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Gamma-Rays from the Decay of ^{75}Ge (*).

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Summary. — Gamma-ray spectra from the decay of 82.2 min ^{75}Ge have been studied with a high-resolution Ge(Li) detector by singles and coincidence methods. In addition to the already reported gamma-transitions two new gamma-rays at energies 136 and 270 keV are observed. The transitions in the decay of ^{75}Ge are placed in a level scheme of ^{75}As consisting of levels at 199, 265, 401, 469 and 618 keV, the 401 keV level being introduced for the first time in the beta-decay, to account for a newly observed gamma-transition. The log ft values for the different beta-transitions are estimated. The level structure of ^{75}As is discussed.

1. – Introduction.

The level structure of ^{75}As was investigated extensively from electron capture decay of ^{75}Se and Coulomb excitation. But relatively few investigations were carried out on beta-decay of ^{75}Ge. The decay of 82.2 min ^{75}Ge was studied by magnetic (1) and scintillation spectrometers (1,2). NG *et al.* (3) for the first time studied the decay of ^{75}Ge using a Ge(Li) detector by means of the singles method. In addition to the gamma-rays observed in the earlier studies, a new gamma-ray of energy 353 keV was observed in their study and it was

(*) To speed up publication, the authors of this paper have agreed to not receive the proofs for correction.

(1) A. W. SCHARDT and J. P. WALKER: *Phys. Rev.*, **99**, 810 (1955).

(2) H. J. VAN DEN BOLD, J. VAN DE CAGJN and P. M. ENDT: *Physica*, **24**, 23 (1958).

(3) A. NG, R. E. WOOD, J. M. PALMS, P. V. RAO and R. W. FINK: *Phys. Rev.*, **176**, 1329 (1968).

fitted between the states at 618 and 265 keV on the basis of energy difference. The relative intensities of gamma-rays determined in their study showed considerable discrepancies from those of the earlier investigations. NG *et al.* used natural germanium for producing the ^{75}Ge activity by neutron irradiation. It was therefore considered desiderable to undertake a re-investigation on the decay of ^{75}Ge using a Ge(Li) detector and Ge(Li)-NaI(Tl) coincidence arrangements, producing the isotope by irradiation of enriched ^{74}Ge instead of natural germanium.

2. – Experimental details.

2·1. – Enriched samples of ^{74}Ge (94.5%, obtained from ORNL, USA) were irradiated in the CIRCUS Research Reactor, Bombay, for periods of time varying between 20 min to 1 h in a flux of 10^{13} n/cm^2 s. The material was activated in quartz capsules and removed from the quartz before the measurements began. No chemical separation was performed. The other Ge isotopes present in the sample were ^{70}Ge (1.71%), ^{72}Ge (2.21%), ^{73}Ge (0.90%) and ^{76}Ge (0.70%). Except ^{77}Ge activity, the interference from other isotopes —^{71}Ge, ^{75}Ge^m and ^{77}Ge^m—could be neglected, because measurements began after a cooling time of 1 h. It is estimated that the ^{77}Ge activity is less than 3000 times that of ^{75}Ge in the present sample. The corresponding gamma-rays associated with the ^{77}Ge decay, however, could be identified based on the half-life (11.2 h) and allowed for.

2·2. – Several types of measurements were performed.

a) The gamma-ray singles measurements were made with a planar-type Ge(Li) detector of 5 cm^3 volume. A charge sensitive FET pre-amplifier TC 130 (Tennelec) was used with the detector. The pre-amplifier signals were further amplified with a TC 200 amplifier and its output was fed into an ND 512 channel pulse height analyser. The resolution (FWHM) of the system was 4 keV at the 662 keV gamma-ray of the ^{137}Cs source.

b) High-resolution coincidence measurements were also made with a Ge(Li)-NaI(Tl) (3×3) in^2 coincidence system. A block diagram of the electronic set-up used in this work is shown in Fig. 1. The detectors were fixed in 125° geometry. The coincidence resolving time (2τ) of the system was about 50 ns.

