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Authors
Sikkeland, Torbjorn
Amiel, Saadia
Thompson, Stanley G.

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Torbjörn Sikkeland, Saadia Amiel, and Stanley G. Thompson
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SPALLATION REACTIONS OF CALIFORNIA-252 WITH HELIUM IONS

Torbjörn Sikkeland, *, Saadia Amiel, ** and Stanley G. Thompson

Lawrence Radiation Laboratory and Department of Chemistry
University of California, Berkeley, California

Previous publications from this laboratory have given results for excitation functions of spallation reactions on heavy elements in the region of $Z > 90$ with helium ions. The heaviest element studied in detail was $\text{Cf}^{249}$. The purpose of the work presented here was to obtain information concerning the reactions of helium ions with $\text{Cf}^{252}$, the heaviest nucleus available in sufficient amount for such studies at the time of this investigation. An additional objective of the work was to verify previous values for some decay properties of the isotopes produced.

The $\text{Cf}^{252}$ was prepared from $\text{Pu}^{239}$ by successive neutron-capture and beta-decay reactions in the Material Testing Reactor. The separated californium containing $\text{Cf}^{249,250,251}$ and $\text{Cf}^{252}$ was put back into the reactor and irradiated again with neutrons for approximately 8 months to convert all light californium isotopes into $\text{Cf}^{252}$. The $\text{Cf}^{252}$ used for thetarget contained < 2% of $\text{Cf}^{254}$ and negligible amounts of the other isotopes.

The $\text{Cf}^{252}$ (2.4x10^{-3} microgram) was chemically purified and electroplated as a uniform thin deposit on a 0.002-inch-thick gold foil in an area of 0.05 cm^2. A measured amount of $\text{Cm}^{244}$ was added in the electroplating step in order to use its well-known $(\alpha,2n)$ excitation function as an internal standard for the cross-section measurements. The bombardments were carried out at the 60-inch cyclotron of the Crocker Laboratory, using a catcher-foil technique with the deflector-channel target assembly previously described. 2

* On leave from JENER, Kjeller, Norway.

** On leave from Israel Atomic Energy Commission, Hakirya, Tel Aviv, Israel.
The energies of the incident helium ions were reduced to the desired values with aluminum absorbers. The recoil products were collected on gold foils of about 5 mg/cm$^2$ thickness. The gold was dissolved in a mixture of hydrochloric and nitric acids. The gold was then separated from the spallation products by sorption on a column of Dowex A-1 anion-exchange resin and the spallation products were electroplated on a platinum disc. The fermium, einsteinium, and californium isotopes were identified by measurements of their decay properties in an ionization-grid chamber with a 48 channel alpha-particle pulse-height analyzer. The decay of the various alpha-particle peaks was usually followed through several half-lives. In some cases the fermium, einsteinium, and californium were separated from each other in the final step by elution with ammonium-alpha-hydroxy isobutyrate from a column of Dowex 50 cation-exchange resin.

The cross sections measured are shown in Figs. 1 and 2, as a function of the energy of the helium ions. The errors given are statistical errors. The broad features of the excitation functions are similar to those of other very heavy isotopes, the interpretation of which has been discussed by other authors.

The product of the ($\alpha$,3$n$)reaction Fm$^{253}$ was found (by following the decay of its alpha particles) to have a half life of 3.0 ± 0.2 days. Its most abundant alpha-particle group had an energy of 6.95 ± .05 Mev. A lower alpha group of about 6.90 Mev energy seemed to be present, in which case the measured ratio of the 6.95 to the 6.90 peak would be of the order of 4. The Fm$^{253}$ decay was also followed by observing the corresponding growth of its electron-capture daughter, $E^{253}$, in the fermium fraction. The rate of formation of $E^{253}$ was consistent with the over-all half life of 3 ± 0.2 days for Fm$^{253}$, and the amount of it
formed gives an electron-capture to alpha-decay branching ratio of $8.5 \pm 1.0$. A previous publication on Fm$^{253}$ reported an alpha-particle energy of 6.94 Mev, a branching ratio of 8.5, and a half life of $4.5 \pm 1.0$ days. The similarity of the excitation function with other $(\alpha,3n)$ reactions in the heavy element region is a confirmation of the mass assignment.

