$\times 10^{-12}$ cm. It is thus indicated that the radii are the same to within the experimental errors. These are somewhat larger than the radius calculated from the formula $R=1.47A^{\frac{1}{3}}\times 10^{-13}$ cm which gives $R=0.856 \times 10^{-12}$ cm.

CONCLUSION

An intensive study of the 4.906-ev gold resonance has yielded the Breit-Wigner parameters listed in Table II. It is hoped that these results might serve to stimulate comparison between various neutron spectrometers and assist in reducing the large discrepancies which now are common in resonance analysis. The one-level formula affords an accurate representation of the experimental data over the entire energy range and to very fine detail. This, of course, does not constitute an experimental verification of the validity of this formula, nor does it eliminate the possibility that other interpretations might succeed in giving equally successful agreement with the data. On the other hand, the excellent agreement indicates that the one-level formula can be applied with full confidence and at large distances from the center of the resonance to cross sections having widely separated resonances.

As must be expected, if the cross section is examined in sufficiently fine detail, the effects of neighboring resonances can be observed. In the case of gold, the effects are negligible on the parameters which pertain strictly to the resonance; however, terms which involve the nuclear radius (i.e., ϑ and σ_p) have increased uncertainty due to lack of knowledge about the spins of the nearest neighbors. The data indicate that one or more bound levels in Au^{198} have appreciable influence on the thermal cross sections.

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Radioactive Decay of 65-Hour Sb^{122}†

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65-hour Sb^{122} was investigated by using Sb^{121} (97.7 percent–99.4 percent) that had been bombarded with thermal neutrons for 70 hours. Spectrometer measurements show three beta groups with end-point energies: 1.987, 1.423, and 0.734 Mev; and logft values: 8.6 [log$ft(w^2-mc^2)=10.0$, p^2+q^2 shape], 7.6 (allowed shape), and 7.7; and four gamma rays with energies: 0.563, 0.693, 1.152, and 1.256 Mev; and intensities: 73 percent, 3.6 percent, 0.75 percent and 0.8 percent. From gamma-gamma and beta-gamma coincidences the excited states of Te^{122} were found at 0.563 and 1.256 Mev. X-gamma coincidences and x-ray critical absorption showed 2.2 percent and 0.8 percent K-capture transitions to the ground state and to a 1.152-Mev level in Sn^{122}. The ft values for the transitions to Sn^{122} are 13 times smaller than the corresponding transitions to Te^{122}. Annihilation radiation was not observed setting an upper limit of 0.005 percent for positrons. The directional correlation of the 0.693- and the 0.563-Mev gamma rays indicated a 2−2−0 cascade, with the 2−2 transition 91+5 percent quadrupole. The first excited state in Te^{122} was also shown to be 2+ from a measurement of the K conversion coefficient of the 0.563-Mev gamma ray. We conclude therefore that the ground state of Sb^{122} is 2− $(g_{7/2}, h_{11/2})$, the first two excited states of Te^{122} are 2+, and the first excited state of Sn^{122} may also be 2+.

I. INTRODUCTION

AT the time this work was started, the decay scheme of Sb^{122} was thought to be simple[1]: Sb^{122} decayed by beta emission to the ground state, and to the first excited state, of Te^{122}; the beta transition to the first excited state being followed by a gamma transition to the ground state. The first part of this work was carried out at the University of Illinois and reported at the May, 1952 meeting of the American Physical Society.[2] At that time we had found that there were at least three beta groups and four gamma rays in the decay, and on the basis of ft values and the beta spectra shapes, K conversion, and gamma-gamma directional correlation, we assigned spins and parities to the ground state of Sb^{122} and to the first two excited states of Te^{122}. The decay scheme we suggested and which is quoted in the literature,[3] is correct as far as it goes, but no allowance was made in it for a 1.152-Mev gamma ray we knew to be present to the extent of 0.75 percent of all Sb^{122} decays. Further work at the University of Illinois[4] revealed high-energy coincidences which would indicate that the 1.152-Mev gamma ray leads to the first excited state of Te^{122} (at 0.563 Mev), and that there exists a 1.7-Mev level in Te^{122}. However, the second part of this work, carried out at the Palmer

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* Formerly at The University of Illinois, Urbana, Illinois. Part of this work was included in a Ph.D. thesis submitted to the Graduate College at the University of Illinois.

[1] K. Way *et al.*, Nuclear Data, National Bureau of Standards Circular 499 (U. S. Government Printing Office, Washington, D. C., 1950).

[2] M. J. Glaubman and F. R. Metzger Phys. Rev. **87**, 203 (1952).

[3] M. Goldhaber and R. D. Hill, Revs. Modern Phys. **24**, 179 (1952); Hollander, Perlman, and Seaborg, Revs. Modern Phys. **25**, 469 (1953).

[4] M. J. Glaubman, thesis, University of Illinois, 1953 (unpublished).