The gamma-ray singles spectra were recorded at regular time intervals to identify the gamma-rays following the desired half-life. The spectra were monitored for 3 half-lives.

The energy and photopeak efficiency calibrations of the detector were

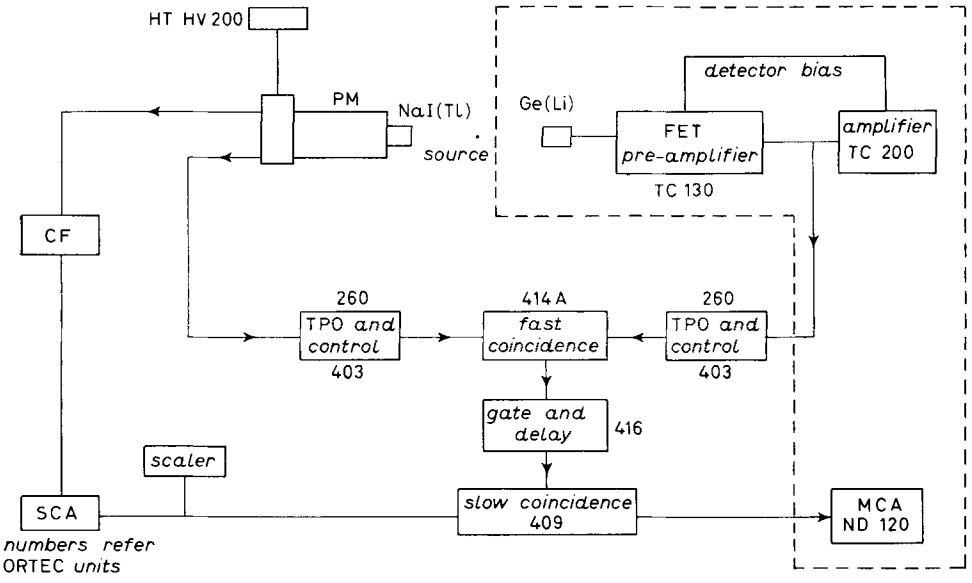

Fig. 1. – Block diagram of Ge(Li)-NaI(Tl) coincidence spectrometer. Ge(Li) singles spectrometer shown in dashed lines.

obtained employing standard gamma-rays from ^{152}Eu ([4,5]) and ^{160}Tb. The relative intensities of the different gamma-rays were obtained by fitting the full energy peaks into Gaussians by a program on an IBM 1130 computer, and extracting the peak areas together with the errors and employing the relative photopeak efficiencies deduced for the system as mentioned above. The errors in the estimation of the relative intensities usually varied between 5 and 10%.

3. – Results.

3·1. *Singles measurements.* – Figures 2 and 3 show the singles gamma-ray spectra of ^{75}Ge at (0÷575) keV and (575÷1200) keV respectively. These spectra are typical representatives of a number of runs which were made with different sources. For a number of sources spectra were recorded as a function of time in order to identify the gamma-rays due to impurities. These are indicated as *C* in Fig. 2 and 3. The peaks at energies around 212, 367, 538 and 633 keV belong to ^{77}Ge decay. Contribution of ^{77}Ge is also expected under the 265 and 419 keV peaks. However, their intensities could be neglected in relation to those of the transitions occurring in ^{75}Ge activity. The present

(4) L. L. RIEDINGER, N. R. JOHNSON and J. H. HAMILTON: *Phys. Rev. C*, **2**, 2358 (1970).
(5) G. T. EWAN and A. J. TAVENDALE: *Can. Journ. Phys.*, **42**, 2286 (1964).

