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The Disintegration of Se^{75}

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The photoelectrons produced in both lead and uranium radiators by the gamma-rays following K-capture in Se^{75} have been investigated using a uniform field, semi-circular magnetic spectrometer. The gamma-rays thus found have energies of 76 kev, 123 kev, 137 kev, 267 kev, 283 kev, and 405 kev with a possible radiation at approximately 99 kev. A tentative decay scheme is proposed.

I. INTRODUCTION

THE 125-day activity which has been assigned[1-2] to Se^{75} and which decays by K-capture to As^{75} has been studied in order to determine the energies of the gamma-rays present in its disintegration. A possible decay scheme has also been proposed.

A somewhat similar investigation using a lens spectrometer reports[3] gamma-rays having energies of 0.097, 0.122, 0.137, 0.265, and 0.400 Mev.

II. APPARATUS

The uniform field semicircular magnetic spectrometer used for these investigations has been previously described in some detail.[4] The radius of curvature of the electron path between source and counter is 14 cm. Baffles have now been placed at 30°, 90°, and 150° from the source in order to reduce possible errors caused by scattering.

The magnetic field is measured by the flip coil and ballistic galvanometer arrangement previously described.

The counter is of the end window type, the opening for the window being in the form of a narrow slit which serves also as the exit slit of the spectrometer.

Windows used in this experiment were made either of Nylon or Zapon, the former having a lower cut-off energy of 26 kev (550 gauss-cm of momentum) and the latter a similar cut-off energy of 2 kev (150 gauss-cm). Pressure in the thin Zapon window counter was kept constant by means of a pressure control device described elsewhere.[5] Both counters were normally operated with an argon-ethylene mixture ratio of four to one and a total pressure of 8 cm Hg.

III. EXPERIMENTAL DETAILS AND RESULTS

The Se^{75} measured in this investigation was obtained through slow neutron bombardment of selenium powder in the pile at Oak Ridge. A spectrographic analysis (as furnished by Oak Ridge) of the selenium used in the bombardment indicates nothing more than traces of any impurity, with the lines of selenium being very strong. A careful study indicates that the chances are very small that any of the gamma-rays found are the result of impurities in the sample bombarded. Since no selenium isotope other than Se^{75} has a comparatively long half-life,[6] the investigation of the gamma-rays was not begun until approximately one month after the active sample had been received from Oak Ridge. For this reason all gamma-rays found should be associated with the decay of the single isotope Se^{75}.

Because of the large number of lines which

[1] H. N. Friedlander, L. Seren, and S. H. Turkel, Phys. Rev. **72**, 23 (1947); Phys. Rev. **72**, 888 (1947).
[2] W. S. Cowart, M. L. Pool, D. A. McCowan, and L. W. Woodward, Phys. Rev. **73**, 1454 (1948).
[3] E. N. Jensen, L. J. Laslett, and W. W. Pratt, AECD-1836 (1948); E. N. Jensen, AECD-2399 (1948).
[4] F. N. D. Kurie and M. Ter-Pogossian, Phys. Rev. **74**, 677 (1948).
[5] M. Ter-Pogossian, J. Townsend, and J. E. Robinson, Rev. Sci. Inst., in press.
[6] G. T. Seaborg and I. Perlman, "Table of the isotopes," Rev. Mod. Phys. **20**, 585 (1948).

