nucleon-nucleon collision using (8) and found

$$\langle \Theta^2 \rangle_{Av} = 4U_0^{-1}\ (\text{radians})^2. \tag{9}$$

The primary energy U_0 is measured in proton mass units.

Consideration of this result leads us to the conclusion that the lateral spread of the high energy nucleon component of the cosmic radiation in extensive air showers must be considerably greater than that for the majority of electrons whose mean square angular deflection is proportional only to U_0^{-2}.

The details and full discussion of the above work will be given in a subsequent publication. We are indebted to Professor E. Schrödinger for valuable suggestions in the course of the above work.

[1] H. Messel, Proc. Phys. Soc. (London), to be published.

Two-Step Isomeric Transition in Hf^{179m}*

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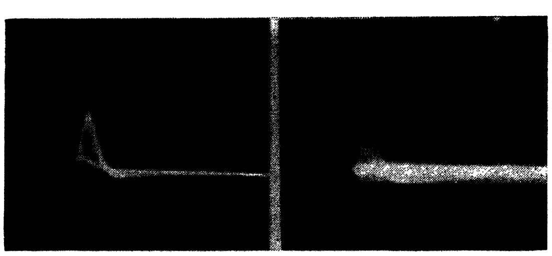
A 19-sec activity was reported in Hf by Flammersfeld,[1] and was assigned to Hf^{179m} by Muehlhause.[2] Hole[3] measured the energy of the conversion electrons in a β-ray spectrometer and obtained a value of 150 kev for the transition energy. The authors,[4] who investigated the unconverted gamma-rays in a scintillation spectrometer, found an intense gamma-ray line of 215-kev energy and suggested the possibility of a two-step isomeric transition. The measurements of Hole were repeated and confirmed by Burson *et al.*,[5] who found 160 kev for the internally converted transition. Thus it was apparent that two gamma-rays were involved in these measurements, a highly internally converted transition of 160 kev and a weakly converted transition of 215 kev.

To test the possibility of a two-step isomeric transition a number of experiments were carried out. Since previous investigations of the lifetime and the assignment of the 19-sec activity to Hf^{179m} had been based on observations of conversion electrons, it was necessary to determine whether the 215-kev gamma-rays were also associated with Hf^{179m}. Enriched isotopes of Hf (Hf^{176}, Hf^{177}, Hf^{178}, and Hf^{179}) were irradiated in the Brookhaven reactor and the 215-kev line was observed with a scintillation spectrometer. It appeared most intense in $Hf^{178}+n$. The γ-rays were found to decay with a half-life of 19 sec.

To record the expected coincidences in such a short-lived activity we made use of the following scheme. The Hf^{179m} sample was placed between two scintillation crystals mounted on RCA 5819 tubes. The pulse from one photomultiplier was used to start the sweep of an oscilloscope, while the pulse from the other photomultiplier was impressed upon the screen (y axis) of a cathode-ray tube. Under these conditions, the distribution seen is due to pulses in coincidence with the triggering pulses. By using either NaI-Tl or anthracene crystals, the detectors were made sensitive to gamma-rays or electrons, respectively. By triggering the sweep with electron pulses from an anthracene crystal and impressing the gamma-ray pulses from a NaI-Tl crystal upon the screen, the pulse distribution due to the 215-kev gamma-ray was seen (Fig. 1), indicating the existence of coincidences with a time delay <0.5 μsec. In coincidence with gamma-rays >160 kev an electron distribution with an upper limit of ~ 95 kev was obtained. Adding the K-work function of Hf we find ~ 150 kev for the energy of the highly converted transition, in good agreement with the beta-spectrographic investigations. The photon pulses obtained in coincidence with gamma-rays >160 kev showed only the Hf K-x-rays. The 160-kev transition is evidently highly converted, as already noticed by Hole,[3] who found a conversion coefficient $\epsilon > 19$. A search was made for L conversion electrons from the 215-kev transition with the help of an anthracene crystal. An upper limit of 10 percent of the intensity of the K electrons of the 160-kev transition was established. (The K conversion electrons would approximately coincide with L conversion electrons from the 160-kev transition.) No cross-over transition of $(160+215)$ kev $=375$ kev was detected. If present, it takes place in <1 percent of the transitions. With the help of the K conversion coefficients calculated by Rose *et al.*[6] (see Table I) and the empirical lifetime energy relations and K/L ratios given by Goldhaber and Sunyar[7] the results given above allow us to conclude that the 160-kev transition is an $M3$ transition and that the 215-kev transition corresponds to a spin change $\Delta I \leq 2$, with an $M2$ transition excluded.



(a) (b)

Fig. 1. (a) Te^{123m} γ-rays (159 kev) for calibration; (b) Hf^{179m} γ-rays (215 kev) and Hf K x-rays which coincide with conversion electrons preceding them.

Table I. K conversion coefficients.[a]

E(kev)	α_1	α_2	α_3	β_1	β_2	β_3
160	0.088	0.31	0.93	1.05	5.4	20.0
215	0.043	0.14	0.43	0.47	2.1	7.0

[a] See reference 6.

A final level assignment must await a measurement of the ground-state spin of Hf^{179} (known to be $\leq \frac{9}{2}$)[8] and the determination of the character of the 215-kev transition. The following tentative decay scheme is compatible with existing knowledge and shell theory, but is not unique:

$$h_{9/2} \xrightarrow{160\text{ kev}} p_{3/2} \xrightarrow{215\text{ kev}} p_{1/2}.$$

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[1] A. Flammersfeld, Z. Naturforsch. 1, 190 (1946).
[2] C. O. Muehlhause, private communication.
[3] N. Hole, Arkiv Mat. Astron. Fysik 36A, No. 9 (1948).
[4] E. der Mateosian and M. Goldhaber, Phys. Rev. 82, 115 (1951).
[5] Burson, Blair, Keller, and Wexler, Phys. Rev. 83, 62 (1951).
[6] Rose, Goertzel, Spinrad, Harr, and Strong, Phys. Rev. 83, 79 (1951).
[7] M. Goldhaber and A. W. Sunyar, Phys. Rev., to be published.
[8] K. Way *et al.*, "Nuclear data," Natl. Bur. Standards (U. S.) Circ. No. 499 (1950).

On the Decay of Neutral V-Particles*

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Several new examples of the decay of neutral V-particles[1-4] have been obtained recently at Pasadena, using two new magnet cloud chambers arranged to respond to cosmic-ray penetrating showers. Nine of these are of special interest in that it is possible to draw some conclusions as to the identity of the charged secondaries in each case. The momentum and estimated specific ionization (relative to the minimum for fast, singly charged particles) and the mass-value computed from these quantities are tabulated for each charged decay-particle in Table I.

It is apparent from this table that all of the negative particles are mesons; one of these underwent a sudden deflection in flight, the angular deviation of 6° being within the allowable range for a $\pi-\mu$-decay, so that the negative particles are indeed probably π-mesons.

On the other hand, it is also apparent that most of the positive particles are surely much heavier than mesons, and while the