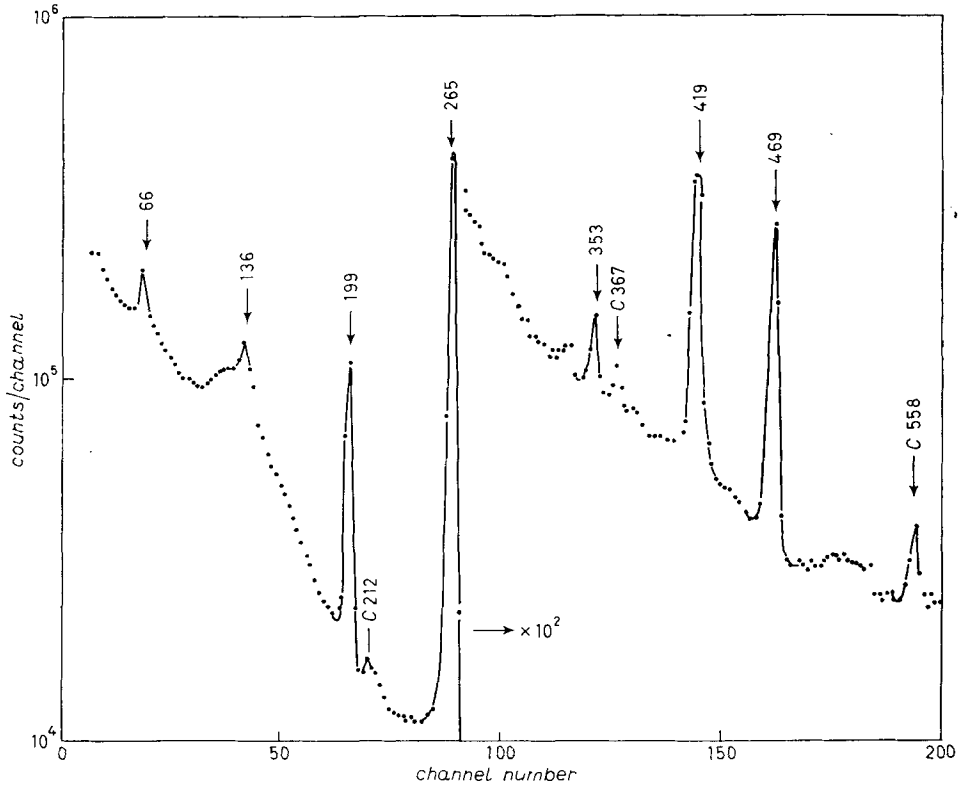

Fig. 2. – Gamma-singles spectrum of ^{75}Ge, (0÷575) keV region.

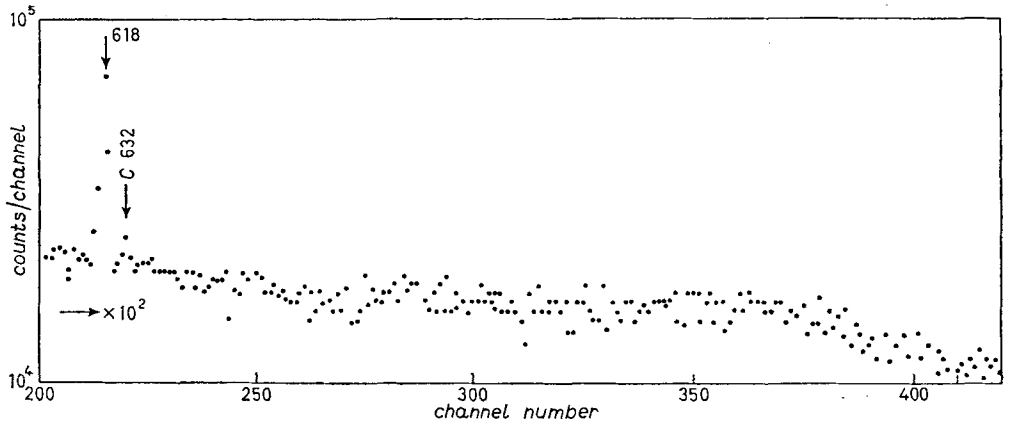

Fig. 3. – Gamma-singles spectrum of ^{75}Ge, (575÷1200) keV region.

results show evidence for 8 gamma-rays, while the study of NG *et al.* [3] indicated 7 gamma-rays. They did not observe a gamma-ray at 136 keV. This peak is superposed on a Compton continuum and it was definitely established by careful recording of spectra a number of times in that energy region. The energies and relative intensities of gamma-rays of the ^{75}Ge decay obtained in this work are listed in Table I together with the results of NG *et al.*

TABLE I. – *Energies and relative intensities of gamma-rays in the decay of* ^{75}Ge.

