range of observation, possibly in the infra-red with a ratio of 3 or more, or that the excited F-center returns to its ground state by a radiationless transition.

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[6] We wish to thank Mr. C. P. Glover of this laboratory for supplying this material.

Beta-Decay of Ag^{111} and Spin-Orbit Coupling in Cd^{111}

STIG JOHANSSON
Nobel Institute for Physics, Stockholm, Sweden
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THE radiation of Ag^{111} has been studied by several investigators.[1] The maximum energy of the beta-rays has been determined to be 1.06±0.03 Mev.[2] No gamma-rays have been observed.

When Pd is irradiated with slow neutrons, Pd^{111} (26 min.) is formed among other isotopes. Pd^{111} gives rise to Ag^{111} (180 hr.). In this way it is possible to obtain Ag^{111} quite free from Ag^{106} (197 hr.). The half-life of a sample was followed during ~1000 hr. and was found to be 180±3 hr.

The gamma-radiation has been studied in a lens spectrometer and a 0.007-mm lead converter was used. The photo-electron spectrum is shown in Fig. 1. Two different gamma-lines can be distinguished. The first photo-line corresponds to the K photo-line of a gamma-ray of 243±2 kev. The L photo-line belonging to this gamma-ray is to some extent masked by the K photo-line of a second gamma-ray of 340±2 kev. Also, the L photo-line belonging to this second gamma-ray gives the energy 340 kev. Estimates based on the curves by Evans and Evans[3] give the intensity ratio 8:1 between the gamma-rays of energy 340 and 243 kev.

The beta-spectrum has been measured in a lens spectrometer. From the Fermi analysis it is evident that the beta-spectrum is complex. The upper limit of the main component is 1.04 Mev. As will be discussed below, the beta-spectrum probably has three components, but since the intensity of the third one is only ~1 percent it cannot be resolved in the Fermi analysis.

A gamma-gamma-coincidence measurement has been carried out. No real effect was observed. The beta-gamma-coincidence measurement gave coincidences, but to such a small extent that none of the gamma-rays could follow the main component of the beta-spectrum.

A distintegration scheme consistent with all experimental results is presented in Fig. 2. A search was made for the internal conversion line and the L photo-line corresponding to a possible gamma-ray of 340 to 243 kev with negative result. The intensity ratio between the components has been determined by means of calibrated beta- and gamma-ray counters. The calculation has been made under the assumption that the intensity ratio between the gamma-lines is 8:1.

It is known that Cd^{111m}, which can be produced for instance by a (n,n) reaction, decays to the ground level by the successive emission of two quanta of 148 and 247 kev, respectively.[4,5] The last gamma-ray is the same as the one observed[6] in the K-capture decay of In^{111}. Although there is a small discrepancy in energy, it seems probable that this excited level in the Cd^{111} nucleus is common for Ag^{111}, Cd^{111m}, and In^{111} disintegrations.

