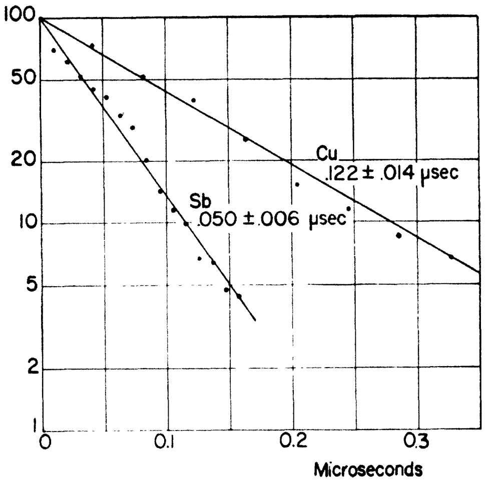

FIG. 2. Integral distributions of delayed counts from the meson capture radiation. The number of counts has been normalized to agree at time zero.

at sea level stops in the absorber, and is followed by a delayed non-ionizing ray which crosses the upper anticoincidence bank and is detected in S_2.

The timing uncertainty was measured by selecting events in which S_1 and S_2 were tripped simultaneously by a fast meson; the resulting lag distribution was approximately gaussian with a mean deviation of 4.5 mμsec. We therefore disregarded events delayed by less than 15 mμsec. Since the total number of instantaneous events selected by our triggering system was only about three times the number of delayed counts, the background due to this source could be ignored.

Integral delay distributions for Cu and Sb are shown in Fig. 2. We have subtracted small backgrounds due to random noise pulses and to the bremsstrahlung of decay positrons from positive mesons stopping in the absorber. The former are due mainly to events where a meson passes obliquely through A and S_1 (but misses the anticoincidence counters X) and is followed by a random noise pulse in S_2. Since noise pulses of this type occur with equal probability before and after the events AS_1, a knowledge of the number of negative lags permits us to correct for the number of positive lags due to noise. The bremsstrahlung background was identified by its characteristic 2.1 μsec decay time, at times long compared to the decay of the negative meson capture radiation, and was corrected for by extrapolation back to the shorter times. For Cu, the combined background rate, per hour of counting and per mμsec of delay, was only 1/10 the maximum counting rate due to meson capture, while for Sb it was only 1/20 the maximum rate.

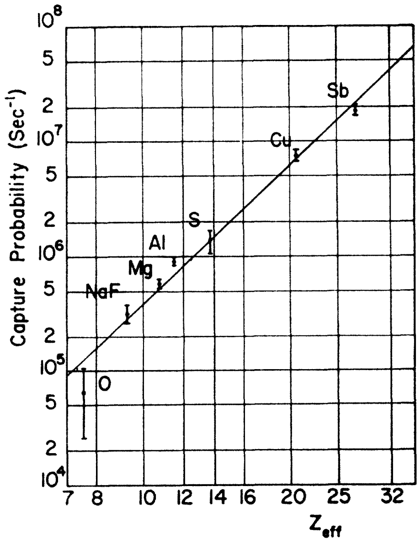

FIG. 3. Capture probability *vs* Z_{eff}. The effective atomic numbers are those calculated by Wheeler. Points for the light nuclei are from Ticho, with the result of Valley for Al averaged in. The line is drawn with a slope corresponding to the Z_{eff}^4 law.

The mean lives given in Fig. 2 have been computed according to the method of Peierls,[3] and the errors quoted are purely statistical. We believe our instrumental errors are smaller than these.

Wheeler[4] has predicted that the capture probability should go as Z_{eff}^4, where Z_{eff} is an effective atomic number defined in his paper. In Fig. 3 we have plotted out values for the capture probability, together with those of Ticho[5] and Valley[6] for the light elements. We find good agreement with the Z_{eff}^4 law. While the earlier results could be fitted fairly well with a simple Z^4 dependence, our results show the need for using Z_{eff} for the heavy elements, where the effect of the finite nuclear radius becomes important.

A knowledge of the capture probabilities permits one in principle to find the value of the coupling constant for the μ-meson-nucleon interaction. An evaluation of this constant more precise than the estimate given by Wheeler and Tiomno[7] awaits, however, a more detailed theoretical analysis of the nucleonic dynamics involved in the meson capture process.