Energy (keV)	Relative intensity	
	Present work	NG *et al.*
66	1.01 ± 0.11	0.89 ± 0.12
136	0.08 ± 0.015	—
199	8.08 ± 0.42	7.48 ± 0.3
265	100	100
270	0.04 ± 0.011 (*)	—
353	0.21 ± 0.018	0.196 ± 0.02
419	2.35 ± 0.13	2.47 ± 0.12
469	1.74 ± 0.09	1.81 ± 0.09
618	0.61 ± 0.041	0.503 ± 0.04

(*) Deduced from coincidence spectrum.

There is a good agreement between the results of the present work and those of NG *et al.* [3]. It is possible that in the work of NG *et al.* the 136 keV gamma-ray was missed because of its low intensity. In addition they employed a source prepared from natural germanium resulting in a large amount of ^{77}Ge activity.

3·2. *Gamma-gamma coincidence measurements.* – In view of the fact no coincidence studies were made in earlier works employing a Ge(Li) detector, these studies were carried out with gates corresponding to intense gamma-lines at energies 199, 265, 419 and 469 keV. Coincidence gamma-rays are observed in the Ge(Li) detector, with the NaI(Tl) detector selecting the

TABLE II. – *Coincidence relationships observed in the* ^{75}Ge *decay.*

Gamma-ray energy selected as the gate in the NaI(Tl) detector (keV)	Coincidence gamma-rays observed in the Ge(Li) detector (keV)
119	66, 270, 419
265	136, 353
419	199
469	—

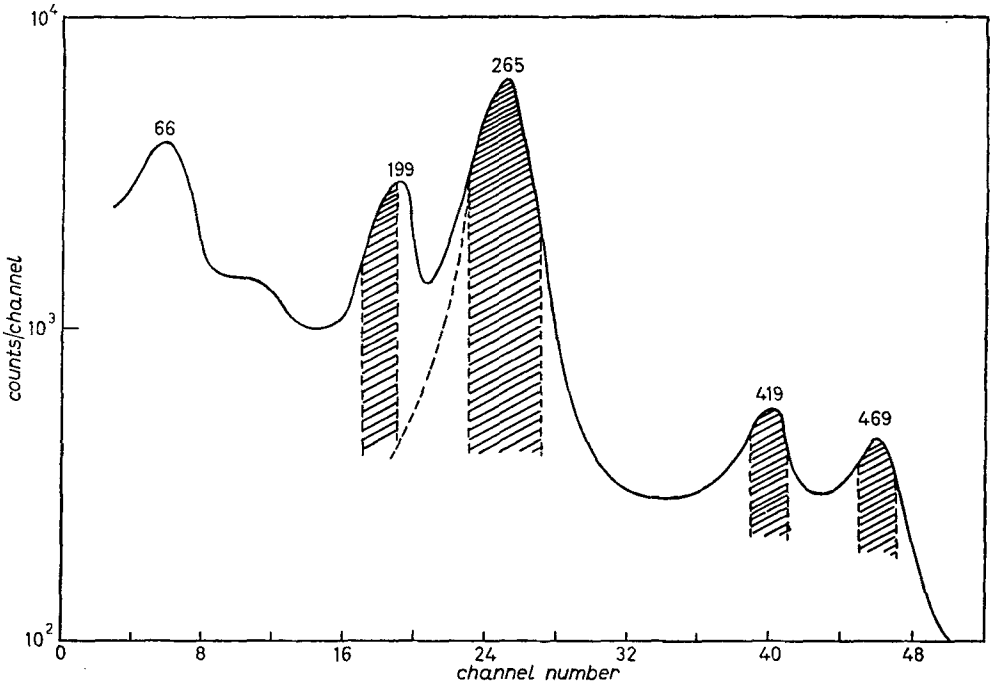

Fig. 3*a*. – ^{75}Ge singles spectrum in NaI(Tl) detector. ▨ gates selected.

