Radioactive decay of ^{139}Ba*

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The decay of ^{139}Ba to levels of ^{139}La was studied to resolve discrepancies in previous determinations of the decay scheme of this isotope. The existence of 1257, 1601, 1691, 1762, and 1797 keV γ rays has been confirmed and some new relative intensities established.

[RADIOACTIVITY ^{139}Ba; measured E_γ:I_γ.]

Since Mitchell and Hebb[1] first established the disintegration scheme of ^{139}Ba from the population of the energy levels of ^{139}La, only two significant studies have been made of the β decay of this isotope.[2,3] An investigation was undertaken to resolve any ambiguity between the ^{139}Ba decay scheme found by Berzins, Bunker, and Starner[3] and that found by Hill and Wiedenbeck.[2] The specific γ rays in question, which appear in the former decay scheme but not in the latter, include 1257, 1518, 1601, 1691, 1762, and 1797 keV.

Sources of ^{139}Ba were produced by exposing 500 mg samples of natural barium in the form of $Ba(NO_3)_2$ to a thermal neutron flux of about 2×10^{13} neutron/cm^3 sec for a duration of 1–4 min in the Breazeale nuclear reactor of The Pennsylvania State University. A delay of approximately 30 min transpired between activation and counting to allow for the decay of the short-lived ^{137}Ba^m. The crystals were irradiated in a small sealed polyethylene tube and then transferred to a polyethylene capsule housed in a plexiglass shield for counting. The shield was designed to absorb the 2.3 MeV β rays associated with this particular decay. A 0.5 cm Pb absorber was used to reduce the intensity of the strong 166 keV γ ray of ^{139}Ba.

The γ-ray spectrum was studied by using a Ge(Li) detector in conjunction with a 2048 channel pulse height analyzer. The detector was a 40 cm^3 spectrometer with a resolution of 3 keV for the 1333 keV γ ray of ^{60}Co. Adequate resolution was obtained to separate all energies except the 1255-1257 doublet. The detector efficiency as a function of energy was established by measuring the peak heights of a standard radium source and comparing the results with the accepted relative intensities of some of the prominent γ rays of ^{226}Ra.

The amplifier gain was established to permit only the counting of energies between 1200-2000 keV. This resulted in a channel width of 0.5 keV. This "window" was used for all samples except for the analysis of the 1255–1257 keV peaks. In the latter case, the resolution of the detector was not sufficient to analyze the two peaks separately. The 1255–1257 keV γ-ray peaks were investigated by decreasing the channel width to 0.25 keV. For this analysis, the drift of the amplifier gain was checked by simultaneously counting a sample of ^{60}Co. The 1173 and 1332 keV peaks of the ^{60}Co source were then used to monitor the counter calibration.

Under the conditions outlined above, 25 samples were analyzed with each spectrum being added to the previous spectra. Each sample was counted for only $1\frac{1}{2}$ half-lives to avoid any significant effects from the longer-lived barium isotopes. Using the 1420 keV peak as an intensity standard, the initial series of runs produced ~4 600 000 counts

TABLE I. Energies and relative intensities [The 1420.5 keV energy is used as the standard (=100).] of specified γ rays observed in the decay of ^{139}Ba.

Energy [c] (keV)	Present investigation Relative intensity	Berzins [a] Relative intensity [d]	Hill [b] Relative intensity
1256.7	1.03 + 0.12	1.7	1.2 [e]
1518	0.02 [f]	0.02	0.01 [e]
1601.4	0.05 + 0.01	0.08	0.06 [e]
1691.2	0.11 + 0.01	0.09	
1762	0.03 + 0.01	0.02	0.009 [e]
1797.4	0.02 + 0.01	0.03	

[a] Reference 3.
[b] Reference 2.
[c] Energies listed are those found by Berzins *et al.* No determination of this was made in the current investigation.
[d] γ-ray intensities only. The experimental uncertainty is <10% for intensity values >1.0 and may be as large as 50% for values <0.1.
[e] Reported upper limit.
[f] Upper limit.

