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Electrodisintegration of ^{238}U

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A search has been made for α particles that might stem from an isoscalar $E2$ giant resonance in ^{238}U near 9 MeV. Using 40 MeV electrons the spectra of protons and α particles emitted in the electrodisintegration of ^{238}U were measured. Peaks in the proton spectrum indicated that the target has an oxygen contamination. The less intense α spectrum contains α particles resulting from the electrodisintegration of ^{16}O, a group that probably stems from ternary fission, and a higher energy feature which may be attributed to the electrodisintegration of ^{238}U. The integrated ^{238}U(e,α) cross section is less than 1% of a recently suggested values.

[NUCLEAR REACTIONS ^{238}U(e,α), ^{238}U(e,p), $E_e = 40$ MeV, particle spectra measured 4–24 MeV, deduced ternary fission cross section.]

The electrodisintegration of ^{238}U has been studied in two recent experiments.[1,2] The cross section for the reaction ^{238}U$(e,n)^{237}$U was determined[1] by measuring the 6.75-day activity from ^{237}U using electrons in the energy range 6–25 MeV. This result is in good agreement with that obtained by folding the established[3] ^{238}U(γ,n) cross section, obtained by single neutron counting, with the electric dipole virtual photon spectrum[4] for uranium. In a similar experiment[2] the ^{238}U$(e,\alpha)^{234}$Th cross section was measured, again by counting the residual activity. It was concluded that this activity was produced as a result of electric quadrupole absorption because (1) the energy dependence of the cross section has the appropriate slope and (2) the intensity did not increase when a radiator was inserted in the electron beam ahead of the target. The conclusion of this experiment was that α particles are emitted from a resonance near 9 MeV accounting for about 50% of the $E2$ isoscalar sum. Since α particles are unbound by 4.5 MeV in ^{238}U and since the Coulomb barrier would strongly favor the population of states near the ground state of ^{234}Th, the α-particle energy distribution might be expected to peak near 13.5 MeV.

The experiment described below was undertaken to detect directly the α particles emitted in the electrodisintegration of ^{238}U. A ^{238}U foil, nominally 4 mg/cm^2 in thickness, was obtained from the Oak Ridge National Laboratory and mounted in the vacuum chamber associated with a magnetic spectrometer. It was handled in an inert atmosphere and was at no time exposed to the air. This foil was bombarded with 40 MeV electrons and the outgoing protons and α particles detected at 48° in counter telescopes located in the magnet focal plane. Mylar foils, 2.5 mg/cm^2 in thickness, were mounted in front of the detectors to stop the profusion of fission fragments which have the same magnetic rigidity as 5–20 MeV α particles. α particles having energies below ~4 MeV were also absorbed.

The energy spectra obtained are displayed in Figs. 1 and 2. The proton spectrum has many peaks in the energy region below 13 MeV; above that energy the cross section decreases monotonically from a value of 0.4 μb/MeV sr. The structure in the lower half of the spectrum may be recognized as the proton spectrum[5-8] resulting from the photodisintegration of ^{16}O and can be produced by a 1% contamination of the target nuclei. The underlying continuum and the upper portion of the spectrum contain a mixture of oxygen and uranium photoprotons, the smooth curve being an estimate of the contribution from uranium.

The α-particle intensity is about one-tenth that of the proton intensity and less than one percent of that suggested by Ref. 2. An important group of α particles coming from the isosclar $E2$ giant resonance of ^{238}U was not observed in this experiment. A negative result was also obtained at Glasgow by McGeorge *et al.*,[9] who used surface barrier detectors.

The α spectrum is shown in Fig. 2. These data have been averaged in half-MeV bins to lessen the errors on the individual points. This spectrum has three features worth pointing out. First, the steep rise at low energies and the peak near 7.25 MeV reflect the peaks between four and five MeV and seven and eight MeV in the α spectrum obtained[10] in the photodisintegration of ^{16}O. The intensities, though uncertain, are consistent with those obtained in the proton spectrum, Fig. 1. At least part of the low energy end of this spectrum comes therefore from an oxygen contamination. The absolute cross section values are based on the number of ^{238}U atoms in the target. Energy-loss corrections,