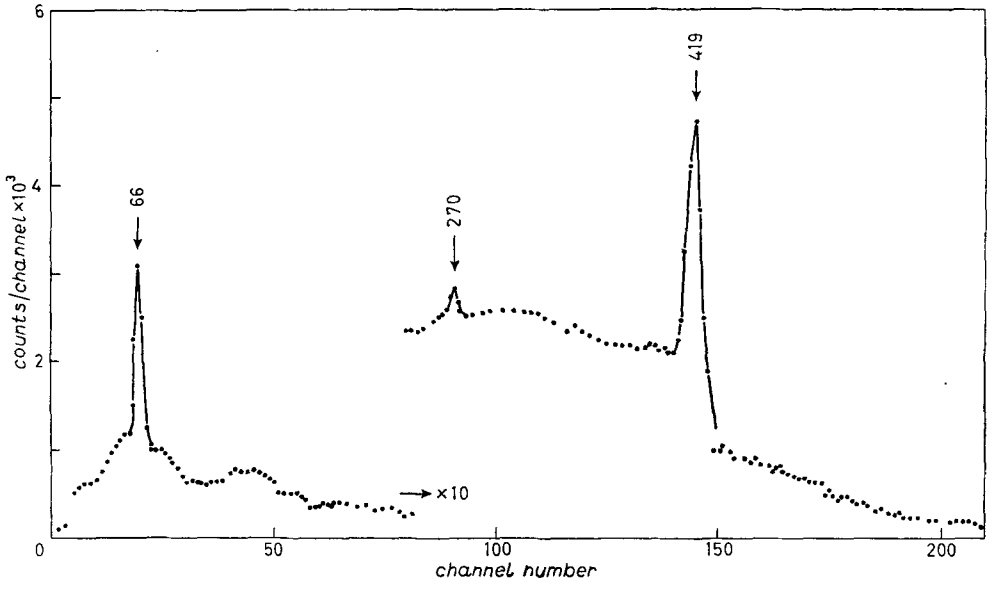

Fig. 4. – ^{75}Ga gamma-ray spectrum in coincidence with the 199 keV gamma-ray.

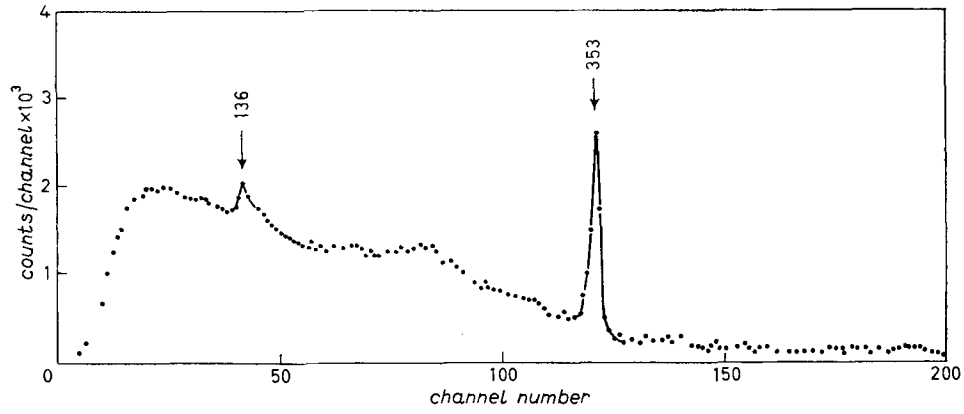

Fig. 5. – ^{75}Ge gamma-ray spectrum in coincidence with the 265 keV gamma-ray.

energies mentioned above. The singles spectrum of ^{75}Ge in the NaI(Tl) detector is shown in Fig. 3*a*, indicating the limits of the bands of interest taken as gates for the coincidence spectra. The results of the Ge(Li)-NaI(Tl) coincidence measurements are listed in Table II.

