electron power put into the crucible. The total elapsed time for this deposit was 215 minutes. This corresponds to a mass of 2.65 micrograms. By recharging the crucible it was found possible to build up a total deposit of about 5 micrograms of completely resolved isotopes of Sm.

Although poor deposits were collected on ordinary metal surfaces, it was found possible to collect good deposits on a plate of pure aluminum whose surface had been microblasted with a water suspension of 325-mesh vermiculite under a pressure of 70 lbs/in.^{2}. A photograph of such a deposit whose mass is approximately 0.9 microgram for the Sm isotopes is shown in Fig. 1. This was obtained under essentially the same conditions as the previous deposit except that the exposure time was 108 minutes and the ion accelerating voltage was 8000 volts. Figure 1 shows that, in the case of samarium, the oxide as well as the metal ions are deposited.

[1] A. E. Shaw, Phys. Rev. **73**, 1222 (1948).

Long-Lived Metastable State of Te^{125}

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WITH the emission of beta-rays, gamma-rays, and Te K x-rays, Sb^{125} (2.7 yr.) decays.[1] It seemed worth while to investigate whether the Te x-rays are emitted from a metastable state of Te^{125}. We, therefore, separated Te chemically from a source of Sb^{125} which had been produced in Oak Ridge by bombardment of Sn with slow neutrons through the reaction $Sn^{124}(n, \gamma)Sn^{125} \xrightarrow{\beta} Sb^{125}$.

The Te fraction was found to be active. Figure 1 shows the absorption curve in Al of the electrons taken with a mica end window counter. The range of $\sim$18 mg/cm^2 Al corresponds to an energy of 120 kev with an uncertainty of about 10 percent. The absorption of the remaining photon component is shown in Fig. 2. In these experiments a stronger source was used. One can conclude that the radiation is largely K radiation of Te and that, if any unconverted γ-rays of an energy of about 120 kev are present, their intensity is <1 percent of the transitions converted in the K-shell. We have so far only determined an approximate value of about two months for the half-life of Te^{125}*.

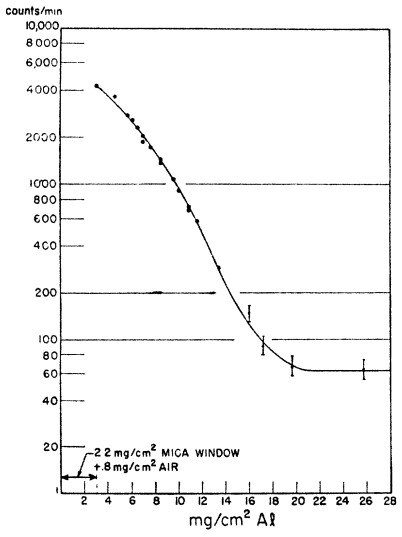

FIG. 1. Absorption of Te^{125}* internal conversion electrons in Al.

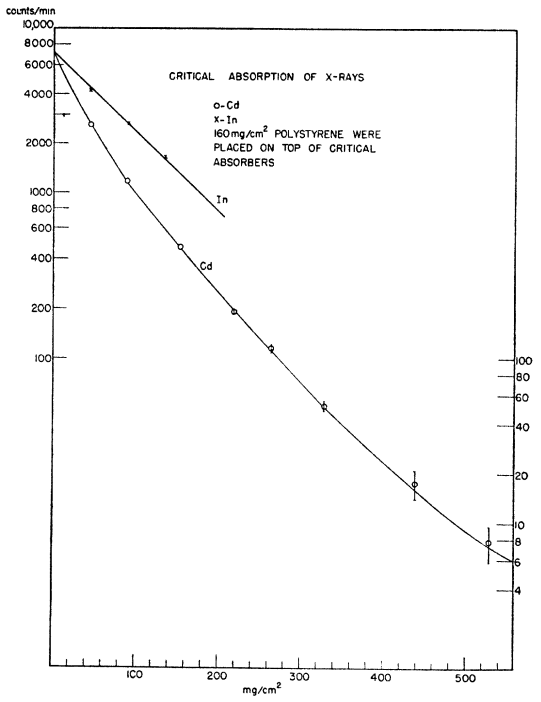

FIG. 2. Absorption of photons from Te^{125}* in Cd and In.