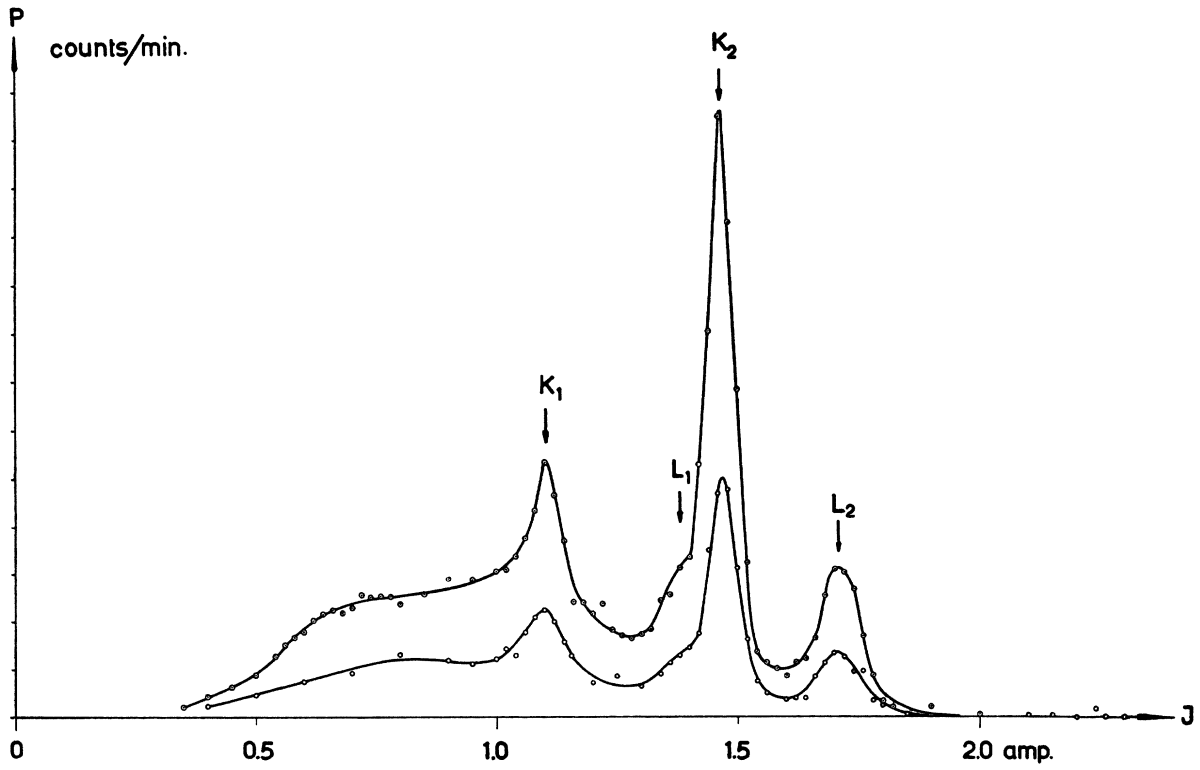

FIG. 1. Photo-electron spectrum of Ag^{111}. The lower curve taken 216 hr. later than the top curve. The half-lives for the three lines K_1, K_2, and L_2 are correct within statistical errors.

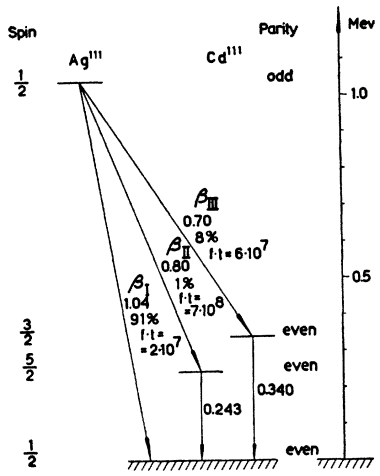

FIG. 2. Disintegration scheme of Ag^{111}.

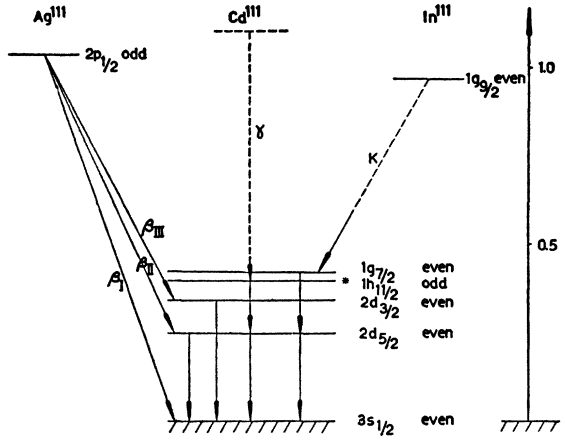

FIG. 3. Term scheme of Ag^{111}, Cd^{111m}, and In^{111}.

The spins given in Fig. 2 are based on the following arguments. The spin of Cd^{111} in the ground state is known to be 1/2. From the beta-spectrum the conversion coefficient of the 340-kev gamma-ray is determined to be ~0.015 and the conversion coefficient of the 243-kev gamma-ray is estimated to be <0.08. Using the calculated values[7] the transitions are found to be electric quadrupole or a mixture of electric quadrupole and magnetic dipole, i.e., the spins of the excited levels are 5/2 or 3/2.

