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AVAILABILITY OF ENRICHED ISOTOPIC MATERIAL FOR ACCELERATOR TARGETS*

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the use of a common, horizontal, magnetic field linking 36 separators. However, this permitted the separation of the isotopes of only one element at a time. Therefore, magnetic shunts were installed which subdivided the "track" into four segments. This subdivision resulted in three banks of eight separators and one bank of six separators. By exciting the magnetic field in each segment independently, it is theoretically possible to enrich the isotopes of four elements simultaneously in the 30 calutrons.

All of the separators have their source and collectors in the magnetic field. The advantage of this configuration is that it allows a high degree of beam-charge neutralization, and thus high-current densities can be maintained without degrading focal qualities. The disadvantage is that pressure in the entire tank must be brought down to atmospheric when the source is replenished. Hence, time is spent in reestablishing a high vacuum.

Two types of separators are available for the enrichment of stable isotopes. The first is the standard 180° focusing mass spectrometer; the second is a 255° sector focusing device with a magnetic field index equal to 0.5. Six of the separators are equipped with magnetic pole-faces to give double focusing properties. These six separators have a higher theoretical mass resolution, and their use results in a product with greater isotopic enhancement than the product available from the standard 180° focusing device. The throughput associated with these separators, however, is less than that achieved with the standard calutron units. In actual practice, the 255° units are used when isotopic assay is the prime consideration, and the 180° units are operated when maximum yield is desired. The actual number of units operated at any one time depends on programmatic funding.

The first step in enrichment is the introduction of feed material, in either elemental or compound form, into a calutron, where it is either directly vaporized or heated in a stream of carbon tetrahalide to form a volatile halide. This vapor is then introduced into an arc discharge, where it is ionized in the high-current source. The ionized particle is extracted from the ion source, accelerated to approximately 40 keV, and bent in the magnetic field with a radius of curvature of 60 cm. The focused individual isotopic beams are intercepted by collectors, which are constructed of carbon, copper, or aluminum and located behind a slotted face plate. Following a run, whose duration may be between fifty and several hundred hours depending on the element, the collectors are removed from the separator and the material is extracted, chemically purified, assayed, and placed in the inventory.

As might be expected, each element or compound has unique operating characteristics. Thus, it is difficult to make generalizations about the throughput capability of the facility. The ion sources produce a beam whose dimensions are approximately 0.4 x 13 cm. Typical beam currents between 10 and 100 mA are obtained, with the average in the 25-50 mA region. As a rule of thumb, one separator can provide approximately 0.1 mole of an element per operational day. This figure must be multiplied by the natural isotopic abundance to determine the yield for a particular isotope.

It is considerably more difficult to present a universal rule for achievable isotopic purity. Isotopic purity is strongly dependent on the isotope required and the abundance of its nearest neighbors. In addition, the vaporization and ionization characteristics of the element, the probability of the isotope remaining in the collector, and the

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Summary

The electromagnetic isotope enrichment facility at the Oak Ridge National Laboratory provides a broad spectrum of highly enriched stable isotopes to the worldwide scientific community. The continued timely availability of these materials is of vital importance in many areas of basic research and, in particular, as source material for the fabrication of accelerator targets. A brief description of the facility and its capabilities and limitations is presented.

Introduction

The existence of the electromagnetic isotope separation facility at Oak Ridge National Laboratory (ORNL) and the availability of enriched stable isotopes from ORNL's Isotope Sales Office are familiar to most research and commercial laboratories throughout the world. The purpose of this paper is to review the goals of the program, the technology employed to produce separated isotopes, and the restrictions and limitations that apply to both isotope quantity and isotopic purity. The discussion will be limited to the approximately 60 multi-isotopic elements made available by the operation of the facility.

The objective of the ORNL isotope program is to *enrich stable isotopes, selected radioactive isotopes, and heavy-element isotopes for use in research and development and in commercial activities.* To accomplish this objective, ORNL, at the direction of the Department of Energy (DOE), operates the electromagnetic isotope enrichment facility. This facility consists of very high current mass separators, known as calutrons, which were used to provide enriched uranium in the 1940's. Research and Development directed toward increasing both the throughput and isotopic purity of the products is also conducted at ORNL. The Isotope Sales Office distributes the isotopes in two ways. Multigram quantities of enriched samples from the Research Materials Collection (RMC) are loaned to members of the DOE research community at a nominal fee for nondestructive research, while enriched isotopes are sold to other research and commercial organizations on a cost-recovery basis.

