the response to both radioactive and stable iodine in an effort to demonstrate the mechanism of the response.

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*Johns Hopkins Hospital, Baltimore, Md.*—The major problems of hypothyroidism in childhood being studied with the aid of radioiodine (I 131) are:

1. Can athyreotic cretinism be diagnosed with certainty at a very early age before clinical signs are definite?
2. Can different degrees of athyreosis be measured?
3. Can congenital absence of the thyroid be distinguished from failure of thyroid function developing later?
4. Can the diagnosis of thyroid deficiency be made when all clinical signs have been obscured by treatment?

Studies are being made of the curves showing radioactive uptake and discharge measured over the neck as compared to curves showing the circulating background measured over various other parts of the body. The urinary excretion of I 131 is also being measured. Studies are being made on children with athyreosis and other types of hypothyroidism, on normal and on hyperthyroid patients. There are striking differences in the various groups. We believe that in the *untreated* patient we can definitely distinguish between athyreotic patients and normal or hyperthyroid individuals. Also it seems possible to distinguish between completely athyreotic patients and those with partial hypothyroidism. The effects of thyroid therapy, iodine, thyrotrophic hormone, antithyroid drugs and potassium thiocyanate on the rates of uptake and discharge will be studied in the various groups of patients. We believe it will be possible to develop methods of accurate diagnosis and that our studies will extend our knowledge of the physiology of the thyroid.

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*Lakeside Hospital, Cleveland, Ohio.*—A doctor of this hospital who has used radioactive iodine (I 131) to treat toxic goiter found that most cases of this disorder could be completely controlled with one or two doses of this isotope. Those cases which do not respond could probably be cured with subsequent doses of larger quantity. There seemed to be no hazards connected with the treatment except that of destroying too much thyroid tissue, which results in hypothyroidism.

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*Los Angeles Tumor Institute, Los Angeles, Calif.*—Using radiophosphorus (P 32) to study the therapeutic effects in polycythemia and leukemia. Clinical improvement of patients suffering from polycythemia has been more marked and the patients remain well longer than with any form of treatment previously available. Some of the patients with chronic myelogenous leukemia have responded as well as with the X-ray therapy previously employed.

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*University of Maryland, Baltimore, Md.*—Radiophosphorus (P 32) has been used exclusively for the successful clinical treatment of patients with polycythemia vera.

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*Mason Clinic, Seattle, Wash.*—We have used radiophosphorus (P 32) in the treatment of patients and in conducting sixteen tracer tests.

Of the ten patients treated, six had polycythemia vera; two had Hodgkin's disease; and two had leukemia. The results in polycythemia vera have been excellent and in our opinion this is the most satisfactory agent for the treatment of this disease. The results in Hodgkin's disease and leukemia have not been particularly impressive.

The tracer tests have been conducted with the object of helping the surgeon and clinician determine the presence or absence of malignancy in superficial or bone lesions. The results have been encouraging and this program is being expanded.

The value of the tracer studies lies in its use in the selection of patients for surgery who are suspected of having malignant tumors. At its present stage it cannot be relied upon exclusively, but evidence is accumulating that it will be a definite aid in selecting patients for surgery in whom cancer is suspected and in avoiding surgery for patients with cancer where metastases, or spread, has already occurred.

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*Massachusetts General Hospital, Boston, Mass.*—Tracer studies with radioiodine (I 131) to estimate thyroid function are made before treating persons for hyperthyroidism. This radioisotope is also used in the diagnosis of difficult cases.

One phase of the problem concerned with the therapeutic use of radioactive iodine has been the advisability of using it in pregnant women. Because the age at which the fetal thyroid begins to function was not known, we have studied this process by tracer techniques in pregnant women who, for other reasons of health, required an interruption of their pregnancy. Indications are that the human fetal thyroid begins to collect radioiodine after the fourth month of pregnancy. It is therefore assumed that treatment up to this time would probably be a reasonably safe procedure.

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*Massachusetts Memorial Hospital, Boston, Mass.*—Radioactive phosphorus (P 32) has made possible the satisfactory treatment, prolongation of life, and relief of suffering of some 50 patients suffering from various types of leukemia and lymphoma.

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*Mayo Clinic, Rochester, Minn.*—Radioiodine (I 131) has proved to be a useful tool in the study of iodide metabolism in man and a valuable diagnostic tool in the recognition of certain thyroid disorders. It has also proved an effective means of treating certain selected cases of hyperthyroidism and is being investigated in the treatment of patients with thyroid malignancy.

Radioiodine has been found to be rapidly absorbed from the stomach at a constant rate, varying from about 3 to 6 percent per minute. It appears in the blood stream as iodide and then disappears at a regular rate, dependent largely upon the state of the thyroid and renal function. In the normal individual most of a dose of radioiodine is excreted in the urine and most of the remainder is fixed in the thyroid. In individuals with hyperthyroidism proportionately more is fixed in the thyroid. In patients with myxedema little or none is fixed in the thyroid. Apparently in all individuals a small amount, averaging about 10 percent of a dose, cannot be accounted for in either the urine or thyroid. Observation of urine samples discloses that radioiodine is excreted at a relatively constant rate which in normal individuals is about 7 percent per hour. This percent refers to the total quantity present in the blood and its equilibrium fluids.

In individuals with depressed thyroid function the excretion rate is reduced. Comparison of blood and urine samples permit the calculation of iodide clearances giving an accurate measure of renal function. *In vivo* measurements over the thyroid gland show the rate of iodide fixation by the gland. This data is interpreted as a measure of the rate at which thyroid hormone is being synthesized. In normal individuals this rate is found to be about 4 percent per minute, but in individuals with hyperthyroidism the rate may be increased 10 to 20 fold. Radioiodine may be used to study another function of the thyroid; namely, its ability to concentrate iodide collected from the blood as distinct from its separate ability to synthesize iodide into organic thyroid hormone. Simultaneous observations made on a patient having radioiodine in the blood, the thyroid, the urine, and other parts of the body result in a fairly complete picture of the behavior of this substance. Such studies offer considerable promise for advancing the knowledge of the normal and pathologic physiology of the thyroid in health and disease.

Radioiodine has also been incorporated into a synthetic thyroid hormone. Its administration to a patient suffering from lack of this hormone permits the observation of its behavior in the body.

Radioiodine has also proved to be an effective agent in treating patients with exophthalmic goiter whose physical conditions make other methods of treatment unduly hazardous. The results of such treatment have been quite satisfactory in approximately 80 percent of the cases treated.

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*Meharry Medical College, Nashville, Tenn.*—Using radioactive gold (Au 198) in the treatment of tumors in humans. For certain types of inoperable and otherwise untreatable tumors this isotope shows considerable promise. A considerable amount of fundamental research must, however, be carried out before its widespread application becomes feasible.

Radioactive iron (Fe 59) has also been used for the differential diagnosis of certain types of anemia and for the determination of the existence of iron deficiency states.

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*Memorial Hospital, New York, N. Y.*—Radiophosphorus (P 32) is considered to be a value in the palliative treatment of polycythemia vera, the chronic leukemias and in some very radiosensitive cases of lymphosarcoma. It is regarded as another therapeutic tool but is seldom relied upon exclusively.

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*University of Michigan, Ann Arbor, Mich.*—It can be stated that without the use of radioactive iodine (I 131) we would have been unable to treat effectively certain patients with cancer and overactivity of the thyroid gland. Also our work on iodine metabolism would not have been possible.

It has been demonstrated that certain patients with cancer or overactivity of the thyroid, who cannot be treated effectively by existing methods of therapy, can be treated effectively with radioactive iodine.

It has been possible to determine with relative accuracy the distribution and excretion of iodine in the human body. This information is necessary for effectively and safely treating diseases and for acquiring more precise knowledge of thyroid physiology.

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*University of Minnesota, Minneapolis, Minn.*—To date eight patients with toxic goiter have been treated with radioactive iodine (I 131) with promising results. This therapy has not been used routinely but has been used in patients who have complications. Studies have been made on the excretion of iodine in the urine over a period of up to 14 days and the influence of Lugol medication on the excretion determined.

Radioiodine has also been used for diagnosing thyroid disorders and determining the uptake in metastases in patients with carcinoma of the thyroid. This method has proved very satisfactory.

In another research program an effort has been made to find dyes that will be concentrated by tumor tissue. The most accurate method of quantitating the amount of dye in tissue is by "tagging" the dye with radioisotopes.

Radioactive diiodofluorescein has been employed in an effort to diagnose and localize brain tumors before operation. To date this method has been used successfully in a majority of clinical cases. In several instances this technique has proved more accurate than clinical opinion based upon routine neurological examination and the electroencephalogram. Perfection of this technique should increase the accuracy of diagnosing and localizing brain tumors, and thereby reduce the present operative mortality and morbidity of such tumors.

Radioactive sulfur (S 35) in methionine is being used to study the metabolism of various organs. These studies will be extended to include certain types of cancer.

Radioactive phosphorus (P 32) has been used for treatment of patients suffering from leukemia and polycythemia vera. Definite patient improvement has been obtained.

Radiophosphorus used in conjunction with pressure cuffs has been used for determining its effect on circulation in the extremities of certain patients. The information thus obtained has been helpful in establishing an improved method of treatment.

Radioactive iron (Fe 59) has been used for determining uptake by red blood cells in one patient suffering from hemochromatosis and one patient with hypochromatic anemia. The information obtained has been of value in formulating therapeutic methods.

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*Montefiore Hospital, New York, N. Y.*—A total of twenty-one patients with metastatic carcinoma of the thyroid have been studied. Of these, on the basis of external counter measurements, seven were positive for uptake of radioactive iodine (I 131) and thirteen were negative. Two additional cases were shown to be positive on the basis of radioautographs obtained. Thus we have positive uptake in 43 percent of the cases on admission.

Two patients were treated with thyroid-stimulating hormone injections in order to attempt to induce radioiodine uptake in the metastases. The procedure was successful in one case. In a third patient in whom there was uptake on admission, this uptake was increased several fold after a course of T. S. H. injections. In two other cases radioiodine uptake was successfully induced by "Radiation thryroidectomy" with radioiodine.

To date, ten patients with metastatic carcinoma of the thyroid have been treated with varying doses of radioactive iodine. Of these, four have shown definite clinical improvement. One improved after the initial treatment, but treatment was discontinued with exacerbation of the disease and treatment has now been resumed. Two have been treated too recently for their cases to be evaluated. Three died. Of these, two were insufficiently treated because of the difficulty of obtaining radioactive iodine at the time; the third was in a terminal condition before treatment was instituted.

To date, fourteen patients with hyperthyroidism have been treated with radioactive iodine. Of these, four have shown excellent therapeutic results, four good, one fair and five questionable (we lost contact with three, one received treatment too recently to be evaluated and in one the present status is complicated by other procedures).

For all therapy doses data is now being compiled on the radiation dosage in equivalent roentgens delivered to the tissues. These results will be correlated with biological effects.

To date, it appears that in thyroid carcinoma there is greater correlation between radioiodine uptake and T. S. H. concentration in the blood than with histological structure of the tumor.

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*University of Nebraska College of Medicine, Omaha, Nebr.*—We have utilized radioiodine (I 131) primarily in the treatment of cancer of the thyroid and in diffuse toxic goiter. Radiophosphorus (P 32) has been used in the treatment of diseases of the blood and in the detection of cancer. We are developing its use in the treatment of certain diseases of the eye.

Radioactive isotopes provide a further means for the internal administration of therapeutic radiation, and provide such selective radiation as may result from concentration of particular elements in certain tissues.

Radiophosphorus, through its concentration in bone and in the nuclei of rapidly growing tissues, provides a means for irradiation of the bone marrow and disseminated neoplastic tissue. Polycythemia vera is effectively controlled by radiophosphorus in 80 percent of the cases treated. Leukemia is treated as effectively by X-ray as by radiophosphorus, although each method has limited individual advantages.

Radioiodine provides a means for the selective irradiation of thyroid tissue according to its functional activity and differentiation. Determination of percentage uptake of radioiodine provides an accurate index of thyroid activity. Diffuse toxic goiter is effectively treated by radioiodine with entirely satisfactory remission comparable to that following subtotal thyroidectomy. Selected carcinomas of the thyroid warrant combined treatment by surgery, radioiodine and deep X-ray therapy.

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*Ochsner Clinic, New Orleans, La.*—We are interested in the optimum therapy for controlling the symptoms of malignant hematologic diseases over the longest possible period of time with a maximum of comfort and useful life for the patients. We are interested in determining how to use radioactive isotopes to the best advantage for the above purpose.

Our investigations have not been completed but the results of treatment of polycythemia vera have been especially encouraging. We have had two patients whose severe hypertension has disappeared after therapy with radioactive phosphorus (P 32); whether this is coincidence or a more significant observation we hope to learn from additional studies.

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Results of treatment of polycythemia vera have been especially encouraging. We have had two patients whose severe hypertension has disappeared after therapy with radioactive phosphorus (P 32). Additional observations will disclose the significance of this type of therapy.

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*Ohio State University, Columbus, Ohio*—We have used radioactive phosphorus (P 32) in controlling the clinical and hematologic manifestations of polycythemia rubra vera. P 32 is a valuable adjunct to other therapy in certain of the more chronic leukemic states, particularly in those patients intolerant of or resistant to roentgen radiation. Although internal radiation therapy may cause an occasional brief favorable effect in the acute leukemias, all too frequently P 32 has appeared to accentuate the clinical acuteness of the leukemic process. P 32 has failed to control Hodgkin's syndrome effectively and may threaten the integrity of the marrow unless great care and discretion are observed in the dosages used. The deep bone pain which characterizes metastatic malignancies to bone may be relieved by P 32. Pruritus secondary to leukemia cutis, polycythemia rubra vera, and exfoliative dermatitis have been effectively controlled by radioactive phosphorus therapy in selected instances.

It must be emphasized that the efficacy of this therapy depends upon "selective" cell destruction. There is a wide variance in individual susceptibility and tissue response. Extreme care in administering internal radiation therapy is therefore essential.

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*University of Oregon, Eugene, Oreg.*—Radioactive phosphorus (P 32) has proved to be of definite value in the treatment of patients with leukemia, a disease of the blood-forming organs characterized by an overproduction of the white cells.

P 32 has been successfully used in the treatment of polycythemia rubra vera, a disease of the bone marrow characterized by an overproduction of red cells.

The use of radioactive phosphorus has enabled us to investigate the rate of formation of the nuclear protein of the white blood cells, both in leukemic patients and in cultures of living human bone marrow. This could not be accomplished except by the use of isotopic tracers.

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*University of Pennsylvania, Philadelphia, Penna.*—Both radiophosphorus (P 32) and radioiodine (I 131) have been used in our work. Radioactive phosphorus is being applied in clinical research in the treatment of polycythemia and leukemia, as well as in diagnosing certain other neoplastic diseases. Radiophosphorus is of demonstrated value in polycythemia vera. Its role in the treatment of other diseases is not definitely established. Some basic research is also being done on the dosage distribution in tissues obtained with radioactive phosphorus.

Radioactive iodine is being used in clinical research and for its therapeutic value in hyperthyroidism and suitable carcinomas of the thyroid. Diagnostic applications in this work are in determining the level of metabolism and suitable carcinomas for such therapy.

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*University of Rochester, Rochester, N. Y.*—Our use of radioiodine (I 131) has been confined to the study and treatment of thyroid disease, both benign and malignant.

The cases are listed as study or therapy:

| | *Study* | *Therapy* |
|---|---|---|
| 1946 | 7 | 5 |
| 1947 | 8 | 6 |
| to May 1, 1948 | 3 | 1 |

This material has been extremely useful in the solution of certain problems relating to thyroid disease and also in the treatment of patients suffering from both benign and malignant disease.

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*Santa Barbara Cottage Hospital, Santa Barbara, Calif.*—One patient suffering with chronic myelogenous leukemia was given two oral administrations of radioactive phosphorus (P 32). The patient who had no subjective symptoms or adenopathy, responded satisfactorily to the treatment as indicated by a lowering of the white blood count.

The use of radium for hemangiomata over epiphyses in infants is dangerous because of the gamma-ray effect on bone growth. Surface application of P 32 instead of radium is being used with satisfactory results to date. Plaques have been designed which afford protection to both operator and patient. No affect on bone growth is expected because of the absence of gamma radiation and the relatively slight penetration of the beta radiation.

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*Simpson Memorial Institute, Detroit, Mich.*—Radiophosphorus (P 32) has been used chiefly in the treatment of patients with polycythemia vera. Twelve patients with this condition are now being satisfactorily treated at variable intervals, ranging from one year to three years. Some patients have been treated for eight years having previously been treated with P 32 received from cyclotron sources. Two patients have developed acute leukemia after treatment with radioactive phosphorus. We have also treated a total of twenty patients with leukemia.

Our experience would indicate that radioactive phosphorus is at least as valuable and may be preferable to X-ray therapy in the management of polycythemia vera and leukemia. We have carried out determinations of P 32 uptake by circulating red blood cells and white cells, as well as by bone marrow, and lymph node tissue. We have also measured the rates of excretion in patients with various pathologic conditions.

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*Sinai Hospital, Baltimore, Md.*—Among the many serious problems in the field of medicine one of the most important is thrombosis of the veins and its graver complication, pulmonary embolism. This particular disease kills more people than cancer of the stomach. In order to attain an ideal objective—that is the prevention of thrombosis of the veins—one must have a thorough knowledge of the venous blood flow throughout the body, but more specifically in the lower extremities. In an effort to understand the blood flow in the lower extremities we have used radiosodium (Na 24) as a tracer to determine the segmental linear venous velocity in the legs. Without the use of this radioactive tracer it would have been impossible to measure precisely the rate of blood flow within any one part of the body. Now with the use of radiosodium and a Geiger counter one can measure quite accurately the linear venous velocity, thereby adding to the fundamental knowledge concerning the dreaded disease, venous thrombosis and pulmonary embolism.

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*Thorndike Memorial Laboratory, Boston, Mass.*—We have used radioactive iodine (I 131) in conducting an extensive investigation of the physiology of the thyroid, and have also treated 102 patients with thyrotoxicosis, 4 with non-toxic nodular goiter, and 2 with cancer of the thyroid. The results in these cases have been excellent.

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*Veterans' Administration Hospital, Bronx, N. Y.*—Radioiodine (I 131) has been used in solving problems of thyroid metabolism. This valuable radioisotope has been of service in the diagnosis and treatment of toxic goiter and hyperthyroidism. Certain cancers of the thyroid gland are now under treatment.

Radiophosphorus is now being employed as an adjunct to X-ray radiation in the treatment of diseases of the bone marrow, lymph nodes, liver and spleen, such as leukemia, Hodgkins' disease and lymphosarcoma.

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*Yale University, New Haven, Conn.*—From a therapeutic point of view it has been possible to use radioiodine (I 131) to suppress disease, notably in goitrous conditions. In smaller doses radioiodine has been used to detect disease of the thyroid. Such usage includes the localization of deposits of cancerous tissue as a prelude to treatment.

## Agricultural Research

### PLANT PHYSIOLOGY

*University of California, Berkeley, Calif.*—Absorption of radioisotopes of molybdenum (Mo), vanadium (V), columbium (Cb), and manganese (Mn) by plants is being studied. The biochemistry of molybdenum and manganese have significance in agriculture in that they play an important role in nitrogen metabolism. By the use of isotopes we can study the distribution of absorbed elements in the various organs of the plant.

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The value of isotopes in our research is to facilitate the study of metabolic processes in plants. There is need for gaining a better understanding of the fundamental biochemical processes that occur in plants.

The problems of how organic compounds, such as sugars, starches, organic acids, cellulose etc. are formed and broken down in plants are of prime importance. The intermediate steps involved in the process of plant respiration are poorly understood. It is hoped that by the use of radioactive carbon (C 14) these problems will be elucidated.

Carbon 14 labeled glucose, fructose, sucrose and starch were prepared by exposing various plants to radioactive carbon dioxide in the presence of light and allowing them to photosynthesize for certain periods of time. These radioactive carbohydrates are used for the study of the mechanism of carbohydrate formation and breakdown in plants and also for the study of carbohydrate metabolism in animals in such problems as diabetes.

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By the use of radiocarbon (C 14) it has been possible to show that a number of non-photosynthetic bacteria can use carbon dioxide to make acetic acid. The study of this process may aid in understanding the photosynthetic process whereby carbon dioxide is used by green plants to make organic compounds.

By the use of C 14 it has been shown that long chain fatty acids are built up of two- or three-carbon pieces, such as acetic acid. Some of the steps involved in fatty acid synthesis have been worked out.

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*University of California—Citrus Experiment Station, Riverside, Calif.*—Sulfur is still one of the most effective and important insecticides and fungicides used on crop plants. Its cheapness may insure this position for some time to come, but it has the shortcoming of injuring plants during hot weather. The physiology of "sulfur-burn" has been studied here for several years to lay a practical foundation for "safening sulfur". It has been found that elemental radiosulfur (S 35) dusted on the peel of intact lemons which were subsequently heated 6 hours at 140° F. penetrated the peel to a depth of 240 microns.

Lemons dusted with S 35 and incubated at 105° F. gave labeled $H_2S$, $SO_2$, and $SO_4$ as $H_2SO_4$. The fruit released an exudate which contained radioactive $SO_4$.

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*California Institute of Technology, Pasadena, Calif.*—An investigator has been using radioactive carbon (C 14) to determine the manner in which rubber is made by the American rubber plant, guayule. He has shown that carbon contained in the simple molecule acetate is incorporated rapidly into rubber and that acetate is an essential building block of the rubber molecule. The use of a radioactive tracer has made possible this work which constitutes the first experimental approach to an understanding of how this important product is formed in nature.

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*University of Chicago, Chicago, Ill.*—Investigators who have been using radiocarbon (C 14) to study photosynthesis in plants state that with the aid of this new tool it has been possible to distinguish compounds which were formed initially and compounds which were formed later in the course of this photochemical process. Since for many reasons it can be expected that intermediary compounds of other metabolic reactions, such as respiration and fermentation, have a great similarity to the intermediates to be found in the synthesis of sugars, it is only by means of tagging certain carbon compounds that one is able to attribute the origin of a substance extracted from the plants to one or the other of these metabolic processes.

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*Connecticut Agricultural Experiment Station, New Haven, Conn.*—Employing a gravel nutriculture procedure, corn of high quality and yield has been produced. Radioactive phosphorus (P 32) was introduced into the nutrient solution when the corn was in the early milk stage of kernel production. The mature corn grain had the highest radioactivity of any part of the corn plant. The radioactive grain contained a sufficient amount of radioactivity to make it satisfactory for a poultry feeding experiment.

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*Cornell University, Ithaca, N. Y.*—Our experimentation with radioactive calcium (Ca 45) has made it possible for us to evaluate directly the efficiency of various methods of liming to supply calcium to plants. It has also confirmed our previous deduction that yield responses to liming cannot be simply attributed to the increased supply of nutrient calcium in the soil.

From 10 to 20 percent of the calcium in the alfalfa plants was derived from $CaCO_3$ applied to an acid soil with the seed at the rate of 500 lbs. per acre. When a ton of $CaCO_3$ was mixed with the upper 4 inches of soil, 50 percent of the total calcium in the plants came from the applied lime. As the application increased to 2 and 4 tons, the percentage of calcium in the plants derived from the applied $CaCO_3$ increased to 65 and 75 percent respectively.

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*Enzyme Research Laboratory, Albany, Calif.*—A new and possibly a very important type of phosphate transfer was strongly suspected to occur in certain plant and animal tissues. With radioactive phosphorus (P 32) it has been possible to confirm this reaction.

In order to assess the role of this phosphate transfer in plant metab-

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olism and particularly in the specific problem of the maturation and storage of citrus fruits, the continued use of radioactive phosphorus is well-nigh indispensable.

An incidental result of the research in this laboratory has been the development of a simple method for converting radioactive phosphate into radioactive phosphorus oxychloride. The latter substance is useful in preparing labeled organic phosphates, which are of importance in the investigation, not only of the life reaction in plants, but also in studying those reactions in animals. These reactions may have a bearing on the cancer problem.

Considerable work on investigating the respiratory processes in citrus fruits is being based on the use of radioactive carbon. The availability of active carbon simplifies the approach to a problem which has resisted understanding by application of conventional chemical procedure.

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*Hawaiian Sugar Planters Association, Honolulu, T. H.*—By use of radiosugars containing radiocarbon (C 14) we have been able to measure more satisfactorily the rate of interchange of glucose, fructose, and sucrose in the sugar cane leaf and to measure the rate of translocation of carbohydrates.

By use of radiocobalt (Co 60) we have measured the movement of the water stream in the plant, and we have found the lethal dose of gamma rays on several organisms.

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*University of Hawaii, Honolulu, T. H.*—Radioiron (Fe 59) has been used for determining the physiological mechanism in the chlorosis of pineapple plants when supplied with great amounts of manganese. It would have been impossible to carry out this investigation with any stable iron isotope.

The results obtained show that iron presumably combines with some enzyme (ferment) which stimulates the formation of the proteins of the chloroplasts which in turn retain the chlorophyll.

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*University of Minnesota, Minneapolis, Minn.*—Our research program is designed to determine the biochemical mechanism of photosynthesis, a reaction of great fundamental biological importance. Current knowledge of this process has reached the stage where further progress would be exceedingly difficult without the aid of appropriate tracers. Currently the most useful isotopes for this study are radiocarbon (C 14) and deuterium.

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*Ohio Agricultural Experiment Station, Wooster, Ohio*—Radiophosphorus (P 32) is being used to study the movement and accumulation of phosphorus in corn plants, to study phosphorus deficiency symptoms in leaf tissues, and to study the phosphorus requirements of blight fungi growing on the leaves. Radiozinc (Zn 65) is being used to study the exact zinc requirements of corn plants.

Radiophosphorus moves readily and rapidly through corn plants and accumulates in great amounts in the embryo of the seed. Radiozinc is strongly adsorbed on the silica gravel of the cultures but enough is absorbed by the plant to indicate that it is about equally abundant in all tissues except the nodal plate where it may be found in concentrations ten times that in other tissues.

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*Purdue University, Lafayette, Ind.*—We have been investigating the ability of plants to utilize sulfur in the form of sulfur dioxide directly in their nutrition. To do this, it is necessary to be sure that the applied sulfur has been reduced by the plant to organic sulfur compounds. By using radioactive sulfur (S 35) in the form of sulfur dioxide, a label is effectively put on the applied $SO_2$. If this sulfur can then be isolated in the organic matter of the plant, the ability of plants to utilize atmospheric $SO_2$ stands unquestioned. Since sulfur is a major nutrient element for plants and an essential part of at least three amino acids and two vitamins, its importance cannot be over emphasized.

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*Stanford University, Palo Alto, Calif.*—We are using radioactive phosphorus (P 32) in a study of the metabolic exchange of phosphorus between tobacco and mosaic virus and its host. It is hoped that this work will throw some light on the unknown processes involved in the important problem of virus metabolism and multiplication. The type of study in which we are engaged is made possible only through the use of isotopes to label various components under investigation.

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*University of Texas, Austin, Tex.*—Despite the fact that plants are the ultimate source of foods for most of the earth's inhabitants, the nature of the first formed food substance in photosynthesis is still not known. The recent availability of such tracer isotopes as stable carbon (C 13) and radioactive carbon (C 14) has afforded a new method for the study of this perplexing problem. Barium carbonate which was enriched with either C 13 or C 14 was converted to carbon dioxide and leaves of bean and barley plants were allowed to use this labeled carbon dioxide in their food making process of photosynthesis.

