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Availability and Uses of Heavy-Actinide Isotopes*

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The reactor production of transuranic isotopes to supply the requirements of groups engaged in fundamental research is clearly a specialized undertaking both in terms of the irradiation and separations processes involved. The needs of the research community in terms of amounts of material are usually relatively modest by normal standards, but they are demanding in terms of the number and isotopic purity of heavier elements required. The intent of this communication is to provide a record of some of the actinide isotopes that are currently available from special production and separation facilities. An effort will also be made to highlight some of the chemical research currently in progress,(1) particularly that with the heavier actinide elements(2). The emphasis of this communication is consequently on the elements from atomic number 95, Am, through 100, Fm, which is the heaviest element regularly available from target irradiation in reactors.

Prior to 1966, national laboratories such as Argonne National Laboratory and Lawrence Berkeley Laboratory were individually responsible for their supplies of transplutonium isotopes for research. They had developed regular production and separation programs, processing plutonium target material irradiated in high flux reactors such as the Materials Testing Reactor at Arco, Idaho. In 1966, these efforts were centralized in a new production - separation facility at Oak Ridge National Laboratory, the High Flux Isotope Reactor (HFIR) and the Transuranium Processing Plant (TRU). This facility has been the cornerstone of the U. S. transplutonium element program ever since that time, and its products have figured prominently in collaborative research throughout the world. Today, kilogram scale targets of the element curium (96) are irradiated and transmuted by successive neutron capture into heavier elements up to fermium where the yield of ^{257}Fm per cycle is measured in picograms. The targets irradiated at HFIR are processed at TRU where pure fractions of each heavy element are separated for distribution to research groups. Some of the material thus obtained is made available for sale.

A great premium is of course placed on the availability of longer-lived α-emitting isotopes. Both shielding requirements and the possible role of ionizing radiation in promoting the decomposition of compounds synthesized or solutions studied are important considerations. For example the intensely radioactive ^{244}Cm isotope, $t_{1/2}$ = 18 years, can now be substituted by the much longer lived ^{248}Cm ($t_{1/2} = 3 \times 10^5$ years) separated as a decay product from older ^{252}Cf neutron sources. This separation is also made at TRU.

Fundamental chemical research interest in the actinide elements stems particularly from their unique electronic structures. The progressive filling of the 5f-electron shell parallels the 4f-electron character of the lanthanides, but actinide chemistry is much richer with, for example, compounds of americium exhibiting valences from two through six. The partial shielding of the electrons in the 5f-shell by filled s and -orbitals is in large part responsible for the unique electronic properties characteristic of these elements. For example, the first report of a lasing transition in U^{3+}:CaF_2 was made in 1960(3), the same year that the first ruby laser was described. Spectroscopic studies of the actinides offer an extremely sensitive method for identification both of the element and its oxidation state. Such studies provide as well insights into the most complex electronic structure in the periodic table. The very sharp nature of the observed lines makes possible the type of highly accurate detailed measurements that are ideal grist for the mill of the atomic theorist.

Research programs that focus on the lighter actinides, address their role in the entire nuclear fuel cycle from mining to waste isolation. In addition to exploring the types of compounds which exhibit the highest stability for waste isolation, new types of volatile compounds and organometallic compounds, are being synthesized. Solution chemistry in weakly basic solutions that model the aquatic environment is being addressed by groups in a number of different laboratories throughout the world(4).

Selected actinide isotopes used as target material in heavy ion accelerators are basic to the nuclear physics experiments that probe beyond the existing defined regions of the periodic table into a new and uncharted range of atomic number. Efforts at present are slowly progressing up the ladder of atomic number with element 109 having been reported. However beyond this region where half-lives are becoming extremely short and cross sections for production extremely small, there is still some hope that there exists an isolated "island of relative stability" near Z=114 and N=184. Current experiments continue to address this exciting potential for "superheavy" elements.

References

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