The products of the $(\alpha,n)$ and $(\alpha,4n)$ reactions, namely Fm$^{255}$ and Fm$^{252}$, have similar half lives and alpha-decay energies. Thus satisfactory resolution of these isotopes could not be accomplished in the pulse-height analyzer used, and the reaction yields are rather uncertain. The curve shown in Fig. 1 for the $(\alpha,n)$ reaction, therefore, includes the contribution from the $(\alpha,4n)$ reaction. However, the $(\alpha,n)$ curve shown must give the true values for the $(\alpha,n)$ cross sections below the energy corresponding to the threshold for the $(\alpha,4n)$ reaction, which is 31 Mev. An extrapolation of the $(\alpha,n)$ curve above 31 Mev was made, based on the shape of the $(\alpha,n)$ excitation functions of U$^{235}$ obtained by Vandenbosch et al. Subtraction of the $(\alpha,n)$ cross sections obtained in this way from the sum of the measured $(\alpha,n)$ and $(\alpha,4n)$ yield gives an $(\alpha,4n)$ cross section at 40 Mev of about $1.2 \pm 1$ millibarns. The peak of the $(\alpha,4n)$ excitation function should occur at about 43 Mev, and it would be of interest to extend the measurements to higher energies in order to obtain more precise values for the cross sections and thus more information about the influence of the 152-neutron subshell.

The $(\alpha,2n)$ excitation function is characterized by a peak around 29 Mev resulting from neutron evaporation. The high tail at higher bombarding energies is a result of direct processes which increases the probability for the residual nuclei to be left at an excitation energy below the fission threshold; therefore relatively high cross sections are observed as compared to the cross section for the evaporation process.
The \((\alpha,p2n)\) reaction proceeds mainly through an \((\alpha,t)\) stripping mechanism\(^3\) leaving the residual nuclei at low excitation energy and therefore relatively high cross sections are observed.

The \((\alpha,\nu n)\) cross section for the production of the short lived isomer of \(E^{254}\) is as high as the \((\alpha,2n)\) cross section at 40 Mev. The \((\alpha,\nu n)\) reaction mechanism cannot be established from an excitation function curve. There is experimental evidence that an \((\alpha,d)\) stripping similar to the \((\alpha,t)\) stripping plays an important part. In addition to stripping \((\alpha,p)\) knock-on followed by an evaporated neutron or possibly \((\alpha,\nu n)\) knock-on probability contributes a significant amount to the cross section.\(^8\)

The upper limit of the \((\alpha,\nu n)\) cross section for production of the long lived isomer was less than 5 millibarns. The upper limit for the \((\alpha,p)\) reaction was 0.5 millibarns in the energy range studied.

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REFERENCES


8. Robert Silva, University of California, private communication.
Fig. 1. Excitation function for Cf$^{252}$ ($\alpha$,xn) reactions. The open squares (□) are $\sigma(\alpha,n) + \sigma(\alpha,4n)$, the open triangles (△) are $\sigma(\alpha,2n)$ and the solid circles (○) are $\sigma(\alpha,3n)$. Errors given are statistical errors.

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Fig. 2. Excitation function for Cf$^{252}$ ($\alpha$,pxn) reactions. The open circles (○) are $\sigma(\alpha,pn) + \sigma(\alpha,d)$ for production of the short lived isomer of E$^{254}$. The cross-section for the long lived isomer was less than 5 mb. The solid circles (○) are $\sigma(\alpha,p2n) + \sigma(\alpha,t)$. The upper limit for $\sigma(\alpha,p)$ was 0.5 mb. Errors given are statistical errors.

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Fig. 1.
Fig. 2.
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