Plants cannot differentiate between the labeled and non-labeled carbon dioxide, yet physical instruments such as the mass-spectrometer and the radioactivity counter can detect these differences accurately. Since carbon is an ever present element in foods, labeled carbon dioxide serves as an indicator of the food which a plant makes. Indication of the first formed foods in plants is afforded by short photosynthesis periods in labeled carbon dioxide, followed by immediate separation of the plant into its biochemical fractions. These biochemical fractions were analyzed for the presence of tracer isotope by means of the mass spectrometer or the radioactivity counter. Results from one hour photosynthetic periods show about one-third of the labeling agent in the sugar and one-third in the starch, small amounts in the soluble and insoluble protein fractions and almost no activity in the cellulose, pigment, and fat fractions.

Although the investigation of this problem is not yet complete, many interesting facts have thus far been learned. Some of these facts will enable us to choose plants which will produce energy-rich chemical compounds in their first or early stages of growth. This is especially important in the case of range grasses which are closely cropped by grazing animals.

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*United States Department of Agriculture, Beltsville, Md.*—Since the discovery of the growth regulating effects of organic compounds as applied to growing plants, it has been of the utmost importance to agriculturists to ascertain the chemical mechanism of their action. Because the amounts of these substances required to produce growth regulating effects is so small, conventional chemical methods cannot be used, and it has been necessary to devise ultra-micro methods for measuring their translocation and accumulation in the plant. The use of radioactive elements as tracers in these organic compounds has provided an extremely sensitive and practical means for accomplishing these purposes. For this reason, radioactive isotopes have provided the first and perhaps the only means for conducting investigations in this very important field.

Results of research conducted with radioiodine (I 131) along these lines have led to the following conclusions:

1 Organic plant-growth regulators actually enter, are translocated and accumulated by the growing plant.

2 Accumulation of the regular is greatest in the parts of the plant which are most actively growing at the time of application of the regulator.

3 No essential differences in the rate of absorption, translocation, or accumulation can be shown between dicotyledonous plants, which are markedly affected by the regulators, and monocotyledonous plants which are unaffected by the same regulators.

4. Evidence, as yet inconclusive, has been obtained to indicate that the differences in response between different plant types are due to differences in the chemical reactions which take place between the growth regulator and essential plant metabolites in the two cases.

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Radiophosphorus (P 32) has proved to be of unique value in assessing the effectiveness of fertilizers. By its use, and only by its use, can the amount of phosphate supplied by a fertilizer for the growth of plants be determined.

The Bureau of Plant Industry, Soils and Agricultural Engineering is cooperating with the various states in applying fertilizers containing radioactive phosphate to the solution of problems of correct placement of fertilizers, suitability of various phosphatic materials as fertilizers, assessment of levels of phosphate soil fertilities, and effectiveness of various field crops in obtaining phosphate from soils and fertilizers.

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*University of Wisconsin, Madison, Wis.—The Biosynthesis of Labeled Compounds.*—In many cases the synthesis of compounds labeled with radiocarbon (C 14) is a difficult, if not impossible, task with the techniques of organic chemistry. The potentialities of the higher plants as biosynthetic agents are being explored, for frequently the plants can accomplish a synthesis from $CO_2$ without difficulty. Simple techniques have been developed so that with a few dollars' worth of equipment one can grow plants in closed systems, supply them with $C^{14}O_2$, allow them to assimilate the $CO_2$ by photosynthesis and incorporate the C 14 into a variety of compounds. The labeled compounds can then be isolated.

C 14 labeled starch has been produced in this manner, and the organic acids malic, succinic, citric and isocitric have been labeled and isolated for other studies.

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*The Mechanism of Photosynthesis.*—In conjunction with our studies on the biosynthesis of organic acids with the plant bryophyllum calycinum it was observed that the C 14 supplied as $CO_2$ accumulated in malic acid after short exposures of the plant to $C^{14}O_2$. As work with algae in recent years has suggested the possible importance of malic acid as an intermediate in photosynthesis our interest was aroused in determining the distribution of C 14 photosynthetically assimilated by bryophyllum. In plants illuminated and supplied with $C^{14}O_2$ for 2 hours, 95 percent of the C 14 of the organic acid fraction was in malic acid and the malic acid had about 10 to 20 times the specific activity of the other organic acids. Fixation of $C^{14}O_2$ in the dark by this plant also incorporates the bulk of the C 14 into malic acid.

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*The Oxidation of Glycolic Acid by Plants.*—Plants contain a powerful glycolic acid oxidizing enzyme. The mechanism of the oxidation remains obscure but there are indications that a condensation of 2-glycolic acid molecules occurs before oxidation is completed. Glycolic acid labeled with C 14 is being synthesized currently to aid in tracing the pathway of glycolic acid oxidation.

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*The Role of Biotin in $CO_2$ Fixation.*—Studies have been made of the function of biotin in the carboxylation of pyruvic acid to form oxalacetic acid. When lactobacillus arbinosus cells are grown on a biotin deficient medium they have very little ability to fix $C^{14}O_2$, but when grown with biotin they fix $C^{14}O_2$ at a rapid rate. Isolation of compounds from the cells indicated that a large share of the C 14 fixed was incorporated into aspartic acid. All evidence suggested that pyruvic acid was carboxylated to yield oxalacetic acid which upon transamination yielded aspartic acid bearing the C 14 label.

*$CO_2$ Fixation in the Urea Cycle.*—It has been shown that in tissue homogenates synthesizing urea, almost all of the $C^{14}O_2$ assimilated is incorporated into urea under the experimental conditions employed. Thus the function of $CO_2$ *per se* in urea synthesis was substantiated.

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In our investigations on the mechanism of biological nitrogen fixation, a problem of fundamental importance in agriculture because of the significance of nitrogen for crop production, we are using stable nitrogen 15 and deuterium (heavy water) for tracer work. As with so many problems in biological mechanisms, such "tracers" are indispensable for many investigations necessary for an understanding of how nitrogen of the air is fixed by bacteria and leguminous plants. Before the labeled atoms were available, the work was simply not done.

### LIVESTOCK PHYSIOLOGY

*University of California, Berkeley, Calif.*—Radioactive phosphorus (P 32) is being used in the study of the avian lymphatic leukosis complex. The disease is of major economic importance to the poultry industry and of considerable interest to cancer research. The isotope is being used to "tag" the phosphorus of normal and neoplastic tissues, and thus to study the phosphorus metabolism of these tissues. The information gained by the use of this technique will be of value in comparing the avian disease to similar diseases of experimental animals and man.

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An investigator who has been using deuterium (H 2) in amino acid metabolism studies with chicks states the following:

"The stable isotope of hydrogen (deuterium) provides a potent tool for the study of the interrelationships of two amino acids in the diet of the chick. The amino acids being studied are important constituents of muscle and other tissue proteins. The fundamental information obtained should aid in providing the most efficient use of valuable protein supplies."

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*Cornell University, Ithaca, N. Y.*—Radioisotopes will be invaluable in our work on the physiological basis of the ability of birds to navigate over long distances without apparent landmarks. This phenomenon of orientation and navigation by migratory birds has baffled scientists for some years, but progress is being made by the detailed study of homing flights in which birds are artificially transported and released in territory where they have never been before. Many species return from hundreds of miles in such homing experiments, and the accurate timing of such returns has been very difficult in the past due to the virtual impossibility of keeping a human watcher constantly at the bird's nest to note the exact time of its return. By placing minute amounts of radioactive zinc (Zn 65) on the bands used to mark these birds it will be possible to time their return by means of automatic recording radiation meters. The amount of material applied to the bands will be so minute that it will barely increase the radiation dose received by the bird above the natural background from cosmic radiation and natural radioactivity.

The results of these investigations are expected to clarify the basis of orientation and navigation in migratory birds, and possibly to suggest methods which might be useful for men who in uninhabited regions or because of accident, must find their way about by rough-and-ready means, without benefit of elaborate instruments.

*University of Florida, Gainesville, Fla.*—Within recent years there has been general recognition that certain minerals in extremely small amounts are essential for animal health, having a regulatory function similar to that of the vitamins. The bodily requirements for these elements are so minute that their function cannot be studied with ordinary methods of chemical analysis. The use of radioisotopes offers unique possibilities for the investigation of the role and function of these minerals in animal metabolism. It is expected that these studies will contribute to improved animal production as well as improved nutrition for all species including man.

Detailed information is available on exactly how animals absorb and utilize copper, molybdenum and phosphorus. Ingested copper is poorly absorbed, whereas intravenously injected copper is highly retained. Assimilated copper reaches all tissues, enters into the red blood cells and all the blood forming centers; however, it is mainly stored in the liver.

Molybdenum is very readily absorbed and tends to be deposited in bone in large amounts. Molybdenum is of importance from the standpoint of interactions with other nutrients.

A study of what happens to phosphorus fed to the lactating dairy cow indicates that about 40 percent will be excreted in the feces, about 10 percent in the urine, about 15 percent will be secreted immediately in the milk, and the rest deposited in the body stores. Roughly 80 percent of the phosphorus in milk is calculated to have reached there via the body stores. The incorporation of ingested phosphorus in blood and milk phospholipids as well as in the casein is relatively slow.

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*New York University, New York, N. Y.*—Radioactive iodine (I 131) and sulfur (S 35) are used in the pipsyl derivative method of estimating amino acids and pyrimidines. Without these radioisotopes it does not appear that methods sufficiently sensitive and selective could have been developed. These methods are used in the investigation of proteins. Differences between the proteins of normal and abnormal tissues, if present, may be demonstrated. An insight into protein structure can be obtained from the use of isotopic reagents to label end groups or partially hydrolyzed proteins.

The method has been developed in detail for eight amino acids and two pyrimidines. It has been used for the estimation of three combinations of two amino acids (dipeptides) and to determine in part the arrangement of amino acids in the simple protein, silk.

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*Parke, Davis and Company, Detroit, Mich.*—Radioactive colloidal iron mixtures (Fe 55 and 59) were administered parenterally in single and multiple doses to ducklings and canaries. These studies reveal the following:

Radioactivity is evident in red blood cells 18 hours following single intravenous administration. During the next 70 hours, increasing amounts of radioactivity are found in blood cells with negligible amounts in plasma.

Radioiron is utilized more rapidly by blood cells following intravenous injection than following intraperitoneal administration.

Radioactivity of perfused tissues of ducklings receiving multiple doses of maximally tolerated amounts of radioiron over a period of 23 days was greatest in the liver, bone marrow, and spleen. Lesser amounts occurred in other tissues studied.

There was no evidence of intolerance of radioiron of specific activity of one millicurie per gram apart from the toxicity of iron itself.

The *in vivo* effects of radioiron on two species of malarial parasites were studied. *Plasmodium cathemerium* infections were established in canaries having 0.12 microcuries per milliliter of blood. *P. lophurae* infections were initiated in ducklings having 0.10 microcuries per milliliter of blood. There was no evidence of radiation damage to the plasmodia on the basis of their morphology and ability to produce an acute parasitemia.

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*University of Pittsburgh, Pittsburgh, Penna.*—Radiocopper (Cu 64) was introduced into the white of Leghorn hen eggs at 0, 24, and 48 hours after incubation and observations were made from 24 to 48 hours after injection. A striking concentration of copper 64 was observed in rapidly developing and/or growing regions, such as the brain, spinal cord and tail. It was shown that these patterns of copper concentration closely paralleled the patterns reported by other workers for the metabolic rate, cytochorome oxidase activity, and oxygen uptake.

These experiments illustrate the usefulness of radioactive isotopes in the study of mineral metabolism under both normal and abnormal conditions.

Similar studies are now being conducted with radiophosphorus (P 32) and the results thus far are paralleling those of the experiments with copper 64.

The studies with phosphorus are being extended to include distribution of phosphorus 32 in the shell, shell membrane and fluids of the egg.

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*Purdue University, Lafayette, Ind.*—Radioiodine (I 131) has been used for testing iodinated casein absorption in animals. It is kown that iodinated casein products are beneficial in agriculture for the increased fattening rates of animals. Iodinated casein prepared with radioactive iodine is used to study the absorption rates from various parts of the alimentary tract of animals to determine the best means of administration of such substances.

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*Washington University, St. Louis, Mo.*—Turnover and metabolic function of phosphate compounds in intact cells, particularly with reference to mechanism for utilization of phosphate bond energy in synthesis of cell constituents such as proteins, fats and carbohydrates have been determined.

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*University of Wisconsin, Madison, Wis.*—In certain areas of this country the element molybdenum occurs in high concentrations in the soil. It is picked up in the herbage and is injurious to the health of farm animals.

We are interested in (a) finding out where a dose of molybdenum goes when given to an animal and (b) studying the effect of substances which will counteract the toxicity of molybdenum.

It is a distinct advantage to use an isotope in (a) since the given dose of radiomolybdenum (Mo 99) is different from any inert molybdenum preexisting in the animal tissues. A chemical assay fails to distinguish between the two forms just as certainly as the animal cannot differentiate between inert and radiomolybdenum.

In (b) a large number of assays are required. These may be carried out in a few minutes with radiomolybdenum but would require a few weeks with ordinary molybdenum.

Therefore, the chief advantages of using the isotope in this research were speed and accuracy.

Our results show:

1 a very rapid uptake of molybdenum into all animal tissues.

2 a higher deposition of molybdenum in the bones and kidneys.

3 an unknown substance exists in beef liver, apparently not copper, which will counteract the toxicity of molybdenum.

This work is a part of a broad problem to study the health and nutrition of farm animals.

## Industrial Research and Metallurgy

*Allied Chemical & Dye Corporation, New York, N. Y.*—Experiments have been started using deuterium (H 2) as a tracer on the quantitative determination of the residual water or hydroxyl content of alumina samples. It is anticipated that at elevated temperatures an exchange reaction will occur between gaseous deuterium and chemically bound water in the alumina.

It is planned to follow the change in the deuterium content by thermal conductivity measurements or, if necessary, by the mass spectrometer.

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*Brush Development Company, Cleveland, Ohio.*—We have undertaken to prepare crystals of potassium pentaborate and lithium sulphate containing heavy hydrogen in order to investigate the piezoelectric * and elastic properties of these crystals.

Crystals of potassium pentaborate containing heavy water were grown and their most important piezoelectric mode studied. It was found that the substitution of heavy hydrogen did not affect this mode materially. This mode therefore, is not connected with hydrogen bonds and differs from similar modes in certain other piezoelectric crystals.

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*California Research Corporation, Richmond, Calif.*—Radioisotopes are beginning to play an increasingly important part in the solution of our research problems. At the present time we have started work with radiocarbon (C 14). Hydrocarbons typical of petroleum compounds are labeled with this isotope and are subjected to catalytic

* (Electricity or electric polarity due to pressure, especially in crystallized substance, as quartz.)

processes. By measuring the activity in the reaction products, we are able to obtain information about the path followed by the labeled compound in the reaction. This work is of considerable importance and will probably be expanded in the future. In addition, we are actively planning radio tracer work using several other tracer materials.

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*Dow Chemical Company, Midland, Mich.*—We are using radiocarbon (C 14) for two research projects which could not otherwise have been undertaken. The first of these is a study on laboratory animals to determine the toxicological effects of some common chemicals which find wide-spread uses in everyday life. The second problem is the detection of carbon in metallic magnesium to determine the role of carbon-containing compounds in altering the grain size and thus physical properties of the metal. In both of these problems the radioisotope furnishes a method of distinguishing carbon from one source from all other carbon in the experimental system as well as providing a more sensitive method of analysis than has been available before.

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*Eastman Kodak Company, Rochester, N. Y.*—Attempts are being made to use radioactive gold (Au 198) as an analytical tool in the determination of metallic silver in a photographic material. The success of the method will depend upon finding conditions such that one atom of gold replaces one atom of silver, and any excess gold salt can be washed out. If this can be done, it should be possible to determine quantities of silver much smaller than those which can be determined by the standard analytical procedures, and, hence, it should be possible to determine directly the minute amount of silver formed in a photographic exposure.

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*General Electric Company, Schenectady, N. Y.*—An investigation of high temperature alloys, as applied to the gas turbine field, is being carried out with the use of radioisotopes as tracers. These radioisotopes offer a means of studying an individual component, in a multicomponent system, entirely independent of the other elements which may be present. Such an investigation is impossible without the use of radioisotopes.

Radiotungsten (W 185) has been added to several melts of high temperature alloys and numerous autoradiographs have been made. Generally speaking, the autoradiographs do not have the high degree of clarity that is required but enlargements of 50 diameters have been made with success. Efforts are being made at the present time to produce autoradiographs with better clarity.

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*Edward S. Gilfillan, Jr., Consulting Engineer, Manchester, Mass.*—Radiocobalt (Co 60) and radiostrontium (Sr 89, 90) have been used to collect electrostatic charge from textile materials and deliver the charge to measuring instruments. This has permitted measurements of the absolute amount of electricity generated during textile processing to be made for the first time. Attempts to do this by means other than radioactivity failed.

Some progress has been made toward the commercial use of these radioactive materials for dissipating unwanted charge around textile machinery. It appears unlikely that Co 60 can be used for this purpose, but the application of radiostrontium seems more promising.

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*B. F. Goodrich Company, Akron, Ohio.*—We have been using radioactive sulfur (S 35) to study the mechanism of vulcanization of rubber. This is one of the fundamental problems in the science of rubber and is practically unsolved in the sense that we do not understand exactly what happens. By using radioactive sulfur we hope to determine more definitely the disposition of this vulcanizing agent in the final product.

Radioactive iodine (I 131) has been used for measuring the thickness of thin films in the neighborhood of 1 micron, which are difficult to measure by more conventional methods. This work is part of an attempt to understand the mechanism by which silicones reduce the adhesion of ice to rubber-like materials. This reduction plays an important part in the outstanding improvements that have been made recently in De-Icers for keeping aircraft free of ice.

Radioactive phosphorus (P 32) has been used in several projects, one of which is concerned with improving abrasion tests, and in particular tire tread wear tests which are now slow and expensive.

We have been able to show that the binding between sulfur and rubber is different depending on the type of accelerators used. We have determined the structure of tetramethyl thiuramdisulfide and find that it is not as commonly accepted. We have arrived at a better understanding of the mechanism of vulcanization with this accelerator, but the process is not yet clearly and definitely established. Several radioactive accelerators have been made, including zinc dimethyl dithiocarbamate, tetramethyl monosulfide, and tetramethyl disulfide. Such radioactive accelerators will permit us to run tracer experiments in which we can supply the radioactive sulfur either as free sulfur or as part of the accelerator molecule.

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*Goodyear Tire and Rubber Co., Akron, Ohio.*—The problem of gaging the thickness of extremely thin films has long been a headache in industry.

The average thickness of a sheet of Pliofilm, a Goodyear product, is about one-thousandth of an inch.

Mechanical gages such as are now in use are difficult to use since the tiniest change in the pressure of the gage on the film will give a false reading. Present gages read with only dubious accuracy to a ten-thousandth of an inch.

The usual mechanical gage compresses the film between a metallic foot and an anvil. The theory is that the weight of the foot will provide the same pressure but it is apparent that the softness of the film will affect the result.

Various refinements may be incorporated but one difficulty about using all such gages in conjunction with a production line is that either the progress of the film must be halted for gaging purposes or a piece of film must be cut from the sheet and subjected to gaging.

The new radioactive gage, using radiocarbon (C 14), makes it possible to gage a sheet of Pliofilm or other film continuously as it comes from the rolls. No mechanical contact with the film is required.

The film passes through a slot in the gage. Below this slot there is a small bit of carbon 14. Above the slot there is an ionization chamber in which is produced a minute electrical current by the rays from carbon 14. This current is amplified by sub-miniature vacuum tubes to the point where it is sufficiently large to operate an ordinary electric meter which will then indicate the strength of the rays. Further amplification could be used to actually control the film gage by regulation of the speed of the production machinery.

Carbon 14 gives off only a weak stream of beta-rays. These are electrons like the electrons released by the filament of an ordinary radio vacuum tube.

The number of electrons getting through the sheet of film depend upon its thickness. Consequently the meter can be graduated to read directly in thickness of film.

The new gage will now read with accuracy to a hundred-thousandth of an inch but it is hoped to attain an accuracy of a millionth of an inch.

In other research programs radioactive phosphorus is being used to study the diffusion rate of plasticizers. Radioactive copper is being used to study the solubility of copper in rubber. Radioactive sulfur is being used to measure the migration and solubility of sulfur in rubber and investigating the chemistry of vulcanization.

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*Industrial Radiography Laboratory, Beaumont, Tex.*—To date our research has dealt with the use of radiocobalt (Co 60) as a high energy gamma-ray source for radiography. The gamma-ray source from Co 60 should increase the depth of penetration for radiography up to 15 inches of steel.

Contrary to what was expected the gamma-rays from Co 60 do not behave in accordance with the same energy levels obtained in the 1,000,000 volt X-ray machine.

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*Arthur D. Little, Inc., Cambridge, Mass.*—Radiosulfur (S 35) has been used to study the role of sulfur in the coking process for the steel industry. This study could not have been conducted without radioisotopes and was aimed at the ultimate production of better quality steel. Results have shown that low sulfur coke results only when low sulfur coal is used in present typical coking practice. S 35 is being used to obtain a better understanding of the role of sulfur as an agent in the processing of metals.

Radiophosphorus (P 32) is being used to study methods of decontamination. This study should ultimately provide information on better safety practices in the handling of radioisotopes.

*Massachusetts Institute of Technology, Cambridge, Mass.*—We are using radioiron (Fe 55 and Fe 59) in metallurgical diffusion studies with particular reference to steel. This is a long-range program designed to establish the diffusion rates that enter into such phenomena as annealing, hardening, recrystallization, grain growth, creep and high temperature behavior. Diffusion in the solid state is a vital process in the general behavior of metals, and radioactive isotopes offer an unique means of investigating the quantitative aspects of the problem.

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Radioactive isotopes of iron (Fe 55, 59) and chromium (Cr 51) are being used as tracers in studying material transfer between rubbing surfaces. The amount of this transfer is extremely small and the tracer technique is the only method sufficiently sensitive to detect it. Study of such transfer of material is essential to elucidating the fundamental mechanism underlying the phenomenon of dry friction between solid surfaces. It has been found that even between the hardest steel surfaces, i. e., those with nitrided surfaces, as much as 5 micrograms of metal may be transferred from one surface to the other when they rub together. This suggests that transfer is an inherent concomitant of friction.

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We are using radiocarbon (C 14) to investigate the 12-carbon-chain amine as a flotation reagent. It is hoped that this research will clear up many of the puzzling and unknown factors entering into the use of amines as flotation reagents.

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*Mellon Institute, Pittsburgh, Penna.*—We have been using carbon monoxide containing radioactive carbon (C 14) in an investigation of the mechanism of the synthesis of hydrocarbons by the Fischer-Tropsch process. The use of this radioactive carbon has enabled us to show that the hydrocarbon synthesis does not take place through the intermediate formation of metallic carbides but through some mechanism, the details of which are not yet known. The carbide theory for formation of hydrocarbons is one that has been generally accepted as correct since its initial formulation by Dr. Fischer who was the originator of the synthetic gasoline process. It is hoped that this continued use of radioactive carbon will permit the elucidation of the detailed mode of operation for this important process for the manufacture of synthetic fuels from coal or natural gas.

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*Shell Development Company, Emoryville, Calif.*—By using radiocarbon (C 14) we have been able to study problems that could not be attacked in any other way. We have followed the course of particular carbon atoms in complex catalytic hydrocarbon reactions. Such experiments will surely lead to a better understanding of chemical reactions involving petroleum and petroleum products. We have also used C 14 in special analytical problems where detection of radioactivity was the only practical analytical procedure.

Deuterium, an isotope of hydrogen, the other element present in hydrocarbons, has similarly been helpful in other studies of hydrocarbon reactions.

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*Sinclair Refining Company, East Chicago, Ind.*—Our studies with radiocarbon (C 14) will deal with the mechanisms of catalytic cracking and Fischer-Tropsch reactions and with the adsorption of very small quantities of radioactive materials.

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*Socony-Vacuum Laboratories, Paulsboro, N. J.*—In the study of oil production from oil sands, the nature of the three phase flow of oil, water, and gas is a basic problem, since the most efficient exhaustion of present petroleum reservoirs depends upon the nature of this flow. To help in understanding this problem we are using radioactive cobalt (Co 60) to study the permeability of naturally occurring or artificially produced porous media to the flow of oil, gas and water mixtures.

By using radioactive tracers in the oil, the location and quantity of oil flowing through the medium can be determined internally by a Geiger counter.

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Despite many years of research on lubrication by various industries, there is still much to be learned about the mechanism of lubrication. We are now using radioactive iron to study the chemical and physical reactions occurring at a lubricated surface. Heretofore, progress on direct studies of such interactions has been limited by the lack of sensitivity in the methods used. Now, however, by using radioactive iron as a bearing surface, any iron which reacts with the oil or chemical additives in the oil can be measured with a sensitivity of one part in ten million in as little as 20 milligrams of oil.

Increased knowledge of this mechanism may eventually lead to improved, lower cost industrial and automotive lubricants.

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*Stevens Institute of Technology, Hoboken, N. J.*—The research project utilizing radioactive isotopes is engaged in the study of self-diffusion in stressed metals. The results will contribute materially to the theory of solids in general, as well as being of importance in applied metallurgy. The use of radioactive isotopes of zinc and copper as tracer materials is essential to this work.

A general description of the technique using the isotopes is as follows: Single crystals of the metal are electroplated with the isotope material and are then placed under stress in a furnace at temperatures approaching the melting point of the metal. When the isotope has had sufficient time to diffuse into the crystal, the specimen is removed and sectioned. The activity of the sections is measured to obtain the amount of diffused material at various distances from the original plated surface. From this, the diffusion coefficient and the activation constant may be obtained and the effect of the stress on these quantities may be ascertained. The general technique is nearly identical for both copper and zinc.

*The Texas Company, New York, N. Y.*—Radiocarbon (C 14) will be invaluable in determining the chemical mechanism of the formation of petroleum products in the catalyzed hydrogenation of carbon monoxide. A more complete understanding of this mechanism can be expected to result in a greater production of synthetic petroleum, a matter of vital concern to the United States.

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*Westinghouse Electric Corporation, Pittsburgh, Penna.*—We have been using radioactive carbon (C 14) for research investigations in metallurgy. More specifically we are attempting to determine the diffusion of carbon in alpha (body-centered cubic) iron. This subject is of theoretical importance because of its bearing on the aging of steels, the magnetic after-effect, and the elastic after-effect; it is of practical importance in decarburization of plain carbon and alloy steels.

We have been successful in introducing C 14 into iron by a pack carburizing method employing a mixture of charcoal and labeled $BaCO_3$. Experiments on autoradiography to determine microstructure have been unsuccessful. Experimentation is underway at present to determine the diffusion coefficient of C 14 in alpha iron at temperatures below 725° C.

We have used radioactive phosphorus (P 32) in measuring the amount and location of phosphorus in steel and alloys by the autoradiographic technique.

We have experimented with radioactive materials as chemical analytical tools in determining the amount of a given element in alloys and chemical mixtures and solutions, as a function of time.