Reid and Keston[2] discovered a 56-day isotope of iodine, which has been assigned by Glendenin and Edwards[3] on plausible grounds to I^{125}. Reid and Keston noted a Te activity growing out of this iodine activity, but with radiations which did not seem compatible with those of Te^{125}*. Dr. Keston kindly sent us an aged sample of I^{125} from which we separated Te. A weak activity was observed, and an absorption curve in Al measured. Within the limits of error this curve agreed with the electron absorption curve shown in Fig. 1.

From our measurements it appears that Te^{125}* decays by an isomeric transition which is probably "2^5-pole." Because of the fact that this metastable state is by far the longest-lived known for a nucleus with a stable ground state and because Te^{125}* can be obtained carrier free and in weighable amounts, it appears to be a particularly suitable example for a test of the theory of nuclear isomerism by a direct measurement of the spins of the two isomers. Such an attempt is at present underway in this laboratory.

We wish to thank Mr. M. McKeown for his valuable assistance. This work was carried out under the auspices of the Atomic Energy Commission.

* Now at University of Illinois.
[1] Plutonium Project, "Nuclei produced in fission," Rev. Mod. Phys. **18**, 513 (1946).
[2] A. F. Reid and A. S. Keston, Phys. Rev. **70**, 987 (1946).
[3] L. E. Glendenin and R. R. Edwards, Phys. Rev. **71**, 742 (1947).

Analytic Behavior of Heisenberg's S-Matrix

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IF scattering of a photon on a hydrogen atom is studied by usual quantum perturbation theory, the wave matrix takes the form[1]

$$(p\alpha'|\psi_1|p^0\alpha^0)=(p\alpha'|p^0\alpha^0)+\delta_+(\nu-\nu')(p\alpha'|r_1|p^0\alpha^0), \quad (1)$$

where p is the momentum, ν is the energy of outgoing photon, and $\nu'=E^0-H_S(\alpha')$ is determined by energy conservation. The "partial" S-matrix is defined by

$$(p\alpha'|S_1|p^0\alpha^0)=(p\alpha'|p^0\alpha^0)+\delta(\nu-\nu')(p\alpha'|r_1|p^0\alpha^0). \quad (2)$$

This should be distinguished from the "complete" S-matrix, which is defined only for energies large enough to ionize the atom and contains elements for electron photon scattering on a proton center. The form of r_1 will depend on the approximation used. For total energy E^0 near to $H_S(\alpha'')$, the energy of an excited state, it can be shown that the matrix element $(p\alpha'|r_1|p^0\alpha^0)$ taken on the energy shell is an analytic function of E^0 if $H_S(\alpha')<H_S(\alpha'')$, and has a singularity at $E^0=H_S(\alpha'')+a-ib$, where b is positive. As remarked by Wentzel,[2] b is related to the total emission probability from state (α'').

If $\alpha^0\alpha'\alpha''$ denote ground level, first excited level, etc., the matrix element $(p\alpha^0|r_1|p^0\alpha^0)$ for elastic scattering is an analytic function of E^0 even at the critical values $H_S(\alpha')$, but the matrix element $(p\alpha'|r_1|p^0\alpha^0)$ for inelastic scattering is zero for $E^0<H_S(\alpha')$ but non-zero and analytic for $E^0>H_S(\alpha')$. This has two consequences: the partial S-matrix goes into the complete S-matrix for high enough energies, and the partial S-matrix is not an analytic function of energy. If the complete S-matrix is analytically continued into the low energy region, it will satisfy the unitary condition $SS\dagger=I$; hence the partial S-matrix is not unitary.

