Beta Decay of Np^{238}

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(Received December 14, 1953)

WE have reinvestigated the beta and conversion electron spectrum of 2.1-day Np^{238} using a precision double-focusing spectrometer[1] and a high-transmission intermediate-image spectrometer.[2] The previous investigation of Freedman *et al.*[3] (with Mihelich's[4] reinterpretation of some low-energy conversion lines) showed gamma transitions of 43, 103, 983, and 1030 kev and a two-component beta spectrum, 47 percent with an end point of 1272 kev and 53 percent with 258 kev. The spectrum of the 1272-kev group was reported to have allowed shape. Decay schemes have been proposed by Freedman *et al.*[3] and by Asaro *et al.*[5] The fine structure observed in alpha decay[5] of Cm^{242} also gives valuable evidence regarding the low-lying levels of Pu^{238}.

Np^{238} was produced by bombardment of uranium metal with a 12.5-Mev internal proton beam. A uranium disk was placed in a cavity of a copper plate soldered to the water-cooled target holder. The uranium surface facing the beam was covered with a 0.015 mm thick platinum foil in order to prevent sputtering of uranium into the cyclotron chamber. Essentially weightless and chemically pure samples of neptunium were isolated using separation procedures previously described,[6] the final step involving separation of neptunium from lanthanum carrier by a cation exchange column elution with 13*M* HCl.

Table I summarizes the energies and intensities of observed conversion lines due to Np^{238} decay. The intensities of the lowest-energy conversion lines were corrected slightly for counter window transmission loss. Of greatest interest is the evidence for additional gamma transitions of 939 and 925 kev, although the latter was so weak as to be somewhat uncertain.

The agreement of energies from this work and from alpha spectroscopy of Cm^{242} indicates that the 44.1-kev transition is between the first excited state and ground state of Pu^{238}, while the 102.1-kev transition is between second and first excited states. The ratios of the *L* subshell conversion coefficients[7] point to *E*2 assignments for these transitions. The energy difference between the 1030- and 986-kev gamma rays is 44 kev, leading us to believe that both of these gamma rays arise from a common level and go to ground and first excited states, respectively. The 939-kev gamma ray evidently most come from a level with energy near that of the 1030-kev level. Although it does not seem possible to construct a unique decay scheme from the available data, it seems probable that both the hard and soft beta groups are themselves complex. We determined the ratio of the intensities of hard to soft beta groups as 55:45, in good agreement with the ratio 53:47 of Freedman *et al.*[3] The 44.1-kev transition, being *E*2, is almost totally converted, and from Table I the total conversion line intensity is 65 percent of total beta disintegrations. Hence, if more than 10 percent of the soft beta particles cascade through the 44.1-kev transition, that percentage excess must equal hard beta particles not cascading through it, that is, going to the ground state. The energy separation between possible hard beta components is not large enough to be clearly resolvable in our Fermi-Kurie plots from intermediate image spectrometer data. These plots do show some slight curvature near the end point consistent with beta groups of 1290 and 1246 kev, but the curvature could be instrumental and interpretation made as a single group of 1260 kev. Electron-electron coincidence studies are needed to clear up this question. Whether or not this complexity exists, the Fermi-Kurie plot for allowed shape is much straighter than that including the unique correction factor for $\Delta I=2$, yes-type spectra. The tables of Rose *et al.*[8] were used to determine the correction factor. The allowed shape determination confirms the finding of Freedman *et al.*[3] Our low-energy beta end point is about 271 kev but conversion lines obscure parts of the spectrum, so the determination is not precise.

TABLE I. Conversion lines in the beta spectrum of Np^{238}.

