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Radiations from F^{18}, Mo^{93}, and Cl^{34}

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The positron spectrum of F^{18} was investigated with a magnetic lens spectrometer and found to be of the allowed type with an upper limit at 649±9 kev. The gamma-radiation from Mo^{93} was found to consist of three lines at 262±2 kev, 692±11 kev, and 1.51±0.035 Mev. The K to L conversion ratio for the low energy line indicates 2^5 pole electric radiation. The positron spectrum of Cl^{34} consists of three components with upper limits at 4.45 Mev, 2.6 Mev, and 1.3 Mev. Gamma-ray lines were found at 3.3 Mev and 2.1 Mev and at 0.145±0.003 Mev. The latter line gives rise to internal conversion electrons.

I. INTRODUCTION

THE radiations of F^{18}, Mo^{93}, and Cl^{34} have been investigated on a large magnetic lens spectrometer, similar in dimensions and internal design to one already described.[1] The chamber is 48″ long and 10″ i.d. Internal baffles include a set of helical fins to separate positive and negative electrons, and a variable ring focus aperture to minimize spherical aberration. The coils are wound of insulated copper ribbon, 1536 turns of which have been combined to form two thick magnetic lenses, placed one at the source and one at the detector position. This produces a field form which has been found to give minimum lens aberration.[2] Iron bands spaced along the spectrometer chamber provide magnetic shielding to stray fields.[3] Current regulation of better than 0.1 percent is accomplished through the use of grid-controlled rectifiers. Using internal conversion electrons from the 661.4-kev gamma-ray of Ba^{137}, the spectrometer has been calibrated at resolutions of 1.75 and 4.11 percent. The calibration was checked with photoelectrons from the gamma-rays of Ni^{60}.

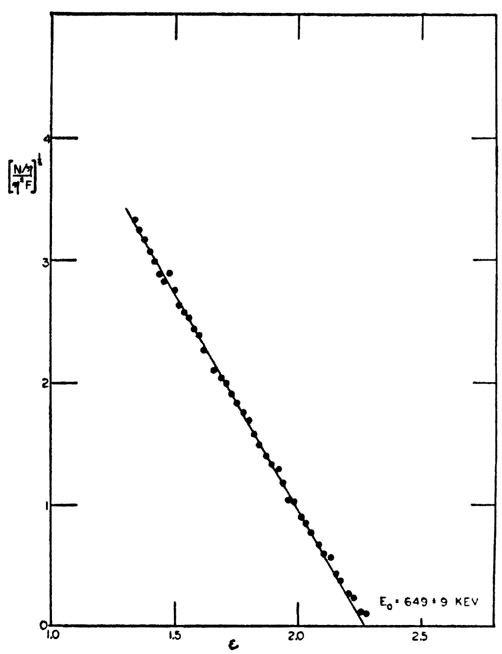

FIG. 1. Kurie plot of positron spectrum of F^{18}.

II. FLUORINE 18

As a preliminary to the measurement of the spectrum of F^{18}, our apparatus was checked by a measurement of the well known spectrum of N^{13}.

The spectrum of 112-min F^{18} has been studied in a spectrometer by Blaser *et al.*[4] The activity was produced in mica by $O^{18}(p,n)F^{18}$. Blaser obtained a position spectrum which gave a straight line Kurie plot with intercept at 635±15 kev. No gamma-rays were mentioned. Knox has also searched with negative result for gamma-rays from F^{18}.

The activity was produced here in Al_2F_6 by $F^{19}(p,pn)$

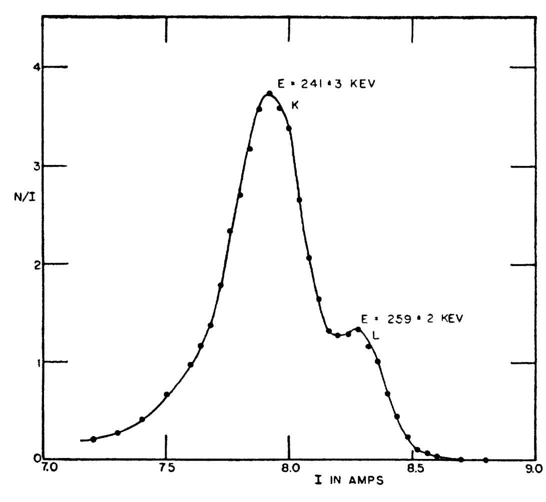

FIG. 2. Conversion electrons from Mo^{93}.

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[1] Hornyak, Lauritsen, and Rasmussen, Phys. Rev. **76**, 731 (1949).

[2] W. Glaser, Z. Physik **116**, 19 (1940).

[3] L. M. Langer, Phys. Rev. **77**, 50 (1950).

[4] Blaser, Boehm, and Marmier, Phys. Rev. **75**, 1953 (1949).

F^{18}. No gamma-rays were found. The Kurie plot is a straight line with intercept at 649±9 kev (see Fig. 1). Below 100 kev the plot becomes distorted, principally because of window absorption. The maximum energy corresponds to a mass difference $M(F^{18})-M(O^{18})=1.795\pm0.0097$ milli-mass units. The value of ft is about 5×10^3, indicating an allowed transition. Since the ground state of O^{18} is assumed to be $^1S_0$, G.-T. selection rules require that the ground state of F^{18} is $^3S_1$.