* Supported by the joint program of the AEC and ONR.
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Gamma-Radiation Associated with Radium and Daughter Products*

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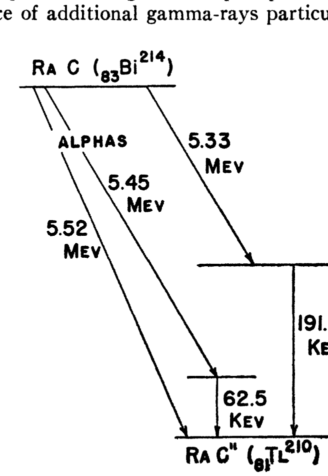
MANY studies have been made of the energies of the gamma-rays emitted by the various decay products of radium. Early spectrometric observations by Ellis[1] and associates and later by Siegbahn[2] have resulted in the correct assignments of many strong, internally converted gamma-rays. Subsequent measurements by various techniques including electron-pair production[3] have shown the existence of additional gamma-rays particularly

FIG. 1. Decay scheme for RaC to RaC″.



at higher energies. Considerable divergence exists in the reported values by even the same observers using different experimental methods. Since pure radium has a high specific activity, it is an ideal source for calibrating fixed-field magnetic spectrometers provided its gamma-energies are accurately evaluated. On this account a re-survey of the electron lines due to internal conversion and to photoemission from various radiators has been carried out in spectrometers calibrated by the known energies of the iodine 131 gamma-rays with extrapolated field values above 400 kev. A strong source of radium *D* was also available.

The *K-L-M* differences in the observed electron spectra in most cases show clearly the atomic number of the isotope in which each gamma-transition occurred. Generally an adjustment in the previously reported energies of the gamma-rays appears to be warranted. Certain previously unreported gamma-rays have been discovered and conversely, some gamma-radiations do not appear to exist as reported.

In the 0.04 percent branching decay of RaC to RaC″ (Tl^{210}) three alpha-groups with energies as shown in Fig. 1 are known to exist[4] but no gamma-rays had been noted. Conversion lines with *K-L* differences characteristic of $Z=81$, giving energies of 62.5 and 191.1 kev are now observed. Since these energies are compatible with the energy differences of the alpha-rays, the level plan as proposed in Fig. 1 appears justified.

A thorough study has been made of the low energy gamma-radiations in RaE (Bi^{210}) following beta-emission from strong sources of RaD. The magnetic field was reduced so as to give a dispersion of about 3 mm per kev, and the 46.4-kev gamma-ray yielded clearly resolved L_I, L_{II}, L_{III}, *M*, *N*, and *O* electron lines of such intensity that any other similar gamma-ray with intensity 1/100 as great would be detected. No evidence whatever could be found for the existence of the 23-kev gamma as reported[5] by Tsien from cloud-chamber observations nor for his other low energy radiations. Aluminum and critical absorption methods also failed to give any evidence for the presence of these energies. However, fairly strong radiations were found with energies of 13.5 to 9.5 kev corresponding very closely with the expected $L\beta$ and $L\alpha$ x-radiations from bismuth.

Several of the high energy gammas as reported by Latyshev were not observed, perhaps because of our lack of sensitivity in the high energy region, but every electron line reported by Ellis and co-workers plus some additional lines have been found. One pair of electron lines having *K-L* differences characteristic of $Z=82$ yield a gamma-energy of 457.5 kev. The radiation was found with a Ra source but not with RaD alone, and hence may be in Pb^{210} or Pb^{214}, probably the former since the alpha-radiation of Po^{214} to Pb^{210} is complex. The *K* electron line for a gamma-ray reported by Ellis in Bi^{214} at 257.8 kev falls together with the *L* electron line of the 185.6-kev gamma-ray in Rn^{222}.

A summary of the electron energies together with their relative intensities on an arbitrary scale and their interpretation is presented in Table I. No attempt is made to interpret certain very weak lines. The gamma-energies as determined in this investigation are shown collectively in Fig. 2.

TABLE I. Summary of observed electron energies, their relative intensities, and their interpretation.