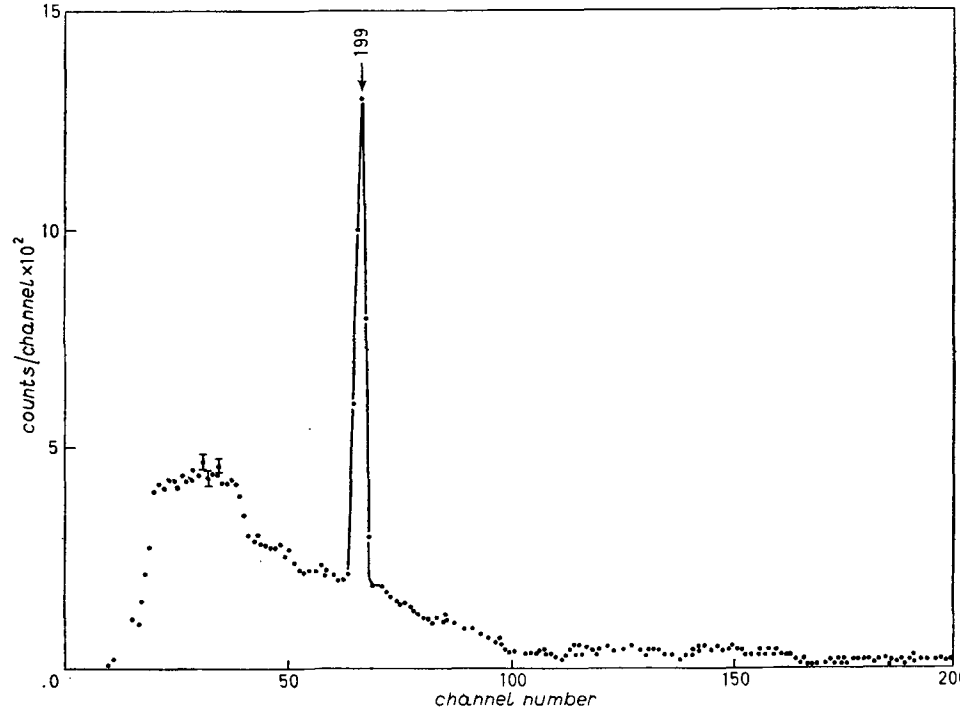

Fig. 6. – ^{75}Ge gamma-ray spectrum in coincidence with the 419 keV gamma-ray.

The gamma-ray at 270 keV, observed in the coincidence studies, is not observed in the singles spectrum. This may be due to the intense 265 keV line. Figures 4 to 6 show typical coincidence spectra corresponding to gate settings at 199, 265 and 419 keV, respectively. In all cases the spectra represent contributions after subtracting the chance coincidence, determined in the usual way by introducing a long delay in one of the channels. The poor resolution of the NaI(Tl) detector and the wide gates used, caused many Compton coincidences to show up in the spectra. Careful relative intensity observations were made to determine the real coincidence gamma-rays.

3·3. *Decay scheme.* – A proposed decay scheme, based on the results given in Tables I and II, is shown in Fig. 7, to account for all the 9 observed gamma-rays. The new gamma-rays and the new level introduced are shown as dashed lines. The levels at 199, 265, 469 and 618 were previously established by