We have used C 14 as a target in nuclear reaction studies, C 14 (p,n) N 14 to measure nuclear masses and to place limits on the neutrino mass.

We have used intense gamma and beta sources for measurement of relative sensitivities of atomic radiation detectors.

## Chemical Research

*American Cyanamid Company, Stamford, Conn.*—Our research program involves the use of radiosulfur (S 35) in studying colloids and colloidal electrolytes. Using S 35, the synthesis of a wetting agent of the sulfosuccinate class has been carried out, and at the present time we are obtaining results on the adsorption of this material. The radiosulfur appears to be giving information which will be of great interest to the general understanding of the behavior of these surface active agents, and we regard its use in this problem as unique.

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*California Institute of Technology, Pasadena, Calif.*—Radiotin and radiothallium are being used to study the color of inorganic compounds and the relation of color to the exchange reactions between different oxidation states of an element in solution. This research program would be impossible without the use of radioactive isotopes.

The research is adding to our understanding of the conditions under which electrons can be transferred from one molecule to another in the presence and absence of light. Since electron transfer is important in all oxidation-reduction reactions in chemistry and in the electrical conductivity of solids, our research contributes to the understanding of these fundamental topics.

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*University of California, Los Angeles, Calif.*—Radiochromium (Cr 51) is being used in our chemical research program to study the ease with which chromium atoms in certain complex compounds may be replaced by other chromium atoms. This type of work can be carried out only with radioactive or separated stable isotopes. The work is expected to add to present information on how atoms are held together in certain types of molecules.

Radiocarbon (C 14) is being used in another investigation to learn more about the possible existence of an interesting form of carbon, namely, dicarbon gas. Studies by conventional chemical approaches are more difficult and less revealing than those made possible by the radioisotope tracer technique.

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*University of Southern California, Los Angeles, Calif.*—We have been studying the catalytic exchange of hydrogen with ammonia by using deuterium (H 2) as a tracer element. The results, when completed, may be of considerable value to the ammonia industry.

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Radiocarbon (C 14) has been an essential tool in the study of the structure and stability of complex ions. Complex ions constitute a large and very important class of inorganic compounds, and one of the best ways of studying them is by tracer exchange experiments. Exchange studies are currently being conducted with a number of complex cyanides, using C 14 labeled cyanide ion.

Extensive work is in progress on the determination of ion self-diffusion coefficients. This can be done only by means of tracers, and both radioiodine (I 131) and radiosulfur (S 35) are being used.

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*Canisius College, Buffalo, N. Y.*—Using radioactive iron (Fe 55, 59) to study the solubility product constant of hydrous ferric oxide. The use of radioactive iron as a tracer in determining the solubility of hydrous ferric oxide shows much promise but it has been found that an instrument having greater sensitivity is necessary before the work can be brought to a conclusion.

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*Carnegie Institute of Technology, Pittsburgh, Penna.*—We have used radiosodium (Na 24) to investigate the diffusion of sodium in sodium chloride as a function of temperature. This self-diffusion problem is one which cannot be studied without the use of isotopes. The importance of the research lies in the fundamental information obtained concerning the mobility of ions in solids. The results of our work to date consist of a determination of the self-diffusion coefficient of the sodium ion in sodium chloride over the range of temperature from 350° to 700° C.

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*University of Chicago, Chicago, Ill.*—A complete understanding of the oxidation of organic compounds requires a knowledge as to which of the various hydrogen atoms in the reacting molecule is removed during the critical step of the oxidation. This question can only be settled by the use of deuterium (H 2) as a tracer.

It was found that, when a particular hydrogen atom in an organic compound (isopropyl alcohol) was replaced by deuterium, the rate of oxidation was considerably reduced. This fact showed that this particular hydrogen atom was the one removed in the critical step of the oxidation.

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When platinum, activated by ferrous chloride, is used as a catalyst, the deuteration of acetone is accompanied by some hydrogen-deuterium exchange. The product here obtained was a mixture containing 55 percent of 2-deuteroisopropanol.

The rate of chromic acid oxidation of this product was only 52 percent of that of ordinary isopropanol. On the basis of this result, it is calculated that the rate of chromic acid oxidation of pure 2-deuteroisopropanol should be about one-sixth that of pure isopropanol.

The lower rate of oxidation of the 2-deutero compound (which arises from differences between the zero point energies of the C-H and C-D bonds) proves that the secondary hydrogen (or deuterium) in isopropanol is removed in the rate controlling step of the chromic acid oxidation.

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Radioiron (Fe 55, 59) and radiogallium (Ga 72) were used to study the distribution of these elements between hydrochloric acid and isopropyl ether. The tracers permitted extension of the partition studies to concentrations lower than could have been conveniently determined by usual methods of chemical analysis.

The efficiency of extraction of ferric chloride and of gallium chloride from hydrochloric acid solutions by isopropyl ether is found to increase markedly with increasing concentrations of these salts. The phenomenon is attributed to a self-promoted increase in the thermodynamic activity of the salts. The extraction may lead to a better understanding of the thermodynamic properties of concentrated aqueous salt solutions.

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In our research program radiocarbon (C 14) is being used in an investigation of the mechanism of a chemical reaction (the benzidine rearrangement) which is not only of considerable scientific interest, but is also important in the dye industry. If the isotopic carbon were not available to serve as a tracer, the evidence obtainable would be much less conclusive.

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*Columbia University, New York, N. Y.*—Radioactive sulfur (S 35) is being used to study the strength and nature of the sulfur bonds in polysulfide polymers.

Deuterium is being used to study the rate of exchange with hydrogen in hydrocarbons and their derivatives in an effort to learn more about the effect of substituents on the strength of the carbon to hydrogen bonds.

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We are using radiothallium (Tl 204) to study the process of electron transfer between the different oxidation states of thallium in solution. Since this is an "exchange reaction", the only convenient method of study is by isotopic tracers.

The reaction proceeds at a measurable rate. We are studying its kinetics.

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We plan to use radioiodine (I 131) in a photochemical exchange reaction as a sensitive measure of iodine atom concentration. By this means we hope to determine what fraction of those iodine molecules which are dissociated by light actually form atoms which are free to move in the solution, and what fraction form atoms which lose their excess energy to the solvent and immediately recombine without escaping from the "cage" of molecules in which they are formed. If these studies are successful, they will constitute a fundamental contribution to the understanding of photochemical processes in liquid solutions.

We also plan to use tracers to obtain additional information on the mechanism of iodide ion catalysis of *cis-trans* isomerism. This program will probably be modified because iodide ion apparently causes the elimination of iodide from diiodoethylene.

Another investigation is designed to study the presence or absence of exchange between iodine atoms and various organic iodides. Such studies have been made with iodide ions, but no similar results are available from diiodoethylene.

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*Cornell University, Ithaca, N. Y.*—We are using radioactive iron (Fe 55, 59) and radioactive cobalt (Co 60) in studying the stability of complex ions of these elements; a study impossible without radioactive isotopes. We have obtained data on the interchange for some of the complex ions but as yet we have not completed a study of the speed of interchange.

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*Duke University, Durham, N.C.*—A research project is using isotopic tracers to study the mechanism of organic chemical reactions. Results obtained to date using deuterium (H 2) as a tracer indicate that the mechanism of several elimination reactions may be less clear than theory indicates. It is probable that each of several alternative mechanisms operate simultaneously. It is planned to extend the program to the use of other tracer elements as soon as facilities are available. In another program compounds containing high percentages of deuterium have been synthesized, and are being used in a study of microwave adsorption.

*Eli Lilly and Company—Purdue University, Lafayette, Ind.*—A study of the exchange reaction would have been impossible without the use of radioactive iron (Fe 55, 59). An understanding of such reactions as this is basic to the further development of our ideas of the nature of chemical reactions.

Using the tagging technique with radioactive iron, it was found that iron in two different, but simple, chemical forms, interact with one another extremely slowly. This is contrary to expectation. As a result new questions of chemical importance appear to require investigation.

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*Harvard University, Cambridge, Mass.*—Radioactive sulfur (S 35) is being used to investigate the mobility of adsorbed gaseous films on solid surfaces. The results of this work, if successful, will contribute to the understanding of the mechanism of adsorption, which in turn is of fundamental importance in the problem of chemical catalysis.

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*University of Illinois, Urbana, Ill.*—We have been studying the theory of organic chemistry using organic molecules labeled with deuterium (H 2) instead of hydrogen. By this method it is possible to determine what becomes of chemical substances in a chemical reaction.

This technique has been very successful in our work and provides the only method whereby the problem can be attacked.

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Our research program designed to study the chemical properties of complex compounds of tin would not be possible without the use of highly radioactive tin. Increased knowledge in this field is desirable to better understand the nature of chemical bonding between atoms. This information will also provide a new procedure for the study of radioactive decay processes.

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Radiophosphorus (P 32) has proved a valuable tool in the study of certain chemical reactions involving thorium and the rare earth elements. We have been concerned specifically with the development of rapid and accurate methods for the analytical determination of thorium in the presence of the rare earth elements, a problem of considerable importance particularly in the large-scale recovery of thorium from minerals. To this end, we have used P 32 as a tracer and have built around its radioactive characteristics a very rapid and convenient analytical method using pyrophosphate. This method is as accurate as any previously reported and should be of considerable use in working with thorium materials.

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*Johns Hopkins University, Baltimore, Md.*—We have been using radioactive silver (Ag 110) in an investigation of several electrochemical problems. One of these involved the study of ion exchange between solid silver metal and a solution containing a very small concentration of silver ions, the latter being partly radioactive. Difficulty was encountered in removing colloidal silver compounds from the solution. The presence of these compounds was found to cause errors in the Geiger counter readings of radioactivity attributable to exchange. Ag 110 was also found to be useful in studying the passivity induced to an iron surface under various conditions.

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*University of Kansas, Lawrence, Kans.*—We believe that our work with deuterium (H 2) will lead to valuable information concerning the nature of coenzyme reduction. This study would be impossible without this hydrogen isotope.

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*Lehigh University, Bethlehem, Penna.*—We are using radiocarbon (C 14) to determine the mechanics of the esterification reaction occurring on solid catalysts. The tracer technique is most helpful in determining the course of the reaction.

Our results to date show that the course of the reaction involves the reaction of an alcohol molecule with the methyl organic acid salt on the surface to yield an ester molecule. The resulting oxide on the surface is subsequently reactive with an acid molecule from a vapor phase.

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*Louisiana State University, Baton Rouge, La.*—The research is part of an attempt to learn more about the nature of the forces holding molecules together and to be able to predict the course of organic reactions. Isotopes have proved of importance in that they enable the vibrational forms of molecules to be better determined. Deuterium (H 2), has proved especially important because it enables each hydrogen atom of a molecule to be studied separately by replacing it with deuterium.

Results of research: Deuterium has been placed upon the toluene molecule in various positions (replacing ordinary hydrogen). This has enabled an experimental check to be made upon the theoretically calculated vibrational forms of toluene. It seems likely to be of great assistance in interpreting the ultraviolet absorption spectrum of toluene and other molecules.

The use of various isotopes in studying the structure of molecules and the forces which hold molecules together is one of the chief ways by which the science of molecular spectra and molecular structure is advancing. Isotopes constitute one of the chief tools in the attempt to extend fundamental knowledge in physics and chemistry.

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*University of Maryland, College Park, Md.*—Research work is under way to determine the mechanism of the chlorination of isobutylene. This study is of theoretical interest to organic chemists. Work to date has involved studies on the preparation of isobutylene, using carbon dioxide from barium carbonate to provide a "labeled" carbon atom. Ordinary barium carbonate has been used so far; after the synthesis has been perfected, radioactive barium carbonate will be used.

We are using an irradiated unit containing radiochlorine (Cl 36) and radiosulfur (S 35) to investigate some possible exchange reactions of chromium coordination compounds. The expected results should be of considerable theoretical interest and could not be obtained by any means other than the use of radioactive isotopes.

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*Massachusetts Institute of Technology, Cambridge, Mass.*—In our research program we are using radiocarbon (C 14) and radiochlorine (Cl 36) as well as the stable isotopes, oxygen 18 and deuterium (H 2) in the study of the structures and reactions of organic chemicals. Among the problems being investigated are the determinations of the structure of ketone dimers, the Wagner-Meerwein rearrangement, the decarbonylation reaction and the hydrogen halide exchange of organic halides.

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*Merck and Company, Inc., Rahway, N. J.*—We expect to use radiocarbon (C 14) for the analysis of complex mixtures by the isotope dilution method. This C 14 is being converted into benzene for our ultimate use.

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*Michigan State College, Lansing, Mich.*—Although our project began only a short time ago, preliminary experiments show that the use of the stable isotope of deuterium (H 2) will aid us in clarifying the mechanism of some fundamental organic chemical reactions.

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*University of Michigan, Ann Arbor, Mich.*—We are beginning a research study on the molecular structure of ethane in which we will substitute deuterium (H 2) for the hydrogen atoms. The information gained from the infrared spectrum of this molecule, $C_2D_6$, will be of great value in interpreting various phases of the molecular structure.

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*New York University, New York, N. Y.*—In a study of the isomerization of n-propyl radicals at temperatures around 100°C, it is necessary to examine the products of reaction of propyl radicals with other propyl radicals. The main product is the dimer of n-propyl radicals, namely, n-hexane. Isomerization of the radicals introduces the possibility of two different products, that is 2-3 dimethyl butane and 2-methyl pentane. Quantitative separation and identification of these products can not be accomplished by means ordinarily available. The introduction of labeled carbon atoms, however, will make possible the separation and estimation of the isomeric products. The procedure will be the familiar one of adding non-radioactive material of the same composition as the constituent sought and separating a small amount of this in rather pure state. The counting rate of this separated sample allows a quantitative estimation of the amount of active product in the mixture. Once the procedure has been standardized, experiments can be carried out rather quickly.

*North Carolina State College, Raleigh, N. C.*—The concentration of phosphorus in a soil solution is at the lower limit of reliability of standard analytical methods. The use of radioisotopes enables us to very markedly extend those limits. Through the use of radioisotopes it is possible to study the kinetics of the reactions of an element. This means that it is possible to obtain information relative to the activity of the phosphorus associated with solid surfaces.

The principle results of our researches have been:

1. Definite knowledge as to the contribution of the applied phosphatic fertilizer. This has been possible through the use of phosphate materials containing radiophosphorus (P 32).
2. The relationship between the phosphorus associated with solid surfaces and the equilibrium solution concentration.
3. The rate of reaction between the phosphorus in solution and that associated with the solid surface. This has been observed when—(*a*) the system has established equilibrium (isotopic exchange); (*b*) the establishment of the equilibrium occurs; or (*c*) the equilibrium is destroyed by removal of the solution phosphorus.

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*Northwestern University, Evanston, Ill.*—The use of rather substantial quantities of deuterium oxide (heavy water) has been essential in our research on the reaction of heavy sulfuric acid and optically active hydrocarbons. We have been able to study three concurrent reactions: (a) racemization, (b) hydrogen exchange and (c) isomerization. The rather surprising finding was made that the rate of hydrogen exchange is fourteen times that of racemization and of alkylation.

The study using heavy sulfuric acid was undertaken for the purpose of increasing present knowledge about fundamental reactions of hydrocarbons. However, in obtaining an understanding of isomerization and alkylation reactions, it may aid in improving manufacture of high-octane gasoline.

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*University of Notre Dame, Notre Dame, Ind.*—We plan to use radiochlorine (Cl 36) as a tracer to follow the fate of chlorine-containing products resulting from the decomposition of organic chlorides produced by high energy beta and gamma radiation. This work is part of a program of study in radiation chemistry.

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We have been using the radioisotope ruthenium (Ru 106) in a study of the chemical effects of the beta decay process. This work is still in a preliminary stage involving the preparation of complex compounds of ruthenium and rhodium.

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*University of Pittsburgh, Pittsburgh, Penna.*—Radioactive sulfur (S 35) is being used as a tracer in solubility studies. No other technique seems possible. Also fundamental nuclear studies of radiocesium (Cs 137) are almost complete.

*Polytechnic Institute of Brooklyn, Brooklyn, N. Y.*—Many crystal phosphors owe their luminescent properties to the presence of small amounts of impurities. It is difficult to determine accurately the concentration of these impurities (activators) in the active component of the luminescent mixtures. We have been able to do this, however, by means of radioactive isotopes of the activators. Radioisotopes of cerium, samarium and europium have been used for this purpose. The results should be useful in contributing to the development of a sound theory of phosphors.

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*Queen College, Flushing, N. Y.*—Radioactive calcium (Ca 45), two radioisotopes of strontium (Sr 89, 90) and radiorubidium (Rb 86) are being used in order to understand the properties of ion-exchange resins and the separation of ion constituents using columns containing the ion exchangers. Radioisotopes are especially suited for studies of this type.

Radiocarbon (C 14) is being used to study the counting of carbon as gaseous carbon dioxide. This method is probably the most sensitive method obtainable, and improvements in the method should be of direct value to biochemical workers who require the analysis of small diluted samples of organic material.

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*Reed College, Portland, Oreg.*—We have carried out a series of experiments to determine the adsorption of mercury vapor on metallic silver in a vacuum system. Our preliminary experiments indicate that the amount of adsorption is much greater than we had anticipated. We have wanted to determine this adsorption for a number of years but have been restrained from attempting it because of the complexity and difficulty of the usual methods of making such measurements. The radioisotope method appears to be quite simple and direct.

We have also attempted to determine the nature of inclusion in silver crystals deposited at the cathode in the course of an electrolysis. Our technique involved the addition of a trace of radioactive sulfur (S 35) in the form of sulfate to the usual silver nitrate electrolyte. At the present stage of our experimentation it appears that the radioactive sulfate becomes associated with the silver deposit to a much greater extent than seems reasonable by any inclusion mechanism. In tracking down the cause of this "association" we shall, of course, be investigating further the much studied problem of the electrolytic deposition of silver. To avoid any misunderstanding, our results in this particular experiment are quite preliminary. The technique, however, offers a great deal of promise.

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The amount and rate at which mercury vapor collects on silver surfaces in a vacuum was determined using radioactive mercury. By this technique, less than one millionth of a gram of mercury was detectable.

The research was carried out in connection with the purification of silver to be used in atomic weight determinations in this laboratory.

The results proved conclusively that the contamination of silver by mercury vapor is sufficient to warrant certain precautions in the purification of the silver to be used in atomic weight work.

*University of Texas, Austin, Tex.*—The effect of chloride ion, as in salt solutions, on destroying the passive nature of some metals, e. g. chromium, is believed to be due to the attachment of the chloride ions to the metal surface and the subsequent removal of the metal atom as a chloride. The amount of chloride ion attached is normally too small to be detected by the usual analytical methods. Radiochlorine (Cl 36) has provided an important tool in the study of this phenomenon.

It was found that the postulated attachment did occur, and that the amount taken up varied with concentration of the chloride in such a manner as to indicate absorption was occurring. Further, the electrode potential of the chromium varied with concentration, the metal becoming more active as the concentration increased.

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*Washington University, St. Louis, Mo.*—Using radioactive sodium (Na 24) and radioactive iodine (I 131) to study self-diffusion in liquids. The study of self-diffusion is important in the theoretical understanding of transport phenomena. The measurement of self-diffusion can be achieved only by means of radioactive tracers or stable isotopes, but since the former class are more convenient to measure they are preferred. Radiosodium and radioiodine have been used for the present research.

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We have used radioiodine (I 131) to study the exchange of iodine atoms between inorganic iodine compounds and believe we have evidence for a new mechanism for a common reaction. This isotope and several others, especially radiosodium (Na 24), have been used in studies to determine the rates of diffusion of individual ions. This information may not be obtained in any other way.

Radioactive chromium (Cr 51) has been used in a study of its exchange reactions. This work was preliminary to an investigation now in progress to determine the chemical effects of the decay of radiomanganese (Mn 51) to Cr 51. (The Mn 51 must be produced in our cyclotron because of its very short half-life.)

We have used radiocarbon (C 14) in a synthesis of radioactive mannose, which is now being employed in metabolic studies. Radioactive glucose was made in the same synthesis, but in the first attempt the yield of purified glucose was small.

We have also studied the kinetics of Tl (I) and Tl (III) exchange reaction in perchloric acid as a function of acid, nitrate, thallium (I) and thallium (III) concentrations and temperature. The study is of importance in adding to an understanding of the electron transfer process which is fundamental to many oxidation-reduction reactions. Radiothallium (Tl 204) made the study possible.

We are using radioiodine to study the distribution of iodine between water and benzene as a function of the iodine concentration and the rate and extent of the oxidation, reduction and precipitation reactions of iodine at tracer concentrations ($10^{-10}$ moles per litter). Work at such low concentrations is only possible with "carrier-free" radioactive iodine. The work is of importance in adding to our knowledge of iodine chemistry in a previously unexplored concentration range. It should also add to our knowledge of the chemical behavior of substances at very low concentrations.

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*University of Wisconsin, Madison, Wis.*—The Mechanism of Chemical Reactions.—Although a great amount of research effort has been expended over a period of years in an endeavor to understand clearly the detailed mechanism whereby molecules and atoms interact to form new substances oin chemical reactions, very little conclusive experimental evidence is yet available. We are using radioisotopes to study some very simple reactions unobservable without the radioactive materials. One of these is the exchange of bromine in the form of the element (Br 82) with bromine bound in a chemical compound ($CCl_3$ Br). This and similar reactions which are under investigation are among the very simplest types of chemical reaction and offer promise of yielding information which will be of basic importance to our understanding of the mechanism of chemical reactions in general. Radiobromine (Br 82), radiochlorine (Cl 36) and radiosulfur (S 35) are being used in the study of eight different reactions of this type.

Reactions Resulting From Nuclear Processes.—The element sulfur normally occurs in the form of molecules in which eight atoms are bound together in a stable unit. However, when sulfur is made by transmutation of the element chlorine, it appears as single isolated atoms, the presence of which can be detected by their radioactivity. It is found that these atoms are very much more reactive chemically than the stable molecules containing eight atoms. Such atoms, produced by neutron bombardment of potassium chloride crystals and also by the neutron bombardment of other chlorine compounds such as carbon tetrachloride and hydrogen chloride, are being studied in order to learn more about their properties. Compounds containing radiocesium (Cs 134) and radiopotassium (K 42) have also been tested for effects which might occur as a result of the nuclear transmutation processes.

Determination of the Presence of Trace Impurities.—Using high specific activity radiobromine (Br 82), it has been found possible to detect the presence of extremely low levels of "brominatable" impurities in carbon tetrachloride by exposing the solvent to the elemental radioactive bromine.

Solubility Determinations.—The use of radiobromine (Br 82) and radiosilver (Ag 110) has made it possible to determine conveniently the solubility of silver bromide under conditions where it had not heretofore been investigated. Similar investigations making use of radiocalcium (Ca 45) are being carried out to determine the solubility of calcium oxalate.

Cellulose Chemistry.—Other workers have carried out studies in our laboratories on the diffusion of solutions of radiozincate ion into and out of cellulose fibers which have been swollen by exposure to zincate solutions. These studies have resolved some of the uncertainties with regard to the measurement of such swelling properties.

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*Yale University, New Haven, Conn.*—Using radiozinc (Zn 65) to study vapor pressure of the metal. The general use of radioactive materials should enable the exact determination of the vapor pressures of metals and their salts over a temperature range hitherto inaccessible because of the limitations of ordinary methods of analysis.

## PHYSICAL RESEARCH

*Bell Telephone Laboratories, Murray Hill, N. J.*—We have used concentrated carbon 13 and oxygen 18 in a study of the angular momenta and shapes of the nuclei of these isotopes. This information is of value in understanding the nature and construction of nuclei. If isotopes were not available in concentrated form, our measurements would have to be postponed indefinitely. We have obtained fairly good evidence on the values of nuclear angular momentum, and that the nuclei of carbon 13 and oxygen 18 are completely spherical.

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*University of California, Berkeley, Calif.*—Research on spins of nuclei of the carbon isotopes could not have been carried out had not these isotopes been available in separated form. The particular isotope used was radiocarbon (C 14).

We have definitely proved that the nucleus of C 14 has no angular momentum (is not spinning). It was of great importance to the theory of nuclear disintegration to know this, since C 14 has a long half-life (5,100 years), and transforms itself into a nucleus of nitrogen, for which the spin is already known. Some present theories indicated a large spin for C 14, and have thus been shown to be wrong.

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Enriched boron 10 will be used to prepare $B_2O_3$. The $B_2O_3$ will in turn be used as a cyclotron target for the production of carbon monoxide labeled with the radioactive carbon 11 isotope. The labeled CO is to be used in studies on the distribution of this gas in the human body in connection with problems of uptake and elimination of CO.

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*University of California, Los Angeles, Calif.*—Deuterium (H 2) is being used in our research project to ascertain the manner in which atoms and groups of atoms rearrange themselves in molecules under the influence of ultraviolet light. A mass spectrometer is used to determine the position of the deuterium in the molecules before and after irradiation. In this study we hope to obtain a better general understanding of the chemical reactions which may be expected when light is absorbed.

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*California Institute of Technology, Pasadena, Calif.*—The availability of the stable isotopes of the light elements—particularly lithium, boron, and carbon—has been of great value in the study of nuclear structure through observations of the behavior of the excited states. In many cases where isotopically pure materials were not formerly available, considerable uncertainty has existed regarding the interpretation of experimental results. With the use of pure targets, many of the ambiguities in the data can now be resolved and many reactions can be studied under much improved conditions, without interference from undesired contaminants. We feel that the production and distribution of stable isotopes represent a major contribution to the progress of nuclear physics.

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A newly developed instrument and technique of direct spectroscopy of nuclear gamma-rays by means of crystalline diffraction has been developed. They have been successfully applied to the precision measurement of the wave-length (of order 30 X-ray units) of the gamma-rays from the artificial radioisotope of gold (Au 198). The range of this instrument, 500 to 8 X-ray units or less, permits establishment of a precision link between the well established scale of X-ray wave-lengths and the wave-lengths of nuclear gamma-rays. In the ultra-short wave-lengths region, strong sources (100 millicuries to 1 curie) are necessary because of the low reflecting power of the crystals developed up to the present time.

The proposed program includes establishment by precision measurements of a large number of precisely defined gamma-ray wave-lengths and energies to serve as easily reproducible fixed points in this region of the spectrum. Since these gamma-ray lines can in turn be used to eject photoelectrons in beta-ray spectrometers, the precision thus made available can be used in the calibration of beta-ray spectra to also increase the precision of this type of measurement. To date five independent measurements of the wave-length and energy of the 0.41 Mev gamma-ray line from radiogold (Au 198) have been made. The new precision can probably be extended to beta-ray measurements by means of a new design of beta-ray spectrometer now under development suitable for calibration by the gamma-ray method outlined. It is hoped, therefore, that this technique of direct spectroscopy of gamma-rays ushers in a new era of precision nuclear energy measurements.

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*University of Chicago, Chicago, Ill.*—The investigation deals with what may be a new type of positively charged particle emitted by radiophosphorus (P 32). A source free from radioactive contaminations is essential. We have obtained additional confirmation for the existence of these particles.

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We have used deuterium (H 2) and deuterium oxide in the cyclotron in an investigation directed toward determining the existence of the neutrino.

Using deuterium gas in the 400 kilovolt accelerator, we have measured the energy release in the, $D^2(d,n)_2He^3$ reaction by observing the energy of the $Helium^3$ nuclei.

