remains a number of the order unity. The *generally* correct theorem can be stated by the condition[1]

$$\pi d\epsilon/\lambda \ll 1, \tag{1}$$

where ϵ is the dielectric constant. For $(\epsilon)^{\frac{1}{2}} \gg 1$ the two conditions differ greatly.

A routine calculation shows that the reflection coefficient of a wall of thickness d and dielectric constant ϵ is given by

$$r = x^2/(1+x^2), \tag{2}$$

where $x = \pi d\epsilon/\lambda$. In the derivation it has been assumed that $2\pi d(\epsilon)^{\frac{1}{2}}/\lambda \ll 1$, but $(\epsilon)^{\frac{1}{2}} \gg 1$. It is clear from (2) that the wall acts like a good mirror until x becomes small compared to one.

This theorem becomes of practical importance if one deals with very thin layers of good metallic conductors. Here the complex index of refraction $\sim(\sigma/\nu)^{\frac{1}{2}}$ so that common practice would lead one to assume that for $(2\pi d/\lambda)(\sigma/\nu)^{\frac{1}{2}} \ll 1$ or $d \ll (\lambda/2\pi)(\nu/\sigma)^{\frac{1}{2}}$ = skin depth, the layer approaches transparency. The true condition[2] now reads

$$\pi d\sigma/c \ll 1. \tag{3}$$

We see that (3) is independent of the frequency. But approximate transparency of the layer now requires a thickness d which for an average good metallic conductor ($\sigma \sim 3\times 10^{17}$ sec^{-1}) becomes smaller than 10^{-8} cm. Every metallic layer in the customary sense of the word is therefore a good mirror for radiowaves down to wavelengths which still have conductivities that do not differ too much from their dc values.

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[1] A potential well of thickness d and depth V remains a good reflector for a de Broglie wave of energy $E \ll V$ as long as $\pi dV/E \geqq 1$.

[2] In the case of ferromagnetic conductors the permeability μ has to enter as a factor in the denominator of (3).

Cross-Over Transition in the Decay of Tc^{99m}

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PREVIOUS attempts to discover cross-over transitions in a number of two-step isomers of Te and Sn have been unsuccessful.[1] These transitions were expected to be electric 2^5-pole. It seemed of interest, therefore, to search for a cross-over transition which could be expected to be magnetic 2^4-pole. Such a transition might occur in Tc^{99m} (6 hr). In this case Medicus, Maeder, and Schneider[2] have shown that the isomeric transition proceeds in two steps. The first lifetime-determining transition has the exceedingly low energy of 1.8±0.3 kev. It is followed "promptly" by a second γ-ray of 141.2±0.5-kev energy. For this transition Medicus *et al.*[2] find an internal conversion coefficient of 0.095 ±0.020 and a ratio $\alpha_K:\alpha_L:\alpha_{M+N} = (7.9\pm 0.5):1:(0.30\pm 0.03)$ which permits its identification as a magnetic dipole transition on the basis of the K-conversion coefficients calculated by Rose *et al.*[3] Kessler and Meggers[4] have recently shown that the spin and magnetic moment of Tc^{99} in the ground state can be ascribed to a $g_{9/2}$ state, in agreement with shell theory, which suggests $p_{1/2}$ as the most plausible assignment for the metastable state. With these level assignments one might expect the cross-over transition $p_{1/2} \rightarrow g_{9/2}$ (magnetic 2^4-pole) with an intensity of the order 1 percent of the two-step transition. We have therefore searched for conversion electrons from a cross-over transition with a high resolution 180° photographic beta-spectrograph of low magnetic field. Tc^{99m} was obtained as a daughter of Mo^{99} (68 hr) which had been produced by bombarding molybdenum with slow neutrons in the Brookhaven reactor. The active molybdenum was dissolved in H_3PO_4 to which a small amount of $HClO_4$ had been added. The solution was distilled once; and the distillate, after addition of inactive molybdenum carrier, was redistilled. The H^+ concentration of the second distillate (containing the technetium) was adjusted to $4M$, and the technetium activity was coprecipitated, as the sulfide, with 0.1 mg of Pt added as H_2PtCl_6. The sulfide was centrifuged, washed, and mounted on a thin Al strip which was inserted in the beta-spectrograph. Figure 1 shows the internal conversion electron spectrum obtained, indicating clearly the presence of a cross-over transition. The approximate relative intensities were obtained by photometering the original film (no screen x-ray film). The results obtained are given in Table I.