Interpretation of line	E_e^- (kev)	Electron binding energy[a] (kev)	E_γ (kev)[b]		Abundance of conversion electrons per 100 disintegrations
L_{II}	21.8	22.3	44.1	γ_1	28.7
L_{III}	25.9	18.1	44.0	γ_1	21.0
M_{II}	38.7	5.6	44.2	γ_1	15.2
M_{III}	39.5	4.6	44.1	γ_1	
N	42.8	1.4	44.2	γ_1	
O	43.6	0.3	43.9	γ_1	
L_{II}	80.1	22.3	102.3	γ_2	1.4
L_{III}	84.1	18.1	102.1	γ_2	0.9
$M_{II,III}$	96.6	5.0	101.6	γ_2	0.7
(K_4)	802.8	121.7	925	(γ_3)	0.05
K_3	817.2	121.7	939	γ_4	0.10
K_1	864.4	121.7	986	γ_5	0.26
K_2	907.2	121.7	1029	γ_6	0.22
$L_{3,II}$	914	22.3	936	γ_4	0.06
$L_{1,II}$	963	22.3	985	γ_5	0.13
$M_{1,II}$	983	~5.6	988	γ_5	—
$L_{2,II}$	1008	22.3	1031	γ_6	0.08
$M_{2,II}$	1024	~5.6	1030	γ_6	0.06

[a] Hill, Church, and Mihelich, Rev. Sci. Instr. **23**, 523 (1952).
[b] The weighted mean energies of the gamma rays, in kev, are: γ_1, 44.1; γ_2, 102.0; γ_3, 925; γ_4, 939; γ_5, 986; γ_6, 1030.

The new high-energy gamma transitions indicate the presence of at least two levels near 1 Mev with spacings of the same order as the close-lying levels above the ground state. The strong surface-coupling model of Bohr and Mottelson[9] predicts rotational band spectra on higher excited states as well as on the ground state. It seems quite likely that the close-lying levels around 1 Mev in Pu^{238} represent such a rotational band system.

This investigation will be reported in more detail later.

One of us (J.O.R.) wishes to acknowledge a fellowship from the Nobel Institute of Physics during the time this work was carried out.

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Influence of the Earth's Magnetic Field on the Extensive Air Showers

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(Received December 11, 1953)

THIS note is written to point out that the displacement from the rectilinear path produced by the action of the earth's magnetic field on the electrons (±) of an extensive air shower (e.a.s.) can be not negligible in comparison with the displacement due to Coulomb scattering.

Several elaborate calculations have been made by various authors to evaluate the lateral spread of e.a.s., but none, to our knowledge, takes this effect into account. A qualitative discussion is given here.

Most of the e.a.s. fall on the earth with small zenith angles; hence we shall consider here only the influence of the horizonta component of the magnetic field:[1] $H=0.31\cos\lambda$ gauss, where λ is the geomagnetic latitude. The corresponding radius of curvature of an electron of energy $E(\gg mc^2)$ is

$$\rho=1.08\times10^{-2}E/\cos\lambda \text{ cm} \quad (E \text{ in ev}).$$

When the displacement D_m due to the magnetic field is small in comparison with the length of the path T, as it always is in air, then

$$D_m=\int_0^T (T-t)dt/\rho.$$

D_m must be compared with D_s, the projected lateral displacement due to multiple Coulomb scattering, which is the main phenomenon responsible for the distribution of the electrons around the core of e.a.s. With sufficiently good accuracy

$$\langle D_s^2\rangle=\tfrac{1}{2}E_s^2\int_0^T \frac{(T-t)^2dt}{E^2X}=\mathfrak{D}_s^2,$$

where $E_s=2.1\times10^7$ ev is a constant, and $X=(3\times10^4/P)$ cm (P=air pressure in atmospheres) is the characteristic radiation length in air.

If the energy losses can be neglected, E and ρ are constants, and if the atmospheric pressure is also taken as a constant, then

$$\frac{D_m}{\mathfrak{D}_s}=\frac{T^2}{2\rho}\bigg/\left(\frac{E_s^2T^3}{6XE^2}\right)^{\frac{1}{2}}=9.3\times10^{-4}(T/P)^{\frac{1}{2}}\cos\lambda \quad (T \text{ in cm}).$$

For $T=1$ km and $P=1$, the ratio, independent of energy, is already 0.3 cosλ.