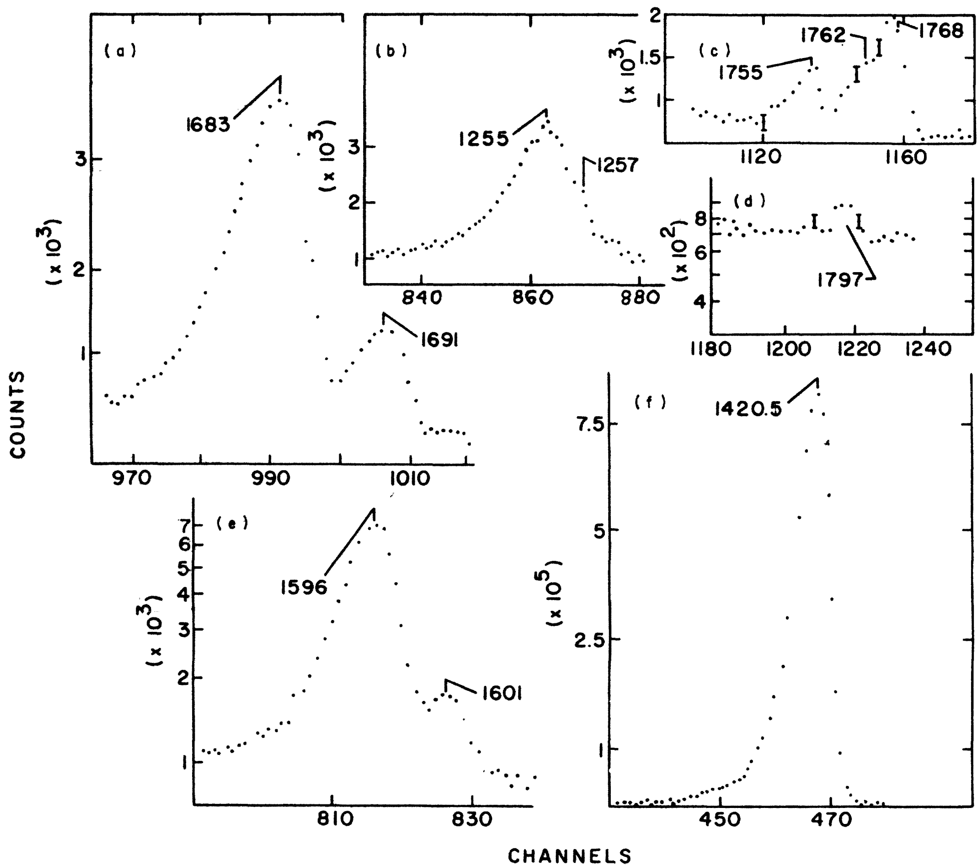

FIG. 1. Regions of the ^{139}Ba spectrum significant in current investigation. Except for the 1255–1257 keV peaks, all curves include the data of both the initial spectrum and the "delayed" spectrum. (a) 1683–1691 keV doublet. (b) 1255–1257 keV peaks. The 1257 keV peak weakly appears in the high-energy tail of the 1255 keV γ ray. (c) 1755, 1762, and 1768 keV peaks. Adjacent channels are combined to better depict the weak 1762 keV peak. (d) 1797 keV peak. Adjacent channels are combined. (e) 1596–1601 keV doublet. (f) 1420.5 keV peak.

in the 1420.5 keV peak. At the conclusion of this series of runs, all of the peaks under investigation were observed except for the 1257 and 1518 keV γ rays. The 1257 keV peak was identified after only three samples were counted using the 0.25 keV channel width. This procedure produced ~87 000 counts in the 1255–1257 keV peaks. Only an upper limit for the intensity of the 1518 keV peak could be established due to poor statistics.

The half-life of each of the established peaks was verified by means of a "delayed" spectrum. The samples were permitted to decay for one additional half-life prior to counting. This "delayed" spectrum was then compared to the original spectrum.

Figure 1 shows the significant regions of the γ-ray spectrum of ^{139}Ba. Except for the 1255–1257 keV peaks, all curves include the results of both the initial observations and those obtained in the half-life measurements. Positive identification of the 1518 keV γ ray was not possible in any of the measurements.

Table I compares the significant intensities found in the present investigation with those in Refs. 2 and 3. The intensities of the double and triple peaks were established by comparison of the full energy peak profile (after the background is subtracted) with a standard profile. This information and the counter efficiency for each energy provides sufficient data to determine the relative intensities. A discussion of the uncertainties associated with this method is outlined by Donnelly *et al.*[4]

The half-life measurements positively verify that all γ rays are due to ^{139}Ba except the 1518 and the 1762 keV peaks. Only an upper intensity limit of 0.02 could be established for the 1518 keV γ ray due to poor statistics. Thus, no accurate half-life measurement could be made. Verification of the 1762 keV γ ray half-life is not possible unambiguously, although the similarities in the shape of the initial spectrum and the delayed spectrum support the supposition that this γ ray is that of ^{139}Ba.

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