III. MOLYBDENUM 93

The 6.7-hour activity of Mo^{93} has been investigated by Kundu and Pool.[5] The latest report describes the activity as an isomer decaying by the emission of three gamma-rays in tandem, followed by a beta-decay of long half-life. The gamma-ray energies are 0.3 and 0.7 Mev, identified by conversion electrons, and 1.6 Mev, identified by Compton electrons.

The activity was produced here in columbium (niobium) foil by $Cb^{93}(p,n)Mo^{93}$. Internal conversion electrons at 241±3 kev for K and 259±2 kev for L conversion were found (Fig. 2). This corresponds to a gamma-ray of 262±2 kev. With the spectrometer adjusted for high transmission, conversion electrons at 672±11 kev were observed, corresponding to a gamma-ray of 692±11 kev. The ratio of intensity for the internal conversion lines from the two gamma-rays is $3.2\times10^2/1$. Photoelectrons from a 2-mil thorium converter occur with maxima at 547±6 kev and 1.37±0.03 Mev (Fig. 3). The peak shift correction, 30±5 kev, has been obtained at the lower energy from measuring the shift in the same converter of the 661.4-kev Ba^{137} gamma-ray. The correction at the higher energy is estimated to be essentially the same.[1] Taking into account peak shift and K binding corrections gives for the gamma-ray energies 687±11 kev and 1.51±0.035 Mev.

From N_K/N_L for the 262-kev gamma-ray, an estimate of the character and multipolarity of the radiation can be made and the K shell partial internal conversion coefficient calculated. Separation of the composite spectrum (Fig. 2) gives $N_K/N_L=2.9\pm0.2$. This value is in agreement with the results of Alburger *et al.*,[6] who obtained a ratio of 2.8±0.3. The theoretically predicted value of N_K/N_L for a 2^5 pole electric transition is 3.0.

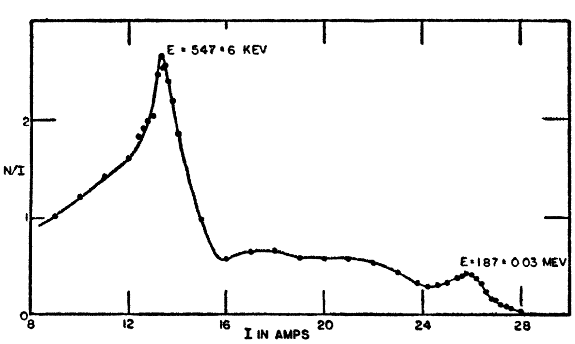

FIG. 3. Photoelectrons produced by Mo^{93} in a 2-mil Th foil.

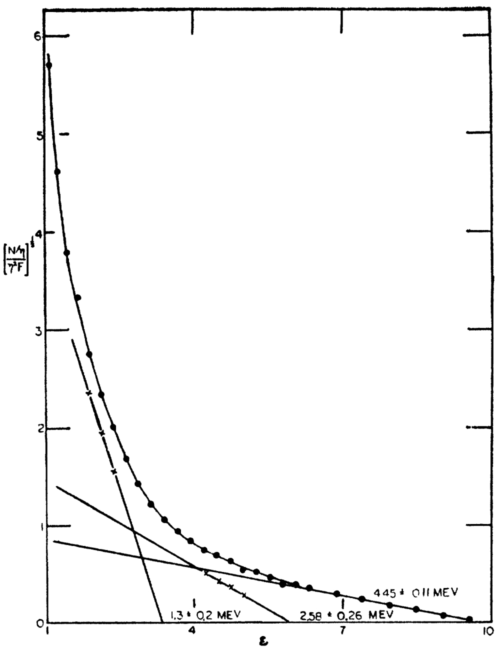

FIG. 4. Kurie plot of positron spectrum of Cl^{34}.

IV. CHLORINE 34

The spectrum of 35-min Cl^{34} has been investigated by Zah Wei-Ho using a cloud chamber.[7] A gamma-ray of 3.4 Mev and two groups of positrons were found. Analysis by means of a modified Kurie plot, involving a Konopinski-Uhlenbeck correction, gave end points at 5.1 and 2.4 Mev.

A preliminary report on this isotope has already been made by the present authors.[8] The activity was produced by $S^{34}(p,n)Cl^{34}$ and by $Cl^{35}(p,pn)Cl^{34}$. For practical reasons, spectroscopic measurements were made by bombarding NaCl, thus making use of the latter mode. Three groups of positrons are indicated. This is evident both from the positron spectrum[8] and the fact that the Kurie plot cannot be resolved into two components (Fig. 4). The maximum energies are 4.45±0.11 Mev, 2.58±0.26 Mev, and 1.3±0.2 Mev.