It is desirable that a consistent physical picture be given by the complete S-matrix, and this requires an interpretation of the analytic continuation of matrix elements $(p\alpha'|r|p^0\alpha^0)$ in region $E^0<H_S(\alpha')$ where inelastic scattering is not possible, i.e., where $(p\alpha'|r_1|p^0\alpha^0)=0$. This is obtained by defining probability as $(p\alpha'|r|p^0\alpha^0)(p^0\alpha^0|r\dagger|p\alpha')$, where $r\dagger$ is the analytic continuation in the E^0 plane of the Hermitian conjugate to r taken for E^0 greater than ionization energy. Thus the probability is $|(p\alpha'|r|p^0\alpha^0)|^2$ for $E^0>H_S(\alpha')$, but because of a factor $(\nu')^{-\frac{1}{2}}$ in $(p\alpha'|r|p^0\alpha^0)$ is $-|(p\alpha'|r|p^0\alpha^0)|$ for $E^0<H_S(\alpha')$. In S-matrix theory we require the interpretation that a negative probability corresponds to a physically impossible process.

Since this work was completed a note by T. S. Chang[3] has appeared, mentioning negative probabilities in connection with the unitary condition on S, but without further details it is not possible to tell if his conclusions are the same as ours. A fuller account of the calculations reported here will be published later. I wish to thank Dr. N. Kemmer for advice and encouragement.

[1] P. A. M. Dirac, *Quantum Mechanics*, third edition, Chapter 8.
[2] G. Wentzel, Helv. Phys. Acta **21**, 49 (1948).
[3] Chang, Am. Phys. Soc. (April 29, 1948).

Neutron Deficient Isotopes of Cerium and Lanthanum

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FAST particle fission of bismuth in this laboratory has produced neutron deficient isotopes in the region of cerium.[1] The studies described herein were undertaken partly to identify some of these.

On the neutron deficient side of stability, two radioactive isotopes of lanthanum assigned to La^{137} [2,3] and La^{138} [4] have been reported, but recent measurements[5] show La^{138} to be stable or extremely long-lived and present in naturally occurring lanthanum to the extent of 0.089 percent. Evidence is presented below for assigning the reported radioactive properties of La^{137} to La^{135} and those of La^{138} to La^{136}.

To prepare the lanthanum activities cesium in the form of $CsNO_3$ was irradiated with 30-Mev helium ions in the 60-inch cyclotron. The lanthanum fraction was separated and the decay curve resolved into two components of 2.1-hour and 19.5-hour half-lives. Both of these activities, therefore, must belong to isotopes of lanthanum of mass number 136 or lower.

A low resolution beta-ray spectrometer showed a positron of 0.82 Mev, decaying with the 2-hour half-life, the energy estimated from the visual end point of the spectrometer curve. No negative particles were detected. A Feather analysis of a beryllium absorption curve, taken soon after

TABLE I.

Isotope	Type of radiation	Half-life	Energy of radiation in Mev: Particle	Energy of radiation in Mev: Electromagnetic	Produced by	Cross section $\times 10^{24}$ cm^2
La^{137}		>400 yr.			decay of Ce^{137}	
La^{136}	β^+	2.1 hr.	0.84	None	$Cs^{133}(\alpha, n)$	0.0003*
La^{135}	K, γ	19.5 hr.	None	0.76	$Cs^{133}(\alpha, 2n)$	0.03*
Ce^{139}	K, γ, e^-	140 days	0.15	0.18 1.8	$La^{139}(d, 2n)$	0.09**
Ce^{137}	K, γ, e^-	36 hr.	0.18	0.28 0.75	$La^{139}(d, 4n)$	0.06† 0.002** 0.04††
Ce^{135}	β^+	16 hr.			$La^{139}(d, 6n)$	

* 30-Mev helium ions.
** 20-Mev deuterons.
† 40-Mev deuterons.
†† 60-Mev deuterons.