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ABSTRACT

The energies of the first excited states of Th^{226}, Ra^{222}, and Em^{218} have been measured from the decay of the U^{230} series using photographic recording beta ray spectrographs. The energy of the second excited state in Th^{226} is reported, and a comparison is made with predictions of the Bohr-Mottelson nuclear model.

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This note will describe the results of a study of the conversion-electron spectrum of the U^{230} series, in which precision measurements have been made of the energies of the first excited states of Th^{226}, Ra^{222}, and Em^{218}, and a value also reported for the second excited state of Th^{226}. This work is part of a program concerned with a study of the detailed behavior of low lying rotational states in heavy nuclei.[1]

The alpha and gamma ray spectra of the U^{230} family have been studied by Asaro, Slater, and Perlman,[2] who reported from scintillation spectrometer measurements the energies of the first excited states in Th^{226}, Ra^{222}, and Em^{218} as 70, 109, and 330 kev, respectively. From later evaluation of the gamma-ray data and inclusion of the alpha particle spectrograph measurements, they obtained values of 72.6 ± 0.5, 112 ± 3, and 325 ± 3 kev. They also found that the 4+ level in Th^{226} lies near the 1- level at 232 ± 3 kev. Grover and Seaborg[3] also found the 1- level at 232 kev from Ac^{226} beta decay.

The present measurements have been made with two 180° photographic recording permanent-magnet spectrographs of effective field strengths 52 and 98 gauss; the instruments and their calibration have been described previously.[1]

The U^{230} was obtained by separation from its parent, Pa^{230}. The Pa^{230} had been prepared by irradiation of a slab of thorium metal with

100-Mev protons in the 184-in. cyclotron. U^{232} was also formed in this bombardment following beta decay of Pa^{232}. About one month after the irradiation the thorium target was dissolved, and a uranium fraction was separated by selective stripping of the activities from a Dowex A-1 resin column with hydrochloric acid solutions. Further purifications of the uranium fraction were made by ether extractions from 0.1 N HNO_3 solutions saturated with ammonium nitrate.

The pure uranium fraction was evaporated to dryness then taken up in 500 μL of 0.4 M $(NH_4)_2C_2O_4$ in a special plating cell[1] from which the uranium was electrodeposited upon a 10-mil platinum wire. The active wire was then mounted in the appropriate spectrograph camera.

Although the spectrographs have been extensively calibrated, it was decided to use an internal standard in these experiments to gain the maximum precision; for this purpose, the 120-day beta emitter $_{69}Tm^{170}$ was used. The energy of the gamma ray of Tm^{170} has recently been measured by Hatch and DuMond[4] (using a 2-m diffraction spectrometer) to be 84.26 ± 0.02 kev. This activity makes a very good standard both because its conversion electrons are quite similar in energy to those of U^{230} and also because thulium is easily electroplated.

Two independent measurements were made in the 52-gauss spectrograph of the energy of the U^{230} gamma ray. In the first, the Tm^{170} was initially plated upon the wire and the U^{230} was subsequently plated on the same wire which was then run in the spectrograph. In the second experiment, wires containing Tm^{170} alone and U^{230} alone were exposed in succession without removing the photographic plate between exposures (care was taken to reproduce as closely as possible the

position of the source holder when changing from Tm^{170} to U^{230} wires). The results of these experiments are given in Table I, in terms of the previous calibration of the instrument; the agreement between the two experiments was better than 0.1 percent for all lines so the results are given as average values. Using the Tm^{170} - U^{230} energy difference obtained here, 12.13 ± 0.06 kev, together with the Tm^{170} energy of Hatch and DuMond,[3] we obtain the energy of the U^{230} gamma ray, 72.13 ± 0.06 kev.