A more specific case can be considered. Above the critical energy most of the electron energy losses are due to radiation. In a simplified model, the energy of an electron is reduced by a factor of 2 for each radiation length. The atmospheric pressure can be considered as a constant. Then $E(t)=E_T \exp[\alpha(T-t)]$, where E_T is the energy of the electron after crossing the thickness T, and $\alpha=(\log2)/X=2.3\times10^{-5}P$ cm^{-1}. One obtains

$$D_m=(e^{\alpha T}-\alpha T-1)/(\rho_T\alpha^2e^{\alpha T}).$$

If $\alpha T>1$, i.e., if $T>1$ km at sea level,[2]

$$D_m\approx1/(\rho_T\alpha^2)=1.75\times10^{11}(\cos\lambda)/(E_TP^2) \text{ cm},$$

independent of T. With the same assumptions,

$$\mathfrak{D}_s=\frac{E_s}{(8X\alpha^3)^{\frac{1}{2}}E_T}\left[1-\frac{(\alpha T+1)^2+\alpha^2T^2}{\exp(2\alpha T)}\right]^{\frac{1}{2}}\xrightarrow[\alpha T>1]{}\frac{E_s}{(8X\alpha^3)^{\frac{1}{2}}E_T}=\frac{3.9\times10^{11}}{E_TP}\text{ cm}.$$

The ratio is

$$D_m/\mathfrak{D}_s=0.45(\cos\lambda)/P \quad (\text{for } \alpha T>1).$$

Up to quite high latitudes the separation in the E–W direction of the negative electrons from the positive ones due to the earth's magnetic field is then about as large as the average lateral displacement due to scattering; the effect increases with altitude.

For electrons of energy smaller than the critical energy, the magnetic displacement presumably becomes small in comparison with that due to Coulomb scattering, because these electrons cannot travel very far in the air and are instead carried away from the axis of the shower mostly by single large-angle scatterings. Thus, the magnetic deflection modifies quite strongly the distribution around the core of the showers of high-energy electrons, and to a smaller extent that of the low-energy ones. At latitudes lower than ~50° and around sea level the distribution of vertical showers is not circular but, roughly speaking, elliptical, with the major axis in the E–W direction and almost two times longer than the small axis.

This phenomenon will make it difficult to analyze experiments on the distribution of high-energy electrons around the core of e.a.s. and in general all experiments whose interpretation depends on the electron lateral distribution.

Probably the magnetic deflection does not strongly affect the distribution of the other components of e.a.s., namely nucleons and mesons. In fact, the angle at which these particles are emitted in nuclear interactions is responsible for a lateral displacement much larger, in most cases, than that produced by the earth's magnetic field.

[1] A more detailed calculation should take into account the fact that the displacement due to the earth's magnetic field is a function of both zenith and azimuthal angles.

[2] D_m converges rapidly when T increases because the energy of the electron increases rapidly with altitude. This justifies the assumption P=constant.

PHYSICAL REVIEW VOLUME 93, NUMBER 3 FEBRUARY 1, 1954

Proceedings of the American Physical Society

Minutes of the Sixth Annual Conference on Gaseous Electronics, Sponsored Jointly by the Division of Electron Physics of the American Physical Society and the U. S. Office of Naval Research, Held at Washington, D. C., October 22–24, 1953

THE Sixth Annual Conference on Gaseous Electronics was held at the Shoreham Hotel, Washington, D. C., on October 22, 23, and 24, 1953. There were 228 registrants. One invited paper "Ultra-Violet Photons in the Decay of Metastable Argon Atoms" by L. Colli and U. Facchini of C.I.S.E., Milan, Italy, was presented *in absentia*. Abstracts of some of the forty-four contributed papers are printed below. A banquet was held on the evening of the 23rd. The guest speaker, Captain C. W. Shilling, Senior Medical Officer at the U. S. Naval Academy, presented an excellent address on the value of basic research, and cited numerous examples in the medical field. Also at the banquet, the conference committee for the forthcoming year was announced as follows: Professor W. P. Allis, *Chairman;* L. Fisher, *Secretary;* E. O. Johnson; W. Gruner; H. D. Hagstrum; M. A. Biondi; S. Githens; and M. Kuper.

A1. Calculated Values of the Parameters of Noble Gas Discharges. Walter J. Graham and Arthur J. Ruhlig, *U. S. Naval Research Laboratory.*—Molar properties of gaseous discharges are determined by the transport cross section which is expressible in terms of the phase shifts defined in electron-atom scattering theory. $\sigma_t(v)$ was calculated for helium, neon, and argon using values of phase shifts η_0 to η_6 derived by