Electron energy (kev)	Assignment	Gamma-energy (kev)	Relative intensity	Electron energy (kev)	Assignment	Gamma-energy (kev)	Relative intensity
30.0	L_1 83	46.3	10	237.3	*M* 83	241.3	4
30.6	L_2 83	46.3	4	240.8	*N* 83	241.7	3
33.0	L_3 83	46.4	1		Also *L* 83	257.1	
36.6	L_1 83	52.9	9	260.8	*K* 83	350.7	10
37.2	L_2 83	52.9	3	278.1	L_1 83	294.4	8
39.5	L_3 83	52.9	1	281.2	L_3 83	294.6	1
42.4	*M* 83	46.4	8	290.2	*M* 83	294.2	4
45.5	*N* 83	46.4	7	293.4	*N* 83	294.3	2
46.2	*O* 83	46.4	3	334.8	L_1 83	351.1	7
47.2	L_1 81	62.5	1	337.5	L_3 83	350.9	1
49.2	*M* 83	53.2	8	346.9	*M* 83	350.9	4
52.2	*N* 83	53.2	5	350.0	*N* 83	350.9	3
52.9	*O* 83	53.1	3	369.6	*K* 82	457.2	3
58.0	$A(\alpha_2-L)$ 83		2	390.4	Unassigned		2
60.9	$A(\alpha_1-L)$ 83		2	442.0	*L* 82	457.6	1
63.3	$A(\alpha_2-L)$ 86		1	516.3	*K* 84	608.8	8
66.0	$A(\alpha_1-L)$ 86		1	572.7	Unassigned		1
70.2	$A(\alpha_2-M)$83		2	592.8	*L* 84	609.0	5
73.4	$A(\alpha_1-M)$83		2	605.0	*M* 84	609.2	1
76.2	$A(\alpha_2-M)$86		1	651	Unassigned		1
79.3	$A(\alpha_1-M)$86		1	676	*K* 84	769	4
87.5	*K* 86	185.3	6	696	*K* 82	784	1
105.9	*K* 81	191.1	4	752	*L* 84	769	1
151.5	*K* 83	241.4	10	842	*K* 84	935	5
168.2	L_2 86	185.5	6	918	*L* 84	935	1
	Also *K* 83	258.1		1029	*K* 84	1122	8
171.3	L_3 86	185.9	4	1105	*M* 84	1122	3
176.2	L_2 81	190.9	1	1117	*M* 84	1122	1
181.4	*M* 86	185.9	5	1148	*K* 84	1241	3
184.6	*N* 86	185.7	4	1326	*K* 84	1419	9
204.7	*K* 83	294.6	10	1402	*L* 84	1419	3
225.5	L_1 83	241.8	5	1673	*K* 84	1766	3
228.1	L_3 83	241.5	1				

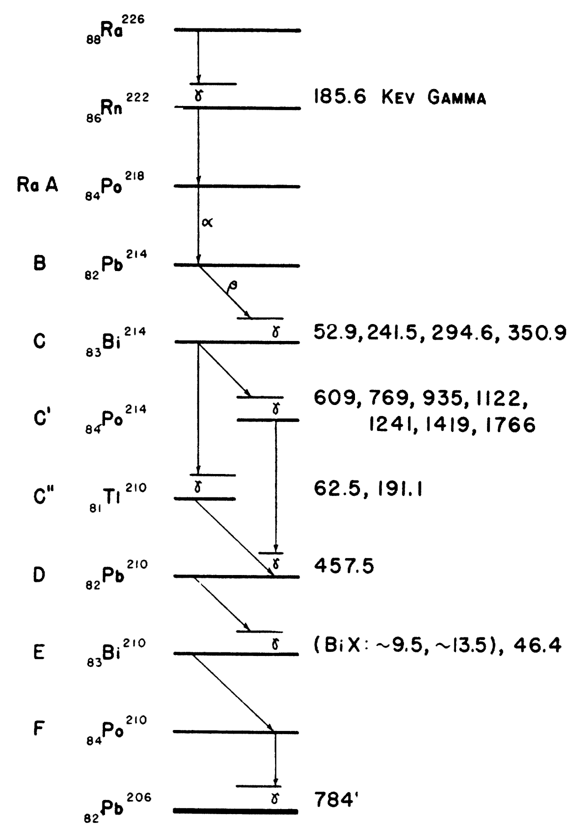


FIG. 2. Summary of the gamma-rays associated with various nuclei.

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