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# ENERGY LEVELS OF $As^{77}$

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**Abstract**: The gamma rays of $As^{77}$ following beta decay of $Ge^{77}$ ($\tau_{\frac{1}{2}} = 11.3$ h) were investigated using coincidence techniques. General features of the level structure were found to be in substantial agreement with the work of previous investigators. Additional complexity was found in the level structure above 2 MeV. Relative intensities of the gamma transitions are reported.

## 1. Introduction

Previous investigations [1-4]) have been made ††† of the energy levels of $As^{77}$ populated in the beta decay of 11.3 h $Ge^{77}$. The most extensive of these, by A. W. Schardt [3]), included prompt and delayed gamma-ray coincidence measurements. In addition to a careful study of transitions involving the 0.475 MeV metastable state ($\tau_{\frac{1}{2}} = 116$ $\mu$sec), a decay scheme was proposed with levels at 0.215 MeV, 0.265 MeV, 0.632 MeV, 1.189 MeV, 1.458 MeV, 1.551 MeV, 1.987 MeV and 2.37 MeV. Schardt suggested that more than one level might be involved above 2 MeV.

We have undertaken an examination of the prompt coincidence spectra in order to reaffirm the structure of low-lying levels as a prelude to gamma-gamma angular correlation measurements [5]). At the same time it was hoped that the present work would help to clarify the details of the higher beta-fed energy levels.

## 2. Experimental Procedure

The gamma ray coincidence measurements were made on samples of germanium metal having a maximum impurity of 1 part in $10^5$. Preliminary measurements were made on samples irradiated with thermal neutrons for periods of 1 to 8 hours in the Ford Nuclear Reactor. Later measurements used samples similarly activated in the reactor of the Western New York Nuclear Research Center. Measurements on each sample were not begun until the 82 min activity of $Ge^{75}$ had sufficiently decayed, and

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††† Additional refs. may be found in ref. [4]).

were concluded before the gamma rays following decay of the 39 h $As^{77}$ could make a significant contribution to the spectrum. No other impurity activities were observed.

The prompt coincidence measurements employed a fast-slow coincidence circuit with a resolving time of 35 ns. Pulses coincident with a selected energy range were fed through a linear gate and recorded on a 256-channel analyser. The detectors in the coincidence measurements were 5.1 cm by 5.1 cm NaI(Tl) crystals mounted on RCA-6342A phototubes. A shield was placed between the detectors to prevent counter-to-counter scattering. Certain of the spectral measurements employed a 7.6 cm by 7.6 cm crystal.

## 3. Results

### 3.1. GAMMA-RAY SCINTILLATION SPECTRUM

Fig. 1 shows the gamma-ray spectrum of $Ge^{77}$ as recorded on a multichannel analyser using a 7.6 cm × 7.6 cm NaI(Tl) crystal. Certain of the higher energy peaks are seen to be wider than would be expected for a single gamma ray.

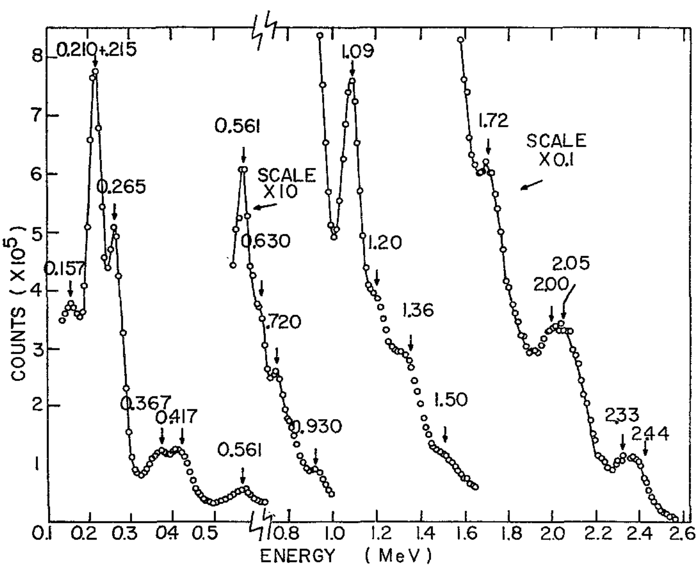


Fig. 1. Gamma-ray spectrum of $Ge^{77}$. (The lower end has been spread out in order to better illustrate the details of the scintillation spectrum. As a result, the ordinate scale does not correspond to that for the remainder of the spectrum.)