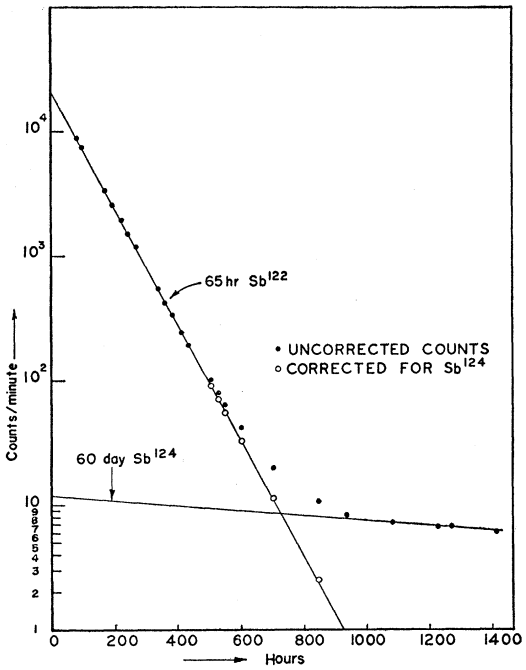

FIG. 1. Beta decay of Sb^{122} as measured with an end-window Geiger counter.

Physical Laboratory with improved equipment, contradicts this. The 1.7-Mev transition and the high-energy gamma-gamma coincidences can be shown to be due to Sb^{124} contamination, and beta-gamma and x-gamma coincidences show that the 1.152-Mev gamma ray is in Sn^{122}.

The sources we used were prepared from Sb^{121}-enriched isotope that had been bombarded with thermal neutrons at the Brookhaven National Laboratory for 70 hours.[5] For the work at the University of Illinois the source material we used was nominally 97.7 percent Sb^{121}; for the work at Princeton it was nominally 99.4 percent Sb^{121}. Figure 1 shows a typical decay curve of a sample of the material used for our studies at Princeton, as measured with an end-window Geiger counter. It can be seen from the intercepts that in the fresh source the Sb^{122} (beta) activity was 2000 times that of the Sb^{124} (beta) activity.

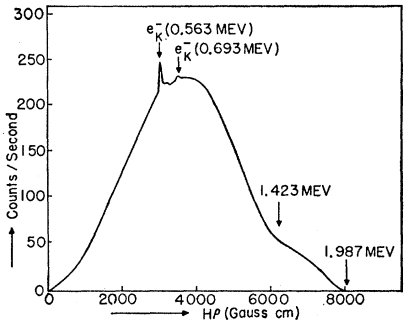

FIG. 2. Beta spectrum of Sb^{122}. The only prominent conversion line is that of the 0.563-Mev gamma.

[5] We wish to express our thanks to the Isotopes Division of the U. S. Atomic Energy Commission for the loan of the source material and to the Brookhaven National Laboratory for the bombardments.

The experiments we conducted are described briefly below, together with the conclusions drawn from them. On the basis of these conclusions we can establish a decay scheme for Sb^{122}. Although there is nothing unusual about the level scheme, there are a few features of the decay that deserve special attention. One is that of the two electric quadrupole transitions from the second excited state of Te^{122}, one is speeded up by a factor of 15 compared to the other. Another is the speeding up of the K capture by a factor of 13 compared to the negatron decay, although both are of the same character as far as spin and parity changes are concerned. We would also like to point out that the first two excited states of Te^{124} have energies that are the averages of the respective states in Te^{122} and Te^{126}.

II. MEASUREMENTS WITH THE MAGNETIC LENS SPECTROMETER

The magnetic lens spectrometer we used had a resolution of 2.3 percent and a transmission of about 1 percent. Thin sources mounted on nylon-zapon films were used for the beta and conversion electron spectra, and strong sources, with gold converters, for the gamma (photoelectron) spectrum. The only internal conversion lines we could measure were the electrons from the 0.563-Mev transition; all other conversion lines were too small compared to the beta spectrum (Fig. 2). The energy loss (scattering) of electrons in the region of interest (0.3–2.0 Mev) had a negligible effect on the analysis of the spectra. (This was proved by using sources of varying average thickness—from 1 to 0.05 mg/cm².)

A. Beta Spectrum

The beta spectrum was analyzed into four partial spectra as shown in Fig. 3. The shape of the highest-energy group is due to a p^2+q^2 factor typical to transitions with $\Delta J=2$, change of parity.[6] The shape of the second group is "allowed" down to 730 kev. This is typical to allowed transitions and to most first-forbidden spectra ($\Delta J=0$, 1, change of parity).[7] The shape of the third beta group is uncertain and the appearance of the fourth beta group may be due to errors of subtraction. (The first beta group may have more low-energy electrons than we allowed for it because the correct shape factor is Λp^2+q^2, where Λ is close to 1 down to about 200 kev,[8] and then starts increasing with lower energy; these may now appear as "β_4.")

[6] C. S. Wu, Revs. Modern Phys. **22**, 386 (1950).
[7] C. S. Wu, International Conference on Nuclear Physics, Chicago, Illinois, 1951 (unpublished).
[8] Laslett, Jensen, and Paskin, Phys. Rev. **79**, 412 (1950); Macklin, Lidofsky, and Wu, Phys. Rev. **87**, 391 (1952).