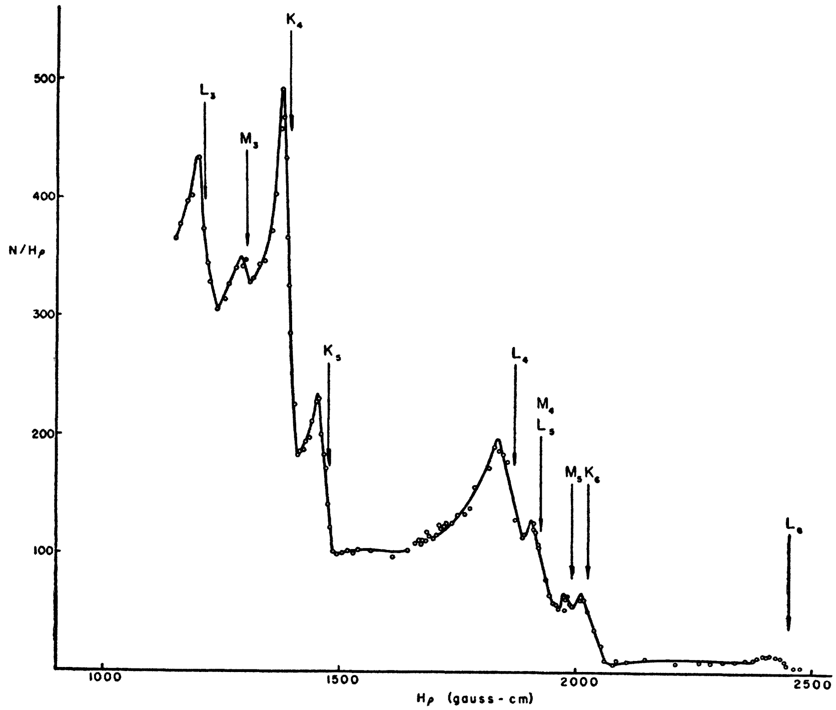

FIG. 1. Spectrum of the Compton and photoelectrons ejected from a 50-mg/cm^2 uranium radiator by the gamma-rays of Se^{75}.

required analysis both uranium and lead foils were used as radiators of photoelectrons. The use of both uranium and lead radiators greatly facilitates the assignment of the observed photoelectron lines to their respective gamma-rays, since the relative position of any one line in the two cases will depend markedly upon whether it is produced by the ejection of an electron from the K, L, or M shell of the atom. The thickness of both lead and uranium radiators was 50 mg/cm^2. The selenium source was placed immediately behind the radiator in either a copper or Lucite capsule.

The relative numbers of Compton and photoelectrons ejected from the uranium radiator are indicated in Fig. 1. Here the total number of electrons per unit momentum interval ($N/H\rho$) is plotted against momentum ($H\rho$ in gauss-cm). The window used in this case was the Nylon window. A similar result using the lead radiator and the Nylon window is shown in Fig. 2. In order to make a more accurate study of the low energy gammas the results shown in Fig. 3 were obtained using the same source and lead radiator as used to obtain Fig. 2, but this time with the thin Zapon window counter.

The photoelectron lines found have been analyzed as indicated in Table I into six distinct groups whose gamma-energies are: 76 kev, 123 kev, 137 kev, 267 kev, 283 kev, and 405 kev. These gammas have been indicated by the numbers 1 through 6, respectively, in the table and in the figures and their K, L, and M lines are indicated in the figures with appropriate subscripts. In addition to the lines thus analyzed there is a slight protuberance discernible in Fig. 3 at approximately 350 gauss-cm. If this slight rise is assumed to be produced by photoelectrons projected from the K shell of the lead atom, then the energy of the gamma-ray which produces these electrons must be approximately 99 kev. This is in agreement with the energy of 97 kev reported by Jensen *et al.*[3] for one of the gamma-rays from Se^{75}. Its proximity to the Zapon window cutoff energy will reduce its intensity by a considerable factor and thereby make it difficult to observe.

These results are in relatively good agreement with the results reported[3] by the Iowa State group. Two additional gammas have however been found, these being at 76 kev and 283 kev. Both of these radiations have more recently been observed[7] by the Iowa State group as indicated in Table I.

IV. POSSIBILITY OF A METASTABLE STATE

Laslett[7] has also indicated that in their work the 99-kev gamma-ray has been found as an internal conversion line but only weakly in the photoelectron spectrum. This, in conjunction with the current results showing a very weak photoelectron line, means that for this particular radiation the coefficient of internal conversion is quite large. There are in this region of the periodic table several cases where a large coefficient of internal conversion exists because of the high multipole order and

[7] L. J. Laslett, private communication.

small energy of the gamma-rays.[8] A nucleus which emits such a high multipole order low energy radiation is, in general, metastable with a half-life appreciably long in comparison to the lifetime of a nuclear state producing the more common dipole or quadrupole radiation.