Using boron 10 we have produced neutron counters of high sensitivity compared to those made from natural boron, and by their use we have made a survey of the neutrons in the upper atmosphere which shows definitely that these neutrons are produced from charged particles in the incoming cosmic rays.

*Consolidated Engineering Corporation, Pasadena, Calif.*—Deuterium (H 2) has been used for the development and improvement of mass spectrometers designed to determine accurately relative isotope abundances.

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*Cornell University, Ithaca, N. Y.*—We are using boron 10 (B 10) to assist in the detection of neutrons in cosmic rays. We believe the research project has been of fundamental importance, not only because neutrons have been found in the extensive showers * (where they were not known to exist), but because we have found the mechanism of their production to be different from that previously supposed. Our results shed light both on the structure of the large air showers and on the probabilities for producing high-energy neutrons by high-energy protrons.

We have used boron 10 as boron trifluoride in our counters for neutron detection. By the use of this stable isotope we have increased counter efficiencies by a factor of almost 5. Without such efficiencies the experiments would not only have required much more time but would have been almost impossible.

We have found the following:

1. Neutrons exist in large number in the extensive air showers, about one neutron for every 50 electrons.
2. The neutrons which are detected with a normal arrangement of apparatus (paraffin about one foot thick around the counters to slow the neutrons down, so that the $BF_3$ counters will detect them) are not produced locally in the paraffin by a gamma, neutron reaction (i. e., by gamma-rays), but are a part of the shower structure in the atmosphere.
3. The neutrons in the shower can only in small part be produced by gamma-rays. Almost all of them must originate from a different kind of nuclear reaction, probably caused by protons in the cosmic rays, or by other neutrons of high energy.
4. These results apply not only to neutrons in the extensive air showers, but to all neutrons in the cosmic rays.

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*Eastman Kodak Company, Rochester, N. Y.*—Deuterium oxide has thus far been used only in preliminary studies of methods of conversion to compounds suitable for mass spectrometer analysis and in a study of the mass spectra obtained. As soon as suitable analytical methods are standardized, we intend to continue our study of vapor diffusion in polymer films.

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*General Electric Co., Schenectady, N. Y.*—We have been studying nuclear reactions which occur when nuclei are bombarded with X-rays. These reactions are of interest in connection with the nature of the

*By extensive air showers we mean the cosmic ray events characterized by a simultaneous arrival of a large number of particles (frequently hundreds of thousands, or even millions), spread over a large area, roughly like that of a football stadium. Such showers are originated high in the atmosphere by a single particle of enormous energy. As the shower develops in the atmosphere, more and more particles of lower and lower average energy are produced, until ultimately the low-energy particles are absorbed and the shower dies out.

interaction between the nucleus and photons of high energy and in connection with the behavior of excited nuclei. When an excited nucleus emits a neutron, a proton, or more than one of these particles, the product nucleus is frequently radioactive; and this radioactivity is used to measure the extent to which the nuclear reactions occur. In many cases the processes cannot be studied with the naturally occurring isotopic concentrations either because the isotope of interest is very dilute or because the presence of other isotopes gives rise to interfering radioactivities. In these cases separated stable isotopes are used as target materials.

Enriched stable isotopes of iron 54 and chromium 50 have been bombarded with X-rays from the 100 Mev betatron to observe the process of single neutron emission in a region of the periodic system where a large change in the probability of this process occurs. Final results are not yet available.

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*Harvard Medical School, Boston, Mass.*—We have used radiocalcium (Ca 45) to determine its absorption spectrum. We have also used radiocarbon (C 14) to study the effect of its beta radiation as related to radioautograph techniques. Work on the perfection of techniques for high resolution radioautographs is being continued.

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*University of Illinois, Urbana, Ill.*—We have used radioantimony (Sb 124) for studies of nuclear energy levels. We have used radiocopper (Cu 64) in studies relative to the theory of beta decay to try to explain discrepancies found by other investigators. We have also used radiostrontium (Sr 90) in similar studies.

The availability of a large number of radioactive isotopes of high specific activity has made possible a number of systematic investigations of the properties of nuclei which would have been difficult or impracticable before the advent of the pile.

Radiocarbon (C 14) has been used to determine the identity of beta rays and atomic electrons. This investigation has demonstrated in a definitive way that beta-rays are identical with the electrons surrounding the nucleus.

Excited states of nuclei occasionally persist for a short time which can be measured if the time exceeds a few hundredths of a microsecond. With the help of radioactive isotopes such states have been studied following beta emission. A new type of nuclear transition has been discovered by following beta decay of radiogallium (Ga 72) in which the energy of the nucleus is transferred to the electrons surrounding it.

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We have used carrier-free radiophosphorus (P 32) and radioyttrium (Y 90) in our research. We have recently carried out experiments which give valuable information about the nature of the beta decay process in radioactivity. These experiments have provided information about the nature of a fundamental particle called the neutrino.

*Indiana University, Lafayette, Ind.*—We are studying the fundamental properties of the radioactive species themselves. The radiations given off by artificially radioactive substances consist of electrons, positrons, and gamma-rays. It is of fundamental importance to measure the energies of the radiations which are given off and the relations between the energies of the gamma-rays and the particles. This is at present the only means we have of making a detailed study of the mechanisms which account for the behavior of radioactive nuclei. Such measurements, for example, may eventually tell us about the forces which hold the nucleus together and their role in causing radioactivity. As a practical byproduct of our studies, we found that some of the earlier work conducted in this field was wrong and that the energies of the radiations from the substances, as presently quoted, must be corrected.

One group uses a magnetic lens and is interested primarily in disintegration schemes and energy levels of radioactive isotopes. A second group uses a small 180° magnetic spectrometer and is likewise interested in disintegration schemes. A third group uses a large 180° magnetic spectrometer, with inhomogenous field and is primarily interested in the shapes of beta-ray spectra.

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*The Johns Hopkins University, Baltimore, Md.*—We plan to utilize deuterium (H 2) in a study of the light emitted from the oxygen-deuterium flame in the infrared region of the spectrum.

Deuterium oxide ($D_2O$) will be used in the preparation of deuterated fatty acids whose infrared absorption spectra will be studied at liquid helium temperatures. The purpose of this latter experiment is to study the structure of the so-called hydrogen bond band.

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*Massachusetts Institute of Technology, Cambridge, Mass.*—The stable isotope, boron 10, has been used for the construction of sensitive boron-lined neutron counters. These counters are being used in studying neutron diffusion in hydrogenous media to provide fundamental information from which to design neutron and gamma-ray shielding.

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We have been studying light and heavy hydrogen with the hope of learning more about the forces which exist between the electron and the nucleus. For this reason we have investigated the radio waves which come in and out of the hydrogen atom. We have learned that new theories are necessary to understand the behavior of the electron inside the atom.

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We have used radioiodine (I 131), radiozinc (Zn 65), radiocopper (Cu 64), and radiosodium (Na 24) to check measured absorption coefficients with theoretical values. Such checks are important not only from the viewpoint of the theory of interaction of gamma-rays with matter, but also for the purpose of shielding personnel and apparatus from radiation, and for studying gamma-rays of unknown energy.

Our results with I 131 showed the presence of an unknown higher energy gamma-ray. A study in the beta-ray spectrometer showed its energy to be about 0.65 Mev. The absorption of the other gamma-rays in aluminum, copper, tin, tantalum, and lead, showed agreement with theory within about 1.5 percent with the exception of radio-cobalt (1.16 and 1.31 Mev) and Zn 65 (1.14 Mev) in tantalum. Here the deviation was about 4 percent. Further work needs to be done before stating that this apparently anomalous absorption in tantalum at about 1.2 Nev is real.

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In the analysis of ultraviolet, infrared, and Raman spectra of molecules, isotopes, especially deuterium (H 2), or "heavy hydrogen", are of great importance because they enable the investigator to change the spectra of molecules in a controllable way. For example, in our laboratory, we have prepared the deuterium derivative of the newly synthesized molecule cyclooctatetraene, whose formula is $C_8H_8$. The infrared, ultraviolet, and Raman spectra of $C_8H_8$ have provided information about the structure of the molecule, but the results of spectroscopic study were so surprising that it was highly important to confirm them. This confirmation has been obtained by making a completely new molecule in which all the hydrogen has been replaced by deuterium to give the formula $C_8D_8$. The spectra of $C_8D_8$ confirm the results obtained from $C_8H_8$ and indicated that our unexpected results are correct.

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*University of Michigan, Ann Arbor, Mich.*—More than 30 radioactive isotopes have been studied particularly to show internally-converted gamma radiation. Also, in several cases, the forms of the beta spectra as well as the half-lives and the value of any high energy gamma radiation, have been determined.

The research program has led to very fruitful results. Many new radioactive emitters have been discovered and in many of the elements several converted gamma-rays have been found. In some instances it has been possible to construct nuclear level schemes to accommodate the observed energies.

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*University of Minnesota, Minneapolis, Minn.*—The availability of deuterium gas has made possible the study of interactions of deuterons with light nuclei. The information revealed is fundamental to the understanding of elementary nuclear structures.

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*National Bureau of Standards, Washington, D. C.*—Radioactive isotopes have been used in this laboratory in connection with the method called tracer micrography. This method extends the known method of radioautography by producing electron optical images. At present the resolution of the new method exceeds by a factor of three the best resolution obtained by means of radioautography. The usefulness of this new method in its application to biology, medicine and metallurgy is being investigated.

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Heavy water has been used in a research program concerned with the mass spectrometer analysis of $C_2H_2$, $C_2D_2$ and $C_2DH$.

Mercury made by neutron attachment to gold has been analysed by the mass spectrometer and found to be nearly pure mercury 198 with a trace (.16 percent) of mercury 199.

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*University of North Carolina, Chapel Hill, N. C.*—A very careful effort is being made, with highly precise apparatus, to obtain more information about the positive particles reputed to be associated with the disintegration-electrons from radiophosphorus (P 32). Special attention is being given to the matter of supporting the radioactive source in the apparatus, and new techniques have been developed for this purpose.

Contrary to the experiences of earlier workers, preliminary results of our research to date have not revealed any positive particles in connection with the disintegration-electrons from the P 32 isotope. It is not possible to state whether the final results will or will not confirm this preliminary report.

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*University of Notre Dame, Notre Dame, Ind.*—Our investigation has been directed toward the determination of the photodisintegration threshold of deuterium (H 2). The result of this investigation will afford a check on existing values and will be used to determine the mass of the neutron.

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*University of Pennsylvania, Philadelphia, Penna.*—The end point of the beta-ray spectrum of radiocarbon (C 14) has been determined precisely. This number is of interest in establishing a transmutation cycle which may ultimately lead to a more accurate and reliable value of the neutron mass.

Initial tests of our beta-ray spectrograph box with radiocopper (Cu 64) radiations have helped us to redesign the box to improve the discrimination against scattered radiation. This should enable us to compare the positive and negative spectra and thus to determine the discrepancy with theory.

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*Princeton University, Princeton, N. J.*—In our research program we have attempted to use radiophosphorus (P 32) as a source of beta particles in crystal counter research. Since the maximum energy of these beta particles is known, the energy per ion pair may be determined. The beta particles enter the crystal at the surface and penetrate only to a small degree, thus the region of production of secondary electrons is accurately known. Until recently we had used gamma-rays exclusively, in which case the region of production of secondary electrons extends throughout the crystal.

The results are:

1. The energy per ion pair AgBr and AgCl is of the order of ten electron volts.
2. Polarization phenomena in such crystal counters can be explained in terms of a simple model.

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We have been using the unseparated isotopes of radiotin to study their nuclear properties. We have established the existence of double beta decay from the nucleus of Sn 124 almost beyond the possibility of doubt. It is hoped that a similar investigation with separated isotopes of zirconium will be even more successful since the effect there should be larger.

The study of this double beta activity has an important bearing on the various theories of nuclear forces and the results on the tin have already shown that the predictions of some of the theories are incorrect.

We have been investigating the production of radiocarbon (C 10) from boron 10 by the bombardment of protons. Previous work had given results that turned out to be in error and only by use of the enriched sample of boron 10 was it possible to be certain that the increased activity really came from C 10.

It has now been definitely established that C 10 has a half-life of 19.1 seconds and emits positrons at a maximum of 2 Mev. It is believed it will be possible to investigate the gamma-ray spectrum by the use of the enriched boron. The entire problem is of great importance to the nuclear theory of the light elements. It would be extremely difficult to investigate this problem further without the enriched isotopes because of the production of C 11 from boron 11.

In another investigation we have been using enriched boron 10 in the form of boron trifluoride gas to fill proportional counters for the determination of the absolute values of the number of neutrons in the atmosphere. Owing to the extremely low intensity of these neutrons, it would have been prohibitively difficult to make accurate investigations of this kind without the enriched boron.

We have investigated the altitude dependence of cosmic ray neutron intensities in order to obtain a better understanding of the mechanism of nuclear transmutations taking place in the upper atmosphere. We have found that the neutron intensity increases exponentially with altitude in a manner closely similar to that in which the intensity of cosmic ray "stars" increases. The absolute value for neutron production at sea level has been determined.

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*Stanford University, Palo Alto, Calif.*—Using boron 10 to study the magnetic moment of the neutron. The use of B 10 has greatly increased the efficiency of our apparatus for neutron detection and has thus materially contributed to our present very accurate knowledge of the neutron moment.

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*Syracuse University, Syracuse, N. Y.*—By an exchange reaction deuterium (H 2) was substituted in place of the hydrogen atoms on aniline and methylaniline. Absorption spectra were obtained of these molecules in the near ultraviolet. The shift of vibrational frequencies with change in mass was observed and seem to indicate that a vibrational assignment given earlier was correct.

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*University of Texas, Austin, Tex.*—We have used deuterium (H 2) in determining the stopping power of this gas for polonium alpha particles as compared to the stopping power of ordinary hydrogen. We also intend to use deuterium as a source of the bombarding deutrons in a D on D neutron generator under construction.

We are also carrying on an investigation directed toward the interpretation of electronic spectra of aromatic hydrocarbons through the use of deuterated compounds.

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*University of Wisconsin, Madison, Wis.*—Certain of the particles that constitute atomic nuclei act like tiny magnetic tops. Two important properties characteristic of each kind of nucleus, now understood partly, but not well enough to allow their prediction for atoms not already studied, are the total angular momentum of this spin and the strength of the resulting magnet. One of the most fruitful means of studying these properties is the analysis of very narrow separations, or so called hyperfine structure, in the spectrum lines emitted by the atom. In the cases of the rarer isotopes, there were no means of studying these subtle effects until samples of the separated single isotopes became available.

After earlier studies on zinc, for instance, the spin of the stable isotope Zn 67, which is present naturally only to the extent of 4 percent, remained uncertain. Our investigation of the isotope in 56 percent concentration easily determined that the spin is two and a half units.

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Radioactive isotopes of carbon (C 14), phosphorus (P 32), sulfur (S 35), yttrium (Y 91), and cobalt (Co 60) have been used in an investigation of the scattering of radiations as a function of the geometrical arrangement of counting equipment. The first four of these elements have also been used in a study of the production of brehmsstrahlung (secondary electromagnetic radiation produced when beta-rays are absorbed in matter) as a function of atomic number of absorber and the energy of the beta radiation.

## (B) USES OF ISOTOPES IN ATOMIC ENERGY COMMISSION PROJECTS

*Excerpts from accounts of the publicly reportable (unclassified) work with isotopes in AEC projects, as reported by the Commission's contractors.*

### OAK RIDGE NATIONAL LABORATORY, AEC

OAK RIDGE, TENN.

(*Carbide and Carbon Chemicals Corporation, Contractor*)

As tracers in chemistry, radioisotopes are used extensively, and in many cases routinely, to obtain information with a speed and precision not previously possible. For example, a radioactive constituent may be analyzed for in a solution at concentrations far below one part per million simply by counting its disintegrations for several minutes. By the addition of a radioactive tracer isotope which follows other atoms of the same element, for example in a chemical reaction, a relatively simple and accurate counting procedure may be substituted for what otherwise would be a very laborious or even impossible chemical analysis. Similarly the degree of separation between various materials in such processes as precipitation, distillation, solvent extraction, and absorption is measured much more rapidly and accurately by using a radioactive tracer isotope in one of the constituents since very small traces of radioactive material can be measured readily where they could not otherwise be detected.

*Separation of Rare Earth Isotopes from Fission Products of Uranium.*—An example of the tracer technique described in the foregoing paragraph is seen in the development of a procedure for separation of radioactive isotopes of the rare earth elements formed from the fission of uranium. Because of the smallness of the amounts, the radioactivity of the isotopes presents the only practical means of determining their presence. All procedures for the separation of these isotopes have been developed by making use of the radioactivity as means of measurement. As a result of this work, purified radioactive rare earth isotopes are available in the isotope distribution program.

*Separation of Stable Rare Earth Elements.*—Similar processes have been developed for separation of nonradioactive rare earth elements which have been almost impossible to separate by previously available means. Addition of small amounts of radioactive rare earth isotopes of the same elements being separated made it possible to develop ion exchange separation processes. A counter which registers the radioactivity is now used to indicate the concentration of a particular rare earth in the solution flowing from the ion exchange columns. With radioactive rare earth isotopes used in this manner, it has been possible to improve the separation processes so that very pure samples of the rare earth elements are now becoming available for research purposes.

*Thermodynamics of Coprecipitation.*—Another example of the application of radioisotopes as tracers is in the study of the equilibria involved in the carrying of traces of an ion by a precipitate of a foreign compound—for example, the carrying of bromine ion by silver chloride precipitate. At the low concentrations at which this work must be done, radioactive isotopes offer the only practical means of measurement. Progress has been made in measuring the free energy and heat of reaction for the formation of dilute solid solutions of silver bromide in silver chloride. This furnishes valuable data on the thermodynamics of coprecipitation.

*Electrodeposition of Traces of Silver.*—The electrodeposition of metals is another instance where radioactive isotopes furnish the only tool sensitive enough to follow the potential versus concentration curve to exceedingly low concentrations. In studying the deposition of silver, for example, the concentration was followed to such a low value that the electrode contained less than a single layer of silver atoms. Such studies are fundamental to the separation of traces of elements and are useful in preparing radioactive isotopes free from nonradioactive atoms of the same element.

*Reaction Mechanisms in Organic Chemistry.*—Radioactive carbon 14 is being used in studying the mechanism of organic reactions. The use of this isotope makes it possible for the first time to determine the role played by each carbon atom in a reaction. From preparing organic compounds for other research, several reaction mechanisms have been elucidated.

*Biological Applications of Radioisotopes.*—Radioactive isotopes are being used as sources of ionizing radiations and as tracers in gathering basic information on the effect of radiation on living tissue. Used as tracers, radioisotopes permit problems to be studied involving single cells, micro-organism, etc. The amounts of material are so small and the reaction so complex that no other means except radioisotope tracers can be used. Much of this work has been in progress only a short time and detailed results are not generally available; however, specific examples of this work can be given.

*Comparison of Killing and Mutation Effects of Radiation.*—Studies comparing alpha, beta, and gamma rays from radioisotopes with X-rays, neutrons, and fission fragments from other sources indicate that the factors causing death and factors causing mutation are at least partly independent of each other.

*Beta Radiation and Skin Cancer.*—Radioactive phosphorus is being used in the study of skin cancer formation—a subject of great importance wherever personnel may be exposed to radiation. Since this isotope emits pure beta radiation it is possible to compare the effects of beta and gamma radiations. This study is being extended to include research on drugs which might influence the rate of production and the development of tumors.

*Studies of the Role of Potassium in Blood.*—Through the use of radioactive potassium it has been possible to study potassium exchange between cells and plasma in blood without disturbance of potassium equilibrium in the animal. Research in this laboratory indicates that potassium in the blood is held in more than one form and throws a new light on potassium exchange mechanisms.

*Effects of Radiation on Mutation and Inheritance in Microorganisms.*—The radiation from radioactive phosphorus is also being employed to produce and study mutations affecting vigor and other characters in single cell animals (paramecia), bacteria, and bacteriophage. By similar experiments it may be possible to determine whether inherited characteristics are carried solely in the gene or elsewhere. Studies are being made of the inherited changes produced by the radiations from radioisotopes contained within the cells of various plants.

*Synthesis of Nucleic Acids in Bone.*—Methods of using radioactive phosphorus 32 in the measurement of organic phosphates are being studied and will be of great importance in research on the synthesis of nucleic acids in bone.

*Effects of Radiation on Metabolism.*—With the aid of radioactive C 14, the normal metabolism of certain basic carbohydrates and fats has been studied using bacteria as test organisms. The results indicate the existence of hitherto unknown relationships between fats, carbohydrates, and carbon dioxide. Additional studies on carbon dioxide with carbon 14 tracer are aimed to show some of the intermediates between carbon dioxide and carbohydrates in green plants (a study of photosynthesis). After it has been determined how normal systems function, attention will be directed to the effects of radiation on metabolism, employing molecules containing radioactive atoms of carbon, phosphorus, sulfur, etc.

## Los Alamos Scientific Laboratory, AEC

### LOS ALAMOS, NEW MEXICO

*(University of California, Contractor)*

Isotopes have been used in the Los Alamos Scientific Laboratory principally by the Health Physics and Experimental Physics Divisions. A major part of the medical research program has centered around the use of Carbon 14 (C 14) in studying animal metabolism. The problems studied and the results obtained are given in the following summary.

*Synthesis of Biologically Important Compounds Labeled with C 14.*—A major problem in the application of C 14 to studies in biology and medicine is that involved in synthesis. C 14 is delivered by the Isotopes Branch of the AEC in the form of barium carbonate. A major problem in applying this isotope to biology and medicine is to synthesize complex biologically important substances from this relatively simple starting material.

During the past six months four biologically important compounds have been synthesized from barium carbonate. These compounds are: Nicotinic acid (the anti-pellagra vitamin), nicotinamide (the therapeutic form of the anti-pellagra vitamin), p-aminobenzoic acid (believed to be important in the physiology of pernicious anemia) and anthranilic acid (believed to be an intermediate in the metabolism of tryptophane). All of these substances were synthesized in excellent yields and with a specific activity, such that one milligram of the material will give 30 million C 14 disintegrations per minute.

*A Study of the Gross Metabolism of Nicotinic Acid and Nicotinamide by the Animal Organism.*—Using C 14 nicotinic acid and nicotinamide a detailed study has been made of the excretion, body deposition, and utilization of these very important nutritional substances. Results indicate that they function in the enzyme systems of the tissues. The more rapidly functioning tissues and organs take up the radioactive substances in greater amounts and utilize them much more rapidly. The major part of the material is excreted in the urine with smaller amounts being broken down and eliminated in the breath as carbon dioxide.

*Gross Metabolism of P-Aminobenzoic and Anthranilic Acids by the Animal Organism.*—Using C 14 labelled compounds it was shown that the gross metabolism of p-aminobenzoic and anthranilic acids in the mouse is quite different from the metabolism of nicotinic acid and nicotinamide. Anthranilic acid and p-aminobenzoic acid are not as readily fixed in the tissues and organs and the rate of urinary elimination is much higher than for the other two substances. There seems to be little breakdown of p-aminobenzoic and anthranilic acids to carbon dioxide.

*A Study of the Uptake of Nicotinic Acid, P-Aminobenzoic Acid and Nicotinamide by Human Red Blood Cells.*—Human red cells were incubated in the presence of C 14 labelled nicotinic acid, p-aminobenzoic acid and nicotinamide. After different periods of incubation the uptake of acids was determined by measuring the radioactivity with a Geiger counter. Human red cells take up nicotinic acid in large amounts and fix it in the cells in a form which cannot be washed out. It has proven that the nicotinic acid is being converted to coenzymes I and II in the cell. Nicotinamide and p-aminobenzoic acid are not so fixed, indicating that they do not serve any appreciable function in the enzyme systems of the red blood cells.

*Effect of Radiation on the Utilization of Nicotinic Acid by Human Red Blood Cells.*—Human red blood cells were given increasing doses of X-rays ranging from 50 to 500 roentgens. The ability of the red blood cells to take up nicotinic acid after different doses of radiation was measured by using C 14 labeled nicotinic acid and a Geiger counter. Doses of radiation as large at 500 roentgens had no effect on uptake, indicating that radiation does not interfere with that particular coenzyme system of the cell.

*A Study of Techniques for Quantitating Weak Beta-Ray Emitting Isotopes.*—An intensive study has been made of methods of measuring quantitatively the radiations coming from C 14 and S 35. These substances emit such weak radiations that it is necessary to work out careful methods of measuring and correcting for absorption effects. This is an essential feature if these radioactive isotopes are to be of value in biological and medical studies. Results indicate that mass absorption corrections may be low by 20 percent, if one accepts the standard absorption correction curves and equations.

*The Use of Radioactive Sodium to Study Circulatory Impairment.*—Radioactive sodium has been used to locate the point of circulatory impairment in a case of Burgers' disease. By injecting radioactive sodium and going along the leg with a Geiger counter, the point where circulation of the leg was impaired was located by the drop in radioactivity. In the same experiment careful measurements of the dilution of the radioactive sodium by the body fluids gave an accurate measure of the total water volume of the human body. Urinary and fecal analysis for radioactivity resulted in a study of the elimination of sodium chloride from the human subject.

*The Effect of Acute Radiation on Phosphorus Metabolism.*—Phosphorous plays an important part in the make up of phosphoproteins and nucleic acids—a major constituent of the nucleus of cells. By equilibrating rats with radioactive phosphorous and then giving them varying doses of actue X-ray exposure, a study has been made of the effect of the radiation on the breakdown of these important nuclear substances. This experiment is still in progress and the results are inconclusive at this time.

Experimental physics activities with reference to the use of separated isotopes can best be summarized as studies contributing to a better knowledge of nuclear structure and properties by the use of isotopes as research tools. Some work has been performed to explore the use of isotopes as detection instruments. For example, boron 10 has been used as a neutron detector, and the following separated isotopes have been used in foils as reaction threshold detectors; iron 54, molybdenum 94, molybdenum 100, nickel 58, and chromium 52.

## Brookhaven National Laboratory, AEC

UPTON, L. I., N. Y.

(*Associated Universities, Inc., Contractor*)

Research is being done with radioactive potassium (K 40) for the purpose of determining the absolute value of the beta disintegration rate, and investigating its dual decay pattern.

Since K 40 is a naturally occurring radioactive isotope, these studies are of considerable interest for giving an independent method of age determination of the earth.

Radioactive carbon (C 14) is being used for studies of the mechanism of heterogeneous catalysis, such as in the liquification of coal.

Radioactive phosphorus (P 32) is being used to study the rate at which phosphorus compounds in the liver, which are concerned with the storage and utilization of fats and sugars, are transformed into one another, and also the effect of radiation on the processes of formation and utilization of these sugars and fats.

The use of P 32 makes it possible to follow these processes.

Radioactive iron (Fe 59 and Fe 55) isotopes are being used to investigate the metabolism of iron in rats, and its distribution in key tissues throughout the body, including the adrenal and pituitary glands. The effect of radiation on metabolism is also being studied.

A special application of iron tracer technique has been undertaken for the purpose of obtaining accurate blood volume data.

## Argonne National Laboratory, AEC

CHICAGO, ILL.

(*University of Chicago, Contractor*)

Fundamental physical investigations conducted with hydrogen 3 (tritium) and helium 3 have demonstrated that nuclear particles exchange their indentity at a rapid rate while confined within the nucleus of the atom. The small number of particles in the nuclei of tritium and helium 3 makes possible the interpretation of measured "magnetic moments."