The Sb^{122} beta spectrum has been analyzed independently by Wu and co-workers,[7] and our results and conclusions are in agreement with theirs for both high-energy beta groups. Cork *et al.*,[9] however, also looked at the beta spectrum, and they claim that the second beta group deviates considerably from the "allowed" shape. The results of our analysis of the spectrum are

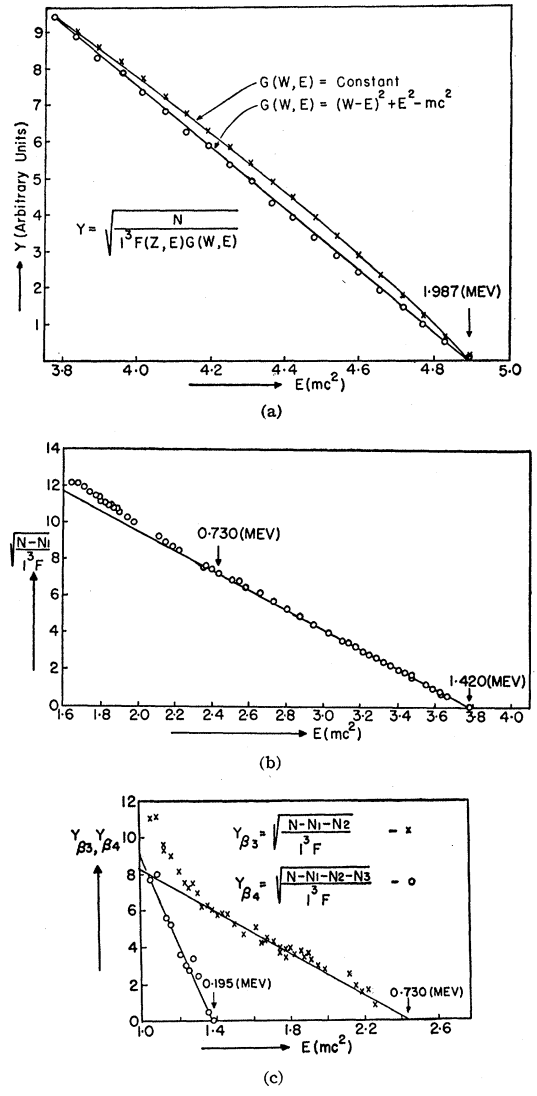

FIG. 3. Analysis of beta spectrum of Sb^{122}. N_1 was extrapolated from the high-energy spectrum (a) using $G(W,E)=(W-E)^2+E^2-mc^2=q^2+p^2$. N_2 was extrapolated from (b) by assuming an "allowed" shape. "β_4" is probably due to subtraction errors.

shown in Table I. "β_4" is not listed since it is probably due to subtraction errors.

From the shape of the spectrum of the first group and from the assumption that it leads to the 0+ ground state of Te^{122}, it can be concluded that the ground state

[9] Cork, Brice, Hickman, and Schmid, Phys. Rev. **93**, 1059 (1954).

TABLE I. Beta rays.

Energy (Mev)	Intensity (%)	Shape	Log(ft)	Type
1.987±0.02	26.5±1.5	p^2+q^2	8.6[a]	first forbidden ("α")
1.423±0.01	69. ±3	allowed	7.6	first forbidden
0.730±0.02	4.4[b]±1	allowed?	7.7	first forbidden

[a] $\log[(W^2-mc^2)ft]=10.0$.
[b] The intensity of the third beta group as determined by the beta spectrum was about 6 percent. This was changed to 4.4 percent to make it conform to the intensities of the gamma rays that it is associated with, since the measurement of the gamma-ray intensities does not involve such large subtractions.

of Sb^{122} is 2−. From the ft values of the other beta groups it may be concluded that the spins of the first two excited states of Te^{122} can have the values 1, 2, or 3, and that their parity is probably even Wu *et al.*[7] reach the same conclusion for the first excited state of Te^{122} from the beta-gamma angular correlation.

B. Photoelectron Spectrum

The photoelectron spectrum was measured with strong (~5 Mc) sources held in special brass containers (to absorb the beta rays) of fixed geometry, and covered with gold foil 24.5 mg/cm² thick. The energy dependence of the effective photoelectron cross section in this experimental arrangement and energy range was found by Metzger[10] to be proportional to $1/E^2$. The uncorrected photoelectron lines are shown in Fig. 4; the results, after correcting for the energy dependence of the efficiency, are summarized in Table II. The intensity of the 0.563-Mev gamma ray is set at 73 percent; this is because it is fed directly by the 1.423-Mev beta group which is 69 percent of all beta decays, as well as by the 0.693-Mev gamma ray (Fig. 9) which

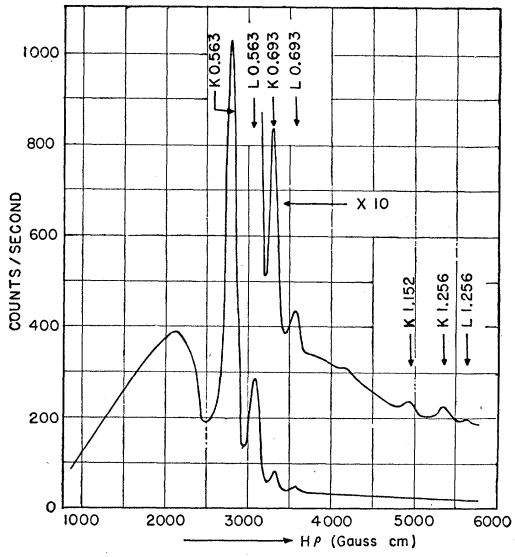

FIG. 4. Photoelectrons in Sb^{122} decay (24.5-mg/cm² gold converter).

[10] F. R. Metzger (private communication).