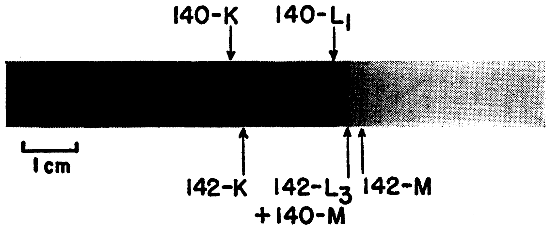

FIG. 1. Internal conversion electrons from Tc^{99m}.

TABLE I. Electron energies and intensities. The work functions of the various shells are given in parentheses in Col. 2.

Electron energy (kev)	Assignment	γ-energy (kev)	Intensity
119.3	$\gamma_1 - K$ (21.04)	140.3	100
121.3	$\gamma_2 - K$ (21.04)	142.3	9.7
137.5	$\gamma_1 - L_I$ (3.05)	140.2	13.1
139.5	$\gamma_2 - L_{III}$ (2.68) $\gamma_1 - M_I$ (0.63)	142.2 140.1	5.3
141.7	$\gamma_2 - M_I$ (0.63)	142.3	0.93

The best values for the γ-ray energies are $\gamma_1 = 140.3\pm 0.2$ kev and $\gamma_2 = 142.3\pm 0.2$ kev. The difference is more accurately known: 2.0±0.1 kev. Our energies differ slightly from those given by Medicus *et al.*[2] A weak electron line of 62 kev was also observed and is probably a K photoelectron line ejected from the Pt carrier by the 140-kev γ-ray.

The experimental K/L ratios are compared with the theoretical ones given by Tralli and Lowen[5] in Table II.

TABLE II. K/L ratios.

γ (kev)	K/L (exp.)	K/L (theor.)
140.3	7.7	12 (2^1 magnetic)
142.3	2.5[a]	4.7 (2^4 magnetic)

[a] The relative intensity of the L line of γ_2 was calculated on the assumption that the M line of γ_1, which coincides with it, has an intensity 10 percent of that of the L line of γ_1.

It is seen that the experimental K/L ratios are lower than expected from theory. Similar findings in the Te and Sn isomers have been previously interpreted as indications of admixtures of 2^5 electric transitions to the 2^4 magnetic transitions.[1] However, a different interpretation is given by Sunyar and Goldhaber,[6] who conclude that 2^4 magnetic transitions are pure, but that the calculated K/L ratios are too high. The 2^1 magnetic transition of Tc^{99m} is also found to be fairly pure.[6] From the table of K-conversion coefficients of Rose *et al.*[3] we find $\beta_4 = 31$. From this value and the observed $K/L+M$ ratio a partial half-life of 430 hr is obtained for the cross-over transition. The partial mean life for γ-ray emission alone, $\tau_\gamma = 1.06\times 10^8$ sec, agrees well with the expected value for a 2^4 magnetic transition, 0.86×10^8 sec, calculated from the semi-empirical formula[6] $\tau_\gamma(\text{sec}) = 10^4(2I+1)/(A^2E^9)$, where I is the spin of the metastable state, A the mass number of the isomer, and E the transition energy (in Mev).

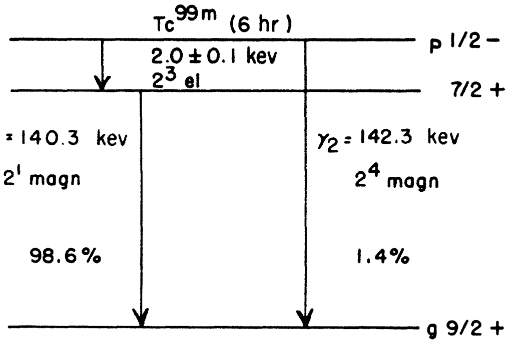

FIG. 2. Decay scheme of Tc^{99m}.

In the decay scheme shown in Fig. 2 we prefer to denote the first excited state of spin 7/2 and even parity as 7/2+ rather than $g_{7/2}$ for the following reason: a splitting of 140 kev between the $g_{9/2}$ and $g_{7/2}$ levels would seem to be too small to be compatible with the otherwise very successful assumption of strong spin-orbit coupling, from which one would expect a splitting of the order of 1–2 Mev. A still smaller splitting between a $g_{9/2}$ and a 7/2+ level (9.3 kev) has been observed in Kr^{83} by Bergström.[7] It is therefore plausible that the experimentally found small splittings are due to low-lying 7/2+ states of the configuration $(g_{9/2})^3$ (in Tc^{99}) and $(g_{9/2})^7$ (in Kr^{83}). This conjecture has been further generalized:[6] for the configurations $(g_{9/2})^{3,\,5,\,\mathrm{or}\ 7}$ the 7/2+ and the $g_{9/2}$ states reverse positions in about half the cases, thus accounting for the occurrence of electric 2^3-pole isomeric transitions in the $g_{9/2}$ shell $(7/2+\rightarrow p_{1/2})$.