The forces in the atomic nucleus—the same forces released in an atomic bomb—are among the most puzzling phenomena of modern physics. These forces do not behave like others known to science, such as gravity and the familiar electromagnetic forces, although previous experiments have shown that both protons and neutrons behave in many respects like small magnets. Their magnetic moments, or strengths, have been determined with great accuracy.

But, under normal conditions, the total magnetic moment of a system should be equal to the sum of the moments of the individual parts of the system. Experiments showed, however, that this was not true in the case of hydrogen 3 and helium 3. In each case, the measured value was higher.

It was to be expected that the magnetic behavior of hydrogen 3 would be like that of a single proton because the two neutronic magnets should cancel each other. Similarly, in helium 3, the two protonic magnets should cancel each other, so that the helium 3 nucleus should be like a single neutronic magnet. The experiment showed that this was almost the case, but not quite.

The measured value differed from that expected and was higher in each case by about 10 percent. This indicated that there must be a "something else,"—something in addition in the magnetic system. The probability that the "something else" is an exchange current flowing clockwise is one nucleus and counter-clockwise in the other, as the protons and neutrons change their identity, was a convincing probability. Magnetism is established by a flow of current, and since an additional magnetic moment was measured, the "exchange force current" appears to be demonstrated by this experiment.

### PARTIAL LIST OF ISOTOPES IN USE AND PROJECTS UNDERTAKEN

*Illinium.*—Identifying the mass of 47 hour activity.

*Phosphorus 32.*—Investigate toxicity of P 32 in mice and rats.

Experiments involving the uptake and metabolism of phosphorus by one-celled organisms such as paramecia and cell-cultures.

Study of the formation of red blood corpuscles.

*Sulfur 35.*—Experiments involving the uptake and metabolism of sulfur by one-celled organisms such as paramecia and cell-cultures.

Synthesis and study of metabolism of organic compounds and the effects of irradiations on these compounds *in vitro* and *in vivo.*

*Carbon 14.*—Studies of carbon metabolism in bone enzymatic reactions as influenced by various types of irradiation and the measurement of the quantity and rate of carbon turnover in animals.

Study of toxicity, retention, and distribution of radiocarbon.

Preparation of standards for instrument calibration.

Synthesis of labeled biologically important organic compounds and studies of their metabolism.

Studies on the role of carbon in bone salts, its disposition and mobilization.

Grow radioactive wheat for experimental purposes.

*Calcium 45.*—Investigations of plutonium therapy.

Development of methods of instrumentation for soft beta radiation.

Study toxicity, metabolism, distribution in laboratory animals.

*Zirconium 95.*—Fission product studies.

*Columbium 95.*—Fission product studies and in development of process for separation of columbium from plutonium.

*Tellurium 128.*—Preparation of iodine isotopes.

*Indium 113.*—Identification of activities or periods.

*Indium 115.*—Identifications of resonances.

*Cadmium 106, 108, 110, 111, 112, 113, 114, 116.*—Identification of activities or periods and identification of resonances.

*Cadmium 106, 108.*—Clarification of status of active tin isotopes.

*Boron 11.*—Identification of activities or periods and identification of resonances.

*Molybdenum 92, 94, 95, 96, 97, 98.*—Search for and identification of isomers.

*Selenium 76, 78, 82, 74, 80.*—Search for and identification of isomers.

*Ruthenium 103.*—Investigations in ruthenium chemistry.

*Antimony 121, 123.*—Activation experiments with slow neutrons and identification of isomers.

Clarification of status of active tin isotopes.

*Technetium.*—Study of crystal structures.

Dry chemistry of technetium.

Alpha source for back scattering.

*Iodine 131.*—Study toxicity and metabolism of radioactive iodine.

*Cerium 141–144 Mixture.*—Fission product studies and for standards.

Study of chemistry and separation of fission product cerium from plutonium.

*Element 61 147.*—Preparation of solid components and study of crystal preparation by X-ray.

*Cesium 137.*—Fission product studies and for standards.

*Cesium 137–134.*—Tracers to follow permeability rates in irradiated plant tissues. Whether or not high doses of radiation have any immediate effect on membrane permeability as apart from genetic effects.

*Strontium 89.*—To be used as means of irradiating enzyme solutions—chronic effects of radiostrontium.

*Nickel 59.*—To calibrate low absorption counters.

*Nickel 62.*—Search for a possible nickel activity as mass 63.

*Rubidium 86.*—To be used as tracers to follow permeability rates in irradiated plant tissues. Whether or not high doses of radiation have any immediate effect on membrane permeability as apart from genetic effects.

*Tin 116, 117, 118, 119, 120, 122, 124.*—Clarification of status of active tin isotopes.

*Iron 55.*—Tracer studies on iron in isolations of new unknown activities of natural ores.

*Yttrium 91.*—Preparation of biologically inert compounds for localized exposure of animal parts to beta radiation.

*Zinc 67.*—Determination of neutron scattering cross-section.

*Mixture of Praesodymium 143, Neodymium 147, Europium 155–156, Element 61 147.*—Investigation of the separation of plutonium from fission products.

## Hanford Plutonium Works, AEC

### RICHLAND, WASH.

(*General Electric Company, Contractor*)

For the calibration of Geiger counters for accurate determination of active materials, isotopes have been used to prepare samples emitting radiations of known energies so that correction factors may be obtained. Values of the radiation scatter from the mounting plate and from the sample itself, as well as the absorption of radiation in sample material and counter walls have been obtained. This is a long-range program which will require several years of study for a complete answer.

The age of a fission product mixture may be determined by the analysis of the ratio of certain pairs of isotopes. Since they decay at different rates the rate at any time is a measure of the age. One of the isotopes decays into an unstable "daughter" that later emits more radiation. The sample is then analyzed for this daughter which is a measure of the one isotope. From this value and the total activity, the ratio of the two isotopes may be obtained and, from this, the age of the solution. Pile-produced isotopes were used to check several of the methods used for determining this ratio. These methods were chiefly physical rather than chemical. Conclusive results will not be available for six months to a year, but the values obtained so far check the theoretical ones expected.

The methods of analyzing for fission products have been devised for solutions of known composition. Certain materials from samples contain large amounts of various organic and nonorganic material. Methods of analyzing for fission products in these materials must be developed. Separated radioisotopes allow the preparation of samples with known amounts of activities which can be used to check yields and train chemists. Several important methods of testing samples for fission products have been developed. In addition older methods that have been used in control and in development work have been tested.

## Knolls Atomic Power Laboratory, AEC

### SCHENECTADY, N. Y.

*(General Electric Company, Contractor)*

Radioisotopes are being used to study: (1) self-diffusion in silver and the effect of prior thermal treatments on the self-diffusion rate and (2) diffusion of nickel in nickel-aluminum alloys. Both investigations are aimed at learning the fundamental mechanism of diffusion in metals. At the present time, it is generally thought that diffusion is permitted by the presence of vacant lattic sites in metals and that atoms may move by jumping into the lattic vacancies. The rate of diffusion is therefore controlled by the number of such vacant sites and the energy barrier which the atom must surmount in making the jump. In the case of pure silver, it is intended to ascertain whether or not the concentration of vacant sites may be altered by thermal treatments such as equilibration at a high temperature followed by quenching to a lower temperature as compared with slow cooling. Other work has showed that the number of vacant sites in aluminum-nickel alloy may be controlled by choice of composition of the alloy and by heat treatment.

Work measuring self-diffusion rates in silver is well under way. The silver isotope with mass number 110 having a 225-day half-life is being used. Techniques have been established which give reproducible results checking previous work under standard conditions. The conditions to establish the effect of previous heat treatment are being worked out at the present time.

Work with the nickel-aluminum alloy uses the nickel isotope, mass number 59 having a 15-year half-life. Suitable alloys are being gathered.

## AMES LABORATORY, AEC

### AMES, IOWA

*(Iowa State College, Contractor)*

The radiations from hafnium 181 (Hf 181) and its decay scheme are being studied by absorption, coincidence absorption, and beta spectrometer technique. This is being done to determine the physical properties of the radioisotope and is important in any use of this isotope as a tracer.

Radiozinc and radiocobalt have been used to calibrate the beta spectrometer. It has been found by using combined sources of these two isotopes that the lower energy gamma ray from cobalt is slightly more energetic than the zinc gamma ray, rather than vice versa as had been reported previously.

The production of various isotopes in the pile by bombardment of titanium has been studied. The various nuclear reactions producible in the pile are of interest since they may make available additional isotopes for general use. A number of reactions were observed in the bombardment of titanium, including the production of the important calcium 45 tracer in low yield.

## UNIVERSITY OF CALIFORNIA, RADIATION LABORATORY, BERKELEY, CALIF.

*(University of California, Contractor)*

Carbon 14 is being used in a comprehensive study of the phenomenon of photosynthesis. Significant progress has already been made in the understanding of this tremendously important process. Carbon 14 is also being used to study the mechanisms of certain fundamental organic reactions with a view toward the development of more efficient methods of synthesizing labeled organic compounds. Considerable effort is now being expended in the synthesis of a large number of C 14 labeled compounds of fundamental biological importance.

One of the major phases of the work is the study of the metabolism of the fissionable elements and their fission products in order to evaluate the hazards involved in working with these substances and also to develop means by which some types of radioactive poisoning may be treated. Considerable work has been done in the past on the study of the behavior of certain fission products and of plutonium in various types of soils and the metabolism of these radioactive substances in several representative plants of significance in the field of agriculture.

Another important phase of the medical research is the determination of the effects of various types and intensities of radiation upon specific organs in the body. This type of investigation is carried out by using various radioactive colloids and certain labeled chemical compounds which are known to localize in specific organs. An important corollary to this research may be the development of techniques which may prove successful in the treatment of certain types of cancer.

Iodine 131 and phosphorus 32 are used in the treatment of certain types of thyroid and blood diseases. Accompanying these therapeutic uses is the study of the long-range biological effects of the administration of large doses of radioactive substances.

COLUMBIA UNIVERSITY (*Contractor*) NEW YORK, N. Y.

*Department of Physics.*—Major research problems center around the investigation of the fundamental nature of radioactive processes involving the emission of electrons, protons and gamma-rays from atomic nuclei. A survey of the radiations emitted by all available radioisotopes is in progress.

Detailed pictures of the nuclear energy level and transitions involved are contributing to building up a picture of nuclear processes on a scale and with precision not heretofore possible.

The radioactivity of the potassium isotope of atomic weight 40 (K 40) found in nature has been known for a long period, but precise information on the nature of the radiation and the half life of K 40 which enters strongly into consideration of nuclear theory, as well as such diverse problems as the age of the earth and the internal heat developed within the earth, and radioactivity within biological organisms which all contain potassium have never been treated or understood quantitatively. The stable isotope separation program carried on at the electromagnetic separation plant at Oak Ridge is providing the first samples of concentrated K 40 which will make possible the first really precise information on the natural radioactivity of this common element. Preliminary results have already been obtained on the energy and half life of K 40 and more precise information will be available as future samples of more concentrated K 40 are made available.

*College of Physicians and Surgeons.*—We have undertaken a thorough study of the dosage problem in the use of radioisotopes in biology and medicine. The study includes the experimental determination of all the quantitative factors involved, by direct or indirect means.

New methods and apparatus have been developed for this purpose. In particular a satisfactory instrument has been built for the measurement of the radiation dose delivered to a tissue by a beta-ray isotope uniformly distributed in the tissue.

This instrument can now be used as a standard for the measurement of beta-ray isotopes in terms of the radiation dosage rate they are able to produce. This, of course, is the chief property of a radioisotope of interest to physicians.

Since in the present state of the art the measurement of isotopes in terms of disintegrations per second is quite unsatisfactory, it is suggested that, at least temporarily, measurements be made in terms of the radiation dosage rate that the material produces. The "roentgen curie" is suggested as a convenient unit, for the obvious reason that one roentgen curie of *any* beta-ray emitting isotope per gram of tissue, produces a dosage rate of one equivalent roentgen per second within the tissue. The chief practical reason, however, is that measurements of beta-ray isotopes in "roentgen curies" can be made accurately today, whereas such is not the case when quantities are expressed in any other unit.

We plan to send out measured samples of the commonly used radioisotopes to different laboratories in order that their instruments may be calibrated in terms of "roentgen curies" for dosage purposes.

UNIVERSITY OF ROCHESTER (*Contractor*), ROCHESTER, N. Y.

Radioactive beryllium (Be 7), thorium (Ux 1), and uranium (U 235) are all highly toxic. The mechanism by which their effects are produced is of great importance. They accumulate in various parts of the body in quantities which are difficult to measure by ordinary chemical means but which can be detected quite readily if the elements are radioactive. Be 7, Ux 1, and U 235 have been used successfully in determining the distribution of beryllium, thorium, and uranium, respectively, in the body.

Radioactive calcium (Ca 45) and phosphorus (P 32) are valuable for following the course of chemical reactions within the body. It is of particular interest to study the process of deposition in the bone of toxic heavy metals such as uranium. Radioactive calcium and phosphorus have yielded valuable information on the processes of bone formation, and also on how heavy metal poisons become incorporated into bone. In addition to studies of bone formation, radioactive phosphorus has been used in determining enzyme distributions in yeast cells; in following the metabolism of phosphorus-containing fatty substances in animals; and in studying injury to cell nuclei by X-radiation.

It is of importance to study the process of formation of hemoglobin and other blood constituents in normal animals and in those injured by radiation. Radiocarbon (C 14), which is incorporated into glycerine, one of the structural components of hemoglobin, has been used for such studies.

Radioactive iodine (I 131) accumulates in the thyroid gland. It has been found valuable, not only for diagnostic purposes, but also for therapy of thyroid diseases in patients who are too ill to stand surgical operations.

Radioactive sodium (Na 24) has been very valuable in studying the movements of salt and water in the body, both in healthy and diseased states.

WESTERN RESERVE UNIVERSITY (*Contractor*), CLEVELAND, OHIO

The study of total blood volumes is carried out with protein tagged with radioactive iodine (I 131). To date, there is no accurate method for determining blood volumes. With tagged protein we have a material that will stay in the blood stream a comparatively long time, and is easily measured. It is too early to predict any results at this time, but the method looks promising. The material was used in animals, and to date in four patients, with good results.

Estimation of the cardiac output may be possible with certain radioactive elements. Preliminary investigations are under way with protein iodinated with iodine 131 and red cells impregnated with phosphorus 32.

Radioactive strontium (Sr 90) may be used for a beta source eye bulb in the treatment of certain eye conditions. It is desirable to use a beta source of long duration for this purpose. In this respect, Sr 90 has the advantage over the conventional radon eye bulb, which has a half life of about 3.8 days, as compared to 25 years for Sr 90. Another advantage of this type of eye bulb is the elimination of the undesirable gamma rays which are present in the radon bulb. The strontium eye bulb is now being used for treatment of eye cases, and a full report of the results will be published.

## APPENDIX 2

# ISOTOPES AND ISOTOPE-LABELED COMPOUNDS AVAILABLE FOR DISTRIBUTION THROUGH COMMISSION FACILITIES

### RADIOACTIVE ISOTOPES

*Atomic Number.*—This gives the number of positively charged protons in the nucleus of the isotope, and also the number of negatively charged electrons outside the nucleus.

*Mass Number.*—This gives the total number of protons and neutrons in the nucleus.

*Half-life.*—The time interval in which half the radioactive atoms in a sample disintegrate; the half-life remains constant regardless of the number of atoms in the sample (m, minutes; h, hours; d, days; y, years).

*Type of Radiation.*—A, alpha-particle emitted; an alpha-particle is a positively charged particle consisting of two protons and two neutrons; atomic number of the original isotope is reduced by 2 units, the mass number by 4.

B−, beta-particle emitted; a beta-particle is a high-speed electron having a negative charge; atomic number increased 1 unit, mass number unchanged.

B+, positive beta-particle or positron emitted; atomic number reduced by 1 unit, mass number unchanged.

K, K-electron capture; the nucleus captures an electron from the innermost (K) electron shell; atomic number reduced 1 unit, mass number unchanged.

e−, internal conversion; gamma radiation from the nucleus interacts with a bound electron in the atom, so that the electron is ejected from the atom; atomic number increased 1 unit, mass number unchanged.

IT, isomeric transition; the nucleus changes from a more to a less energetic state with emission of gamma rays or X-rays; atomic and mass numbers remain unchanged.

C, gamma radiation is non-material short-wave radiation of the same general nature as X-rays and ordinary light.

| Element | Symbol | Atom No. | Mass No. of Isotope | Half-life | Type of radiation |
|---|---|---|---|---|---|
| Antimony | Sb | 51 | 122 | 2.8 d | B−, C |
| | | | 124 | 60 d | B−, C |
| | | | 125 | 2.7 y | B−, C |
| Argon | A | 18 | 37 | 34 d | K |
| Arsenic | As | 33 | 76 | 26.8 h | B−, C |
| | | | 77 | 40 h | B− |
| Barium | Ba | 56 | 131 | 12 d | K, e− |
| | | | 140 | 12.8 d | B−, C |
| Bismuth | Bi | 83 | 210 | 5 d | B− |
| Bromine | Br | 35 | 82 | 34 h | B−, C |
| Cadmium | Cd | 48 | 109 | 300 d | K |
| | | | 115 | 2.33d | B−, C |
| | | | | 43 d | B−, C |
| Calcium | Ca | 20 | 45 | 180 d | B− |
| Carbon | C | 6 | 14 | 5100 y | B− |
| Cerium | Ce | 58 | 141 | 28 d | B−, C |
| | | | 143 | 33 h | B−, C |
| | | | 144 | 275 d | B− |
| Cesium | Cs | 55 | 131 | 10.2 d | K |
| | | | 134 | 2 y | B−, C |
| | | | 137 | 33 y | B−, C |

| Element | Symbol | Atom No. | Mass No. of Isotope | Half-life | Type of radiation |
|---|---|---|---|---|---|
| Chlorine | Cl | 17 | 36 | 1,000,000 y | B− |
| Chromium | Cr | 24 | 51 | 26.5 d | K, C |
| Cobalt | Co | 27 | 60 | 5.3 y | B−, C |
| Columbium | Cb | 41 | 95 | 35 d | B−, C |
| Copper | Cu | 29 | 64 | 12.8 h | B−, B+, K, C |
| Europium | Eu | 63 | 152 | 9.2 h | B− |
| | | | 154 | 7 y | B−, C |
| | | | 155 | 2 y | B−, C |
| | | | 156 | 15.4 d | B−, C |
| Gallium | Ga | 31 | 72 | 14.1 h | B−, C |
| Germanium | Ge | 32 | 71 | 40 h | B+ |
| | | | | 11 d | B+, C |
| | | | 77 | 12 h | B− |
| Gold | Au | 79 | 198 | 2.7 d | B−, C |
| | | | 199 | 3.3 d | B−, C |
| Hafnium | Hf | 72 | 181 | 46 d | B−, C |
| Illinium | Il | 61 | 147 | 3.7 y | B− |
| | | | 149 | 2 d | B−, C |
| Indium | In | 49 | 114 | 48 d | IT, e− |
| Iodine | I | 53 | 131 | 8 d | B−, C |
| Iridium | Ir | 77 | 192 | 75 d | B−, C |
| | | | 194 | 19 h | B−, C |
| Iron | Fe | 26 | 55 | 4 y | K, C |
| | | | 59 | 44 d | B−, C |
| Lanthanum | La | 57 | 140 | 40 h | B−, C |
| Mercury | Hg | 80 | 197 | 64 h | K, e−, C |
| | | | | 25 h | K, e−, C |
| | | | 203, 205 | 51.5 d | B−, C |
| Molybdenum | Mo | 42 | 99 | 67 h | B−, C |
| Neodymium | Nd | 60 | 147 | 11 d | B−, C |
| | | | 149 | 47 h | B−, C |
| Nickel | Ni | 28 | 59 | 15 y | K, e− |
| Osmium | Os | 76 | 185 | 80 d | K |
| | | | 191 | 32 h | B−, C |
| | | | 193 | 17 d | B−, C |
| Palladium | Pd | 46 | 103 | 17 d | K |
| Phosphorus | P | 15 | 32 | 14.3 d | B− |
| Platinum | Pt | 78 | 197 | 18 h | B− |
| | | | | 3.3 d | B−, C |
| | | | 199 | 31 m | B− |
| Polonium | Po | 84 | 210 | 140 d | A, e−, C |
| Potassium | K | 19 | 42 | 12.4 h | B−, C |
| Praseodymium | Pr | 59 | 142 | 19.3 h | B−, C |
| | | | 143 | 13.8 d | B− |
| Rhenium | Re | 75 | 186 | 90 h | B− |
| | | | 188 | 18 h | B−, C |
| Rhodium | Rh | 45 | 105 | 36 h | B−, C |
| Rubidium | Rb | 37 | 86 | 19.5 d | B− |
| Ruthenium | Ru | 44 | 97 | 2.8 d | K, e−, C |
| | | | 103 | 42 d | B−, C |
| | | | 106 | 1 y | B− |
| Samarium | Sm | 62 | 153 | 47 h | B−, C |
| | | | 155 | 25 m | B−, C |
| Scandium | Sc | 21 | 46 | 85 d | B−, C |
| | | | 47 | 3.4 d | B− |
| | | | 48 | 44 h | B−, C |
| Selenium | Se | 34 | 75 | 125 d | K, e−, C |
| Silver | Ag | 47 | 110 | 225 d | B−, C |
| | | | 111 | 7.5 d | B− |
| Sodium | Na | 11 | 24 | 14.8 h | B−, C |
| Strontium | Sr | 38 | 89 | 55 d | B− |
| | | | 90 | 25 y | B− |
| Sulfur | S | 16 | 35 | 87.1 d | B− |
| Tantalum | Ta | 73 | 182 | 117 d | B−, C |
| Technetium | Tc | 43 | 97 | 93 d | K, e−, C |
| | | | 99 | 1,000,000 y | B− |
| Tellurium | Te | 52 | 127 | 90 d | IT, e−, C, X-ray |
| | | | | 9.3 h | B− |
| | | | 129 | 32 d | IT, e−, C, X-ray |
| | | | | 70 m | B−, C |
| | | | 131 | 30 h | IT, e−, C |
| | | | | 25 m | B− |
| Thallium | Tl | 81 | 204 | 2.7 y | B− |
| Tin | Sn | 50 | 113 | 100 d | K, e−, C |
| | | | 121 | 62 h | B− |
| | | | 123 | 10 d | B−, C |
| Titanium | Ti | 22 | 51 | 72 d | B−, C |
| Tungsten | W | 74 | 185 | 77 d | B− |
| | | | 187 | 24 h | B−, C |
| Yttrium | Y | 39 | 90 | 62 h | B− |
| | | | 91 | 57 d | B− |
| Zinc | Zn | 30 | 65 | 250 d | B+, K, e−, C |
| | | | 69 | 13.8 h | IT, C |
| | | | | 59 m | B− |
| Zirconium | Zr | 40 | 95 | 65 d | B−, C |

## Stable Isotopes

Antimony: 121, 123 (Sb 121, 123)
Boron: 10 (B 10)
Cadmium: 106, 108, 110, 111, 112, 113, 114, 116 (Cd 106, 108, 110, 111, 112, 113, 114, 116)
Calcium: 40, 44 (Ca 40, 44)
Carbon: 13 (C 13)
Chromium: 52 (Cr 52)
Copper: 63, 65 (Cu 63, 65)
Helium: 3 (He 3)
Hydrogen: 2 (H 2 Deuterium also Deuterim Oxide)
Indium: 113, 115 (In 113, 115)
Iron: 54, 56, 57, 58 (Fe 54, 56, 57, 58)
Lead: 204, 206, 207, 208 (Pb 204, 206, 207, 208)
Lithium: 6, 7 (Li 6, 7)
Mercury: 198 (Hg 198)
Molybdenum: 92, 94, 95, 96, 97, 98, 100 (Mo 92, 94, 95, 96, 97, 98, 100)
Nickel: 58, 60, 61, 62, 64 (Ni 58, 60, 61, 62, 64)
Nitrogen: 15 (N 15)
Oxygen: 18 (O 18)
Potassium: 39, 40, 41 (K 39, 40, 41) (Although technically radioactive, K 40 has a half-life of 400,000,000, 4 x $10^8$ years)
Selenium: 74, 76, 77, 78, 80, 82 (Se 74, 76, 77, 78, 80, 82)
Silicon: 28, 29, 30 (Si 28, 29, 30)
Silver: 107, 109 (Ag 107, 109)
Strontium: 84, 86, 87, 88 (Sr 84, 86, 87, 88)
Tellurium: 122, 123, 124, 125, 126, 128, 130 (Te 122, 123, 124, 125, 126, 128, 130)
Thallium: 203, 205 (Tl 203, 205)
Tin: 115, 116, 117, 118, 119, 120, 122 (Sn 115, 116, 117, 118, 119, 120 122)
Zinc: 64, 66, 67, 68, 70 (Zn 64, 66, 67, 68, 70)
Zirconium: 90, 94 (Zr 90, 94)

## Labeled Compounds

### CARBON 14 COMPOUNDS

Acetic acid (methyl or carboxyl)
Acetyl chloride
Acetylene
Barium carbide
Ethyl acetate (methyl or carboxyl)
Ethyl alcohol (methyl or methylene)
Ethyl bromide (methyl or methylene)
Ethyl iodide (methyl or methylene)
Glucose-fructose mixture (biologically synthesized)
Glycine (methyl or carboxyl)
Methyl alcohol
Methyl iodide
Potassium pyruvate (carbonyl)
Sodium acetate (methyl or carboxyl)
Sodium butanate (carboxyl)
Sodium cyanide
Sodium formate
Sodium heptanoate (carboxyl)
Sodium hexanoate (carboxyl)
Sodium pentanoate (carboxyl)
Sodium propionate (methyl, methylene, or carboxyl)

### GOLD COMPOUNDS

Aurothiosulphate
Colloidal gold

### CARBON 14 COMPOUNDS THAT WILL BE AVAILABLE FOR DISTRIBUTION WITHIN THE NEXT 6 MONTHS

Acetaldehyde
Acetone
Alanine
Benzene
Chloracetic acid
Diazomethane
Ethylene dichloride
Ethylene oxide
Formaldehyde
Formic acid
Lactic acid
Malonic ester
Methylamine
Phthalic acid
Propionic acid
Stearic acid
Steroid hormones
Testosterone
Toluene