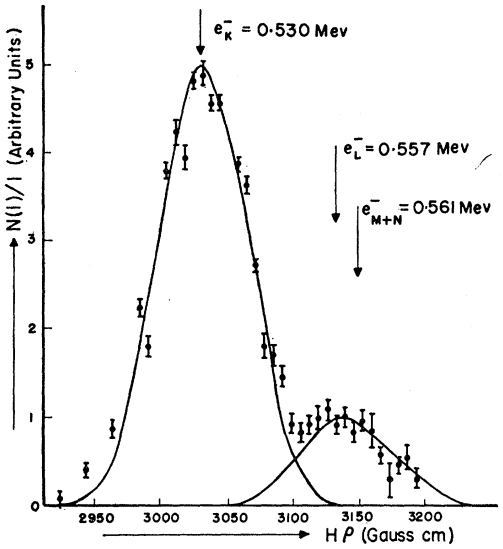

FIG. 5. Te^{122} internal conversion electrons from 0.563-Mev gamma ray.

is responsible for one-twentieth of the 0.563-Mev gamma-ray intensity.

C. Internal Conversion Electrons

The internal conversion lines of the 0.563-Mev transition were measured together with the beta spectrum. Figure 5 shows the internal conversion lines after the beta-ray background had been subtracted and the residual counts divided by the current and fitted with a standard (for this spectrometer) resolution curve.

It has been shown above (Table I) that about 73 percent of the Sb^{122} beta decays are associated with the 0.563-Mev gamma rays. The number of electrons in the K conversion line (Fig. 5) was therefore divided by 73 percent of the total number of electrons in the beta spectrum to yield the K conversion coeffieicnt of the 0.563-Mev gamma ray. The experimental value is compared in Table III with some theoretical values taken from the tables of Rose *et al.*[11] It can readily be seen that the transition is an electric quadrupole one. Assuming the ground state of Te^{122} is 0+, it follows that the first excited state of Te^{122} is 2+ (in agreement with the rule of Goldhaber and Sunyar[12]).

The $K/(L+M+N)$ ratio of 5.4±0.7 shown in Table III should be compared with the ratio obtained by Tomlinson *et al.*[13] for the 0.602-Mev electric quadrupole transition in Te^{124}. Their value is 6.3±0.3, and taking into account the energy dependence of K/L (see reference 12, Fig. 11), the two values agree well with each other.

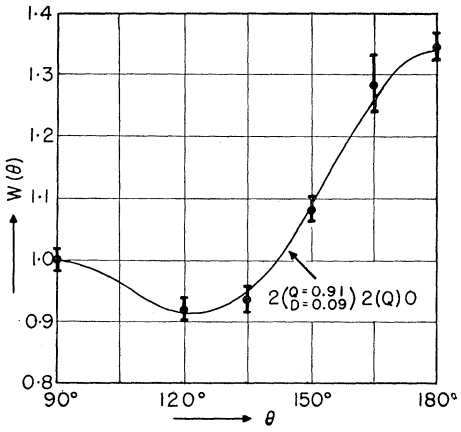

FIG. 6. Directional correlation of gamma-gamma coincidences in Te^{122}. Flags indicate standard deviation (due to statistics) of (693±90)—563 kev coincidences from measured coincidence rate. Existence of 0.005 percent positrons would mean that anisotropy of directional correlation curve should be 1.23 instead of 1.33.

III. MEASUREMENTS WITH SCINTILLATION COUNTERS

A. Directional Correlation of Gamma-Gamma Coincidences

Gamma-gamma coincidences were observed and their directional correlation was measured using NaI crystals with lead and copper absorbers to eliminate scattering from counter to counter (in addition to beta-ray absorbers of carbon), but without pulse-height selection.

TABLE II. Gamma rays.

Energy (Mev)	0.563±0.005	0.693±0.007	1.152±0.015	1.256±0.012
Intensity (%)	73±3	3.6 ±0.7	0.75 ±0.1	0.8 ±0.1

The ratio of single counts to coincidences indicated that 7±2 percent of all gamma rays detected as singles belonged to a gamma-gamma cascade. From Table II it can be seen that such a high percentage of coincidences cannot occur unless the 0.693-Mev gamma ray is in cascade with the 0.563-Mev gamma. This is consistent with the assumption that the 1.256-Mev gamma ray is the crossover from the second excited state in Te^{122}, and is also consistent with the energies and intensities of the beta groups. Furthermore, experiments to be described below prove that of the "weak" gamma rays in Table II, the 0.693-Mev one, and only it, is in coincidence with another gamma ray.

The directional correlation of the 0.693–0.563 Mev cascade is shown in Fig. 6. After correcting for finite angular resolution the points can be fitted (by the least-squares method) to a curve $W(\theta)=1+A_2P_2(\cos\theta)+A_4P_4(\cos\theta)$, where $A_2=0.158\pm0.061$, and $A_4=0.305\pm0.080$. The errors assigned to A_2 and A_4 are compounded from the statistical errors shown in Fig. 6 and "discrimination" errors. We define the "discrimination" error as the possible deviation of the 0.693–0.563 Mev

[11] Rose, Goertzel, and Perry, Oak Ridge National Laboratory ORNL-1023 (unpublished).
[12] M. Goldhaber and A. W. Sunyar, Phys. Rev. **83**, 906 (1951).
[13] Tomlinson, Ridgway, and Gopalakrishnan, Phys. Rev. **91**, 484 (1953).

coincidence rate at angle θ from the total coincidence rate at that angle as measured in our experiment. The "discrimination" errors were determined in a special experiment in which an unsteady fast coincidence circuit was used in conjunction with a differential discriminator. Although the circuitry was not stable enough for a reliable directional correlation measurement, it was good enough to allow us to determine the ratio of coincidences in which one of the pulses corresponded to 0.693±0.090 Mev gamma rays, to the total coincidence counting rate. Within certain statistical errors (the "discrimination" errors), this ratio was independent of the angle between the counters. We therefore can exclude bremsstrahlung, scattering, and annihilation radiation from having a significant effect on our measured correlation. This also sets an upper limit of 0.005 percent for positrons in the beta decay.

