energy immediately above the edge. The cells were placed in contact with the NaI counter, and, as a consequence, one could detect about 30 percent of the fluorescent radiation following the photoelectric absorption process.

The results of a typical run are plotted in Fig. 1. This shows the pulse-height distributions obtained when the π-mesonic M line of phosphorus is observed with the sequence of absorbing cells, $Z=57$, 58, 59, and 60. In each case the data are reduced to 2×10^6 stopping mesons. A transmission discontinuity is apparent between $Z=58$(Ce), and $Z=59$(Pr), indicating that the phosphorus mesonic line lies between the K edges[2] of these two elements. The peaks observed for

TABLE I. Comparison between theory and experiment.

	Line studied	P $4f\rightarrow3d$		Al $4f\rightarrow3d$		K $4f\rightarrow3d$
Theoretical	Klein-Gordon energy (kev) (for $m_\pi=272.5m_e$)	40.39		30.31−		64.90
	Vacuum polarization correction[a] (kev)	0.100		0.065		0.190
	Computed energy (kev)	40.49		30.37		65.09
Experimental	Absorbers bracketing transmission discontinuity	Ce(58)	Pr(59)	Sn(50)	Sb(51)	Hf(72)
	K edges[b] (kev)	40.45	42.00	29.19	30.49	65.35
	Meson mass limits	$\geq 272.2m_e$		$\leq 273.6m_e$		$\leq 273.6m_e$

[a] See reference 3. [b] See reference 2.

$Z=57$ and 58 are due, in part, to the fluorescent x-rays of the absorption cells, as evidenced by their magnitude and by their displacement to lower energies.

The absorption discontinuity of this line is due to the $4f\rightarrow3d$ transition. Higher lines of the M series, such as $5\rightarrow3$, $6\rightarrow3$, etc., would appear at higher energy and thus be strongly absorbed by all the cells used. Other transitions between the total quantum numbers 4 and 3 (such as $4s\rightarrow3p$ etc.) should be much less probable than the $4f\rightarrow3d$ because of statistical considerations.

For the purpose of comparison with the experimental results the energies of the lines investigated were computed with the Klein-Gordon equation (including reduced mass correction, using a point charge potential and $m_\pi=272.5m_e$) and corrected for vacuum polarization.[3] Corrections for finite nuclear size, fine structure, nuclear polarization,[4] electronic screening, etc., were estimated, but found to be smaller than 10 ev in all the cases considered. A specifically nuclear interaction of the meson corresponding to a potential up to 100 Mev over the nuclear volume would introduce negligible corrections for the M lines studied.

The comparison between theory and experiment is shown in Table I.

As one can see, from this experiment one obtains the following limits for the mass of the π^- meson:

$$272.2m_e \lesssim m_{\pi-} \lesssim 273.6m_e.$$

(This value is in good agreement with the determination at Berkeley,[5] but does not agree well with a recent publication from Columbia.[6]) The greatest error in these limits is due to the uncertainty in our knowledge of the electronic K edges (which we hope to have remeasured) and of the vacuum polarization correction.

* Supported in part by the U. S. Atomic Energy Commission.

1 Stearns, DeBenedetti, Stearns, and Leipuner, Phys. Rev. **93**, 1123 (1954).
2 The K-absorption edges were taken from a recent compilation of Lewis Slack, Naval Research Laboratory. They are in satisfactory agreement with those reported by Hill, Church, and Mihelich, Rev. Sci. Instr. **23**, 523 (1952).
3 H. C. Corben and A. Mickelwait (private communication).
4 Wilbur Lakin (private communication).
5 Smith, Birnbaum, and Barkas, Phys. Rev. **91**, 765 (1953).
6 Cornelius, Sargent, Rinehart, Lederman, and Rogers, Phys. Rev. **92**, 1583 (1953).

Decay Scheme of Pb^{204m}

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IN the course of investigating the angular correlation of the gamma rays of the 68-min isomer of Pb^{204}, we have found that the decay scheme consists of three, rather than two, gamma rays in cascade [Fig. 1(a)].

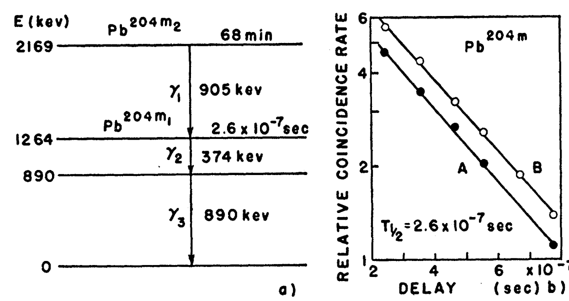

FIG. 1. (a) Proposed decay scheme for Pb^{204m}. (b) Decay of the intermediate state of the 905–890-kev cascade (curve A) and the 905–374-kev cascade (curve B).

The order of the two gamma rays following the 2.6×10^{-7} second state has not been determined experimentally.

Part of our study of the decay scheme was performed with apparatus which used two NaI(Tl) scintillation crystals together with a fast-slow coincidence scheme. The fast coincidence circuit had a resolving time of 10^{-7} second and the slow ($\sim2\times10^{-6}$ second) triple coincidence circuit received the output of the fast circuit plus pulses which had passed through discriminators operated as either differential or integral pulse-height analyzers. 1500-ohm delay lines were inserted as desired ahead of the fast coincidence unit.