797148—48——11

# APPENDIX 3

## DISTRIBUTION OF ISOTOPES FROM ISOTOPES DIVISION OAK RIDGE, TENN.

| | Number of shipments | | | | Total to June 30, 1948 |
|---|---|---|---|---|---|
| | July 1 to Dec. 31, 1946 | Jan. 1 to June 30, 1947 | July 1 to Dec. 31, 1947 | Jan. 1 to June 30, 1948 | |
| Shipments classified by broad field of utilization: | | | | | |
| Radioactive Isotopes: | | | | | |
| Medical Therapy | 88 | 319 | 397 | 487 | 1, 291 |
| Animal Physiology | 78 | 202 | 306 | 406 | 992 |
| Chemistry | 27 | 47 | 91 | 97 | 262 |
| Physics | 17 | 65 | 69 | 106 | 257 |
| Plant Physiology | 16 | 33 | 29 | 78 | 156 |
| Industrial Research | 14 | 18 | 33 | 25 | 90 |
| Bacteriology | 4 | 7 | 26 | 27 | 64 |
| Metallurgy | 2 | 8 | 2 | 8 | 20 |
| Other | | | | 4 | 4 |
| Total | 246 | 699 | 953 | 1, 238 | 3, 136 |
| Stable Isotopes: | | | | | |
| Physics | | 27 | 77 | 98 | 202 |
| Chemistry | | 12 | 45 | 24 | 81 |
| Animal Physiology | | 16 | 19 | 16 | 51 |
| Industrial Research | | | 7 | 14 | 21 |
| Plant Physiology | | | 5 | | 5 |
| Bacteriology | | | 1 | 1 | 2 |
| Total | | 55 | 154 | 153 | 362 |
| Shipments classified by kind of isotope: | | | | | |
| Radioactive Isotopes: | | | | | |
| Phosphorus 32 | 48 | 212 | 325 | 422 | 1, 007 |
| Iodine 131 | 68 | 208 | 287 | 454 | 1, 017 |
| Carbon 14 | 47 | 41 | 67 | 67 | 222 |
| Sodium 24 | 1 | 31 | 49 | 64 | 145 |
| Gold 198, 199 | 17 | 46 | 6 | 17 | 86 |
| Sulfur 35 | 12 | 19 | 20 | 15 | 66 |
| Calcium 45 | 5 | 17 | 25 | 15 | 62 |
| Iron 55, 59 | 5 | 21 | 20 | 14 | 60 |
| Potassium 42 | 6 | 17 | 14 | 10 | 47 |
| Cobalt 60 | 4 | 20 | 12 | 10 | 46 |
| Strontium 89, 90 | 3 | 4 | 5 | 10 | 22 |
| Others (49) | 30 | 63 | 123 | 140 | 356 |
| Total | 246 | 699 | 953 | 1, 238 | 3, 136 |
| Stable Isotopes: | | | | | |
| Deuterium oxide (heavy water) | | 31 | 60 | 55 | 146 |
| Deuterium (hydrogen 2) | | 22 | 58 | 39 | 119 |
| Boron 10 | | 2 | 22 | 13 | 37 |
| Oxygen 18 | | | 14 | 9 | 23 |
| Electromagnetically concentrated isotopes | | | | 37 | 37 |
| Total | | 55 | 154 | 153 | 362 |

| | Total number of shipments to June 30, 1948 | |
|---|---|---|
| | Radioactive | Stable |
| Shipments classified by State, Territory, and foreign country: | | |
| Alabama | 3 | ---------- |
| Arkansas | 2 | ---------- |
| California | 269 | 27 |
| Colorado | ---------- | 1 |
| Connecticut | 83 | 20 |
| Delaware | 19 | 3 |
| Florida | 44 | ---------- |
| Georgia | 41 | 2 |
| Illinois | 184 | 37 |
| Indiana | 54 | 13 |
| Iowa | 7 | 1 |
| Kansas | 2 | 1 |
| Kentucky | 7 | ---------- |
| Louisiana | 43 | 3 |
| Maine | 1 | ---------- |
| Maryland | 125 | 10 |
| Massachusetts | 419 | 38 |
| Michigan | 141 | 11 |
| Minnesota | 145 | 15 |
| Missouri | 131 | 6 |
| Montana | ---------- | 1 |
| Nebraska | 24 | ---------- |
| New Jersey | 37 | 15 |
| New York | 441 | 52 |
| North Carolina | 16 | 1 |
| Ohio | 252 | 33 |
| Oklahoma | 2 | 4 |
| Oregon | 29 | ---------- |
| Pennsylvania | 186 | 33 |
| Tennessee | 99 | ---------- |
| Shipments classified by State, Territory, and foreign country—Continued | | |
| Texas | 106 | 12 |
| Utah | 10 | 2 |
| Virginia | 12 | 1 |
| Washington | 34 | ---------- |
| Wisconsin | 103 | 9 |
| District of Columbia | 60 | 11 |
| Hawaii | 5 | ---------- |
| Total | 3,136 | 362 |
| Shipments classified by State, Territory, and foreign country: | | |
| Argentina | 17 | ---------- |
| Australia | 35 | ---------- |
| Belgium | 5 | ---------- |
| Canada | 13 | ---------- |
| Denmark | 5 | ---------- |
| Great Britain | 33 | ---------- |
| Italy | 1 | ---------- |
| Netherlands | 16 | ---------- |
| Norway | 2 | ---------- |
| Peru | 1 | ---------- |
| Union of South Africa | 1 | ---------- |
| Spain | 1 | ---------- |
| Sweden | 25 | ---------- |
| Switzerland | 3 | ---------- |
| Turkey | 1 | ---------- |
| Total | 159 | ---------- |

# APPENDIX 4

# USERS OF ISOTOPES BY STATE, INSTITUTION, AND DEPARTMENT

## RADIOACTIVE ISOTOPES

*(July 1, 1946, to June 30, 1948)*

ALABAMA
1. Southern Research Institute, Birmingham
   (1) Biochemistry
2. University of Alabama, University
   (1) Biology

ARKANSAS
1. Robert L. Dortch, Seed Farm, Scott
   (1) Agronomy

CALIFORNIA
1. Birmingham Veterans' Administration Hospital, Van Nuys
   (1) Radioisotopes
2. University of California, Berkeley
   (1) Anatomy
   (2) Biochemistry
   (3) Engineering
   (4) Physiology
   (5) Chemistry
   (6) Plant Nutrition
   (7) Physics
   (8) Medical Physics, Donner Laboratory
   (9) Soils
   (10) Soil Microbiology
   (11) Veterinary Science
3. University of California, San Francisco
   (1) Medicine
   (2) Pharmacology
   (3) Radiology
4. University of California, Los Angeles
   (1) Chemistry
   (2) Medicine
   (3) Plant Physiology
5. University of California, Riverside
   (1) Soils and Plant Nutrition
6. California Research Corporation, Richmond
   (1) Process Research
7. Children's Hospital, Los Angeles
   (1) Medicine
8. Cedars of Lebanon Hospital, Los Angeles
   (1) Research Laboratory
   (2) Medicine

CALIFORNIA—Continued
9. Los Angeles County Hospital, Los Angeles
   (1) Main Laboratory
   (2) Pathology
10. Los Angeles Tumor Institute, Los Angeles
   (1) Pathology
11. Navy Medical Research Unit #1, Berkeley
   (1) Bacteriology
12. Santa Barbara Cottage Hospital, Santa Barbara
   (1) Radiology
13. Shell Development Company, Emeryville
   (1) Physics
14. University of Southern California, Los Angeles
   (1) Chemistry
   (2) Zoology
15. University of Southern California, College of Medicine, Los Angeles
   (1) Biochemistry
16. Stanford University, Palo Alto,
   (1) Chemistry
17. Stanford University Hospital, San Francisco
   (1) Radiology
18. Union Oil Company of California, Wilmington
   (1) Research
19. Wadsworth General Hospital, Los Angeles
20. California Institute of Technology, Pasadena
   (1) Biochemistry
   (2) Biology
   (3) Chemistry
   (4) Physics
21. U. S. Department of Agriculture, Albany
   (1) Agricultural and Industrial Chemistry
22. Weather Bureau, Soda Springs
   (1) Snow Research Laboratory

CONNECTICUT
1. American Cyanamid Company Stamford Laboratories, Stamford
   (1) Chemistry
   (2) Physics

CONNECTICUT—Continued
2. Connecticut Agricultural Experiment Station, New Haven
    (1) Soils
3. Yale University, New Haven
    (1) Chemistry
    (2) Osborn Zoological Laboratory
    (3) Physics
4. Yale University Medical School
    (1) Aeromedical Research Unit
    (2) Physiological Chemistry
    (3) Pediatrics
    (4) Bacteriology
    (5) Pharmacology

DISTRICT OF COLUMBIA
1. Georgetown University, Washington
    (1) Oncology
    (2) Pathology
2. Howard University, Washington
    (1) Physics
    (2) Physiology
3. Howard University College of Medicine, Washington
4. National Bureau of Standards, Washington
    (1) Radioactivity Section
5. Carnegie Institution of Washington
    Department of Terrestrial Magnetism, Washington
    (1) Biophysics
6. National Research Council, Washington
    (1) Committee on Growth

DELAWARE
1. Biochemical Research Foundation, Newark
    (1) Cytology
    (2) Physics
2. E. I. du Pont de Nemours and Company, Wilmington
    (1) Chemistry

FLORIDA
1. University of Florida, Agricultural Experiment Station, Gainesville
    (1) Animal Industry

GEORGIA
1. Emory University, Emory University
    (1) Robert Winship Memorial Clinic
    (2) Surgery

HAWAII, TERRITORY OF
1. Experiment Station
    Hawaiian Sugar Planters' Association, Honolulu
    (1) Biochemistry and Physiology

ILLINOIS
1. Abbott Laboratories, North Chicago

ILLINOIS—Continued
2. American Scientific Company, Chicago
3. Anderson Physical Laboratories, Champaign
4. University of Chicago, Chicago
    (1) Chemistry
    (2) Rubber Research
    (3) Institute for Nuclear Studies
    (4) Toxicity Laboratory
    (5) Institute for Study of Metals
5. University of Chicago School of Medicine, Chicago
    (1) Anatomy
    (2) Biochemistry
    (3) Radiobiology and Biophysics
    (4) Pharmacology
    (5) Physiology
    (6) Medicine
    (7) Surgery
6. Cook County Hospital, Chicago
    (1) Radiology
7. University of Illinois, Urbana
    (1) Animal Science
    (2) Chemistry
    (3) Pharmacology
    (4) Physiology
    (5) Physics
8. University of Illinois College of Medicine, Chicago
9. Illinois Institute of Technology, Chicago
    (1) Chemistry
10. Illinois State Water Survey, Champaign
11. Loyola University, Chicago
    (1) Biological Chemistry
    (2) Medicine
12. Northwestern University, Evanston
    (1) Physics
    (2) Chemistry
13. Northwestern University Medical School, Evanston
14. Presbyterian Hospital, Chicago
    (1) Radiology
15. Veterans' Administration Hospital, Hines
    (1) Medicine

INDIANA
1. Indiana University, Bloomington
    (1) Physics
2. Purdue University, Lafayette
    (1) Agronomy
    (2) Chemistry
    (3) Pharmacy
    (4) Pharmaceutical Chemistry
    (5) Physics
3. Miles Laboratories, Inc., Elkhart
4. University of Notre Dame, Notre Dame
    (1) Chemistry

INDIANA—Continued
5. Sinclair Refining Company, East Chicago
    (1) Catalysis Research

IOWA
1. Iowa State College, Ames
    (1) Bacteriology
    (2) Chemistry
    (3) Physics
2. State University of Iowa, Iowa City
    (1) Physics
    (2) Radiation Research

KANSAS
1. University of Kansas, Lawrence
    (1) Chemistry

KENTUCKY
1. University of Kentucky, Lexington
    (1) Chemistry
2. Medical Department, Fort Knox
    (1) Field Research

LOUISIANA
1. Louisiana State University School of Medicine, New Orleans
    (1) Pharmacology
2. Ochsner Clinic, New Orleans
    (1) Medicine
3. Tulane University, New Orleans
    (1) Biophysics
4. Tulane University School of Medicine, New Orleans
    (1) Medicine
    (2) Physiology

MARYLAND
1. Army Chemical Center Chemical Corps School, Frederick
    (1) Chemistry
    (2) Radiological Safety Branch
    (3) Research and Development
2. The Johns Hopkins University, Baltimore
    (1) Biochemistry
    (2) Medicine
    (3) Pediatrics
    (4) School of Hygiene
3. The Johns Hopkins University Applied Physics Laboratory, Silver Spring
    (1) High Altitude Research
4. University of Maryland, College Park
    (1) Chemistry
    (2) Zoology
5. University of Maryland Medical School, Baltimore
6. National Naval Medical Center, Bethesda
    (1) Physiology

MARYLAND—Continued
7. Sinai Hospital, Baltimore
    (1) Surgery
8. U. S. Department of Agriculture, Beltsville
    (1) Division of Biologically Active Compounds
    (2) Horticulture
    (3) Bureau of Plant Industry, Soils and Agricultural Engineering, Biochemistry and Physics
    (4) Bureau of Agricultural and Industrial Chemistry
9. U. S. Public Health Service, Bethesda
    National Institute of Health
    (1) Pathology
    (2) Industrial Hygiene Research
    (3) Venereal Disease Research
    (4) Zoology Laboratory
    (5) Division of Tropical Diseases

MASSACHUSETTS
1. Amherst College, Amherst
    (1) Physics
2. Arthur D. Little, Inc., Cambridge
3. Atomic Instrument Company, Boston
4. Beth Israel Hospital, Boston
    (1) Medicine
5. Boston University, Boston
    (1) Physics
6. General Electric Company Thomson Laboratory, West Lynn
7. Edward S. Gilfillan, Consulting Engineer, Manchester
8. Harvard University, Cambridge
    (1) Chemistry
    (2) Physics
9. Harvard Medical School, Boston
    (1) Biological Chemistry
    (2) Biophysical Laboratory
    (3) Industrial Hygiene
    (4) Medicine
    (5) Pharmacology
    (6) Physiology
    (7) Surgery
    (8) Thorndike Memorial Laboratory
10. Harvard School of Dental Medicine, Boston
    (1) Oral Pathology
11. Massachusetts General Hospital, Boston
    (1) Medicine
    (2) Surgery

MASSACHUSETTS—Continued

12. Massachusetts Institute of Technology, Cambridge
    (1) Biochemistry
    (2) Chemistry
    (3) Mechanical Engineering
    (4) Metallurgy
    (5) Physics
13. Massachusetts Memorial Hospital, Boston
    (1) Medicine
14. New England Deaconess Hospital, Boston
15. Peter Bent Brigham Hospital, Boston
    (1) Medicine
16. Joseph H. Pratt Diagnostic Hospital, Boston
    (1) Medicine
17. Raytheon Manufacturing Company, Newton
    (1) Special Tube Section
18. Sylvania Electrical Products, Inc., Salem
    (1) Engineering
19. Tracerlab, Inc.. Boston
20. Tufts College, Boston
    (1) Dental School
21. Worcester Foundation for Experimental Biology, Shrewsbury
    (1) Physiology

MICHIGAN

1. Detroit Edison Company, Detroit
2. Detroit Institute of Cancer Research, Detroit
3. Dow Chemical Company, Midland
    (1) Spectroscopy Laboratory
4. Ford Motor Company, Dearborn
    (1) Chemical and Metallurgical Research
5. Harper Hospital, Detroit
    (1) Radiology
6. Industrial Health Conservancy Laboratories, Detroit
7. University of Michigan, Ann Arbor
    (1) Physics
    (2) Roentgenology
8. University of Michigan Medical School, Ann Arbor
    (1) Medicine
9. Parke, Davis and Company. Detroit
    (1) Pharmacology
10. Wayne University, Detroit
    (1) Surgery
11. Western Michigan College of Education, Kalamazoo
    (1) Physics

MINNESOTA

1. Central Research Laboratories, Inc., Red Wing
    (1) Physics
2. Mayo Foundation, Rochester
    (1) Medicine
3. University of Minnesota, Minneapolis
    (1) Biophysics
    (2) Botany
    (3) Chemistry
    (4) Medicine
    (5) Physiological Chemistry
    (6) Physics
    (7) Physiology
4. University of Minnesota Medical School, Minneapolis
5. University of Minnesota Hospital, Minneapolis
    (1) Radiation Laboratory

MISSOURI

1. Barnard Free Skin and Cancer Hospital, St. Louis
2. Mallinckrodt Institute of Radiology, St. Louis
    (1) Radiology
3. St. Louis University, St. Louis
    (1) Anatomy
    (2) Biochemistry
4. Washington University, St. Louis
    (1) Chemistry
    (2) Physics
5. Washington University School of Medicine, St. Louis
    (1) Anatomy
    (2( Biochemistry
    (3) Medicine
    (4) Radiology
    (5) Surgery

NEBRASKA

1. University of Nebraska Medical School, Omaha
    (1) Radiology

NEW JERSEY

1. Allied Chemical and Dye Corporation, Morristown
2. Bell Telephone Laboratories, Murray Hill
    (1) Chemistry
    (2) Dept. 1150
    (3) Physical Research
3. General Foods Corporation, Central Laboratories, Hoboken
    (1) Biophysics Section
4. Johnson and Johnson Research Foundation, New Brunswick
5. Merck and Company, Inc., Rahway
    (1) Physical Measurements Laboratory
6. Ortho Research Foundation, Raritan
    (1) Biochemistry

NEW JERSEY—Continued

7. Princeton University, Princeton
   (1) Physics
8. R. C. A. Laboratories, Princeton
   (1) Tube Research
9. Rockefeller Institute for Medical Research, Princeton
   (1) Animal and Plant Pathology
   (2) General Physiology
10. Rutgers University, New Brunswick
   (1) Chemistry
   (2) Soils
11. Socony Vacuum Oil Company, Inc., Paulsboro
   (1) Research and Development
12. Stevens Institute of Technology, Hoboken
   (1) Physics
13. U. S. Rubber Company, Passaic
   (1) Physical Research

NEW YORK

1. Bellevue Hospital, New York City
   (1) Psychiatric Division
2. Brooklyn Cancer Institute, Brooklyn
   (1) Radium Therapy
3. Canisius College, Buffalo
   (1) Chemistry
4. Columbia University, Barnard College, New York City
   (1) Zoology
5. Columbia University, New York City
   (1) Biochemistry
   (2) Chemistry
   (3) Pharmacology
   (4) Radiation
6. Columbia University, College of Physicians and Surgeons, New York City
   (1) Biochemistry
   (2) Neurology
   (3) Radiology
7. Cornell University, Ithaca
   (1) Agronomy
   (2) Animal Husbandry
   (3) Chemistry
   (4) Laboratory of Nuclear Studies
8. Cornell University Medical College, New York City
   (1) Biochemistry
   (2) Pediatrics
9. Distillation Products, Inc., Rochester
   (1) Biochemistry
10. Eastman Kodak Company, Rochester
   (1) Photographic Theory

NEW YORK—Continued

11. General Electric Company, Schenectady
   (1) General Engineering Laboratory
   (2) High Frequency Laboratory
12. Harlem Hospital, New York City
   (1) Radiation Therapy
13. Memorial Hospital, New York City
   (1) Medicine
   (2) Experimental Therapy
   (3) Urology
14. Montefiore Hospital, New York City
   (1) Medical Physics
   (2) Laboratory Division
15. Mount Sinai Hospital, New York City
   (1) Physics
   (2) Physiology and Hematology
16. New York Medical College, New York City
   (1) Metropolitan Hospital
17. New York Skin and Cancer Unit, New York City
   (1) Physical Therapy
18. New York University, New York City
   (1) Chemistry
19. New York University College of Medicine, New York City
   (1) Chemistry
   (2) Medicine
   (3) Psychiatric Division
20. Peck Memorial Hospital, Brooklyn
21. Polytechnic Institute of Brooklyn, Brooklyn
   (1) Chemistry
22. Public Health Research Institute, New York City
   (1) Nutrition
   (2) Physiology
23. Queens College, Flushing
   (1) Chemistry
24. Rensselaer Polytechnic Institute, Troy
   (1) Chemistry
   (2) Physics
25. University of Rochester, School of Medicine and Dentistry, Rochester
   (1) Biochemistry
   (2) Radiology
26. Rockefeller Foundation, New York City
   (1) International Health Division Laboratories
27. Sloan-Kettering Institute of Cancer Research, New York City
   (1) Physics

NEW YORK—Continued

28. Strong Memorial Hospital, Rochester
    (1) Radiology
29. Sun Chemical Corporation, New York City
    (1) Physical Chemistry
30. The Texas Company, New York City
    (1) Research
31. United States Public Health Service, New York City
    (1) Tuberculosis Control
32. U. S. Marine Hospital, Staten Island
    (1) Venereal Disease Research
33. U. S. Veterans' Hospital, Bronx
    (1) Radiotherapy

NORTH CAROLINA

1. Bowman Gray School of Medicine, Winston-Salem
    (1) Biochemistry
2. University of North Carolina, Raleigh
    (1) Agriculture
3. University of North Carolina, Chapel Hill
    (1) Physics

OHIO

1. Air Material Command, Wright Field, Dayton
    (1) Equipment Laboratory
2. Antioch College, Yellow Springs
    (1) Physics
3. Batelle Memorial Institute, Columbus
    (1) Physics
4. Case School of Applied Science, Cleveland
    (1) Physics
5. Cleveland Clinic Foundation, Cleveland
    (1) Research Division
6. Crile General Hospital, Cleveland
    (1) Radiology Service
7. University of Cincinnati, Cincinnati
    (1) Chemistry
8. University of Cincinnati, College of Medicine, Cincinnati
    (1) Medicine
    (2) Gastric Laboratory
9. B. F. Goodrich Company, Akron
    (1) Physical Research
10. Goodyear Tire and Rubber Company, Akron
    (1) Physical Research
11. Monsanto Chemical Company, Dayton
    (1) Physical Chemistry
12. National Advisory Committee for Aeronautics, Cleveland
    (1) Flight Propulsion Research

OHIO—Continued

13. Ohio Agricultural Experiment Station, Wooster
    (1) Agronomy
    (2) Plant Physiology
14. Ohio State University, Columbus
    (1) Bacteriology
    (2) Biochemistry
    (3) Chemistry
    (4) Medicine
    (5) Physics
    (6) Surgical Research
15. Victoreen Instrument Company, Cleveland
16. Western Reserve University, School of Medicine, Cleveland
    (1) Biochemistry
    (2) Medicine
    (3) Radiology

OKLAHOMA

1. Phillips Petroleum Company, Bartlesville
    (1) Research

OREGON

1. University of Oregon, Eugene
    (1) Physics
2. University of Oregon Medical School, Portland
    (1) Experimental Medicine
    (2) Thoracic Surgery
3. Oregon State College, Corvallis
    (1) Chemistry
4. Reed College, Portland
    (1) Chemistry

PENNSYLVANIA

1. Bartol Research Foundation, Swarthmore
2. Carnegie Institute of Technology, Pittsburgh
    (1) Metals Research
    (2) Physics
3. General Aniline Film Corporation, Easton
    (1) Central Research Laboratory
4. Gulf Research and Development Company, Pittsburgh
    (1) Physics
5. Houdry Process Corporation of Pennsylvania, Marcus Hook
    (1) Fundamental Research
6. Jefferson Medical College, Philadelphia
    (1) Biochemistry
    (2) Hematology
7. Jefferson Hospital, Philadelphia
    (1) Hematology
8. Jewish Hospital, Philadelphia
    (1) X-Ray
    (2) Radiology
9. Lankenau Hospital, Philadelphia
    (1) Metabolic Chemistry
10. Lehigh University, Bethlehem
    (1) Chemistry

PENNSYLVANIA—Continued
11. Mellon Institute of Industrial Research, Pittsburgh
12. University of Pennsylvania, Philadelphia
    (1) Botany
    (2) Physics
13. University of Pennsylvania School of Medicine, Philadelphia
    (1) Clinical Neurology
    (2) Pharmacology
    (3) Physiological Chemistry
    (4) Radiology
14. Philadelphia General Hospital, Philadelphia
    (1) Radiology
15. University of Pittsburgh, Pittsburgh
    (1) Physics
    (2) Biological Sciences
    (3) Radiation Laboratories
16. Publicker Industries, Inc., Philadelphia
    (1) Chemical Research
17. Temple University Hospital, Philadelphia
    (1) Radiology
18. Westinghouse Research Laboratories, East Pittsburgh
    (1) Magnetism
    (2) Metallurgical and Ceramics
19. Wyeth Inc., West Chester
    (1) Penicillin Division

TENNESSEE
1. Fairchild Engine and Airplane Corporation, Oak Ridge
    (1) NEPA Division
2. Meharry Medical College, Nashville
    (1) Biochemistry
    (2) Cancer Research
    (3) Radiobiology
3. University of Tennessee, Memphis
    (1) Chemistry
    (2) Physiology
4. University of Tennessee, Knoxville
    (1) Agricultural Experiment Station
5. Vanderbilt University, Nashville
    (1) Physics
6. Vanderbilt University School of Medicine, Nashville
    (1) Biochemistry
    (2) Pathology

TEXAS
1. Air University School of Aviation Medicine, Randolph Field
    (1) Biophysics

TEXAS—Continued
2. Baylor University Hospital, Dallas
3. Industrial Radiography Laboratory, Beaumont
4. Maxfield X-Ray and Radium Clinic, Dallas
5. Rice Institute, Houston
    (1) Physics
6. Southwestern Medical College, Dallas
7. Texas Radiation and Tumor Institute, Dallas
8. University of Texas, Austin
    (1) Botany and Bacteriology
    (2) Chemistry
9. University of Texas Medical School, Galveston
    (1) Physiology
    (2) Medical Physics

UTAH
1. American Smelting and Refining Company, Salt Lake City
    (1) Agricultural Research
2. University of Utah, Salt Lake City
    (1) Physiology
3. University of Utah Medical School, Salt Lake City
    (1) Biochemistry
    (2) Medicine

VERMONT
1. University of Vermont College of Medicine, Burlington
    (1) Biochemistry

VIRGINIA
1. Medical College of Virginia, Richmond
    (1) Oncology
    (2) Surgical Research
2. University of Virginia, Charlottesville
    (1) Pharmacology
    (2) Physics

WASHINGTON
1. The Mason Clinic, Seattle
    (1) Radiology
2. University of Washington School of Medicine, Seattle
    (1) Anatomy
    (2) Chemistry
3. Washington State College, Pullman
    (1) Botany

WISCONSIN
1. Gibbs Manufacturing Corporation, Janesville
2. University of Wisconsin, Madison
    (1) Biochemistry
    (2) Chemistry
3. University of Wisconsin Medical School, Madison
    (1) Biochemistry
    (2) Medicine

## STABLE ISOTOPES

*(May 1, 1947 to June 30, 1948)*

CALIFORNIA
- 1. Union Oil Company, Wilmington
  - (1) Research
- 2. University of California, Berkeley
  - (1) Medical Physics
  - (2) Poultry Husbandry
  - (3) Radiation Laboratory
- 3. University of California, Los Angeles
  - (1) Chemistry
  - (2) Physics
- 4. University of Southern California, Los Angeles
  - (1) Biochemistry
- 5. California Institute of Technology, Pasadena
  - (1) Physics
  - (2) Kellogg Radiation Laboratory
- 6. Consolidated Engineering Corporation, Pasadena
- 7. National Technical Laboratories, South Pasadena
- 8. Shell Development Company, Emeryville
  - (1) Physics
- 9. Stanford University, Palo Alto
  - (1) Chemistry
  - (2) Physics
- 10. Stuart Oxygen Company, San Francisco
  - (1) Heavy Water Department

COLORADO
- 1. University of Colorado, Boulder
  - (1) Chemistry

CONNECTICUT
- 1. University of Connecticut, Storrs
  - (1) Chemistry
- 2. Yale University, New Haven
  - (1) Chemistry
  - (2) Botany and Microbiology
  - (3) Physiological Chemistry
  - (4) Physics
- 3. Yale University School of Medicine, New Haven

