TRITIUM IN THE PHYSICAL AND BIOLOGICAL SCIENCES

In recent years, tritium (the radioactive isotope of hydrogen) has been increasingly used as a research tool in chemistry, physics, biology, meteorology and hydrology. In a variety of investigations, such as the study of biological and metabolic processes, tritium or a chemical compound with tritium as one of the constituents can be used as a tracer. It is also useful in studying the effects of radiation on plants and animals or the nature of biochemical regulators such as vitamins and hormones. In hydrology a major practical use of tritium is in the study of ground-water, which is of obvious importance to irrigation plans in arid or semi-arid areas.

The variety of studies and investigations that can be made with tritium or tritiated compounds is steadily growing, and in many cases the results obtained have widened our knowledge of many physical and biological processes.

Various aspects of the detection and use of tritium in the physical and biological sciences were discussed at an international symposium at Vienna from 3 - 10 May 1961. About 270 scientists from 27 countries and five international organizations participated in the symposium, which was organized by the International Atomic Energy Agency in co-operation with the Joint Commission on Applied Radioactivity of the International Council of Scientific Unions. Sixty-five papers were presented and discussed on a number of specific subjects grouped under the following headings: Distribution of Tritium in Nature; Methods of Enrichment and Applications in Hydrology; Tritium in Chemistry and Physics; Detection and Counting of Tritium; Preparation of Tritiated Compounds; and the Use of Tritium and Tritiated Compounds in Biological Studies.

Opening the symposium, Mr. Sterling Cole, IAEA Director General, pointed out that it was the first international meeting to discuss the progress which had taken place in the uses of tritium in physics and biology. Mr. Cole said that some of the papers to be presented and discussed dealt with work in which the Agency itself was playing an active part; he referred in particular to the distribution of tritium in nature and the applications of tritium in hydrology. In collaboration with the World Meteorological Organization, IAEA has initiated a world-wide survey to determine the concentration of hydrogen and oxygen isotopes in rainwater in order to study the water cycle in different parts of the world. Besides, the Agency is at present using tritium in studying some ground-water problems in Greece.

Tritium in Nature

The first day of the symposium was devoted to discussions on the distribution of tritium in nature, methods of enrichment and applications in hydrology.

Willard Libby, the well-known American scientist, gave a lecture on tritium geophysics, based on recent data and results obtained in studying the movement of the tritium released in nature as a result of thermonuclear tests, by measuring a selection of recent rain and surface water and ground water samples. The tritium water method used in these measurements seems to hold promise of general geophysical use, particularly in meteorology, oceanography and hydrology.

Professor Libby said that there was at present an urgent need for making water collections for the investigation of questions arising in the future. (It is such a survey that has been initiated by IAEA in collaboration with the WMO.) In particular, a carefully planned collection of continental rain, river, and lake waters and a widespread sampling of surface ocean waters should be made in order to follow the movements of the bomb tritium.

Studies on the tritium content of rainwater, which have been performed during the last few years, have

Professor Willard F. Libby presiding over one of the sessions of the symposium

outlined some features of the circulation of tritium in the atmosphere following its release through thermonuclear explosions. However, some important details, such as the extent of exchange of atmospheric tritium with water in land and ocean areas as well as the rate of descent into the troposphere of tritiated water from a stratospheric reservoir, remain controversial and await final solution.

A paper by R. Gat, U. Karfunkel and A. Nir, of Israel, gave additional data on these aspects obtained through measurements of tritium content in rainwater from the Eastern Mediterranean area.

C. W. Carlston and L. Thatcher, of the United States, pointed out that tritium produced by the 1958 thermonuclear test series provided a useful label for studying the movement of atmospheric moisture from the Pacific Ocean and its distribution across the United States. A Tritium Rainout Study (1958) was undertaken by the US Geological Survey to trace this movement.

Mr. Carlston and Mr. Thatcher also reported that during the spring of 1961 a tracer study using tritiated water as a label would be conducted in the United States. The tracer-test site is at Lake McMillan, a shallow reservoir on the Pecos River near Carlsbad, New Mexico. A large amount of water leaks through the floor of the lake into an underground reservoir. Water from this reservoir is discharged from springs in the Pecos River channel about three miles downstream from the lake. Tritiated water will be released into the lake as a tracer and the movement of the tracer through the underground reservoir and out of the springs will be determined by sampling the springs and observation wells between the springs and the lake. Movement of the tracer through this system, as well as other data, will be used to estimate the volume of water in the underground reservoir and the rate of movement of the tracer through the system.

W. Kaufman and D. Todd (USA) described the Madera Canal (California, USA) field study, the objective of which was to examine techniques of estimating canal seepage losses. Tritium was introduced into the canal impoundment and its arrival at the test wells was observed.

Detection and Counting of Tritium

Tritium occurs on the earth as a result of the interactions of cosmic rays on atmospheric oxygen and nitrogen, and, more recently, as a result of the testing of nuclear bombs. But because of the rapid mixing of this isotope with the large amounts of water and hydrogen gas existing in the atmosphere, the natural samples are of quite low specific activity. Since tritium disintegrates by emitting beta particles of very low energy, its detection is not easy. These two facts render precise measurements of naturally occurring tritium rather difficult. Of great interest therefore, were the various techniques and methods for the detection and counting of tritium reported at the symposium.