The large value of A_4 implies a large quadrupole content in each of the two transitions. Since the ground state of Te^{122} presumably has zero spin, the transition to it is a pure multipole (quadrupole), and the spin of the first excited state is 2. The spin of the second excited state cannot be 4, 3, or 1, since these values would imply[14] either a small (for spin 4) or a negative

TABLE III. Conversion electrons of 0.563-Mev gamma rays.

K conversion coefficient $\times 10^3$						$K/(L+M+N)$
	theoretical					
experimental	$E1$	$E2$	$E3$	$M1$	$M2$	experimental
5.2±0.4	1.8	5.2	13.6	6.6	20	5.4±0.7

(for spin 1 or 3) value of A_4. The assignment of spin 0 to the second excited state, assuming the values of A_2 and A_4 to be reduced from 0.357 and 1.143 to 0.158 and 0.305, respectively, by the influence of atomic electric and magnetic fields, can be ruled out by the evidence for the assignment of the 1.256-Mev gamma ray as the cross over from the second excited state (see beta-gamma coincidences described below). In addition to that, one would assume that the ft values of the transitions from Sb^{122} to two 0+ states in Te^{122} would be about equal (or the $(W_0^2-1)ft$ values would be the same); they are not by a factor of ten [and the $(W_0^2-1)ft$ values by a factor of 50]. The only satisfactory interpretation that remains is to assume that the second excited state has spin 2, and that the 2−2 transition has an appreciable quadrupole content.

The relative quadrupole and dipole content of a mixed transition can be expressed in terms of their reduced matrix elements[15] β and α; if $x=\beta/\alpha$, the quadrupole content of the radiation Q will be equal to $x^2/(1+x^2)$, the dipole content being equal to $1-Q$. The theoretical values of $A_2(Q)$ and $A_4(Q)$ are plotted in Fig. 7 together with our experimental values. It can be

[14] D. S. Ling and D. L. Falkoff, Phys. Rev. **76**, 1639 (1949).

[15] See S. P. Lloyd, Phys. Rev. **85**, 910 (1952), reference 22, for a discussion of the definition of β and α and the proper sign of x.

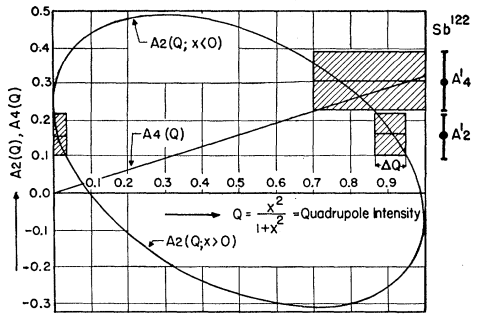

FIG. 7. A_2 and A_4 for a $2(Q,D)2(Q)0$. Shaded areas indicate values of Q consistent with values of A_2 and A_4 of Sb^{122} decay.

seen from Fig. 7 that the data are consistent with a 2−2−0 cascade, the 2−2 transition having $Q=0.91\pm0.05$ and x negative. A curve $W(\theta)=1+A_2(Q)P_2(\cos\theta)+A_4(Q)P_4(\cos\theta)$ was calculated using this value of Q, and after being corrected for finite resolution and normalization it was plotted in Fig. 6.

B. Measurements with Pulse-Height Selection

In these measurements we used a 20-channel analyzer for display of spectra, and differential discriminators to

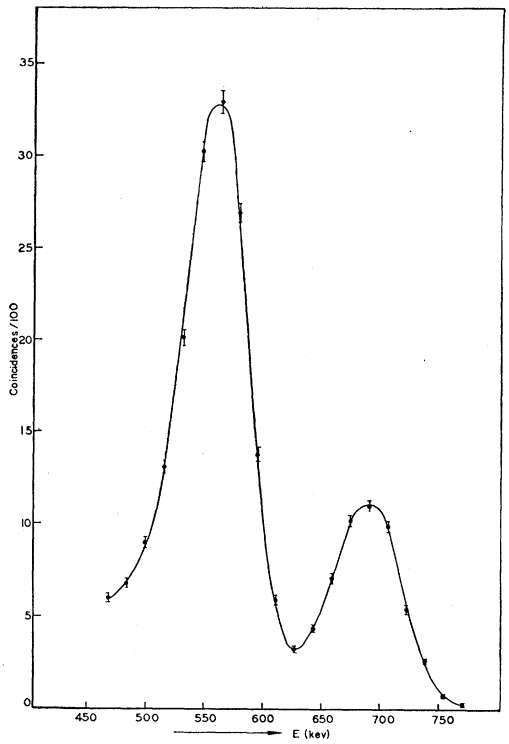

FIG. 8. Gamma-gamma coincidences (including chance coincidences). Both channels accepted pulses only in the gamma energy range of 400–800 kev. The total chance coincidence rate was ⅓ of all coincidences; since the 0.563-Mev gamma is more than 20 times stronger than the 0.693-Mev one, most of the chance counts are in the 0.563-Mev peak. This curve is consistent with the assumption that only the 0.693- and the 0.563-Mev gammas are in coincidence.