DELAWARE
- 1. The Biochemical Research Foundation, Newark
  - (1) Physics

DISTRICT OF COLUMBIA
- 1. Carnegie Institution of Washington, Washington
  - (1) Biophysics

DISTRICT OF COLUMBIA—Con.
- 2. Naval Research Laboratory, Washington
  - (1) Sound Division, Crystal Section
- 3. National Bureau of Standards, U. S. Department of Commerce, Washington
  - (1) Mass Spectrometry
- 4. National Research Council, Washington
  - (1) Medical Sciences

GEORGIA
- 1. Emory University, Emory University
  - (1) Physics

ILLINOIS
- 1. Armour Research Foundation, Chicago
- 2. Bradley University, Peoria
  - (1) Chemistry
- 3. University of Chicago, Chicago
  - (1) Chemistry
  - (2) Biochemistry
  - (3) Nuclear Studies
  - (4) Physics
- 4. University of Illinois, Urbana
  - (1) Chemistry
  - (2) Physics
- 5. Illinois Institute of Technology, Chicago
  - (1) Physics
- 6. Northwestern University, Evanston
  - (1) Chemistry

INDIANA
- 1. Eli Lilly and Company, Indianapolis
  - (1) Chemistry
- 2. Indiana University, Bloomington
  - (1) Physics
- 3. University of Notre Dame, Notre Dame
  - (1) Physics
- 4. Purdue University, Lafayette
  - (1) Physics
- 5. Sinclair Refining Company, East Chicago
  - (1) Research and Development
- 6. Standard Oil Company, Whiting
  - (1) Research

IOWA
- 1. State University of Iowa, Iowa City
  - (1) Physics

KANSAS
- 1. University of Kansas, Lawrence
  - (1) Chemistry

LOUISIANA
1. Louisiana State University, Baton Rouge
   (1) Chemistry
2. Tulane Medical School, New Orleans
   (1) Medicine
3. Tulane University, New Orleans
   (1) Physics

MARYLAND
1. Army Chemical Center, Chemical Corps, Frederick
   (1) Research and Development.
2. Johns Hopkins University, Baltimore
   (1) Chemistry
   (2) Physics
3. Johns Hopkins University, Silver Spring
   (1) Applied Physics Laboratory
4. National Institute of Health, Bethesda
   (1) Physiology

MASSACHUSETTS
1. Harvard University, Cambridge
   (1) Chemistry
   (2) Physics
2. Harvard Medical School, Boston
   (1) Biochemistry
   (2) Surgery
3. Massachusetts Institute of Technology, Cambridge
   (1) Chemistry
   (2) Physics
   (3) Electronics
   (4) Food Technology
   (5) Spectroscopy Laboratory
4. Metal Hydrides, Inc., Beverly.
5. National Research Corporation, Cambridge

MICHIGAN
1. Dow Chemical Company, Midland
   (1) Spectroscopy Laboratory
2. University of Michigan, Ann Arbor
   (1) Physics
3. Michigan State College, Lansing
   (1) Chemistry
   (2) Physics
4. Upjohn Company, Kalamazoo
   (1) Research

MINNESOTA
1. University of Minnesota, Minneapolis
   (1) Botany
   (2) Physics
   (3) University Farm

MISSOURI
1. Washington University, St. Louis
   (1) Chemistry
   (2) Physics
2. Washington University School of Medicine, St. Louis

MONTANA
1. Montana State University, Missoula
   (1) Physics

NEW JERSEY
1. Bell Telephone Laboratories, Inc., Murray Hill
2. Merck and Company, Inc., Rahway
   (1) Physical and Inorganic Research
   (2) Research and Development Laboratory
3. Princeton University, Princeton
   (1) Physics
4. Rutgers University, New Brunswick
   (1) Physics
5. Vickers, Inc., Red Bank
   (1) Otto Saslaw Laboratory

NEW YORK
1. College of the City of New York, New York City
2. Columbia University, New York City
   (1) Biochemistry
   (2) Chemistry
   (3) Physics
3. Cornell University, Ithaca
   (1) Chemistry
   (2) Nuclear Studies
4. Cornell University Medical School, New York City
   (1) Biochemistry
5. General Electric Company, Schenectady
   (1) Research
6. New York State Psychiatric Institute, New York City
   (1) Biochemistry
7. New York University, New York City
   (1) Experimental Surgery
   (2) Physics
8. New York University College of Medicine, New York City
9. Queens College, Flushing
   (1) Chemistry
10. University of Rochester, Rochester
   (1) Chemistry
   (2) Physics
11. Sloan-Kettering Institute for Cancer Research, New York City
12. Syracuse University, Syracuse
   (1) Physics
13. The Texas Company, New York City

NORTH CAROLINA
1. Duke University, Durham
   (1) Chemistry

OHIO
1. Battelle Memorial Institute, Columbus
   (1) Fuels Division
2. B. F. Goodrich Company, Akron
3. Brush Development Company, Cleveland
   (1) Crystal Research
4. Monsanto Chemical Company, Dayton
   (1) Central Research
5. Ohio State University, Columbus
   (1) Physics
6. Western Reserve University, Cleveland
   (1) Biochemistry

OKLAHOMA
1. University of Oklahoma, Norman
   (1) Physics
2. Phillips Petroleum Company, Bartlesville

PENNSYLVANIA
1. Allied Chemical and Dye Corporation, Barrett Division, Philadelphia
2. Bartol Research Foundation, Swarthmore
3. Gulf Research and Development Company, Pittsburgh
   (1) Physics
4. Jefferson Medical College, Philadelphia
   (1) Biochemistry
5. Lehigh University, Bethlehem
   (1) Physics
6. Mellon Institute, Pittsburgh
7. Pennsylvania State College, State College
   (1) Chemistry
8. University of Pennsylvania, Philadelphia
   (1) Physics

PENNSYLVANIA—Continued
9. University of Pittsburgh, Pittsburgh
   (1) X-Ray Laboratory
   (2) Engineering
   (3) Physics
10. Presbyterian Hospital, Philadelphia
11. Sun Oil Company, Marcus Hook
12. Temple University Hospital, Philadelphia
   (1) Obstetrics and Gynecology
13. U. S. Bureau of Mines, Pittsburgh
   (1) Chemistry
14. Westinghouse Electric Corporation, Pittsburgh
   (1) Research Laboratories
15. Westinghouse Research Laboratories, East Pittsburgh

TEXAS
1. Baylor University Hospital, Dallas
   (1) Biophysics
2. Humble Oil and Refining Company, Baytown
   (1) Research and Development
3. Rice Institute, Houston
   (1) Physics
4. Southwestern Medical College, Dallas
   (1) Medicine
5. University of Texas, Austin
   (1) Chemistry
   (2) Medical Branch
   (3) Physics

UTAH
1. University of Utah School of Medicine, Salt Lake City

VIRGINIA
1. University of Virginia, Charlottesville
   (1) Physics

WISCONSIN
1. University of Wisconsin, Madison
   (1) Agricultural Bacteriology
   (2) Chemistry
   (3) Physics

# APPENDIX 5

## BIBLIOGRAPHY ON ISOTOPE UTILIZATION

*This bibliography contains a partial list of scientific papers published during 1946, 1947, and 1948 as the result of research work with isotopes. The papers listed are those that have come to the attention of the Isotopes Division of the Atomic Energy Commission.*

*MDDC reports (recently changed to AECD) represent unclassified and declassified reports prepared and issued by the Manhattan District and the Atomic Energy Commission. Many of these documents are on sale at the Atomic Energy Commission, Document Sales Agency, Oak Ridge, Tennessee, or may also be obtained through the Office of Technical Services, Department of Commerce. Price lists of documents for sale to the public may be obtained on request from:*

U. S. Atomic Energy Commission
Document Sales Agency
P. O. Box 62
Oak Ridge, Tenn.

### Biological and Medical Research

### Animal Physiology

#### PART I MDDC AND AECD REPORTS


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"Handling of Radioactive Materials in the Experimental Biology Section", Broido, A., Tompkins, P. C., Teresi, J. D. *MDDC 377.*
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"Short-Lived Metastable State in an 'Even-Even' Nucleus: $Ge^{72}$", Bowe, J. C., Goldhaber, M., Hill, R. D., Meyerhof, W. E., and Sala, O. *Bulletin of American Physical Society,* December (1947).
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## Symposia on Isotope Utilization

### ATOMIC ENERGY FORUM SPONSORED BY AMERICAN PHARMACEUTICAL MANUFACTURER'S ASSOCIATION

### *The Waldorf-Astoria, New York, N. Y., December 9–11, 1946*

"Atomic Energy in The Physical Sciences." Allison, S. K., Institute for Nuclear Studies, University of Chicago, Chicago, Ill.
"General Medical Aspects of Atomic Energy." Krusen, F. H., Mayo Clinic, Rochester, Minn.
"Nuclear Physics and Medical Research." Failla, G., Columbia University, New York, N. Y.
"Physiological Reactions to Radioactive Isotopes." Warren, S., Harvard University, Cambridge, Mass.
"Use of Radioactive Isotopes by the Pharmaceutical Profession." Aebersold, P. C., Isotopes Division, Atomic Energy Commission, Oak Ridge, Tenn.

### THE USE OF ISOTOPES IN BIOLOGICAL RESEARCH SPONSORED BY THE COMMITTEE ON GROWTH OF THE NATIONAL RESEARCH COUNCIL

### *The University of Chicago, March 3–4, 1947*

"Assay of C 14." Shonka, F. R., Argonne National Laboratory, Chicago, Ill. Discussion: Libby, W. F., University of Chicago, Chicago, Ill.
"Assay of C 14 and Other Radioactive Materials." Henriques, Jr., F. C., University of California, Berkeley, Calif. Discussion: Borkowski, C. J., Clinton Laboratories, Oak Ridge, Tenn.
"Assay of Stable Isotopes." Nier, A. O. C., University of Minnesota. Minneapolis, Minn. Discussion: Thode, H. G., McMaster University, Westdale, Canada, and Moyer, B. J., University of California, Berkeley, Calif.
"Biosynthesis with the Use of Isotopes." Barker, H. A., University of California, Berkeley, Calif. Discussion: Kamen, M., Washington University, St. Louis, Mo.
"Synthesis of Nitrogen Compounds." Shemin, D., Columbia University, New York, N. Y. Discussion: Bloch, K., University of Chicago, Chicago, Ill., and Burris, R. H., University of Wisconsin, Madison, Wis.
"Synthetic Procedures Involving Isotopic Carbon." Gurin, S., University of Pennsylvania, Philadelphia, Pa. Discussion: Marvel, C., University of Illinois, Urbana, Ill., and Weinhouse, S. Houdry Process Corporation, Marcus Hook, Pa.
"Synthetic Reactions Involving Hydrogen." Rittenberg, D., Columbia University, New York, N. Y. Discussion: Stetten, D., Harvard University, Cambridge, Mass.
"Synthetic Reactions Involving Sulfur and Other Elements of Biological Interest (excluding carbon, nitrogen, hydrogen)." Tarver, H., University of California Medical School, San Francisco, Calif.

***Discussions Initiated by the Speaker Indicated:***

"Discussion of Desirable Intermediates for Synthetic Work." Kenyon, W. O., Eastman Kodak Co., Rochester, N. Y.
"Discussion of Procedure for Earliest Publication of Technical Details of Assay and Synthesis During the Coming Year, and the Possibility of Some Central Agency Receiving and Distributing Such Information." Aebersold, P. C., Isotopes Division, Atomic Energy Commission, Oak Ridge, Tenn.
"Health Hazards and Restrictions on the Use of Isotopes in Human Experimentation." Brues, A. M., Argonne National Laboratory, Chicago, Ill.
"Opinions as to the Relative Need for Various Radioactive and Stable Isotopes." Urey, H. C., University of Chicago, Chicago, Ill.

METABOLIC ASPECTS OF CONVALESCENCE SPONSORED BY JOSIAH MACY, JR., FOUNDATION

## *Hotel Beekman, New York, N. Y., March 31–April 1, 1947*

"Application of Compounds Labelled with Heavy and Radioactive Isotopes to Metabolic Studies. The Role of Arginase in Protein Formation." Rittenberg, D., Columbia University, New York, N. Y.

"Chemical Methods and Their Limitations: Practical Problems in the Synthesis of Labelled Compounds." Brown, G. B., Memorial Hospital, New York, N. Y.

"Clinical Methods and Their Limitations: Practical Problems and Hazards in the Application of Labelled Compounds to Clinical Investigation." Bale, W. F., University of Rochester, Rochester, N. Y.

"Gamma and Beta-Ray Hazards: The Diagnosis of Early Radiation Injury." Hempelmann, L., Los Alamos Scientific Laboratory, Los Alamos, N. Mex.

"General Considerations in the Use of Radioactive and Stable Compounds." Evans, E. A., University of Chicago, Chicago, Ill.

"Illustrative Problems in the Synthesis of Labelled Compounds." Stetten, D., Harvard University, Cambridge, Mass.

"A Method for Improving the Measurement of Radioactive Isotopes." Armstrong, W. D., University of Minnesota, Minneapolis, Minn.

"Organized Research with Compounds Labelled with Radioactive Sulfur." Gyorgy, P., University of Pennsylvania, Philadelphia, Pa.

"Physical Methods and Their Limitations: Practical Problems in the Measurement of Labelled Compounds." Evans, R. D., Massachusetts Institute of Technology, Cambridge, Mass.

"Problems in the Use of Radioactive Iodine." Rawson, R. W., Massachusetts General Hospital, Boston, Mass.

"The Role of the Atomic Energy Commission in the Future Work with Isotopes." Aebersold, P. C., Isotopes Division, Atomic Energy Commission, Oak Ridge, Tenn.

"Some Practical Points in the Measurement of Isotopes." Marshak, A., U. S. Public Health Service, New York, N. Y.

"Some Problem in the Measurement of Labelled Compounds." Marinelli, L. D., Memorial Hospital, New York, N. Y.

"Tracer Studies From a General Biological Viewpoint." Kamen, M. D., Washington University, St. Louis, Mo.

THE USE OF RADIOACTIVE ISOTOPES AS TRACERS AND THERAPEUTIC AGENTS SPONSORED BY VANDERBILT UNIVERSITY

## *Nashville, Tenn., April 21–25, 1947*

"Availability of Isotopes from the Cyclotron and Pile." Cohn, W. E., Clinton Laboratories, Oak Ridge, Tenn.

"Criteria for Use of Radioactive Isotopes in Therapy." Sheppard, C. W., Vanderbilt University, Nashville, Tenn.

"The Cyclotron and the Chain-Reacting Uranium Pile." Aebersold, P. C., Isotopes Division, Atomic Energy Commission, Oak Ridge, Tenn.

"Demonstration of Typical Tracer Experiment." Hahn, P. F., Sheppard, C. W., Goodell, J. P. B. and Oettinger, L., Vanderbilt University, Nashville, Tenn.

"General Aspects of the Use of Isotopes as Tracers." Bale, W. F., University of Rochester, Rochester, N. Y.

"Handling Radioactive Isotopes in the Hospital and Small Laboratory." Goodell, J. P. B., Vanderbilt University, Nashville, Tenn.

"Health Physics: Problems in Protection from Radiation." Morgan, K. Z., Clinton Laboratories, Oak Ridge, Tenn.

"The Interaction of Radiation with Matter: Chemical and Biological Effects." Hollaender, A., Clinton Laboratories, Oak Ridge, Tenn.

"The Measurement of Radiations by Various Methods." Borkowski, C. J., Clinton Laboratories, Oak Ridge, Tenn.

"Monitoring Equipment in the Use of Isotopes." Morgan, K. Z., Clinton Laboratories, Oak Ridge, Tenn.

"The Nuclear Structure of Matter." Nordheim, L. W., Clinton Laboratories, Oak Ridge, Tenn.

"The Precise Measurement of Radiations." Peacock, W. C., Massachusetts Institute of Technology, Cambridge, Mass.
"Principles of Radioactivity." Slack, F. G., Vanderbilt University, Nashville, Tenn.
"Studies on Blood Volume and Shock Using Tagged Red Blood Cells." Gibson, II, J. G., Harvard Medical School, Boston, Mass.
"Use of Isotopes in Metabolic Studies." Ross, J. F., Boston University School. of Medicine, Boston, Mass.
"Use of Radioactive Phosphorus in Therapy." Reinhard, E. H. Washington University, St. Louis, Mo.
*Round Table Discussion.*—"Scientific Cooperation in the Use of Isotopes in Biology and Medicine."
*Panel Discussion.*—"Problems of Radioactive Standards." Peacock, W. C., presiding.
"The Leukemias." Handen, R. L., Cleveland Clinic, Cleveland, Ohio.
"Red Cell Preservatives as Studied with Tagged Cells." Ross, J. F., Boston University School of Medicine, Boston, Mass.
*Panel Discussion.*—"Recent and Future Developments in Isotope Tracer Studies."
"Use of Radioactive Manganese and Gold in the Therapy of Malignant Disease." Hahn, P. F., and Sheppard, C. W., Vanderbilt University, Nashville, Tenn.
(1) "Avenues of Investigation in Isotope Therapy."
(2) "Demonstration of Clinical Subjects Under Isotope Therapy."

## RADIOACTIVE ISOTOPES IN THERAPY OF MALIGNANT DISEASE SPONSORED BY THE AMERICAN ASSOCIATION FOR THE ADVANCEMENT OF SCIENCE

### *New London, N. H., August 12, 1947*

"Radiation Effects on Normal and Malignant Tissues." Goldfeder, A., New York University, New York, N. Y.
"Radioactive Colloidal Sols." Hahn, P. F. and Sheppard, C. W., Vanderbilt University, Nashville, Tenn.
"Radioactive Iodine." Rawson, R. W., Skansa, N. B., Marinelli, L. D., and Fluharty, R. G. Massachusetts General Hospital, Boston, Mass., Memorial Hospital, New York, N. Y., Massachusetts Institute of Technology, Cambridge, Mass.
"Radioactive Phosphorus." Hall, B. E., Mayo Clinic, Rochester, N. Y.

## NUCLEAR PHYSICS IN RELATION TO CANCER, SPONSORED BY AMERICAN ASSOCIATION FOR CANCER RESEARCH

### *Jefferson Hotel, St. Louis, Mo., September 6, 1947*

"The Collection of Radioactive Iodine by Benign and Malignant Tumors of the Thyroid." Rawson, R. W., Dobyns, R. M., Hill, R. and Fluharty, R. G., Massachusetts General Hospital, Boston, Mass., and Massachusetts Institute of Technology, Cambridge, Mass.
"Destruction of Rat Thyroid by Large Doses of Radioiodine I 131." Leblond, C. P. and Findlay, D., McGill University, Montreal, Canada.
"Distribution of Zinc in Normal Blood and Organs Studied by Means of Zn 65." Vallee, B. L., Fluharty, R. G. and Gibson, J. G., Massachusetts General Hospital, Boston, Mass., Massachusetts of Technology, Cambridge, Mass., and Harvard Medical School, Boston, Mass.
"Effects of Urethane on Normal and Leukemic Hemopoietic Tissues of the Mouse." Lu. C. S. and Kirschbaum, A., University of Minnesota Medical School, Minneapolis, Minn.
"Evidence for a Nuclear Precursor to Ribonucleic Acid and Desoxyribonucleic Acid." Marshak, A., U. S. Public Health Service, New York, N. Y.
"The Metabolism in the Mouse of 1:2:5:6—Dibenzanthracene Labeled in the 9—Position with C 14." Heidelberger, C and Jones, H. B., University of California, Berkeley, Calif.
"The Possible Carcinogenic Effect of the Hiroshima and Nagasaki Atomic Bombs." Warren, S., Division of Biology and Medicine, Atomic Energy Commission, Washington, D. C.

"Problems in Production, Distribution and Use of Isotopes." Aebersöld, P. C., Isotopes Division, Atomic Energy Commission, Oak Ridge, Tenn.
"Quantitative Aspects of Radiation Carcinogenesis." Brues, A. M., Argonne National Laboratory, Chicago, Ill.
"Studies of the Zinc Content of the Leucocytes in Myelogenous Leukemia." Gibson, J. G., Vallee, B. L., Fluharty, R. G., and Nelson, J. E., Harvard Medical School, Boston, Mass., Massachusetts General Hospital, Boston, Mass.. and Massachusetts Institute of Technology, Cambridge, Mass.
(To be Announced), Ussing, H. H., Denmark.

THE USE OF ISOTOPES IN BIOLOGY AND MEDICINE SPONSORED BY THE UNIVERSITY OF WISCONSIN

*Madison, Wis., September 10, 11, 12, and 13, 1947*

"Application of Tracer Research to Medicine." Hamilton, J. G., University of California, Berkeley, Calif.
"Detection of Radioactive Isotopes." Coryell, C. D., Massachusetts Institute of Technology, Cambridge, Mass., and Kamen, M. D., Washington University, St. Louis, Mo.
"Detection of Stable Isotopes." Nier, A. O. C., University of Minnesota, Minneapolis, Minn.
"The Future and Atomic Energy." Urey, H. C., University of Chicago, Chicago, Ill., and Daniels, F., University of Wisconsin, Madison, Wis.
"Health Hazards Involved in the Use of Radioactive Isotopes." Bale, W. F., University of Rochester, Rochester, N. Y., and Nickson, J. J., Memorial Hospital, New York, N. Y.
"Historical Background Lecture." Clarke, H. T., Columbia University, New York, N. Y.
"Preparation of Compounds Containing Isotopes." Melville, D. B., Cornell University Medical School, New York, N. Y.
"Preparation of Radioactive Isotopes." Seaborg, G. T., University of California, Berkeley, Calif.
"Preparation of Stable Isotopes." Urey, H. C., University of Chicago, Chicago, Ill.
"Present Development in the Production and Availability of Isotopes." Aebersold, P. C., Isotopes Division, Atomic Energy Commission, Oak Ridge, Tenn.
"Studies on Metabolism of Carbohydrates." Wood, H. G., Western Reserve University, Cleveland, Ohio.
"Studies on Metabolism of Iodine." Chaikoff, I. L., University of California, Berkeley, Calif.
"Studies on Metabolism of Lipids." Bloch, K., University of Chicago, Chicago, Ill.
"Studies on Metabolism of Minerals." Greenberg, D. M., University of California, Berkeley, Calif.
"Studies on Metabolism of Proteins." Sprinson, D. B., Columbia University, New York, N. Y.
"The Therapeutic Use of Radioactive Elements: Leukemia and Polycythemia." Hall, B. E., Mayo Clinic, Rochester, Minn.
"The Therapeutic Use of Radioactive Elements: Thyroid Disease." Hertz, S., Harvard Medical School, Boston, Mass.
*Panel Discussion.*—Plant Metabolism and Photosynthesis. Huskins, C. L., Presiding, University of Wisconsin, Madison, Wis.
 Biddulph, O., Washington State College, Pullman, Wash.
 Calvin, M., University of California, Berkeley, Calif.
 Gaffron, H., University of Chicago, Chicago, Ill.
 Kamen, M., Washington University, St. Louis, Mo.
*Panel Discussion.*—Intermediary Metabolism of Animals. Potter, V. R., Presiding, University of Wisconsin, Madison, Wis.
 Gurin, S., University of Pennsylvania, Philadelphia, Pa.
 Vennesland, B., University of Chicago, Chicago, Ill.
 Weinhouse, S., Houdry Process Corporation, Marcus Hook, Pa.
 Wood, H. G., Western Reserve University, Cleveland, Ohio.
*Panel Discussion.*—Chemical Reactions. Hall, N. F., Presiding, University of Wisconsin, Madison, Wis.

Corvell, C. D., Massachusetts Institute of Technology, Cambridge, Mass.
Daniels, F., University of Wisconsin, Madison, Wis.
Seaborg, G. T., University of California, Berkeley, Calif.
Willard, J. E., University of Wisconsin, Madison, Wis.

*Panel Discussion.*—Bacterial Metabolism and Nitrogen Fixation. Baldwin, I. L., Presiding, University of Wisconsin, Madison, Wis.
Barker, H. A., University of California, Berkeley, Calif.
Burris, R. H., University of Wisconsin, Madison, Wis.
Werkman, C. H., Iowa State College, Ames, Iowa.
Wilson, P. W., University of Wisconsin, Madison, Wis.

*Panel Discussion.*—Cancer. Rusch, H. P., Presiding, University of Wisconsin, Madison, Wis.
Brues, A. M., Argonne National Laboratory, Chicago, Ill.
Cantril, S. T., Swedish Hospital, Seattle, Wash.
Hamilton, J. G., University of California, Berkeley, Calif.

## PREPARATION AND MEASUREMENT OF ISOTOPES FOR USE IN BIOCHEMISTRY—SPONSORED BY AMERICAN CHEMICAL SOCIETY

### *New York, N. Y., September 15–19, 1947*

"Chemical Methods of Isotope Separation." Reid, A. F., Sun Oil Co., Marcus Hook, Pa.
"Determination of Hard Radiation, Including Preparation of Samples." Bale, W. F., University of Rochester, Rochester, N. Y.
"Determination of Soft Radiation, Including Preparation of Samples." Solomon, A. K., Harvard Medical School, Boston, Mass.
"Dosage Levels in Administration of Isotopes to Animals and Man." Lisco, H., Argonne National Laboratory, Chicago, Ill.
"Fundamentals of Isotope Separation." Cohen, K., Standard Oil Development Co., Elizabeth, N. J.
"Hazards Presented by Radioactive Materials and How to Cope with Them." Morgan, K. Z., Clinton Laboratories, Oak Ridge, Tenn.
"Identification of Intermediate Compounds. Criteria of Purity." Kamen, M. D., Washington University, St. Louis, Mo.
"An Illustration of the Power of Isotopes in a Biochemical Problem." du Vigneaud, V., Cornell University Medical School, New York, N. Y.
"Laboratory Handling of Radioactive Material. Protection of Personnel and Equipment." Tompkins, P. C., Clinton Laboratories, Oak Ridge, Tenn.
"Preparation of Samples for Mass Spectrographic Analysis." Sprinson, D. B., Columbia University, New York, N. Y.
"Production of Radioactive Isotopes by the Cyclotron and Other Methods." Irvine, Jr., J. W., Massachusetts Institute of Technology, Cambridge, Mass.
"The Production of Useful Radioactive Isotopes in the Uranium Pile." Cohn, W. E., Clinton Laboratories, Oak Ridge, Tenn.
"Radioautographic Technique." Hamilton, J. G., and Axelrod, D., University of California, Berkeley, Calif.
"Synopsis of Basic Ideas in the Theory of Radioactivity and the Detection of Radiation." Present, R. D., University of Tennessee, Knoxville, Tenn.
"Thermal Diffusion and Other Physical Methods of Isotope Separation." Watson, W. W., Yale University, New Haven, Conn.
"Theory and Practice of the Use of the Mass Spectrometer," Washburn, H. W., Consolidated Engineering Corporation, Pasadena, Calif.

## CONFERENCE IN BIOLOGY AND MEDICINE SPONSORED BY BROOKHAVEN NATIONAL LABORATORY

### *Upton, L. I., N. Y., October 16–18, 1947*

"Handling of Radioactive Materials: Procedures and Demonstration." Tompkins, P. C., Clinton Laboratories, Oak Ridge, Tenn.
"Procurement of Isotopes." Aebersold, P. C., Isotopes Division, Atomic Energy Commission, Oak Ridge, Tenn.