### 3.2. COINCIDENCE MEASUREMENTS

Measurements were made of the spectra of gamma rays in coincidence with the 0.210+0.215 MeV, 0.265 MeV, 0.417 MeV, 0.561 MeV, 0.632 MeV, 0.718 MeV and 1.09 MeV photopeaks. These measurements are consistent with the decay scheme shown in fig. 2. Evidence for this structure may be seen in the delayed-coincidence

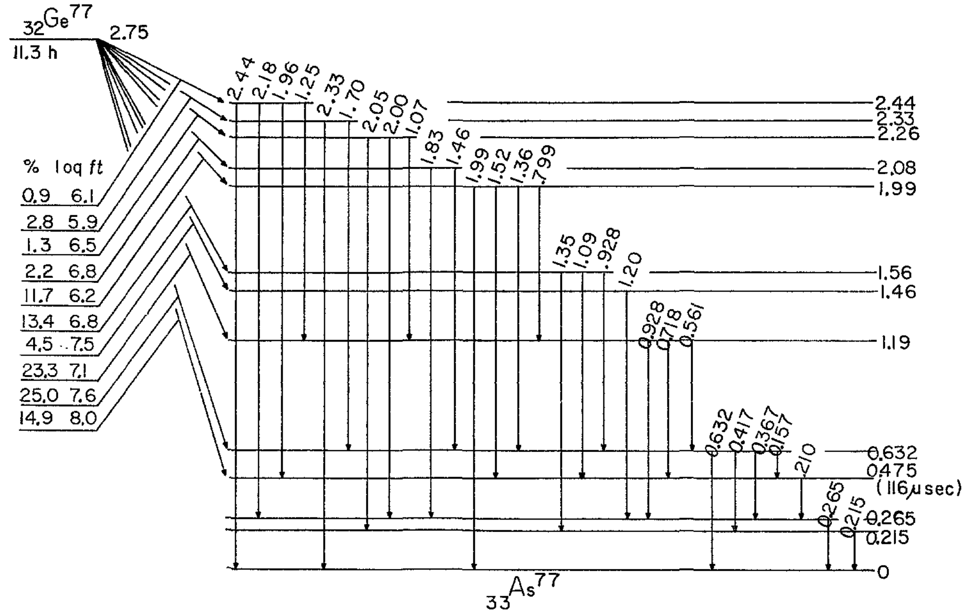


Fig. 2. Decay scheme of $Ge^{77}$. Energies are given in MeV. Beta decay information has been deduced from the gamma-ray intensity data.

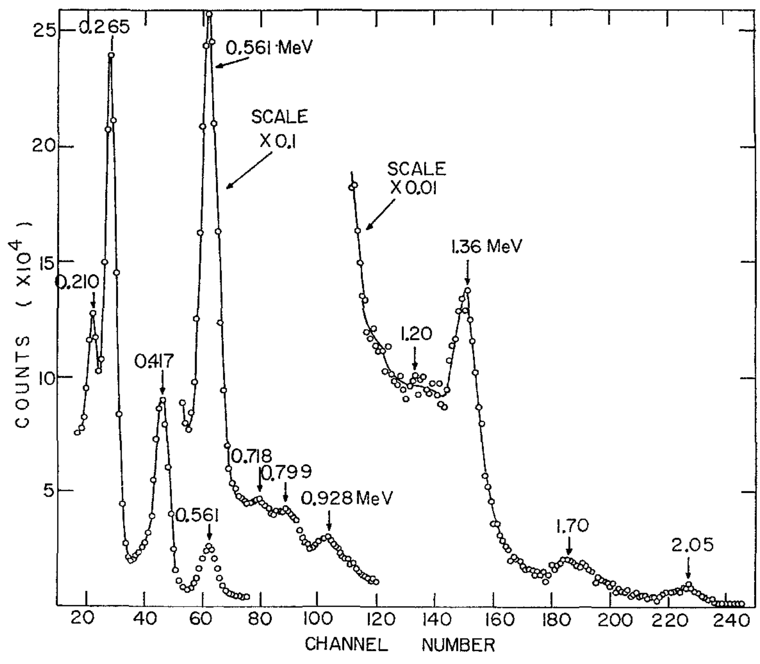


Fig. 3. Spectrum of gamma rays in coincidence with the 0.210 MeV and 0.215 MeV gamma rays.

measurements of Schardt and in the following figures which illustrate the present prompt-coincidence measurements.