Facility

The calutron facility is a unique national asset, since the USSR is the only other nation possessing a similar capability. Many other countries have laboratories where isotopic enhancement is performed, but their facilities are usually of limited size and the isotopes are utilized for specific purposes.

The electromagnetic enrichment program utilizes the existing equipment by relegating the production of enriched actinide and radioactive isotopes to one part of the facility and the production of stable isotopes to another. The original physical layout of the stable isotope area was degree of focusing which can be achieved are all intimately related to the final product assay. With the above considerations clearly in mind, one can approximate the assay by applying a decontamination factor. The ratio of the final assay divided by the tails contamination to the initial assay divided by the feed contamination is given approximately by 23,000 divided by the mass of the isotope. In the lead region, for example, this would yield a decontamination factor on the order of 110. This would mean that an isotope of an initial abundance of 5 percent could be enriched to approximately the 85 percent level in a single pass.

The products from one separation can be recycled to obtain a significantly higher isotopic assay in a two-pass process. This is expensive, however, since the efficiency of the process is significantly less than unity. Process efficiency is defined as the ratio of the quantity of material removed from the collectors to the quantity of charge material vaporized. As one might expect, process efficiency is a function of source performance and is typically between 5 and 25 percent, with the average being approximately 10 percent.

Direct production of isotopically enriched surface-deposited targets is also done at the facility. The device used for the preparation of these targets is a 180° sector separator, with the source and collector external to the magnetic field. This device has a dispersion roughly ten times that of the 180° production calutron unit. Therefore, the isotopic enrichment that can be achieved is significantly greater. The ion throughput is correspondingly lower, however, and while the machine is useful for making special targets, it is not efficient for producing multigram quantities of highly enriched isotopes. In the fabrication of a typical target, the ions are slowed to approximately 200 eV and allowed to impinge on a suitable backing, such as carbon, aluminum, or gold foil. The material is deposited as a line image 1-2 cm x 2 mm, with thicknesses up to approximately 100 $\mu g/cm^2$.

Current Status

Current DOE policy regarding the Research Materials Collection is that the materials are available on loan to U.S. scientists for use in nondestructive experiments. These materials can also be used in experimental facilities outside the United States, but with restrictions. Among the stipulated conditions are that the experiment must be of relevance to the DOE mission and that the research must be a collaborative effort with a U.S. scientist who has assumed responsibility for the integrity of the sample. There are certain exceptions to this policy, for example, the use of RMC samples within the European community for the study of neutron cross sections. In such cases, the samples are placed in the custody of EURATOM. Such loans are usually made only at the strong recommendation of the European-American Nuclear Data Committee (EANDC).

The current inventory is being depleted faster than it is being replenished. Approximately 65 isotopes are totally depleted from the present sales inventory. With a few notable exceptions, these isotopes are needed almost exclusively for research purposes. However, the isotopes for which the demand is greatest are those used in nuclear medical health-care delivery. Obviously, our main concern is to replenish the supplies of these isotopes as rapidly as possible.

Accomplishing that will mean that other items in the inventory will be unavailable for some period of time. Requests for special separations of relatively small quantities of material can be accommodated, but the cost is usually greater than that for materials obtained through normal channels. From our viewpoint, the inventory size and associated cost are prime concerns. One must balance efficient production with anticipated demand for a particular isotope. The time needed to provide material through the normal processes is on the order of 6 to 8 months. This is the amount of time required to construct new equipment, prepare for the separation of a particular element, recover the material, and process it to a chemically pure element.

Conclusions

This paper has attempted to present a brief description of the production of isotopically enriched materials. The ORNL facility used for this purpose suffers from utility and support systems that are rapidly becoming obsolescent and from the fact that the current operational level is insufficient to maintain the sales inventory in equilibrium. The facility does, however, have the equipment and operational capability to almost triple current production. Doubling the number of separators currently in operation, that is, utilizing the full complement of 30 calutrons in the stable isotope track, would make it possible to restore inventory equilibrium and permit the production of isotopes now out of stock. This increased production could be achieved as rapidly as an expanded operational crew can be trained.