The pulse-height distribution of the gamma rays following the 2.6×10^{-7} second state of Pb^{204m} was obtained as follows: One discriminator was set with an integral bias at 500 kev and the corresponding input to the fast coincidence circuit was delayed 2.4×10^{-7} second. The other discriminator had a 50-kev window whose bias was varied with the results shown in Fig. 2.

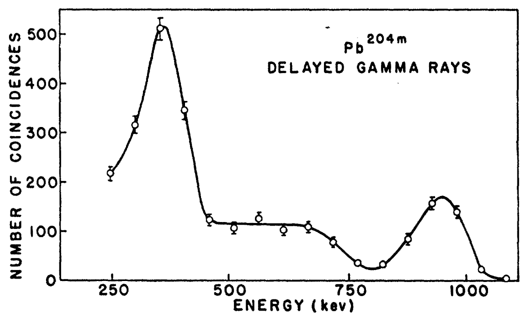

FIG. 2. Delayed coincidence spectrum of the gamma rays following the 2.6×10^{-7} second state of Pb^{204m}. The curve was taken with $\frac{1}{8}$ in. of lead shielding each NaI crystal from the source, and the data were corrected for the 68-min decay of the source and for chance coincidences.

The relative heights of the two full-energy peaks in the figure indicate that the second and third gamma rays of Fig. 1(a) are of approximately equal intensity. As the sources used for this work contained a variety of activities produced by bombardment of thallium with 22-Mev deuterons, several checks were made to verify the assignment of three gamma rays to Pb^{204m}.

First, the intermediate lifetimes of the 905–374-kev cascade and the 905–890-kev cascade were measured and found identical within two percent. This result was obtained by setting one discriminator with an integral bias at 500 kev and varying the corresponding delay [Fig. 1(b)]. The second discriminator was set with an integral bias at 500 kev for the 905–890-kev cascade (curve A) and then with a 250-kev window centered at 374 kev in order to maximize the contribution of the 905–374-kev coincidences (curve B). These curves indicate a half-life of $2.6\pm0.2\times10^{-7}$ seconds in agreement with the result of Sunyar *et al.*[1]

Second, the energies of the first gamma ray of the 905–890-kev cascade and the first gamma ray of the 905–374-kev cascade were compared by coincidence techniques similar to those used to obtain Fig. 2. The results were identical within 1 percent. The energies of the first and second gamma rays of the 905–890-kev cascade were compared by means of similar coincidence techniques. The results indicated that the second high-energy gamma ray of this cascade has 15 ± 5 kev less energy than the first. As there is no evidence of two gamma rays with energy near 900 kev in the internal conversion spectra of Sunyar *et al.*,[1] we have assumed that the internal conversion coefficients of the second high-energy gamma ray are small compared to those of the gamma ray originating from the 68-min state. Hence, 905 kev has been tentatively retained for the energy of the first gamma ray.

Third, the lifetime of the delayed 905–374-kev and 905–890-kev cascades was found to be approximately 68 min.

Fourth, the decay of one of the sources was observed in an apparatus which added the light output of thirteen 2-in. NaI cubes surrounding the source. There is evidence of interference from shorter and longer lived sum lines, but the presence of the expected sum line of about 2170-kev energy and 68-min half-life is demonstrated (Fig. 3).

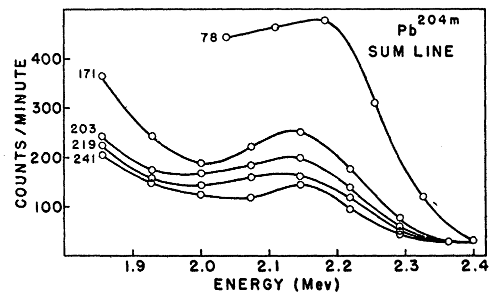

FIG. 3. The 2170-kev sum line of Pb^{204m}. The numbers to the left of the curves indicate the time at which the curves were taken, in minutes, after the end of a 20-min cyclotron irradiation.

The presence of an extra gamma ray in the cascade probably does not affect the measurements[2,3] of the gyromagnetic ratio of the 2.6×10^{-7} sec state of Pb^{204m}. At present our result for the gyromagnetic ratio is $+0.055\pm0.01$ nuclear units.

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[1] Sunyar, Alburger, Friedlander, Goldhaber, and Scharff-Goldhaber, Phys. Rev. **79**, 181 (1950).
[2] Frauenfelder, Lawson, and Jentschke, Phys. Rev. **93**, 1126 (1954).
[3] V. Krohn and S. Raboy, Phys. Rev. **95**, 1354 (1954).

Nuclear Magnetic Resonance in Solid Hydrogen with Various *Ortho*-Concentrations

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HATTON and Rollin,[1] and Reif and Purcell[2] investigated the proton magnetic resonance in solid normal hydrogen. We performed[3] the same experiments using an autodyne detector technique near 8 Mc/sec in the temperature range from the triple point to 1.2°K. Experimental results were as follows: Only one peak was obtained with a line width of about