Fig. 3 shows the spectrum of gamma rays coincident with the composite photopeak made up of the 0.210 MeV and 0.215 MeV transitions. Direct coincidences are noted for the 0.210 MeV gamma ray with the 0.265 MeV gamma ray and for the 0.215 MeV gamma ray with the 0.417 MeV gamma ray. The 2.05 MeV photopeak is interpreted as a transition from a level at 2.265 MeV to the first excited state. The 0.561 MeV, 0.799 MeV, 0.928 MeV and 1.70 MeV peaks are coincident with the 0.215 MeV gam-

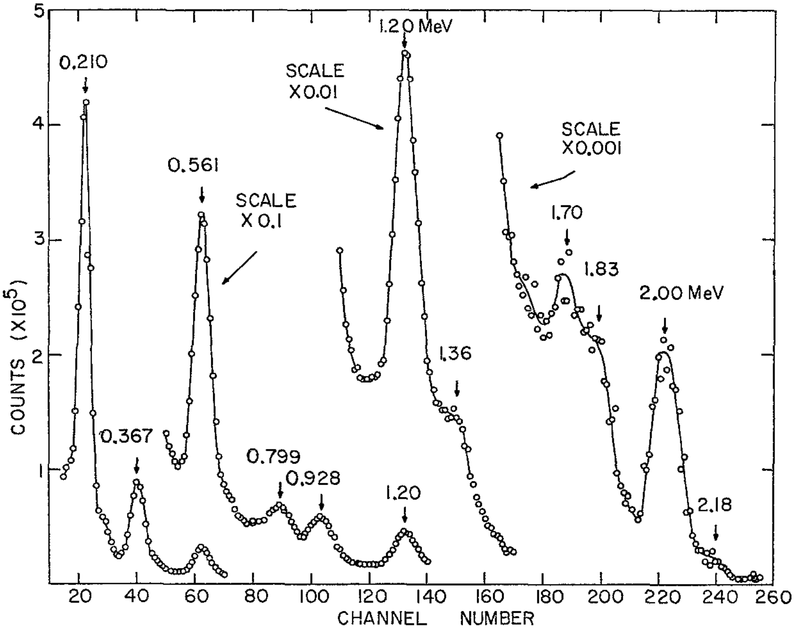


Fig. 4. Spectrum of gamma rays coincident with the 0.265 MeV photopeak.

may ray through the 0.417 MeV transition. The photopeak at 1.36 MeV is partly due to a coincidence through the 0.417 MeV line and partly a direct coincidence with a 1.35 MeV transition to the first excited state. Interference from the tail of the 0.265 MeV photopeak in the energy-selecting discriminator is seen in the presence of 0.210 MeV and 1.20 MeV lines in this spectrum. The peak at 0.718 MeV is due to the small fraction of coincidences through the metastable state at 0.475 MeV which are accepted by the prompt coincidence circuit.

Fig. 4 shows the spectrum of gamma rays coincident with the transition from the 0.265 MeV level to the ground state. Direct coincidences are noted with gamma rays of 0.210 MeV, 0.367 MeV, 1.20 MeV, 2.05 MeV and 2.18 MeV. The 0.561 MeV, 0.799 MeV, 1.36 MeV and 1.70 MeV lines are interpreted as indirect coincidences through the 0.367 MeV transition. As may be seen from the 0.632 MeV coincidence data, the 0.928 MeV photopeak found here is too strong to be entirely interpreted as an indirect coincidence. Thus, in addition to the 0.928 MeV transition to the 0.632 MeV level, there appears to be a gamma transition of the same energy between the 1.19 MeV and 0.265 MeV levels. The weak peak at ≈ 1.83 MeV may be tentatively interpreted as evidence for a new level at ≈ 2.08 MeV.

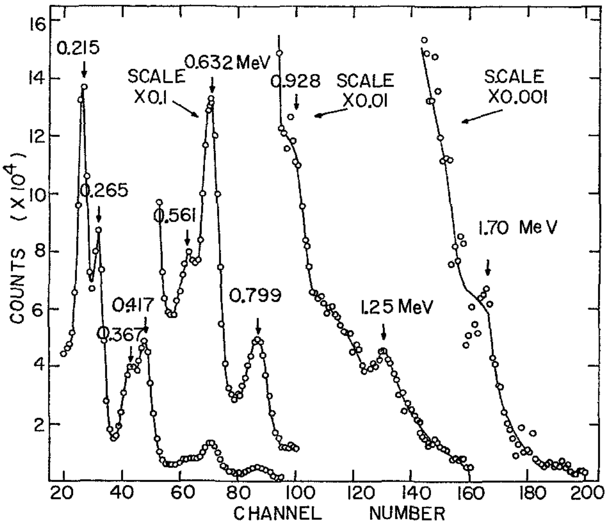


Fig. 5. Spectrum of gamma rays coincident with the 0.561 MeV photopeak.