A promising development which may make tritium counting simpler and more reliable was reported by J. Sharpe and V. Stanley, of the United Kingdom, who presented a paper on an improved design of photomultiplier tubes for scintillation counting.

Another paper by two British scientists, I. S. Boyce and J. F. Cameron, described a method for the assay of tritiated water with low specific activity. Other scientists reported the results of their study of a scintillation counting system in which the scintillating material is a liquid. They were of the view that the liquid scintillation method was better than all other known techniques for routine low level tritium detection. Some other papers dealt with the measurement of natural tritium levels in biological materials.

There were several papers on methods of preparing tritium compounds. In 1957, K. Wilzbach of the Argonne National Laboratory, USA, reported that tritium could be introduced into organic compounds by keeping them in the presence of tritium gas, and since then this technique has been used to label many hundreds of compounds. It has been applied to gases, liquids and solids, and has been used successfully for compounds as simple as methane and as complex as insulin. In all but a few cases, tritium has been found in the compound, but labeling has invariably been accompanied by the appearance of tritium in a number of by-products. A paper presented by the author of this method reported that in some cases considerable difficulties had been encountered in removing these impurities and isolating a radiochemically pure product. Mr. Wilzbach reviewed the results of this technique for tritium labeling so as to assess the area of usefulness of the method and provide information concerning conditions of exposure and procedures of purification.

Several other papers presented by scientists from Australia, the Federal Republic of Germany, and the USA, emphasized the usefulness of the Wilzbach procedure, and dealt with tritium labeling of organic compounds and some properties of tritiated compounds.

Biological Studies

The use of tritium as a tracer in biological studies has proved advantageous due to the ease with which compounds can be synthesized with a high specific activity; this makes it possible to introduce only trace quantities of the labeled compound causing the least disturbance of physiological levels. Besides, since tritium has a relatively short radioactive life, there is a higher margin of safety in its use for metabolic studies in man. The disadvantages are the possibility of unstable labeling and the difficulty of tritium assay; the latter, however, is now largely overcome by new methods of detection and counting.

Biological tracer studies with tritium, and particularly those involving tritiated water, are subject to the effect of a frequently occurring exchange between tritium and some ordinary hydrogen atoms. This exchange very often affects the precision and,

at times, the interpretation of experimental results.

W. Siri (USA) reported on studies in which direct measurements were made in rats, guinea pigs, pigeons, and rabbits; tritium labeled water was administered intravenously or by mouth, and tritium space and turnover were determined from the concentration of tritium in the blood. Preliminary findings from these studies indicated that a correction for hydrogen-tritium exchange depended to some extent on the length of time the animal - or human - contained the tritiated water, and perhaps on the species of animal and its degree of obesity.

O. Okita and J. L. Spratt (USA) emphasized that the recent extensive use of tritium-labeled compounds in biological studies made it imperative that investigators verify the radiotracer stability of tritiated compounds. Even purification of labeled compounds to constant specific activity does not exclude the possibility of the tritium atom exchanging with hydrogen within a biological system.

Other papers presented by scientists from Belgium, France, Italy, the Federal Republic of Germany, the United Kingdom and the United States dealt mainly with general aspects of tritium in biology, synthesis of tritiated biological compounds, and radiation effects of tritium.

A paper presented by D. Marrian (United Kingdom) discussed the treatment of cancer by a tritium-labeled drug, known as synkavit. This compound concentrates to a very high degree in tumor tissue so that its radiation effects are mainly centered on that tissue, sparing the associated normal organs. Mr. Marrian said that some 40 advanced cases had been treated with tritiated synkavit, of which at least 12 had shown a temporary improvement in general. He, however, warned against over-emphasizing the results and said that further investigations were being conducted.

A paper was presented by B. Schultze and W. Maurer (Federal Republic of Germany) on the distribution and metabolism of tritiated thymidine and related compounds for studying cell metabolism.

Other papers discussed tritium autoradiography in cell biology; the use of tritium labeled compounds in the study of nucleic acids and protein metabolism of bone marrow cells; and various aspects of tritium as a tracer in the study of cell metabolism.

Summing up

The papers presented during the ten scientific sessions of the symposium demonstrated that tritium tracer techniques had already established their usefulness in hydrological and meteorological studies as well as in physics and chemistry. Tritium is also useful in biological studies because of the ease with which a very great number of metabolically active compounds, such as hormones, vitamins and other important constituents in the body can be labeled with it. The other useful property of tritium is that it is a weak beta emitter, and autoradiography of tissues and single cells containing tritium-labeled compounds permit an excellent localization of the tracer.

At the closing session, Dr. Henry Seligman, President of the Joint Commission on Applied Radioactivity and IAEA's Deputy Director General for Research and Isotopes, said that in many cases there was no substitute to tritium that could do the same job with the same degree of accuracy. He added: "Quite apart from the many applications of tritium, the more recent improvements in the efficiency of determining this isotope by scintillation methods have no doubt contributed a great deal to the much wider use of tritium in the physical and biological sciences."

Dr. Richard L. Doan, one of the leading US experts in the atomic energy field, arrived in Ankara at the beginning of June to advise the Turkish Government on atomic energy planning. Dr. Doan (left in the picture above), who took up this assignment under IAEA's program of technical assistance, is seen here conversing with the Director General, Mr. Sterling Cole, at the Agency's headquarters in Vienna – while on his way to Ankara