In order to test for a metastable state in As^{75} a chemical separation of the type described by Friedlander *et al.*[1] was carried out with arsenic carrier being added to the active selenium. A check of the activities after separation revealed all the activity in the selenium fraction. From this, one concludes that a metastable state in As^{75}, *if it exists*, has a half-life sufficiently short that it cannot be measured by these techniques; that is of the order of magnitude of 20 seconds or less. Another investigation[9] reports that As^{75} has no metastable state whose half-life is in the range 10^{-6} second to 10^{-3} second. This narrows considerably the possible range of half-life values available to an As^{75} metastable state. The only other alternative is that the metastable state, *if it exists*, occurs in the parent nucleus, Se^{75}.

That the isomeric state should occur in Se^{75} seems quite reasonable in view of recent work[10] on the shell structure theory of the nucleus. It has been pointed out in this work that isomerism should in general be correlated with the odd member of the pair N, Z, where N represents the number of neutrons in a nucleus and Z the number of protons. For Se^{75} the odd member is $N=41$ whereas for As^{75} the odd member is $Z=33$. Two general islands of isomerism have been found in the regions $39 \leqslant (Z$ or $N) \leqslant 51$, and $63 \leqslant (Z$ or $N) \leqslant 81$. No such case of isomerism has been reported in the region $31 \leqslant (Z$ or $N) \leqslant 37$.

Experimental evidence for such a metastable state in Se^{75} is however non-existent. Using a Cauchois bent crystal spectrograph, Stokes[11] has studied the K_α radiation emitted by the active selenium. No trace of radiation having a wavelength corresponding to the K_α lines of selenium could be found whereas a strong arsenic K_α line was obtained.

TABLE I. Gamma-ray energies as calculated from photoelectron lines in the three sets of data compiled in the current investigation with comparative energies as reported by Jensen, Laslett, and Pratt.*

Gamma	Fig. 1	Fig. 2	Fig. 3	Jensen, Laslett and Pratt
1	—	76	76	77**
			(99?)	99**
2		124	122	122
3	139	137	137	137
4	267	267		265
5	283	283		281**
6	407	404		400

* See reference 3.
** Private communication from Dr. L. J. Laslett.

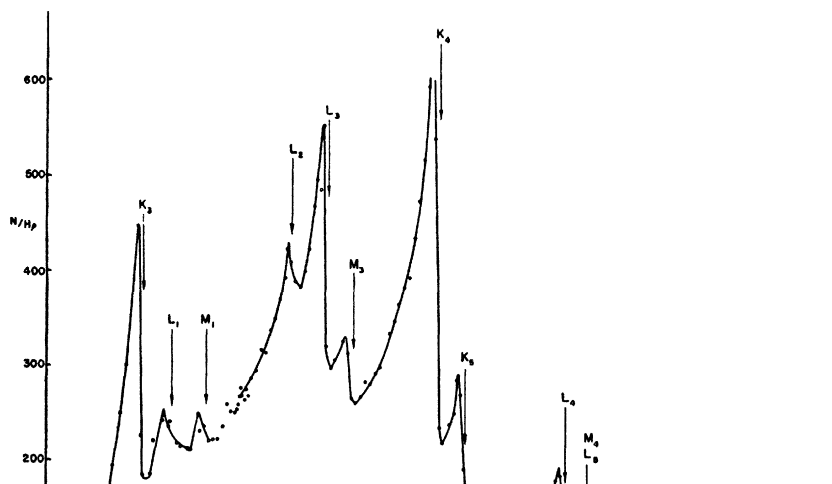

FIG. 2. Spectrum of the Compton and photoelectrons ejected from a 50-mg/cm² lead radiator by the gamma-rays of Se^{75}. The G-M counter used to obtain these data had a Nylon window which passed electrons whose energies were greater than 26 kev (550 gauss-cm of momentum).

[8] A. C. Helmholz, Phys. Rev. **60**, 415 (1941). Bradt, Gugelot, Huber, Medicus, Preiswerk, and Scherrer, Helv. Phys. Acta **XVIII**, 351 (1945).
[9] S. De Benedetti and F. K. McGowan, Phys. Rev. **74**, 728 (1948).
[10] E. Feenberg and K. C. Hammack, Phys. Rev. **75**, 332 (1949) and private communication.
[11] R. H. Stokes, AECD-1943 (1948) and private communication from Professor L. J. Laslett.