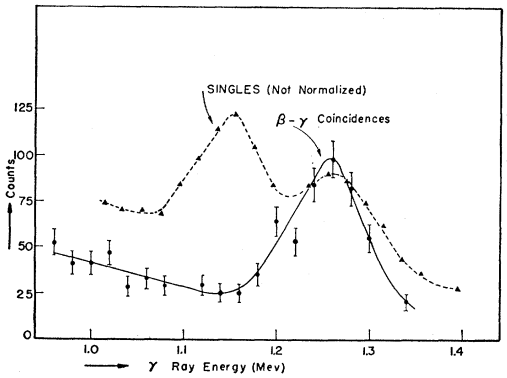

FIG. 9. Beta-gamma coincidences. The beta-ray channel was set once at 100–450 kev and once at 450–900 kev. In both cases the energy dependence of the beta-gamma coincidences on the gamma-ray energy was the one shown above.

determine the channels that the pulses from the counters had to be in to register coincidences. (The 20-channel analyzer was gated with coincidences associated with pulses in the proper channels.) Figures 8 and 9 show the dependence of the gamma-gamma and beta-gamma coincidence counting rates on the gamma-ray energy. There were no gamma-gamma coincidences in the 65-hour decay when one of the channels was set above 0.8 Mev; we conclude from that, that the 1.152- and 1.256-Mev gammas are each fed directly by the decay of Sb^{122} and lead, in each case, to a ground state. The beta-gamma coincidences show that the 1.256-Mev gamma is in coincidence with beta rays in the regions 0.1 to 0.45 Mev and 0.45 to 0.9 Mev. This indicates that the 1.256-Mev gamma is associated with the 0.73-Mev beta group and leads to the ground state of Te^{122}. The 1.152-Mev gamma is not associated with any beta rays and is probably in Sn^{122} (following orbital electron capture in Sb^{122}).

In order to show that we indeed have K capture in the 65-hour decay, we performed a critical absorption

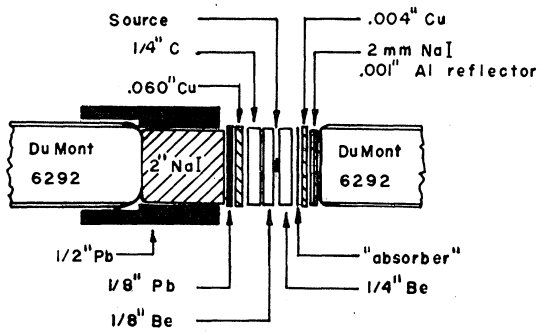

FIG. 10. Geometry for x-gamma coincidence measurements. The Be and C are for absorbing beta rays with minimum emission of bremsstrahlung. The Cu and Pb in front of the gamma detector prevent secondary radiations from the gamma counter from reaching the x-ray detector. The Cu in front of the x-ray detector is sufficient to cut down the "absorber" fluorescence so as not to influence the apparent transmission of the "absorbers."

measurement on the x-rays and looked both at the x-ray intensity, and at the gamma ray in the x-gamma coincidences. Figure 10 shows the geometry employed; the "absorbers" were Ag (critical absorber for Sb and Te x-rays) and Pd (critical absorber for Sn x-rays). Figure 11 shows an x-ray spectrum of a 60-day Sb^{124} source; presumably there are no Sn x-rays there, and the absorbers are about equivalent in their transmission. Figure 12 shows an x-ray spectrum of the 65-hour activity; it is clear that some of the x-rays are strongly absorbed by the Pd but not by the Ag, i.e., they are Sn x-rays.

Figure 13 shows the dependence of the x-gamma coincidences on the gamma-ray energy. It is clear that only the 1.152 Mev is in coincidence with the x-rays. From curves such as shown in Fig. 13, taken with no-, Ag-, and Pd-"absorbers" we obtained the transmission

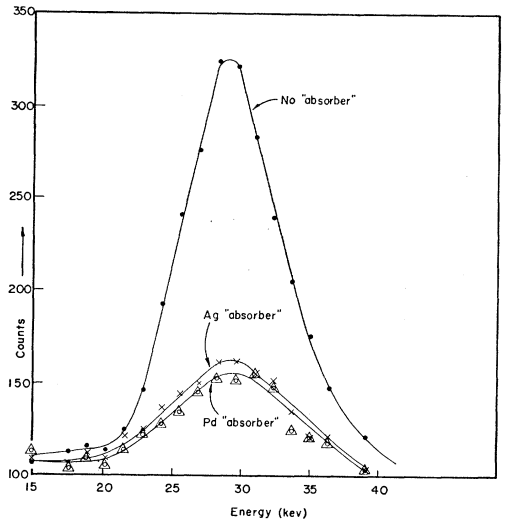

FIG. 11. X-rays in the decay of Sb^{124}. These curves show that the Pd- and Ag-"absorbers" are practically equivalent for Te and Sb x-rays.

of the various "absorbers" for the x-ray in the x-gamma coincidences. These are compared in Table IV with the values computed from tables in Compton and Allison[16] and with the transmissions of the "absorbers" for the x-rays in the x-ray spectrum. We can conclude immediately that the x-gamma coincidences are in Sn. Because of the wide aperture of the x-ray counter and other effects due to our geometry it may be better to take the x-gamma data for the purpose of determining the transmission ratios of the "absorbers" for Sn x-rays in our experiment. We can then estimate from the data in Table IV, and from curves such as in Fig. 12, how many of the x-rays are Sn x-rays. Our conclusion is that

[16] A. H. Compton and S. K. Allison, *X-Rays in Theory and Experiment* (D. Van Nostrand Company, Inc., New York, 1935), second edition, pp. 784, 800, and 804.

