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Actinides Produced by $^{12}C + ^{242}Pu$ and $^{16}O + ^{238}U$ Reaction*

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Many actinides have been produced by various heavy-ion-induced nuclear reactions. The reactions, which form actinide isotopes from the targetlike nuclei to the compound nucleus, have been studied recently.

In the field of heavy actinides, however, it is not easy to investigate such nuclear reactions because of the small reaction cross sections encountered. For the purpose of understanding the nuclear reactions, comparative studies of the different reactions is an effective means in the actinide region. The study of the reactions that occur when the same target is irradiated with several different types of projectiles is one example. When the kind of projectile ion is fixed and several different types of elements or isotopes are used as targets, other information on the reactions can be obtained.

We have initiated a systematic study using radiochemical methods to investigate the formation cross sections for actinides produced in bombardment of ^{242}Pu with ^{12}C ions and ^{238}U with ^{16}O ions at energies near the Coulomb barriers.

The plutonium (99.8% ^{242}Pu) and uranium (99.98% ^{238}U) targets were prepared by electrodeposition from isopropyl alcohol solution onto aluminum foils of 7 μm thickness. The uranium targets varied in thickness from 0.3 to 2.0 mg/cm^2 and the plutonium target was 0.25 mg/cm^2. A target assembly consisted of a stack of aluminum foils for degrading the beam energy at the upstream side of the target and an aluminum foil (7 μm thickness) for catching the recoil nuclei at the downstream side. Irradiations with ^{12}C and ^{16}O ions were performed at the tandem accelerator of the Japan Atomic Energy Research Institute. The beam energy was varied from 60 to 95 MeV for ^{12}C ions and from 85 to 130 MeV for ^{16}O ions. The beam intensities were up to 200 particle nA for the $^{12}C + ^{242}Pu$ system and 150 particle nA for the $^{16}O + ^{238}U$ system, and typical irradiation durations were 0.5 to 3 h. After irradiation, both the target and the aluminum catcher foil were dissolved in aqua

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regia and the solution was heated to near dryness. The residue was then redissolved in a mixture of 1*M* nitric acid and 90% methyl alcohol. Each actinide was isolated by elution from a 2 mm diam × 80 mm column of MCI GEL CA08Y anion exchange resin (23.5±4 μm) with heated (80—90°C) 0.1—1*M* HNO_3-80—95% methyl alcohol solutions which were supplied to the column by 1×10^6 Pa pressure. The time for complete separation is about 20 minutes including the source preparation for alpha spectrometry. The chemical yield was determined to be 90±10%. The alpha activities from fermium, californium, curium, and americium isotopes were assayed with Si (Au) surface-barrier detector systems. The measurements were continued for about two months after irradiation.

Both reactions form the same compound nucleus, ^{254}Fm, by a complete fusion reaction :

$$^{12}C+^{242}Pu\rightarrow^{254}Fm^*,$$

$$^{16}O+^{238}U\rightarrow^{254}Fm^*,$$

The investigation of the production of identical actinide isotopes in reactions where the same compound nucleus is formed by different projectile-target combinations is another method which can be used in addition to studies of fixed-projectile and -target reactions. This paper deals with the excitation functions of actinides synthesized in these heavy-ion bombardments and a comparative study of the reactions between ^{242}Pu(^{12}C, 4n)^{250}Fm and ^{238}U(^{16}O, 4n)^{250}Fm and between ^{242}Pu(^{12}C, αxn)$^{250-x}$Cf and ^{238}U(^{16}O, αxn)$^{250-x}$Cf (x= 4, 5, 6) as well as the transfer reactions for these systems which lead to $^{242-244}$Cm and ^{242}Am isotopes.

Each actinide nuclide synthesized from the reactions was identified by its chemical behavior, alpha energy, and half-life. The ^{243}Cm and ^{244}Cm isotopes could not be identified separately, because these isotopes have similar alpha energies and half-lives. Detector efficiencies and geometries were determined from measurements of LMRI (Laboratoire de Métrologie des Rayonnements Ionisants, France) standard sources. The cross sections were calculated from the measured activities, the number of ^{242}Pu or ^{238}U atoms in the target, and the integrated beam intensities. It was assumed that all of the actinide products were caught in the aluminum catcher foil. Corrections were made for growth and decay in the case of the parent-daughter isotopes such as ^{250}Fm-^{246}Cf and ^{246}Cf-^{242}Cm. The statistical standard deviations of the counting data and uncertainty of the chemical yield were considered in the calculation of the reaction cross sections. Excitation functions for the actinides produced by the reactions and for the total fission cross section were also calculated with the code ALICE.