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"Protective Measures for Personnel." Nickson, J. J., Memorial Hospital, New York, N. Y.

"Protective Measures for Public Health." Williams, E. G., U. S. Public Health Service, Bethesda, Md.

"Shipping of Isotopes." Morgan, K. Z., Clinton Laboratories, Oak Ridge, Tenn.

*Panel Discussion.*—Legal Aspects in the Use of Radioactive Materials. Brues, A. M., Presiding, Argonne National Laboratory, Chicago, Ill.

Aebersold, P. C., Isotopes Division, Atomic Energy Commission, Oak Ridge, Tenn.
Dunbar, C. F., Brookhaven National Laboratory, Upton, Long Island, N. Y.
Evans, R. D., Massachusetts Institute of Technology, Cambridge, Mass.
Hollaender, A., Clinton Laboratories, Oak Ridge, Tenn.
Newman, J. R., Yale University, New Haven, Conn.

*Panel Discussion.*—Evaluation of Procedures Used in the Examination of Individuals Exposed to Radioactive Materials. Beller, C., Oklahoma.

Evans, R. D., Massachusetts Institute of Technology, Cambridge, Mass.
Hempelmann, L. H., Los Alamos Scientific Laboratory, Los Alamos, N. Mex.
Howland, J. W., University of Rochester, Rochester, N. Y.
Jacobson, L. O., Argonne National Laboratory, Chicago, Ill.
Lyon, G. M., Isotopes Branch, Veterans' Administration, Washington, D. C.
Parker, H. M., General Electric Nucleonics Project, Richland, Wash.
Warren, S., New England Deaconess Hospital, Boston, Mass.

*Panel Discussion.*—Disposal of Radioactive Materials. Demonstration of Radiation Detection Instruments

Bennett, R., University of Rochester, Rochester, N. Y.
Cowan, F. P., Brookhaven National Laboratory, Upton, Long Island, N. Y.
Deal, L. J., Brookhaven National Laboratory, Upton, Long Island, N. Y.
Kuper, J. B. H., Brookhaven National Laboratory, Upton, Long Island, N. Y.
Rose, J. E., Argonne National Laboratory, Chicago, Ill.
Sacks, J., Brookhaven National Laboratory, Upton, Long Island, N. Y.
Sharp, L. M., Brookhaven National Laboratory, Upton, Long Island, N. Y.
Vyverberg, R. G., University of Rochester, Rochester, N. Y.

## THE USE OF RADIOACTIVE ISOTOPES IN SOIL AND FERTILIZER INVESTIGATIONS, SPONSORED BY AMERICAN SOCIETY OF AGRONOMY AND SOIL SCIENCE SOCIETY OF AMERICA

### *Hotel Netherlands Plaza, Cincinnati, Ohio, November 17–20, 1947*

"Application of Tracer Technique to Studies of Phosphatic Fertilizer Utilization by Crops: I. Greenhouse Experiments." Dean, L. A., Nelson, W. L., MacKenzie, A. J., Armiger, W. H. and Hill, W. L., Bureau of Plant Industry, Soils and Agricultural Engineering, U. S. Department of Agriculture, Beltsville, Md., and North Carolina Agricultural Experiment Station, Raleigh, N. C.

"Application of Tracer Technique to Studies of Phosphatic Fertilizer Utilization by Crops: II. Field Experiments." Nelson, W. L., Krantz, B. A., Colwell, W. E., Hawkins, A., Woltz, W. G., Dean, L. A., MacKenzie, A. J., and Rubins, E. J., North Carolina Agricultural Experiment Station, Raleigh, N. C., and Bureau of Plant Industry, Soils and Agricultural Engineering, U. S. Department of of Agriculture, Beltsville, Md.

"Basic Concepts of Soil and Fertilizer Studies with Radioactive Phosphorus." Hendricks, S. B. and Dean, L. A., Bureau of Plant Industry, Soils and Agricultural Engineering, U. S. Department of Agriculture, Beltsville, Md.

"Exchange Reactions Between Phosphates and Hydroxylic Surfaces of Soil Minerals." McAuliffe, C. D., Hall, N. S., Dean, L. A. and Hendricks, S. B., Cornell University, Ithaca, N. Y., North Carolina Agricultural Experiment Station, Raleigh, N. C., and Bureau of Plant Industry, Soils and Agricultural Engineering, U. S. Department of Agriculture, Beltsville, Md.

"Measurement of Radioactive Phosphorus." Hall, N. S. and MacKenzie, A. J., North Carolina Agricultural Experiment Station, Raleigh, N. C., and Bureau of Plant Industry, Soils and Agricultural Engineering, U. S. Department of Agriculture, Beltsville, Md.

"The Use of Radioactive Tracers in Plant Nutrition Studies." Stout, P. H. Overstreet, R., Jacobson, L. and Ulrich, A., University of California, Berkeley, Calif.

SPONSORED BY RADIOLOGICAL SOCIETY OF NORTH AMERICA, INC.

## *The Statler Hotel, Boston, Mass., November 30–December 1–5, 1947*

"Application of Radioisotopes in Medicine." Aebersold, P. C., Isotopes Division, Atomic Energy Commission, Oak Ridge, Tenn.
"Biological Effects of Fast Neutrons and X-rays." Evans, T. C., Columbia University, New York, N. Y.
"Dosage Problems in the Use of Radioactive Isotopes." Failla, G., Columbia University, New York, N. Y.
"The Measurement of High Energy Ionizing Radiation." Failla, G., Columbia University, New York, N. Y.
"Plans for Brookhaven National Laboratory." Morse, P. M., Brookhaven National Laboratory, Upton, Long Island, N. Y.

*Panel Discussion.*—Radioactive Iodine.

"Clinical Experiences in Diagnosis and Treatment of Toxic Goiter with Radioactive Iodine (8-day half-life)." Werner, S. C. and Quimby, E. H., Columbia University, New York, N. Y.
"Factors Involved in the Experimental Therapy of Metastatic Thyroid Cancer with I 131." Marinelli, D., Hocker, A. H. and Trunell, J., Memorial Hospital, New York, N. Y.
"Radioactive Iodine as a Tool in the Study of Thyroid Physiology." Rawson, R. W., Massachusetts General Hospital, Boston, Mass.
"Radioactive Iodine Studies of Functional Thyroid Carcinoma." Frantz, V. K., New York, N. Y.
"Radioactive Isotopes and Their Use in Problems of the Thyroid Gland." Quimby, E. H. and Werner, S. C., Columbia University, New York, N. Y.
"Treatment of Hyperthyroidism with Radioactive Iodine (8-day half-life)." Chapman, E. M., Massachusetts General Hospital, Boston, Mass.

WINTER MEETING OF THE AMERICAN SOCIETY OF AGRICULTURAL ENGINEERS SPONSORED BY NATIONAL JOINT COMMITTEE ON FERTILIZER APPLICATION

## *Stevens Hotel, Chicago, Ill., December 15–17, 1947*

*Panel Discussion.*—Radioactive Applications To Agriculture.

Nelson, W. L., North Carolina Agricultural Experiment Station, Raleigh, N. C.
Sauchelli, V., The Davison Chemical Corporation, Baltimore, Md.
Woodruff, N. H., Isotopes Division, Atomic Energy Commission, Oak Ridge, Tenn.

THE USE OF RADIOACTIVE ISOTOPES IN AGRICULTURAL RESEARCH SPONSORED BY THE ALABAMA POLYTECHNIC INSTITUTE AND THE OAK RIDGE INSTITUTE OF NUCLEAR STUDIES

## *Auburn, Ala., December 18, 19, and 20, 1947*

"Agricultural Research with Radiophosphorus." Hendricks, S. B., U. S. Department of Agriculture, Beltsville, Md.
"Agricultural Research with Radioactive Sulfur and Arsenic." Thomas, M. D., American Smelting & Refining Co., Salt Lake City, Utah.
"Contributions of the Atomic Energy Commission to Agricultural Research." Representative of U. S. Atomic Energy Commission, Introduced by Franklin, J. C.
"Demonstration of a Typical Tracer Experiment." Overman, R. T., Oak Ridge National Laboratory, Oak Ridge, Tenn.
"Induced and Naturally Occurring Mutations in Relation to Heterosis and their Value in Plant and Animal Improvement." Jones, D. F., Connecticut Agricultural Experiment Station, New Haven, Conn.
"Isotopes Available for Research." Aebersold, P. C., Isotopes Division, Atomic Energy Commission, Oak Ridge, Tenn.
"The Measurements of Radiation by Various Methods." McDaniel, P. W., Atomic Energy Commission, Washington, D. C.
"Nutrition Studies with Radiocobalt and Radiocopper." Comar, C. L. and Davis, G. K., U. S. Department of Agriculture, Gainesville, Fla.

"Protective Precautions in the Handling of Radioactive Materials." Morgan, G. W., Isotopes Division, Atomic Energy Commission, Oak Ridge, Tenn.
"Radioactivity and Radioisotopes." Allison, F., Alabama Polytechnic Institute, Auburn, Ala.
"Some Biological and Medical Uses of Radioactive Isotopes." Copp, D., University of California Radiation Laboratory, Berkeley, Calif.
"Studies of Chlorosis Using Radioactive Phosphorus and Iron." Biddulph, O., University of Washington, Pullman, Wash.
"Techniques of Tagged Atom Research." Arnold, W. Oak Ridge National Laboratory, Oak Ridge, Tenn.
"Tracer Studies with C 14-Urethan." Skipper, H. B., University of Alabama, Birmingham, Ala.

## SYMPOSIUM SPONSORED BY AMERICAN ASSOCIATION FOR THE ADVANCEMENT OF SCIENCE AND ASSOCIATED SOCIETIES

### *Chicago, Ill., December 26–31, 1947*

*Isotopic Tracers in Photosynthesis.*

"C 14 and P 32 in the Dark Fixation Reaction of Different Algae." Kamen, M. D., Washington University, St. Louis, Mo.
"C 14 in Photosynthesis." Calvin, M. and Benson, H., University of California, Berkeley, Calif.
"C 14 in Photosynthesis." Gaffron, H., Brown, A. H., and Fager, E. W., University of Chicago, Chicago, Ill.
"Theories of Photosynthesis." Franck, J., University of Chicago, Chicago, Ill.

*Radioactive Isotopes in Plant Physiological Research.*

"The Assay of Isotopes Which Emit Low Energy Beta Rays." Shonka, F. R., Argonne National Laboratory, Chicago, Ill.
"The Movement of Inorganic Solutes into Plants as Revealed by the Use of Radioactive Isotopes." Broyer, T. C., University of California, Berkeley, Calif.
"The Role of Iron in the Formation of Chlorophyll." Miller, A. and Knorr, H. V., Antioch College, Yellow Springs, Ohio.
"The Use of Carbon 14 as a Tracer in Studies of the First Products of Photosynthesis." Brown, A. H., Gaffron, H. and Fager, E. W., University of Chicago, Chicago, Ill.
"The Use of Radioactive Iodine in the Study of Growth-Regulating Substances." Mitchell, J. W., Wood, J. and Irving, G., University of Tennessee, Memphis, Tenn.

*Subsection on Pharmacy.*

"The Application of Radioactive Tracer Techniques to Pharmacy and Pharmaceutical Research." Christian, J., Purdue University, Lafayette, Ind.
"A Comparative Study of the Effect of Various Solutions on the Phosphorus Depletion of the Rat Tooth Using Radioactive Phosphorus." Jarvis, A. E., Pittman-Moore & Co., Indianapolis, Ind.
"The Determination of Residues of Applied Phospholipids and Alkyl Sulfates on Rat Skin Using Radioactive Tracers." Thoms, R. K., Edwards, L. D. and Christian, J. E., Purdue University, Lafayette, Ind.

*Panel Discussion.*—Application of Radioactive Tracers in Pharmaceutical and Medical Research.

Calvin, M., University of California, Berkeley, Calif.
Christian, J. E., Purdue University, Lafayette, Ind.
Rice, W. J., Eli Lilly and Company, Indianapolis, Ind.
Tabern, D. L., Abbott Laboratories, North Chicago, Ill.

*Other Papers Presented on Atomic Energy Developments*

"Action of Temperature During X-Ray Treatment of Tradescantia Chromosomes." Faberge, A. C., University of Missouri, Columbia, Mo.
"Appraisal of Atomic Energy Progress." Morrison, P., Cornell University, Ithica, N. Y.
"Beta and Gamma Rays of Ga (72)." Mitchell, A. C. G., Kern, B. D. and Zafarano, D. J., University of Indiana, Bloomington, Ind.

"Boron Deficiency Symptoms in Apricots." Bullock, R. M. and Benson, N. R., Tree Fruit Branch Station, Wenatchee, Wash.

"Brookhaven Laboratory and Plans for Fundamental Research in the Atomic Energy Commission." Haworth, L. J., Brookhaven National Laboratory, Upton, Long Island, N. Y.

"Chemical Effects of Hydrogenous Neutron Moderators." Dodgen, H., University of Chicago, Chicago, Ill.

"Chemistry of the Isomeric Transition of Br 80." Devault, D., University of Chicago, Chicago, Ill.

"Chromosome Irregularities Produced by Atomic Irradiation." Brown, M. S., Texas Agricultural Experiment Station, College Station, Tex.

"Concentration of I 131 by the Thyroid Gland of the Bermuda Parrot Fish." Matthews, S. A. and Smith, D. C., Williams College, Williamstown, Mass., and University of Maryland, College Park, Md.

"Death After Autogamy in *Paramecium Aurelia* Following Exposure in Solution to the Radioactive Isotopes P 32 and Sr 89, 90 and Y 90." Powers, Jr., E. L., Argonne National Labortory, Chicago, Ill.

"Developments of Atomic Energy at the Argonne National Laboratory." Zinn, W., Argonne National Laboratory, Chicago, Ill.

"Direct Determination of Oxygen in Petroleum Products." Dinerstein, R. A. and Clipp, R. W., Standard Oil Co., Whiting, Ind.

"The Distribution of Copper in the Early Chick Embryo." Smith, E. and Gray, P., University of Pittsburgh, Pittsburgh, Pa.

"Effects of Heat on Breakage of Chromosomes by X-radiation." Gaulden, M. E. University of Tennessee, Knoxville, Tenn.

"The Effects of Pile Bombardment on Uncured Elastomers." Davidson, W. L. and Geib, I. G., B. F. Goodrich & Co., Akron, Ohio.

"The Effects of Single Dose Total Body X-Irradiation on the Peripheral Blood of the Rat." Sterner, S. P., Simmons, E. L. and Jacobson, L. O., Argonne National Laboratory, Chicago, Ill.

"The Eight New Synthetic Elements." Seaborg, G. T., University of California, Berkeley, Calif.

"The Electro-Disintegration of Cu (63), Ag (107) and Ag (109)." Laughlin, J. S., et al., University of Illinois, Urbana, Ill.

"Energy Dependence of Fission Yield Curve in Thorium." Turkevich, A., University of Chicago, Chicago, Ill.

"Fischer-Tropsch Reaction Rates on Cobalt Catalyst." Anderson, R. B. and Krieg, A., U. S. Department of Interior, Bureau of Mines, Pittsburgh, Pa.

"Fission Yields in Uranium 233." Steinberg, E. P., Seiler, J. A., Goldstein, A. and Dudley, A., Argonne National Laboratory, Chicago, Ill.

"Gamma Radiation From Sc, Ce and Te." Cork, J. M., Shreffler, R. G. and Fowler, C. M., University of Michigan, Ann Arbor, Mich.

"The Hyperfine Structure of K (40)." Davis, Jr., L. and Zacharias, J. R., Massachusetts Institute of Technology, Cambridge, Mass.

"Increase in I 131 Uptake of Thyroid After Whole Body Roentgen Irradiation." Evans, T. C., Clarke, G. and Sobel, E., Columbia University, New York, N. Y.

"Induction of Mutations in *Paramecium Aurelia* by Beta Radiation." Kimball, R. F., Clinton Laboratories, Oak Ridge, Tenn.

"The Intermediate Nucleus and the Liquid Drop Model." Harkins, W. D., University of Chicago, Chicago, Ill.

"Isotopic Analysis of the Oxygen Evolved by Illuminated Chloroplasts Suspended in Normal Water and in Water Enriched with O 18." Holt, A. S. and French, C. S., Clinton Laboratories, Oak Ridge, Tenn., and Stanford University, Stanford, Calif.

"Kinetics of Iodate-Iodine Exchange Reaction." Myers, O. E. and Kennedy, J. W., Washington University, St. Louis, Mo.

"The 4N+1 Radioactive Series." Katzin, L., Argonne National Laboratory, Chicago, Ill.

"Natural Radioactivity of Rhenium." Naldrett, S. N. and Libby, W. F., University of Chicago, Chicago, Ill.

"A New Era in Coal Technology." Hockett, S. W., Iowa Wesleyan College, Mt. Pleasant, Iowa.

"A New Radioactive Series." Studier, M. and Hyde, E., Argonne National Laboratory, Chicago, Ill.

"The Nitrogen Metabolism of Women." Ohlson, M. A., Michigan State College, East Lansing, Mich.

"Potassium Deficiency in Two Peach Orchards in Maryland." Schrader, A. L., Dunbar, C. O. and Scott, L. E., University of Maryland, College Park, Md.

"Practical Applications of Tantalum in Industrial Chemical Processes." Scribner, L. R., Fansteel Metallurgical Corporation, North Chicago, Ill.

"Radiation Injury and Trauma as Factors in the Regression of X-rayed Non-regenerating Limb Stumps of Urodele Larvae." O'Brien, J. P., Marquette University, Milwaukee, Wis.

"Radioactive Isotopes and Their Application to Peacetime Use of Atomic Energy." Aebersold, P. C., Isotopes Division, Atomic Energy Commission, Oak Ridge, Tenn.

"Radioactive Selenium 73 and 75." Cowart, W. S. and Pool, M. L., Ohio State University, Columbus, Ohio.

"Radioactivity Measurement Techniques." Pannell, J. H., Natick, Mass.

"Radiosensitivity in Relation to Metabolic Rate in Urodele Larvae." O'Brien, J. P., Marquette University, Milwaukee, Wis.

"Radiocarbon From Cosmic Radiation." Anderson, E. C. and Libby, W. F., University of Chicago, Chicago, Ill.

"Relative Effectiveness of Different Intensities of Gamma Radiation in Retarding Mitosis in the Grasshopper Neuroblast." Carlson, J., Snyder, M. L. and Hollaender, A., Clinton Laboratories, Oak Ridge, Tenn.

"The Relative Effectiveness of Fast Neutrons and Gamma Rays in Producing Somatic Crossing Over in Drosophila." Lefevre, Jr. G., Clinton Laboratories, Oak Ridge, Tenn.

"The Role of Zinc in Auxin Synthesis in the Tomato Plant." Tsue, C., University of Wisconsin, Madison, Wis.

"Scientists and the Atomic Energy Program." Waymack, W. W., Atomic Energy Commission, Washington, D. C.

"Search for Weak Natural Radioactivities by the Method of Active Daughter Extraction." Kohman, T. P., Argonne National Laboratory, Chicago, Ill.

"Short-Lived Halogen Fission Products." Sugarman, N., University of Chicago, Chicago, Ill.

"Some Inter-relationships Between Ca, Mg and K in One-Year Old Apple Trees Grown in Sand Culture." Cain, J. C., New York Agriculture Experiment Station, Geneva, N. Y.

"Studies on Aerobic Phosphorylations." Lehninger, A. L., University of Chicago, Chicago, Ill.

"Studies on Sodium, Potassium and Water Balance in Insects." Tobias, J. M., University of Chicago, Chicago, Ill.

"Technique of Putting Radioactive Phosphorus into Corn Grain." Jacobson, H. G. M., Connecticut Agricultural Experiment Station, New Haven, Conn.

## BIOLOGICAL APPLICATIONS OF TRACER ELEMENTS SPONSORED BY LONG ISLAND BIOLOGICAL ASSOCIATION

### *Cold Spring Harbor, Long Island, N. Y., June 8–16, 1948*

"Amino Acid Metabolism in *Torulopis* Utilis." Ehrensvard, G., Wenner-Gren Institute, University of Stockholm, Stockholm, Sweden.

"The Application of the Isotope Technique to the Study of the Intermediary Metabolism of Glycine." Rittenberg, D., Columbia University, New York, N. Y.

"Biological Oxidation of Fatty Acids." Hurin, S., and Crandall, D. I., University of Pennsylvania School of Medicine, Philadelphia, Pa.

"The Biological Synthesis of Porphyrins." Shemin, D., Columbia University, New York, N. Y.

"Biosynthesis of Lipids." Bloch, K., University of Chicago, Chicago, Ill.

"C 14 in Photosynthesis." Gaffron, H., University of Chicago, Chicago, Ill.

"Chromosome Breakage Induced by Absorbed Radioactive Phosphorus." Arnason, T. J., University of Saskatchewan, Saskatoon, Canada.

"Comparative Metabolism of Radium, Strontium, and Calcium." Norris, W. P., Argonne National Laboratory, Chicago, Ill.

"Cytogenetical Effects of Internal Radiations from Radioisotopes." Giles, Jr., N. H. and Hollaender, A., Oak Ridge National Laboratory, Oak Ridge, Tenn.

"Design and Interpretation of Carbon-Isotope Experiments in Bacterial Metabolism," Carson, S. F., Oak Ridge National Laboratory, Oak Ridge, Tenn.

"Experiments with N 15 on Purines from Nuclei of Normal and Regenerating Liver." Hammarsten, E., Karolinska Institutet, Stockholm, Sweden.

"Formation of Lipids by the Microorganisms *Phycomyces Blakesleeanus*." Bernhard, K., University of Zurich, Zurich, Switzerland.

"Historical Sketch of the Biological Application of Tracer Elements." Hevesy, G., University of Stockholm, Stockholm, Sweden.
"Mechanism of Phosphate Transfer Across Cell Membranes." Sacks, J., Brookhaven National Laboratory, Upton, Long Island, N. Y.
"Photosynthesis." Calvin, M., University of California, Berkeley, Calif.
"Recent studies on the Metabolism of Fixation of Formic Acid and $CO_2$." Wood, H. G., Western Reserve University School of Medicine, Cleveland, Ohio.
"Studies on Capillary Permeability with Tracer Substances." Flexner, L. B., Carnegie Institution of Washington, Baltimore, Md.
"Studies on the Mechanism of Protein Synthesis with Radioactive Carbon-Labeled Compounds." Greenberg, D. M., Friedberg, F., Schulman, M. P., and Winnick, T., University of California, Berkeley, Calif.
"Studies of the Over-All $CO_2$ Metabolism of Tissues and Total Organisms." Brues, A. M., and Buchanan, D. I., Argonne National Laboratory, Chicago, Ill.
"Studies of Purine Metabolism." Brown, G. B., Sloan-Kettering Institute for Cancer Research, New York, N. Y.
"Tracer Studies in Phosphate Metabolism of Unicellular Organisms." Kamen, M. D., and Spiegelman, S., Washington University School of Medicine, St. Louis, Mo.
"Tracer Studies with Radiosodium in Man." Burch, G. E., Tulane University School of Medicine, New Orleans, La.
"The Use of Isotopes in Obtaining Data for an Integral Equation Description of Metabolizing Systems." Branson, H., Howard University, Washington, D. C.
"The Use of the O 18 Isotope." Bentley, R., National Institute for Medical Research, London, England.
"The Use of Tracers in the Study of Active Ion Transport Across Animal Membranes." Ussing, H. H., University of Copenhagen, Copenhagen, Denmark.

## BIOLOGY CONFERENCE SPONSORED BY BROOKHAVEN NATIONAL LABORATORY

### *Upton, Long Island, N. Y., July 26–30, 1948*

*Health Physics.*—Nims, L. F., Presiding, Brookhaven National Laboratory, Upton, Long Island, N. Y.
"Basic Concepts in Radiation Protection." Wolf, B. S., Aatomic Energy Commission, New York, N. Y.
"Health Physics—Laboratory Problems." Merkle, C. R. E., Brookhaven National Laboratory, Upton, Long Island, N. Y.
"Health Physics—Practice." Cowan, F. P., Brookhaven National Laboratory, Upton, Long Island, N. Y.
"Measurements of Tissue Dose of Ionizing Radiation." Failla, G., Columbia University, New York, N. Y.
*Isotope Applications.*—Nims, L. F. Presiding, Brookhaven National Laboratory, Upton, Long Island, N. Y.
"Biosynthesis." Gibbs, M., Brookhaven National Laboratory, Upton, Long Island, N. Y.
"Isotope Techniques in Intermediary Metabolism." Radin, N. R., Columbia University, New York, N. Y.
"Radioiron—Review." Sharpe, L. M., Brookhaven National Laboratory, Upton, Long Island, N. Y.
"Radiophosphorus in Study of Intermediary Metabolism." Sacks, J., Brookhaven National Laboratory, Upton, Long Island, N. Y.
"Use of Tracers in Analysis of Substances of Biological Interest." Keston, A. S., New York University, New York, N. Y.
*Symposium on Radioiodine—Physiology.*—Salter, W. T., Presiding, Yale University School of Medicine, New Haven, Conn.
"The Mechanism of Action of Anti-Thyroid Drugs." Astwood, E. B. and Stanley, M. M., Pratt Diagnostic Hospital, Boston, Mass.
"Radioiodine as a Tool in Evaluating the Functions and Certain Physiological Aspects of Thyroid Tumors." Rawson, R. W., Memorial Hospital New York, N. Y.
"Some Effects of Radioiodine on the Function of the Thyroid." Skansa, B., Massachusetts General Hospital, Boston, Mass.
*Laboratory Topics.*—Nims, L. F., Presiding, Brookhaven National Laboratory, Upton, Long Island, N. Y.
"Calculation of Dosage in Radioiodine Therapy: I. Dosage to the Patient. II. Radiation Hazard." Quimby, E., Columbia University, New York, N. Y.

"Standardization of Radioiodine." Feitelberg, S., Mt. Sinai Hospital, New York, N. Y.

"Uptake and Excretion Measurements and their Significance." Oshry, E. and Schmidt, S., Monetfiore Hospital, New York, N. Y., and Presbyterian Hospital, New York, N. Y.

*Hyperthyroidism.*—Hertz, S., Presiding, Beth Israel Hospital, Boston, Mass.

"Radioiodine in Diagnosis and Treatment of Hyperthyroidism." Chapman, E. M., Soley, M. and Werner, S. C., Massachusetts General Hospital, Boston, Mass., State University of Iowa, Iowa City, Iowa, and Presbyterian Hospital, New York, N. Y.

*Pathology and Allied Topics.*—Craver, L., Presiding, Memorial Hospital, New York, N. Y.

"Histologic Types of Thyroid Carcinoma and their Respective Abilities to Store Radioiodine." Fitzgerald, P. J., Memorial Hospital, New York, N. Y.

"Radioautographs—Methods and Uses." Evans, T. C., University of Iowa, Iowa City, Iowa.

"Studies on Dosage in Cancer Therapy." Marinelli, L. D. and Hill, R., Memorial Hospital, New York, N. Y.

*Cancer.*—Parsons, B., Presiding, Presbyterian Hospital, New York, N. Y.

"Clinical Methods and Results of Radioiodine Therapy in Metastatic Thyroid Cancer." Seidlin, S. M. and Trunnell, J. B., Montefiore Hospital, New York, N. Y., and Memorial Hospital, New York, N. Y.

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