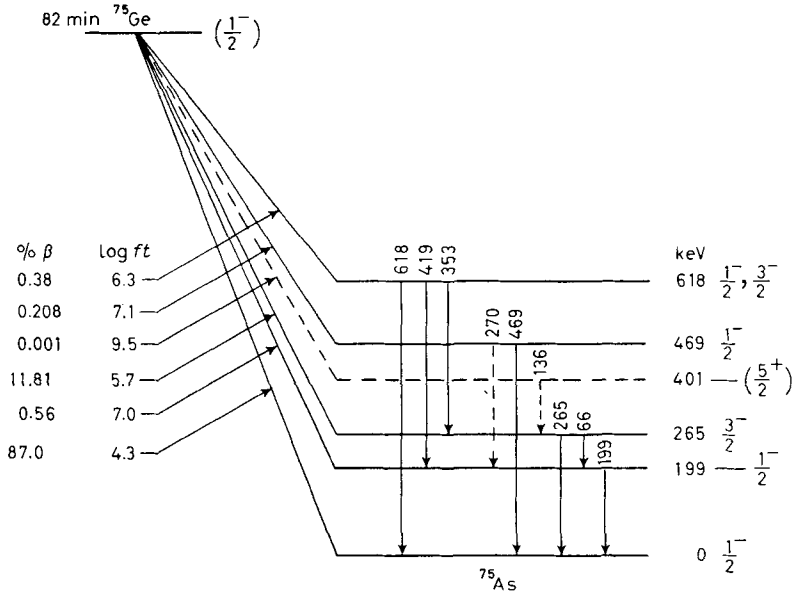

Fig. 7. – Decay scheme of ^{75}Ge proposed in the present work.

gamma-ray singles ([3]) and gamma-gamma coincidence data ([1,2]) and are confirmed by the same data here. The 353 keV gamma-ray which was first detected by NG *et al.* ([3]) and placed between the 618 keV and 265 keV levels, based on the energy difference only, is confirmed in the present work, based on the coincidence spectrum with gate at 265 keV (*vide* Fig. 5). A peak at 136 keV is also observed in coincidence with the 265 keV gamma-ray. The observed

coincidence may mean the need for a level at 401 keV. A level at 401 keV in ^{75}As is well known from the decay of ^{75}Se as well from the Coulomb-excitation work. The 401 keV level may be fed from the beta-decay or from gamma-decay of higher-lying energy states. There are two levels at energies 618 and 469 keV which are known to be fed by beta-decay of ^{75}Ge. A gamma-decay of these levels to the 401 keV state should show gamma-rays of energies 217 and 68 keV. A 66 keV gamma-ray is observed in this study, as well as in the earlier works, and is fitted between the 265 and 199 keV states. A 217 keV gamma-ray is, however, not noticed in any work. Thus it may be possible that the 66 keV gamma-ray observed may be a doublet representing gammas occurring at two places in the decay scheme, and could not be resolved with this detector. If this gamma-ray is ruled out, then the feeding of the 401 keV state has to be through beta-decay. The new gamma-ray of energy 270 keV which is observed in coincidence with 199 keV is fitted between the well-established levels at 199 and 469 keV.

If we use the present relative intensities of the gamma-rays and assume the ground beta-transition characteristics, the percentage beta-feedings to different levels in ^{75}As and log *ft* values are estimated and shown in the decay scheme. These values agree approximately with those of NG *et al.* [3].

4. – Discussion.

The ground-state spin of ^{75}As was established to be $\frac{3}{2}^-$ from direct measurement [6] using microwave spectroscopy. The ground-state spin of ^{75}Ge was inferred from the beta-decay characteristics to the ground state of ^{75}As to be $\frac{1}{2}^-$, the nature of ground to ground transition being of the allowed type.

The spin of the 199 keV state was established to be $\frac{1}{2}^-$ from Coulomb-excitation studies [7], lifetime measurements [8] and conversion data [6] of the 199 keV transition. The character of the 265 keV state was established as $\frac{3}{2}^-$ based on Coulomb-excitation studies [7,9,10], resonance fluorescence studies [11,12] and lifetime measurements [13]. A $\frac{5}{2}^+$ spin was assigned to the 401 keV state, based