75 percent±10 percent of all the x-rays in the decay are in Sn.

In order to determine what fraction of x-rays are associated with the 1.152-Mev gamma ray we measured the ratio of x-ray singles to x-gamma coincidences and compared it with the ratio of singles to coincidences in Ni^{60}. The geometry for the x/x-γ measurements was that shown in Fig. 10, except that there was no "absorber" and the 0.004-in. copper absorber was also removed. For the γ/γ-γ measurement in Ni^{60} we used the identical geometry except that a 2-in. crystal was substituted for the 2-mm one; the pulses from this crystal were displayed on the 20-channel analyzer and the area of the higher-energy half of the 1.33-Mev line was measured as the counting rate. From the gamma detector used in both experiments, only pulses corresponding to 1.04–1.28 Mev (1.15_{-11}^{+13}, 1.17_{-13}^{+11}) were admitted by the differential discriminator, thus insuring equal efficiency for the singles to coincidences ratios in both experiments. [The resolving time of the coincidence circuit was $2\tau=1.5\times10^{-7}$ second, and the coincidence efficiency (for x-gamma coincidences) was flat within statistics (2 percent) for a delay range (between

TABLE IV. Ratios of "absorber" transmissions for Sn x-rays [Compton and Allison (see reference 16)], and for x-rays in the 65-hour activity.

"Absorbers"	Compton and Allison	X-gamma	X-spectrum
Pd/Ag	0.22	0.38	0.32
Ag/no	0.78	0.59	0.52
Pd/no	0.17	0.22	0.17

the x and the gamma pulses) of 0.9×10^{-7} second = twice the length of the pulse-shaping delay lines; the efficiency of the circuit therefore is practically 100 percent and independent of whether we are measuring x-gamma or gamma-gamma coincidences.] We found that only 20 percent of the x-rays were involved in x-gamma coincidences.

In order to determine the x-ray intensities in terms of the beta decay we measured the x-ray counting rate at a certain solid angle subtended from a calibrated source. [The source was calibrated by measuring the singles and coincidences of the 0.563- and 0.693-Mev (separated) peaks.] After correcting for fluorescent yield[17] and absorption in the beta (Be) absorber,[16] the total K ionization was found to be 4±0.5 percent. The K ionizations associated with the 1.152-Mev level, the ground state of Sn^{122}, and Te+Sb, are therefore: 0.8 percent±0.15 percent, 2.2 percent±0.7 percent, and 1.0 percent±0.4 percent of all beta decays, respectively. The intensity of the 1.152-Mev level, however, is 0.75 percent±0.1 percent of all beta decays (Table II); the L electron capture, therefore, must be negligible.

[17] C. E. Ross, Phys. Rev. **93**, 401 (1954).

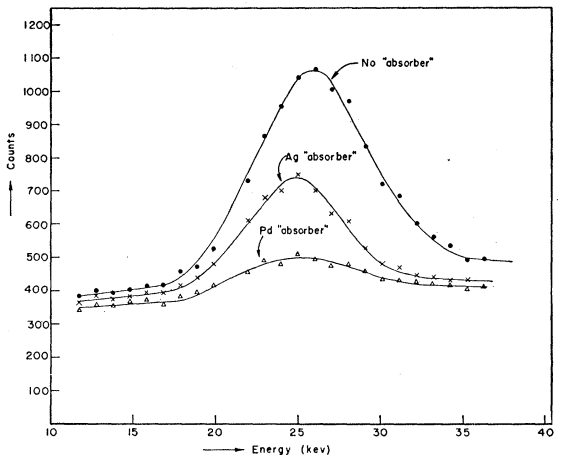

FIG. 12. X-rays in the decay of Sb^{122}. The Ag "absorber" transmits about 3 times as much as the Pd "absorber," showing the presence of Sn x-rays.

The transition from the ground state of Sb^{122} to the ground state of Sn^{122} is probably a (2−)—(0+) one. Neglecting screening and finer effects of the Coulomb field,

$$f_K/f_{\beta^+}=\{(W_0+W_K)^2/(W_0^2-1)\}\{f_K/f_{\beta^+}\}_{\text{allowed}},$$

where W_0 is the nuclear transition energy and W_K is the total K electron energy (all in units of mc^2). From the upper limit we set for position emission: f_K/f_{β^+}

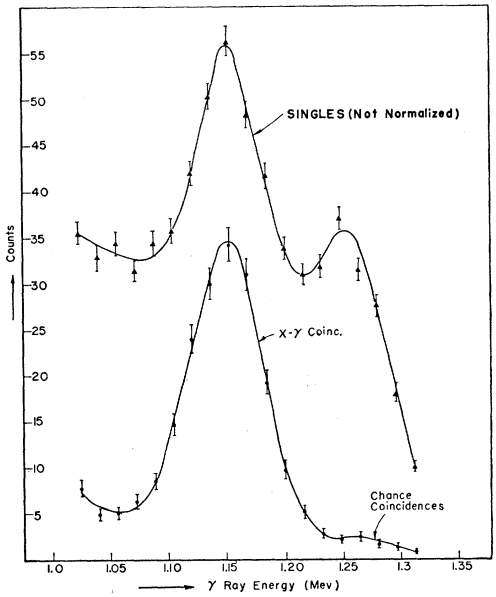

FIG. 13. X-gamma coincidences. Only the 1.152-Mev gammas are in coincidence with the x-rays. The high-energy tail is due to chance coincidences, and by taking account of the singles counting rate it can be extrapolated over the range of the 1.152-Mev gamma. This curve was taken with a Pd "absorber;" the curves taken with Ag- and no-"absorber" are similar except that the number of chance coincidences is relatively smaller.