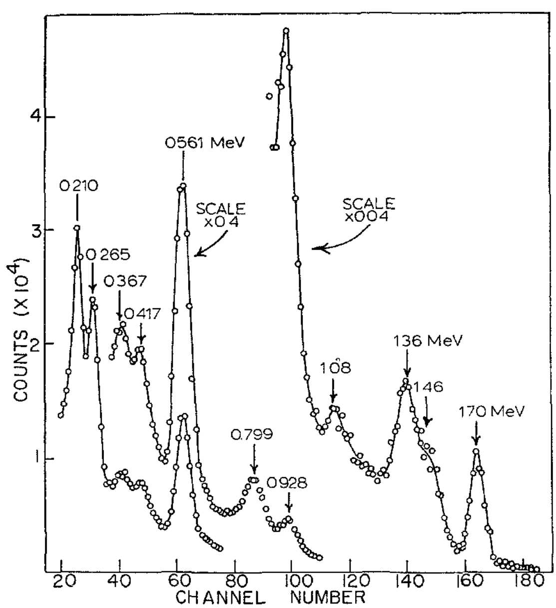


Fig. 6. Spectrum of gamma rays coincident with the 0.632 MeV gamma ray.

Fig. 5 shows the spectrum of gamma rays coincident with the 0.561 MeV photopeak. The 0.215 MeV, 0.265 MeV, 0.367 MeV, 0.417 MeV and 0.632 MeV photopeaks confirm the position of the 0.561 MeV transition between the 1.19 MeV and 0.632 MeV levels. The 0.799 MeV line and weak lines at $\approx$ 1.07 MeV and 1.25 MeV are interpreted as transitions to the 1.19 MeV level. This was confirmed by the 0.718 MeV coincidence data. Some interference from the Compton distribution of the 0.632 MeV gamma ray is apparent in the peaks at 0.561 MeV, 0.928 MeV and 1.70 MeV.

TABLE 1

Intensities of the gamma rays of $Ge^{77}$

| Energy (MeV) | Transition intensity (%) |
|---|---|
| 0.157 | 1.0 |
| 0.210 | 34 [a] |
| 0.215 | 29 |
| 0.265 | 59 |
| 0.367 | 16 |
| 0.417 | 27 |
| 0.561 | 19 |
| 0.632 | 11.5 |
| 0.718 | 9.5 |
| 0.799 | 7.5 |
| 0.928 (to 0.265 level) | 3.0 |
| 0.928 (to 0.632 level) | 4.3 |
| 1.07 | 0.5 |
| 1.09 | 7.7 |
| 1.20 | 4.5 |
| 1.25 | 0.4 |
| 1.35 | 1.4 |
| 1.36 | 2.8 |
| 1.46 | 1.9 |
| 1.52 | 1.0 |
| 1.70 | 2.4 |
| 1.83 | 0.3 |
| 1.96 | 0.2 |
| 1.99 | 0.5 |
| 2.00 | 0.6 |
| 2.05 | 0.3 |
| 2.18 | 0.05 |
| 2.33 | 0.4 |
| 2.44 | 0.3 |

[a]) corrected for internal conversion, assumed M2

Fig. 6 shows the spectrum of gamma rays coincident with the 0.632 MeV transition. Interference from the tail of the strong 0.561 MeV photopeak gives rise to a number of peaks which are not in coincidence with the 0.632 MeV transition. The direct coincidences with the 0.632 MeV gamma ray are at 0.561 MeV, 0.928 MeV, 1.36 MeV, 1.46 MeV and 1.70 MeV. The 0.928 MeV gamma ray is relatively too weak to account for all of the intensity at this energy. The 1.46 MeV gamma ray supports the claim that there is a weakly-fed level at 2.08 MeV. The transitions at 0.799 MeV and 1.08 MeV are indirect coincidences through the 0.561 MeV gamma ray. The 0.417 MeV coincidence spectra (not shown), where interference is relatively less, confirm these conclusions.

### 3.3. GAMMA-RAY RELATIVE INTENSITIES

The relative intensities of the gamma rays are given in table 1. Energies and relative intensities were measured from the scintillation spectrometer curves and corrected for efficiency. Relative intensities for transitions which feed the 0.475 MeV metastable level are due to Schardt [3]).

The log *ft* values shown on the decay scheme have been calculated using the gamma transition intensities and assuming that the ground state and 0.215 MeV and 0.265 MeV levels are not beta fed from the $Ge^{77}$ ground state. An energy difference of 2.75 MeV was assumed between the $Ge^{77}$ and $As^{77}$ ground states.

## 4. Summary

The principal features of the level structure of $As^{77}$ following $Ge^{77}$ beta decay have been confirmed by the present gamma ray measurements. Apart from minor changes in relative intensities and in the position of certain weak gamma rays, Schardt's conclusions in regard to the low-lying levels are confirmed. A weakly-fed level at 2.08 MeV has been proposed. Three levels, at 2.265 MeV, 2.33 MeV and 2.44 MeV replace the single level previously proposed in this region. No spin assignments are shown on the decay scheme. These will be discussed in detail in a later paper [5]).

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