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Neutral Mesons Produced in the Capture of π^- Mesons in Hydrogen*

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THE spectrum of the gamma-rays emitted in the interaction of π^- mesons with hydrogen has been measured by Panofsky, Aamodt, and Hadley.[1] They observe two groups of gamma-rays, one at 130 Mev and one at 70 Mev. The analysis of the experiment and the conclusions which may be derived from it rest on the assumptions (a) that the gamma-rays are due to mesons, (b) that these mesons have come to rest, and (c) that the low energy gamma-rays are the decay products of neutral mesons. We have experimentally verified these assumptions for the low energy group.

The experimental arrangement (Fig. 1) is the following: Mesons produced in the Columbia cyclotron are magnetically analyzed in the fringing field of the main magnet. They are collimated and monitored in two stilbene crystal counters, 2½ in. in diameter. They are decelerated from an initial energy of 80 Mev in absorber A, and enter the vessel B. This is filled with hydrogen at a pressure of 2500 lb/in.^{2} and cooled to 80°K, corresponding to a density of 0.04 g/cm^3. On each side of the container, behind 1.5 radiation lengths of lead converter, two 3¼-in. diameter liquid scintillators are placed. All six counters are in coincidence, with a resolving time of 10^{-8} sec between pairs 1–2, 3–6, and 4–5. The coincidences are measured with and without lead converters, with hydrogen and helium gas fillings, and with various amounts of absorber.

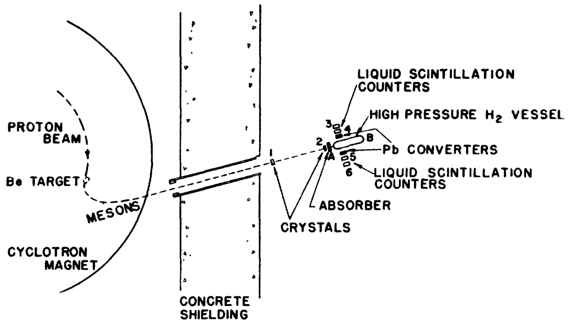

FIG. 1. Experimental arrangement.

The counting rate without converters is negligible. This shows that gamma-rays are detected. The fact that two gamma-rays are detected in coincidence shows that they are the decay products of a neutral meson. The counting rate with the helium-filled target is also negligible compared to that with hydrogen, showing that the coincidences are indeed due to a reaction in hydrogen. Finally, the variation of coincidence rate with absorber thickness shows that the gamma-rays are produced by stopping mesons (Fig. 2).

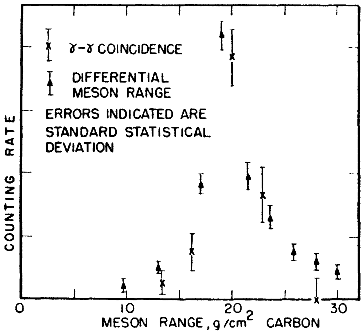

FIG. 2. Counting rate of gamma-gamma-coincidences as a function of the thickness of absorber *A*, showing that the coincidences are caused by stopped mesons.

It is therefore clear that some fraction of negative mesons coming to rest in the atomic orbits of hydrogen nuclei are converted into neutral mesons.

We wish to thank J. Spiro and H. F. Edwards for the operation of the cyclotron.

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An Attempt to Detect μ-Meson Pairs from 322-Mev Bremsstrahlung*

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IT has been suggested that high energy photons should create pairs of μ-mesons, either by an electromagnetic process (since it is thought probable that the μ-meson is a Dirac particle) or by virtue of recent considerations of Wentzel.[1] Steinberger suggested one might look for the effect using the Berkeley synchrotron.

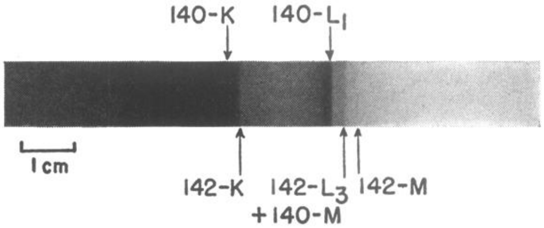

FIG. 1. Internal conversion electrons from Tc^{99m}.