The *ft*-values are given in Fig. 2. According to the rules given by Nordheim[8] the components β_I and β_{III} are first forbidden with $\Delta L=1$ and $\Delta I=0$ or 1, which would give a spin 1/2 or 3/2 for Ag^{111}. The high *ft*-value for β_{II} suggests that this can be a transition with $\Delta L=1$ and $\Delta I=2$. (In that case the beta-spectrum should differ from the allowed shape, but as the intensity is only ~1 percent it is impossible to see it from the Fermi plot.) If this is assumed, one gets the spins given in Fig. 2. From half-life measurements Deutsch and Stevenson[9] have found that the 247-kev (from In^{111}) gamma-transition ($\tau=(8\pm1)\cdot10^{-8}$ sec.) is probably electric quadrupole. This gives some support for spin 5/2 for the first excited level.

Spins and parities in the Ag^{111} disintegration scheme are in agreement with the spin-orbit coupling scheme of the nuclear shell model.[10,11] The quantum state of the ground level would then be $3s_{1/2}$, the first excited level $2d_{5/2}$ and the second $2d_{3/2}$. For Ag^{111} the spin-orbit scheme predicts spin 1/2 or 9/2 but from the *ft*-values 9/2 is impossible, leaving as the only alternative for Ag^{111} to be a $2p_{1/2}$ state, which gives $\Delta L=1$ for the beta-transitions.

In Fig. 3 a complete term scheme[5,6,12] is given for Ag^{111}, Cd^{111m}, and In^{111}. According to this scheme Cd^{111} possesses four excited levels one of which is metastable with the spin 11/2. It is interesting to note that the spin-orbit coupling scheme predicts all these low excited levels and no more for an odd neutron in the shell between the magic numbers 50 and 82.

The transition $1g_{7/2}-2d_{5/2}$ with an energy of 173 kev should be a mixture of electric quadrupole and magnetic dipole radiation. The internal conversion coefficient of this line has been measured before[2] and was found to be 0.18, which is consistent with the calculated values[7] $\alpha_2=0.17$ and $\beta_1=0.092$. The gamma-transition from the excited level should have $\Delta I=3$ and change in parity which gives electric 2^3 pole radiation. This however is not in agreement with the classification by Axel and Dancoff.[13]

Details of the investigation, also describing the chemical procedure, will be given in *Arkiv för Fysik*.

The author wishes to express his gratitude to Dr. Kai Siegbahn for many helpful discussions.

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The Radiations of Ce^{141} and Pa^{233}

M. S. FREEDMAN AND D. W. ENGELKEMEIR
Argonne National Laboratory, Chicago, Illinois
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OUR studies of the radiations of Ce^{141} result in essential confirmation of the findings of Shepherd[1] and indicate the source of the disagreement with the results of Ter-Pogossian *et al.*[2] with respect to their reported 315 kev gamma-ray. The alleged 70 μsec. state[3] in Pr^{141} was sought in vain.

Cerium oxide samples irradiated in the Clinton and Argonne piles were purified (after the 33 hr. Ce^{143} had decayed) by fluoride and iodate precipitations, including specific separation of praseodymium activity. A Zr $(IO_3)_4$ scavenging was made to separate suspected zirconium and hafnium impurities. Uniformly spread spectrometer samples of <0.2 mg/cm² were prepared on LC-600 films (rendered conductive with Aquadag) by precipitating the fluoride in a drop of $CeCl_3$ solution on the film using hydrogen fluoride vapor.

The electron spectrum (Fig. 1) obtained in our automatic recording double lens spectrometer showed two allowed shape components (see Kurie plot, Fig. 2) with $E_0=0.581\pm0.003$ Mev and $E_0=0.442\pm0.003$ Mev although the *ft*-values (5.16×10^7 and 9.8×10^6, respectively) indicate empirically first-forbidden transitions. On the basis of both shapes being allowed the intensities are 33 percent and 67 percent, respectively.

Conversion lines at 102.9 kev and 138 kev which arise in the *K* and *L* conversion of a gamma of 145 kev were found. No conversion electrons corresponding[4] to a 137.1 gamma-ray appeared.

Photo-electron spectra with ~2 mg/cm² gold radiators revealed only *K* and *L* lines of the 145 kev gamma, whereas the photoelectron spectrum of unpurified CeO_2 showed, in addition to the 145 kev gamma, a strong 316 kev gamma and others of lower intensity. The 316 kev gamma-emitter followed zirconium during purification of the cerium. Measurement of the extraction coeffi-