Title
THE RADIOACTIVITY OF CU67

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ABSTRACT

The β-spectrum of Cu^{67} is found to contain three groups with maximum energies and relative intensities of 577 kev, 20 percent; 484 kev, 35 percent; 395 kev, 45 percent. Conversion electrons from 92 and 182 kev transitions were observed. These results and the absence of γ-γ coincidences indicate that the β-transitions go to the ground and first two excited states of the known Zn^{67} levels.

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The level scheme for Zn^{67} has been derived independently by two groups[1, 2] by investigating the K-capture decay of Ga^{67}. Their results are indicated in Figure 1, showing the transitions involved. The purpose of this report is to show the fit of the Cu^{67} β-activity to this scheme.

The Cu^{67} activity was produced by two reactions, (α, p) on Ni using 40 Mev α's and $(d, 2p)$ on Zn using 195 Mev deuterons. The half life was found to be 61 ± 1 hours followed over ten half lives. Since thin samples are essential for the analysis of a β-spectrum, chemical separations were made carrier free employing ion-exchange columns. The β-spectrometer used was a thick lens type of two percent transmission and four percent resolution and was equipped with a halical baffle which allowed either positrons or electrons to be transmitted. The baffle was used to check samples for the 12.8 hour Cu^{64} activity which if present could distort the Fermi plot. Figure 2 shows the β- and conversion electron spectra and Figure 3 is the Fermi analysis. Table I gives the end point energies, relative intensities and ft values for the β-spectra, and the γ-ray energies.

TABLE I

Beta- and Gamma-rays of Cu^{67}

Transition Energy (Kev)	Relative Intensity (percent)	ft-values
Beta 577	20	6.26 (1-forbidden)
484	35	5.73
395	45	5.35
Gamma 92		
182		

In order to verify the lack of β-transitions to the uppermost level, a careful search was made for conversion electrons with the β-spectrometer and γ-rays with crystals[3] from the 296 kev transitions, but none were found to occur. If the Fermi analysis is correct, no γ-γ coincidences should be observed since the 92 and 182 kev transitions are not in cascade. A branching of greater than five percent to the highest level would produce observable coincidences even though the 92 kev level has a lifetime longer than the resolving time of the coincidence apparatus. The results of the measurements indicate that there are no γ-γ coincidences above the normal background.

In order to attempt to make spin assignments for the Zn^{67} levels the multipole order of the γ-rays were determined by measuring the conversion coefficients and comparing them with the theoretical values given in Rose's Tables.[4] The photoelectron converter was a 7.5 mg/cm^2 Ag foil whose conversion efficiency had been determined from the In^{113} lines. The conversion coefficient for the 92 kev transition is 0.5 ± 0.2 which makes the transition an E2 by comparing the extrapolated values from Rose's table. A possible mixture of M1 + E2 can be ruled out since according to curves in Ref. 5, the half life given by the Weisskopf formula for a M1 transition of this energy in A=67 would be roughly 5×10^{-10} whereas an E2 would be 2.5×10^{-6} second. Therefore, the spin and parity of the first excited state are 1/2 and odd. A similar type of M1 transition with 80 kev energy in Xe^{131} has a half life of 5×10^{-10} sec.[6] This agrees with the assignment of Meyerhof, Mann, and West.[7] The conversion coefficient of $12 \pm 2 \times 10^{-3}$ for the 182 kev transition lies closest to the value for an M1, so the second excited level is a p 3/2 state. The experimental error in the measurements for the weaker lines was large enough to make it impossible to decide between M1 and E1 transitions. The spin assignments shown in Figure 1 are made on the basis of these multipole order determinations and the states available in this region by the one particle model.[8] The ground state configurations beyond 28 nucleons of the nuclei involved* and the basis for the choice are as follows:

Cu^{67}	$(\pi_{3/2})^{1}_{3/2}\,(f_{5/2})^{6}\,(p_{3/2})^{4}$	(Cu^{63} and Cu^{65} have I = 3/2 with μ value closest to $\mathcal{l} + 1/2$ Schmidt line and $Q < 0$)
Zn^{67}	$(\pi_{3/2})^{2}\,(f_{5/2})^{5}_{5/2}\,(p_{3/2})^{4}$	(Zn^{67} has a measured I = 5/2 with μ value closest to $\mathcal{l} - 1/2$ Schmidt line and $Q > 0$)

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* Greek letters indicate proton states; Roman letters indicate neutrons.