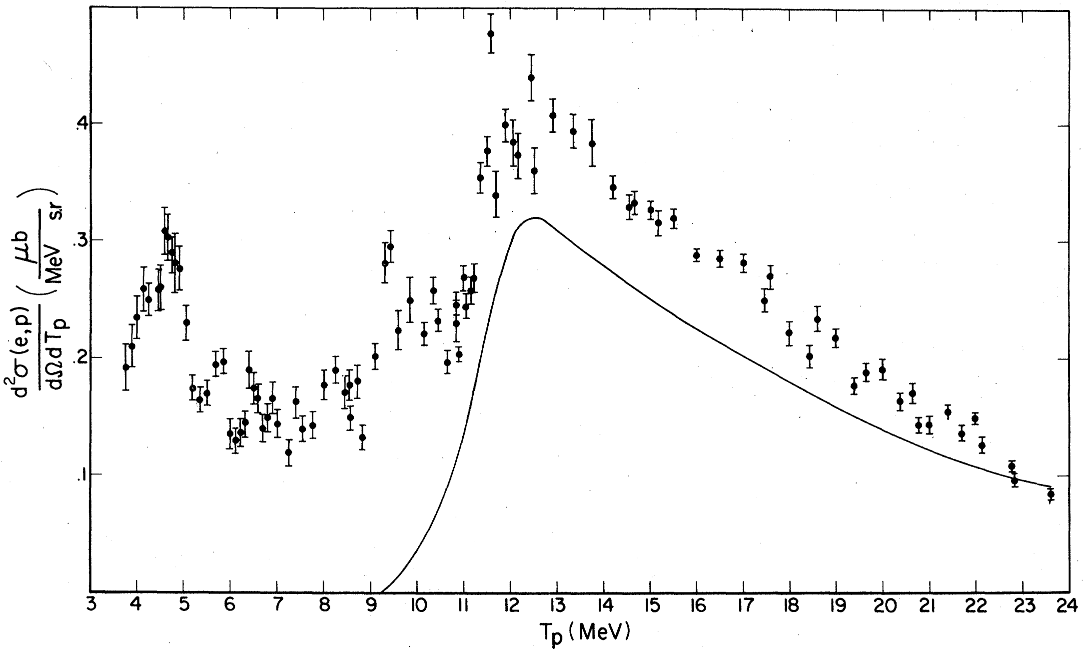

FIG. 1. The proton spectrum obtained in the electrodisintegration of ^{238}U. The peaks below 13 MeV result from the electrodisintegration of a ^{16}O contaminant. The smooth curve is a rough estimate of the proton spectrum from ^{238}U. The absolute values are based on the number of uranium atoms in the target.

which amount to 0.4 MeV at 5 MeV and 0.2 MeV at 16 MeV, have not been made.

The second interesting feature of this spectrum is the broad maximum centered near 16 MeV and having a reproducible dimple in the middle. This maximum is reminiscent of the spectrum of α particles observed in ternary fission. Accordingly, this spectrum has been fitted in the energy range 15–20 MeV by a Gaussian centered at 16.5 MeV having a peak cross section of 0.021 μb/MeV sr and a full width at half maximum of 7.5 MeV. Multiplying the area under the Gaussian by 4π yields the cross section for ternary fission by 40 MeV electrons

$$\sigma(e,f_t) = 2.1\ \mu\text{b}.$$

This result has an estimated error of ±15%. It may be compared to the cross section for binary fission obtained by Shotter *et al.*,[12]

$$\sigma(e,f_b) = 2.3\ \text{mb}.$$

The ratio, 9×10^{-4}, is close to the value quoted[11] for the fission of ^{238}U by 2.5 MeV neutrons.

If this Gaussian is subtracted from the α spectrum, a continuous distribution extending up to 15 MeV remains; these are presumably α particles from ^{16}O. Above 20 MeV the spectrum begins to rise again and perhaps goes through a maximum near 23 MeV. This is exactly the characteristic of the α spectra produced in the electrodisinte-

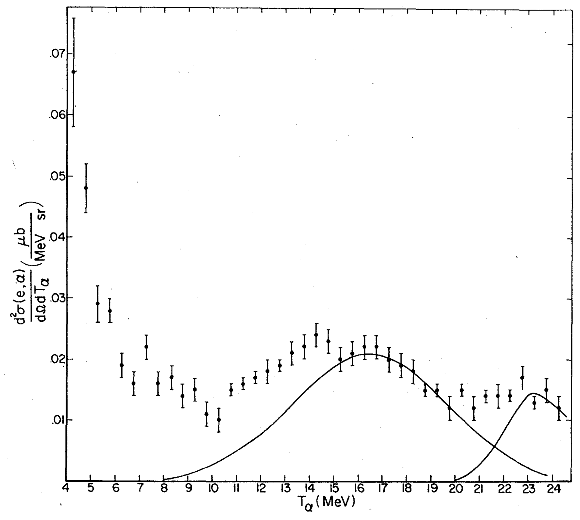

FIG. 2. The α-particle spectrums obtained in the electrodisintegration of ^{238}U. The data have been averaged in half-MeV bins to lessen the error on the individual points. The absolute cross section values are based on the number of ^{238}U atoms in the target. Energy-loss corrections, which amount to 0.5 MeV at 5 MeV and 0.2 MeV at 16 MeV, have not been made. The low energy part of the spectrum results largely from an oxygen contamination of the target. A Gaussian has been fitted through the points between 15 and 20 MeV to map out the part of the spectrum which is thought to result from ternary fission. The higher energy α's near 23 MeV probably stem from the electrodisintegration of ^{238}U.

gration of a heavy element,[13] in this case ^{238}U. An extrapolation of the survey given in Ref. 13 would predict a spectrum peaking near 23 MeV and having the observed intensity.

At the same time these charged particle spectra were being measured, a search was made for delayed α particles emitted by the target during a 1 msec period between beam bursts. This experiment produced a totally negative result.

Both the protons and α spectra generated in the electrodisintegration of uranium are governed largely by the Coulomb barrier; they are smooth distributions peaking at about the Coulomb barrier height. α particles are also emitted in a comparable intensity as a result of the ternary electrofission of ^{238}U. No α particles were observed that might result from the excitation of the isoscalar $E2$ giant resonance near 9 MeV.

The source of the radioactivity reported in Ref. 2 is still not understood. Attempts to repeat this experiment have failed in three different laboratories, Glasgow,[9] Illinois,[14] and the Bates Laboratory at MIT[15]; in fact, when remeasured in Sao Paulo the intensity was only one-third that reported in Ref. 2. Barber[15] has suggested a possibility that is consistent with all of the observations, namely that the ^{234}Th activity was generated by fast neutrons via the $(n, n'\alpha)$ reaction.

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