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[6] S. C. PANCHOLI and H. IKEGAMI: *Nuclear Data*, B1-6-81 (1966).
[7] R. L. ROBINSON, F. K. MCGOWAN, P. H. STELSON and W. T. MILNER: *Nucl. Phys.*, **104** A, 401 (1967).
[8] H. SINGH, B. SETHI and S. K. MUKHERJEE: *Phys. Rev. C*, **2**, 2278 (1970).
[9] G. M. TEMMER and M. P. HEYDENBERG: *Phys. Rev.*, **104**, 967 (1956).
[10] A. C. RITTER, P. H. STELSON, F. K. MCGOWAN and R. L. ROBINSON: *Phys. Rev.*, **128**, 2320 (1962).
[11] F. R. METZER: *Phys. Rev.*, **127**, 220 (1962).
[12] R. MOREH and O. SHEHAL: *Phys. Rev.*, **188**, 1765 (1969).
[13] H. LANGHOFF and M. SCHUMACHEW: *Phys. Rev.*, **155**, 1246 (1967).

on the electron capture decay studies ([14]) on ^{75}Se. The character of the 469 keV state was established as $\frac{1}{2}^-$ from Coulomb-excitation data. Possibilities of $\frac{1}{2}^-$, $\frac{3}{2}^-$ spins were suggested for the 618 keV state based on Coulomb-excitation data and electron capture decay data.

The log *ft* values of the beta-branches deduced from the gamma-ray intensities in the present work are consistent with spin assignments inferred from other data, as mentioned above. Since the parities of all the states (except for the 401 keV state) are odd, the nature of all beta-transitions from ^{75}Ge to ^{75}As should be of the allowed type. However the log *ft* values of different beta-branches vary between 4.3 and 7.1. The two beta-branches $(\frac{1}{2}^- \to \frac{1}{2}^-)$ to 469 and 199 keV states are characterized by high log *ft* values, while the two beta-branches $(\frac{1}{2}^- \to \frac{3}{2}^-)$ to 265 keV and ground states are characterized by low log *ft* values. On the other hand, the beta-branch to the 618 keV state $(\frac{1}{2}^- \to \frac{3}{2}^-)$ has a log *ft* value intermediate between these two sets. The beta-transition to the 401 keV level is suggested only in the present work and has a log *ft* value of 9.5. Since the 401 keV state is of spin $\frac{5}{2}^+$, the beta-decay to this state must be of the first forbidden unique type. A log *ft* value of 9.5 for such a transition is rather low. On the whole, considerable variation of the log *ft* values of the allowed type to the different states is suggestive of different structures for the different states.

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([14]) T. PARADELLIS and S. HONTZEAS: *Can. Journ. Phys.*, **49**, 1750 (1971).

● RIASSUNTO (*)

Si sono studiati con metodi di singoli e di coincidenze gli spettri di raggi gamma derivanti dal decadimento del ^{75}Ge di 82.2 min, rilevati con un rivelatore Ge(Li) ad alto potere risolutivo. Si osservano due nuovi raggi γ alle energie di 136 e 270 keV in aggiunta alle transizioni gamma documentate precedentemente. Si collocano le transizioni del decadimento del ^{75}Ge in uno schema a livelli dell'^{75}As composto dai livelli a 199, 265, 401, 469 e 618 keV, introducendo per la prima volta il livello di 401 keV nel decadimento beta, per tener conto delle nuove transizioni gamma. Si valutano i valori del log *ft* per le diverse transizioni beta. Si discute lo schema dei livelli dell'^{75}As.

(*) *Traduzione a cura della Redazione.*

Гамма излучения при распаде ^{75}Ge.

Резюме (*). — Были исследованы спектры гамма-лучей при распаде ^{75}Ge (82.2 мин) с помощью Ge(Li) детектора с высоким разрешением, причем, использовались метод совпадений и метод регистрации одиночных событий. Кроме уже известных гамма-переходов, наблюдались два новых гамма-перехода с энергиями 136 и 270 кэВ. Переходы при распаде ^{75}Ge укладываются в схему уровней ^{75}As, которая состоит из уровней: 199, 265, 401, 469 и 618 кэВ, причем, впервые вводится уровень 401 кэВ в бета-распад, чтобы объяснить недавно наблюденный гамма-переход. Оцениваются величины $\log ft$ для различных бета-переходов. Обсуждается структура уровней ^{75}As.

(*) *Переведено редакцией.*

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