Ga^{67} $(\pi_{3/2})^{3}_{3/2}\,(f_{5/2})^{6}\,(p_{3/2})^{2}$ (Ga^{69} and Ga^{71} have $I = 3/2$ with μ value closest to $\ell + 1/2$ Schmidt line and $Q > 0$)

β-transitions from Cu^{67} to the ground state of Zn^{67} are $f_{5/2} \rightarrow \pi_{3/2}$ which are ℓ-forbidden whereas transitions to the ground state from Ga^{67} would involve a two particle change which is forbidden.

As indicated in Figure 1, the spin values of the first and second excited states are 1/2 - and $p_{3/2}$ respectively. If a $p_{3/2}$ neutron is excited to a $f_{5/2}$ state to form a completed f-shell and the two $\pi_{3/2}$ protons couple to give zero spin as expected from the shell model, a $p_{3/2}$ state results from the closed shell minus one particle configuration of the neutrons. Since both protons and neutrons exist in incomplete p-shells, it is possible that they can interact so the two $\pi_{3/2}$ protons can also couple to give spin two (spin one is excluded) with a 1/2 - state resulting for the level. The first two excited states then have the configuration:

$$\left\{(\pi_{3/2})^{2}_{0,\,2}\,(p_{3/2})^{3}_{3/2}\right\}_{3/2,\ 1/2}\,(f_{5/2})^{6}$$

K-capture and β-transitions to these states would then involve 3/2 - to 3/2 - or 1/2 - changes which are allowed in agreement with the decay scheme.

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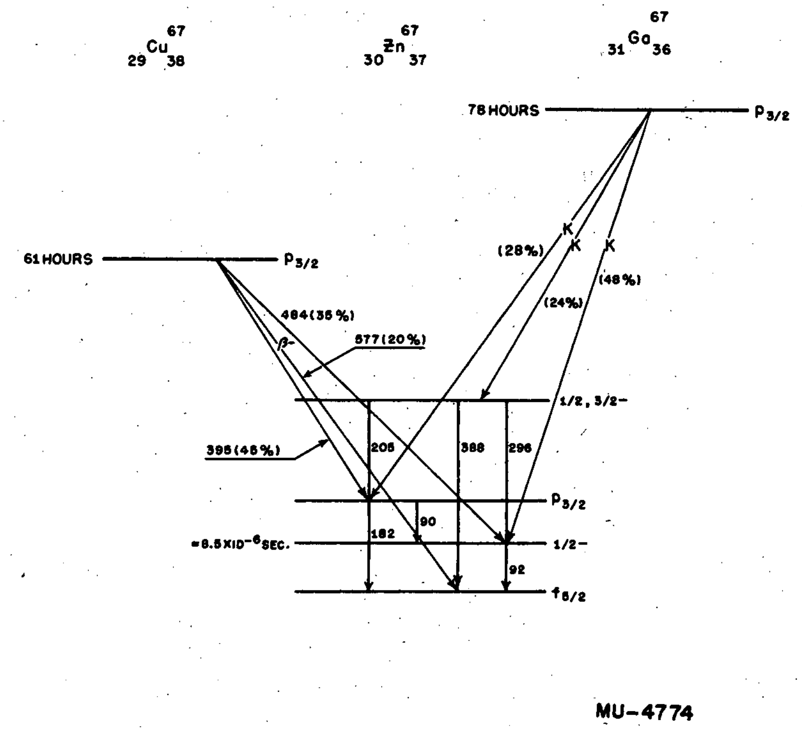

Fig. 1

Level scheme for Zn^{67}.