Conversion electrons at 142±3 kev, corresponding to a 145±3 kev gamma-ray, have been found.[8] The decay of this line has been followed for three half-lives in the spectrometer to verify its origin in Cl^{34}. The ratio

[5] D. N. Kundu and M. L. Pool, Phys. Rev. **70**, 111 (1946), and Phys. Rev. **76**, 183 (1949); M. L. Pool, Helv. Phys. Acta, Supplement III (1950).

[6] D. Alburger, *et al.*, Brookhaven National Laboratory Quarterly Progress Report, July 1–September 30, 1950 (unpublished).

[7] Zah Wei-Ho, Phys. Rev. **70**, 782 (1946).

[8] L. Ruby and J. R. Richardson, Phys. Rev. **80**, 760 (1950).

of positrons to conversion electrons is 17/1. The *L* photoelectron spectrum has been observed with a thorium converter.

The Compton spectrum produced in a copper radiator has inflection points corresponding to gamma-rays of 3.30±0.14 Mev and 2.13±0.12 Mev.

It seems plausible to assume that Cl^{34} decays to S^{34} alternatively by three beta-gamma transitions. This is summarized in the following table. The figures involving the low energy gamma-ray are in parentheses because its position in the disintegration scheme is uncertain.

Beta-energy	Branching ratio	*ft*	Gamma-energy	Total energy
4.45±0.11 Mev	0.46	1.2×10^7	(0.145±0.003 Mev)	(4.6±0.11 Mev)
2.58±0.26 Mev	0.28	1.7×10^6	2.13±0.12 Mev	4.7±0.3 Mev
1.3 ±0.2 Mev	0.26	8.9×10^4	3.30±0.14 Mev	4.6±0.2 Mev

The portion of the Kurie plot due exclusively to the high energy positron component has been examined more extensively in this laboratory.[9] However, using the allowed Fermi function, no evidence of any divergence from linearity was found in the resulting plot.

[9] David Green (private communication).

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Neutron-Deuteron Scattering Amplitudes

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The diffraction of neutrons from deuterium containing compounds gives the coherent scattering section of deuterium which can be used to determine the spin dependent scattering amplitudes. Studies have been made on a number of deuterium containing compounds but the results reported here are concerned primarily with recent measurements on NaD. X-ray measurements have been used in interpreting the thermal vibration effects in the crystal and use has been made of Na scattering cross-section data obtained from various sodium containing compounds. This experiment gives $\sigma_{coh}=5.2\pm0.3$ barns. This value can be combined with the results of other deuterium cross-section measurements to give pairs of values for the individual quartet and doublet spin amplitudes for *n-d* scattering. Various experimental results bearing on this point are summarized. Recent theoretical work seems to have eliminated the ambiguity in the experiments with regard to which of two sets of values of the spin amplitudes is to be chosen.

THE first measurements of the coherent scattering cross section for neutrons on deuterium were made by studying the powder diffraction pattern of NaD.[1] These measurements showed the coherent scattering amplitude to have a positive sign and although the accuracy of the cross-section measurements suffered from uncertainty in the sample purity, they definitely indicated that the coherent scattering cross section is smaller than the total scattering cross section and hence that the scattering is spin dependent.

Since the time of these early experiments a number of other measurements involving the deuterium scattering amplitudes have been made. Powder diffraction patterns have been obtained at this Laboratory on several deuterium containing compounds; Fermi and Marshall[2] have studied the transmission of neutrons by deuterium gas, and Hurst and Alcock[3] have measured the angular dependence of the scattering by the gas.

Compounds studied by the powder technique include heavy ice,[4] ThD_2 and UD_3,[5] and more recent measurements on NaD and LiD, and in addition, a study by Levy and Peterson[6] has been made on ND_4Br. Most of these compounds have been studied for the primary purpose of determining the hydrogen positions in the respective crystal lattices. Pure compounds have, however, been used in every case and each experiment can be considered as a separate determination of the coherent scattering cross section of deuterium. The recent measurements with NaD and LiD* have, however, been made for this express purpose and these compounds have the advantage over the more complex compounds in that the determination of the cross section is not tied in with a simultaneous crystallographic study of the hydrogen atom locations. Only the recent measurements on NaD will be discussed in detail; the large absorption by Li makes the LiD results less significant. Samples were carefully prepared and analyzed for us by Mr. D. Lavalle of this Laboratory. A sufficient number of powder diffraction patterns were obtained by the automatic recording technique to obtain good statistics. The crystal structure scattering amplitudes calculated from the pattern by the powder formula are represented by the points in Fig. 1 plotted on semilog scale against $\sin^2\theta/\lambda^2$. The ordinate scale of

[1] Shull, Wollan, Morton, and Davidson, Phys. Rev. **73**, 842 (1948).
[2] E. Fermi and L. Marshall, Phys. Rev. **75**, 578 (1949).
[3] D. G. Hurst and N. Z. Alcock, Can. J. Phys. **29**, 36 (1951).
[4] Wollan, Davidson, and Shull, Phys. Rev. **75**, 1348 (1949).
[5] Unpublished data by R. E. Rundle and the present authors.
[6] H. Levy and S. W. Peterson, private communication.
* The sample of LiD was kindly supplied by Metal Hydrides, Inc., Beverly, Massachusetts.