Table I

Energy of U^{230} and Tm^{170} Gamma Rays in kev*

Isotope	E_e	Shell	E_γ
U^{230}	52.45	L_{II}	72.12
	55.82	L_{III}	72.10
	67.30	M_{II}	72.11
	68.08	M_{III}	72.11
Tm^{170}	73.74	L_I	84.23
	74.26	L_{II}	84.25
	75.29	L_{III}	84.24
	82.07	M_{II}	84.25
	82.28	M_{III}	84.24
U^{230} (E_γ) = 72.11 kev			
Tm^{170} (E_γ) = 84.24 kev			

*Binding energies have been taken from the compilation of Hill, Church, and Mihelich, Rev. Sci. Instr. 23, 523 (1952).

In the 98-gauss spectrograph, the Th^{226} gamma ray energy was measured from six conversion lines to be 111.1 ± 0.3 kev as the result of two experiments. A separate internal standard was not used in these exposures, but the value also obtained for the U^{230} gamma ray, 72.1 kev, was in good agreement with the result of the more accurate measurement just described. In addition, the K line of the Ra^{222} gamma ray was observed and corresponded to a gamma energy of 324.6 kev; since only one line was seen in this case, a probable limit of error is not quoted.

Two weak lines were also seen from L_{II} and L_{III} conversion of the weak 4+ → 2+ gamma ray in Th^{226} following alpha decay of U^{230}. The corresponding gamma ray energy is 154.3 kev indicating that the 4+ state in Th^{226} lies at 226.4 kev.

Although relative intensities of the U^{230} series conversion lines were not measured because of the high background caused by the radium emanation, the line patterns were easily observed to possess the familiar characteristics of low-energy E2 transitions, that is, prominent conversion in the p electron shells and extremely weak s electron conversion.

In addition, six extremely weak lines with the following energies were observed: 120.0, 122.4, 127.4, 143.0, 159.9, and 199.0. These lines did not seem to correspond to any of the known gamma rays in the U^{230} family[2] and hence were unassigned.

The presence of U^{232} in the uranium fraction would cause Th^{228} and its daughters to grow into the sample. At the time the measurements were made the most intense line in the U^{232} family above 100 kev would be the "F" line of Pb^{212} at 148.1 kev;[5] this line was not observed.

In the unified nuclear model of Bohr and Mottelson[6] the following formula is given for the rotational energy level spacings in even-even nuclei:

$$E_i = AI_i(I_i + 1) - BI_i^2(I_i + 1)^2$$

where $A = \hbar^2/2\mathcal{J}$ and $B = 2(1/\hbar\omega)^2(\hbar^2/\mathcal{J})^3$.

Using the energies obtained for the first two excited states of Th^{226}, 72.13 and 226.4 kev, the above constants were evaluated to be A = 12.16 kev and B = 0.043 kev. These values can be compared with those found for the excited states of Pu^{238} observed from the alpha decay of Cm^{242} which were A = 7.37 kev and B = 0.0035 kev. The wider rotational energy spacings seen as one approaches closed nucleon shells are reflected in the larger value of A (smaller deformation) obtained for Th^{226} than for the heavier even-even nuclei. Also, the tenfold increase in the deviation constant B over that for Pu^{238} indicates vividly the failure of the simple I(I + 1) dependence to describe the energies of excited states of even-even nuclei in the mass region of A = 226.

REFERENCES

1. W. G. Smith and J. M. Hollander, "Conversion Electron Spectra of Cm^{242} and Cm^{244}," Phys. Rev. (in press).
2. Asaro, Slater, and Perlman, reported by Stephens, Asaro, and Perlman, Phys. Rev. 96, 1568 (1954) and Phys. Rev. (to be published).
3. J. R. Grover and G. T. Seaborg, unpublished results (1954).
4. E. Hatch and J. W. M. DuMond, private communication (September 1955)
5. D. I. Meyer and F. H. Schmidt, Phys. Rev. 94, 927 (1954).
6. A. Bohr and B. R. Mottelson, Kgl. Danske Videnskab Selskab, Mat.-fys. Medd. 27, No. 16 (1953); K. Siegbahn, Editor, Beta and Gamma Ray Spectroscopy (Interscience Publishing Company, Inc., New York, 1955), Chapter 17, p. 468.