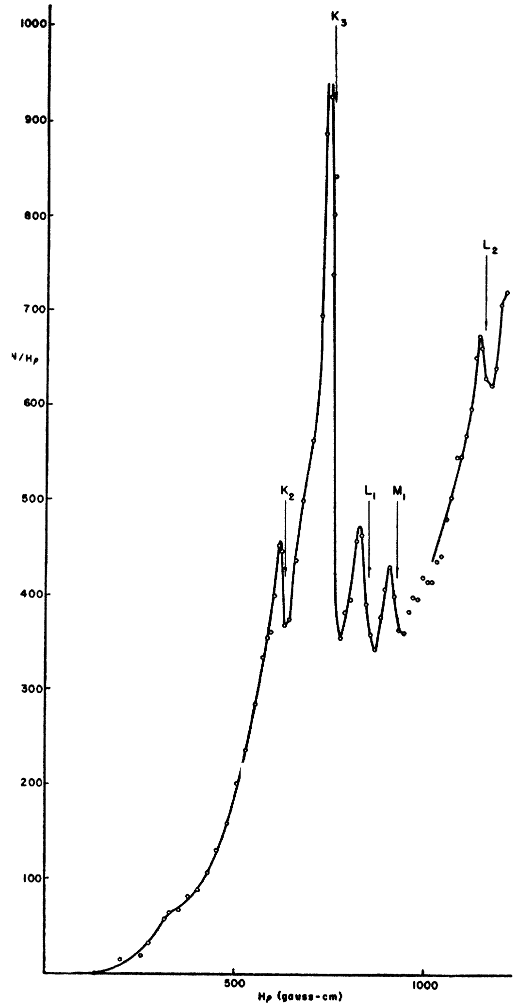

FIG. 3. The low energy region of the Compton and photoelectron spectrum produced by the gamma-rays of Se^{75}. The G-M counter used to obtain these data had a Zapon window with a lower cut-off energy of 2 kev (150 gauss-cm of momentum).

Except for the fact that the 99-kev gamma-ray is highly converted, there is no positive evidence of a metastable state in either the Se^{75} or the As^{75} nucleus. The evidence, however, is not yet sufficiently complete to make any definite conclusions regarding the existence of such a state. The absence of Se^{75} K_α radiation would seem to indicate that the metastable state, if it exists, is present in the daughter element, As^{75}.

Using the formula derived by Dancoff and Morrison[12] relating the conversion coefficient in the K shell and the multipole order (l) of the radiation:

$$\alpha_K = Z^3\alpha^4(l/l+1)(2/E)^{l+5/2},$$

where α is the fine structure constant, one finds that a multipole order $l=2$ would yield approximately 2 internal conversion electrons for every gamma-ray corresponding to the 99-kev transition. A half-life[8] of about 10^{-7} second would be expected for such a multipole order. For a multipole order $l=3$ about 25 internal conversion electrons are predicted for each gamma-ray with an expected half life of about 10^{-2} second. These half-lives are in the regions yet unexplored as indicated above and one of these half-lives may well be found upon the development of new techniques.

V. A TENTATIVE DISINTEGRATION SCHEME

It is of interest to note that the 123-kev and 283-kev gammas and the 137-kev and 267-kev gammas add, respectively, to 406 and 404 kev. These sums are identical within experimental errors with the single quantum transition producing the 405-kev gamma. It therefore seems quite reasonable to assume that the 137-kev and 267-kev gammas are in cascade as well as the 123-kev and 283-kev gammas, both of these groups then going to the ground state of As^{75} in parallel with the 405-kev gamma. One cannot immediately fit either the 76-kev nor the 99-kev gamma into such a scheme. Their positions in any tentatively proposed scheme would be quite arbitrary.

In addition to the ones reported here there has also been a gamma-ray at 10.3 kev reported by Stokes.[11] No attempt has been made to fit it into the level scheme here.

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[12] S. M. Dancoff and P. Morrison, Phys. Rev. **55**, 122 (1939).