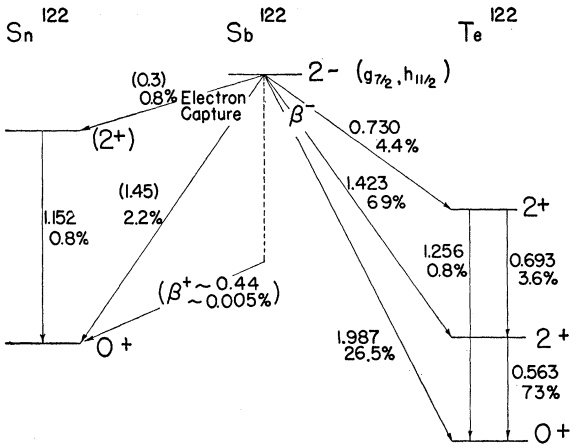

FIG. 14. Decay scheme of Sb^{122}. All energies are in Mev. Quantities in brackets are consistent with the experimental evidence but are not directly inferred from experiments.

>400.[18] Using the graphs of Feenberg and Trigg[19] for $(f_K/f_{\beta^+})_{\text{allowed}}$, we find: $W_0<1.87mc^2$. Using this value, we obtain[19]: $\log[(W_0+W_K)^2ft]<8.8$, an unusually small value for a (2−)—(0+) transition.[7] From the maximum energy available for K capture to the 1.152-Mev level and the intensity of the transition we get: $\log ft<6.5$. In view of the fact that we hardly have any L capture, W_0 is probably not much smaller than the maximum value we assigned to it and the ft values should be taken at their maximum value. The transition to the first excited state in Sn^{122} is probably first-forbidden, and the state could be 2+ (in agreement with the rule of Goldhaber and Sunyar[12]).

IV. DISCUSSION

Summarizing the conclusions from the experiments described above, we arrive at the decay scheme shown in Fig. 14.

The first excited state in Sn^{122} is similar in energy to the first excited states of the other known even Sn isotopes, and the excited states of Te^{122} are similar to those of the known even Te isotopes, as can be seen from the data compiled in Table V. All of the levels in that table have even parity and spin 2 (except that there is no conclusive evidence as to the spin of the 1.33-Mev level in Te^{124}; we guess it to be 2). The relationship between energy and the number of neutrons in the even Te isotopes is remarkably linear. There is no comparable smooth variation of energy with Z. The ft values of the β^- decay of Sb^{122}, and the decay of I^{126}, are practically identical[20]; on the other hand, the transitions to Sn^{122} are considerably faster (by a factor of 13).

TABLE V. (2+) Excited states of even-even nuclei (in Mev).

		Z				
		50	52		54	
State		1st	1st	2nd	1st	2nd
	66	1.27[a]				
N	70	1.30[a]	1.56	1.26		
	72	1.15	0.60[a]	1.33[a]	0.38[b]	0.86[b]
	74		0.64[b]	1.40[b]	0.43[a]	

[a] See reference 3.
[b] See reference 20; the energy of the second excited state is estimated here from the energies of the (stronger) cascade gammas instead of from the (weaker) crossover.

The radiation from the 1.256-Mev level in Te^{122} can be broken up into three parts: 0.693-Mev $M1$, 0.693-Mev $E2$, and 1.256-Mev $E2$. Their intensities (or transition rates), as determined from the value of Q in the analysis of the directional correlation and from the relative intensities of the 0.693- and 1.256-Mev gamma rays, are: 1, 10, and 2.5, respectively. The 0.693-Mev $E2$ transition is fast, not only compared to the $M1$ transition, but also compared to the 1.256-Mev $E2$ one (by a factor of 15).[21] In general the relative speeding up of $E2$ transition rates from the second excited state in 2−2−0 cascades will vary in different nuclei, from about normal (as in Cd^{114})[3,22] to very large (as in Pt^{196} where no crossover has been observed at all).[23]

ACKNOWLEDGMENTS

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[18] *Note added in proof.*—We have since measured the annihilation radiation and can set $K/\beta^+=300\pm130$. Using Zweifel's [P. F. Zweifel, Phys. Rev. **96**, (1954)] values of

$$f_K/f_{\beta^+}\}_{\text{allowed}}$$

(which includes screening corrections) and $\frac{1}{2}(W_0^2-1)$ for the shape factor of the β^+ spectrum, we obtain the position end-point energy $480<E_0<580$ kev, and $\log[W_0^2-1)ft]=9\pm0.15$.

[19] E. Feenberg and G. Trigg, Revs. Modern Phys. **22**, 399 (1950).

[20] M. L. Perlman and Joan P. Welker, Phys. Rev. **95**, 133 (1954).

[21] J. M. Blatt and V. F. Weisskopf, *Theoretical Nuclear Physics* (John Wiley and Sons, Inc., New York, 1952), p. 627.

[22] E. D. Klema and F. K. McGowan, Phys. Rev. **87**, 524 (1951); R. M. Steffen and W. Zobel, Phys. Rev. **88**, 170 (1952).

[23] R. M. Steffen, Phys. Rev. **89**, 665 (1953).