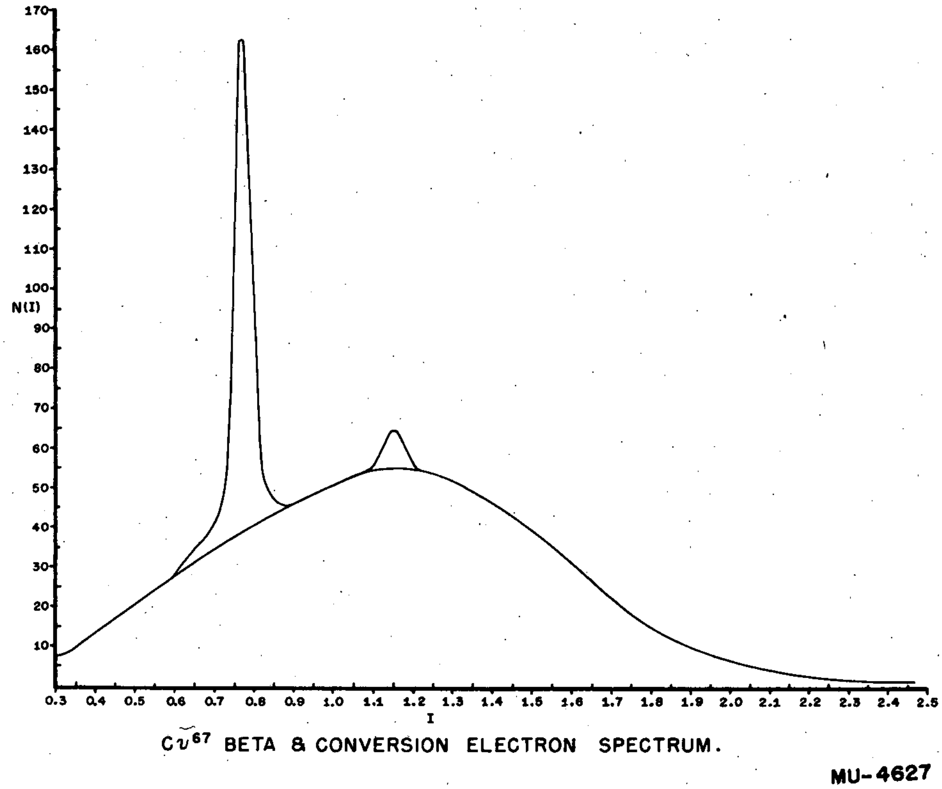

Fig. 2

β- and conversion electron spectrum of Cu^{67}.

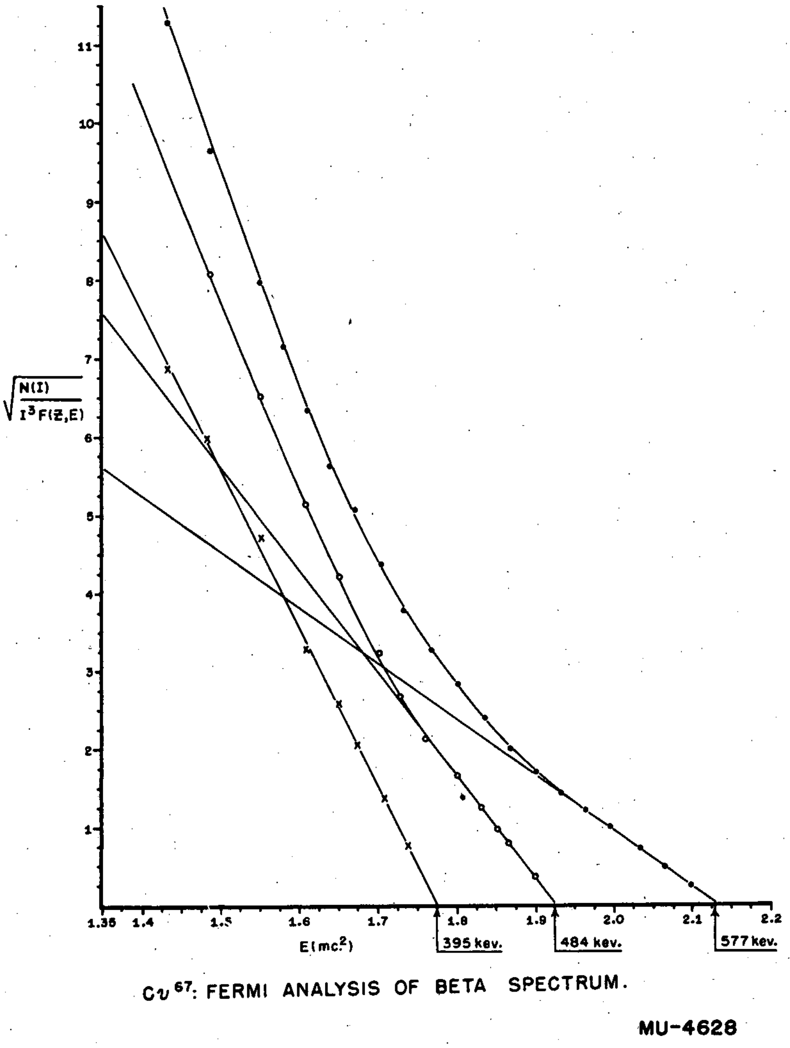

Fig. 3

Fermi analysis of the β-spectrum.