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Energy Levels in Ge^{74} from the Reaction $Ge^{73}(n, \gamma)\,Ge^{74}$

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The level structure of Ge^{74} has been investigated at the Karlsruhe research reactor using thermal neutron capture in Ge^{73}. Neutrons were monochromized by Bragg reflection from a lead single crystal. The target was Ge^{73} enriched to 86.1 %. Precision measurements of the capture gamma-ray spectrum have been performed over the whole energy range by means of a $4\,\mathrm{cm}^2 \times 0.5\,\mathrm{cm}$ lithium-drifted germanium detector. 148 gamma transitions have been observed. Considerable aid in analysis of the level structure is provided by double and triple coincidence measurements with $4'' \varnothing \times 5''$ NaI(Tl) detectors. Data were processed using the Karlsruhe Multiple Input Data Acquisition System (MIDAS). A level scheme of Ge^{74} is proposed involving 38 excited states in the energy range from 0 to 4400 keV. The neutron binding energy of Ge^{74} is determined to be 10202 ± 10 keV.

1. Introduction

The rapid progress in nuclear theories asks for improvement of the present knowledge of experimental nuclear data. In view of the possible existence and systematics of multiple phonon states in even spherical nuclei it seemed interesting to investigate the level structure of the Ge^{74} nucleus.

Excited levels of Ge^{74} can be populated by β^- decay of 8 min-Ga^{74}, and most of the Ge^{74} data now available have been collected from this process[1,2]. Other authors* made use of the β^+/EC decay[3] of 18 day-As^{74}, Coulomb excitation[4-9] and inelastic scattering of protons[10,11] and

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* The list of previous publications is not exhaustive; further references can be found in the literature cited.

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[2] EICHLER, E., G.D. O'KELLEY, R.L. ROBINSON, J.A. MARINSKY, and N.R. JOHNSON: Nuclear Phys. 35, 557 (1962).

[3] YAMAZAKI, T., H. IKEGAMI, and M. SAKAI: J. Phys. Soc. Japan 15, 957 (1960).

[4] MCGOWAN, F.K., and P.H. STELSON: Phys. Rev. 126, 257 (1962).

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[7] GANGRSKII, YU.P., i I.KH. LEMBERG: Izvest. Akad. Nauk S.S.S.R., Ser. Fiz. 26, 1001 (1962); — Bull. Acad. Sci. U.S.S.R. 26, 1009 (1962).

[8] GANGRSKII, YU.P., i I.KH. LEMBERG: Zhur. Eksptl. i Teoret. Fiz. 42, 1027 (1962); — Soviet Phys. JETP 15, 711 (1962).

[9] ROBINSON, R.L., P.H. STELSON, F.K. MCGOWAN, J.L.C. FORD jr., and W.T. MILNER: ORNL-3778, 116 (1964).

[10] DICKENS, J.K., F.G. PEREY, and R.J. SILVA: ORNL-3499, vol. 1, 20 (1963).

[11] DARCEY, W.: Compt. rend. congr. intern. phys. nucléaire, Paris 2, 456 (1964).

neutrons[12] as well as of (*t*, *p*) and (*d*, *p*) stripping reactions[11,13]. Except a preliminary report on the present work[14] no papers, however, have been published up to now concerning the investigation of the Ge^{74} level structure by neutron capture in Ge^{73}.

As the ground state spin and parity of Ge^{73} are $\frac{9}{2}^+$, thermal neutrons may be captured into a 4^+ or 5^+ state. The binding energy of the last neutron in Ge^{74} is of the order of 10.2 MeV; the method therefore seems to be particularly useful for the detection of high spin high energy levels part of which, at least, may be assumed to be collective in nature.

2. Experimental Procedure

2.1. Target

The major difficulty of the method when using natural germanium consists in the relatively low isotopic abundance of Ge^{73} leading to a cross section contribution of no more than 50% (see, e.g., Ref. [15]), and tremendous difficulties are encountered in assigning the γ-rays found. An enriched sample (86.1% Ge^{73}), therefore, is used as a target. The chemical form is GeO_2. The capture cross section contributions are as follows:

Ge^{73}	>98.3%
Ge^{70}	0.8%
Ge^{72}	0.3%
Ge^{74}	0.3%
Ge^{76}	0.03%
other elements	<0.3%

2.2. Geometric Arrangement

A schematic drawing of the experimental setup is shown in Fig. 1. A neutron beam from the Karlsruhe research reactor FR-2 is diffracted from a lead single crystal in order to remove gammas and fast and epithermal neutrons. The diffracted neutrons have a wavelength of 1.2 Å corresponding to an energy of 0.057 eV. The neutron flux at the target position is between 0.8 and 1.0×10^6 cm^{-2} s^{-1}. Scattered neutrons are kept off the detectors by a double-wall polyethylene tube filled with 7.5 mm of packed Li^6H.

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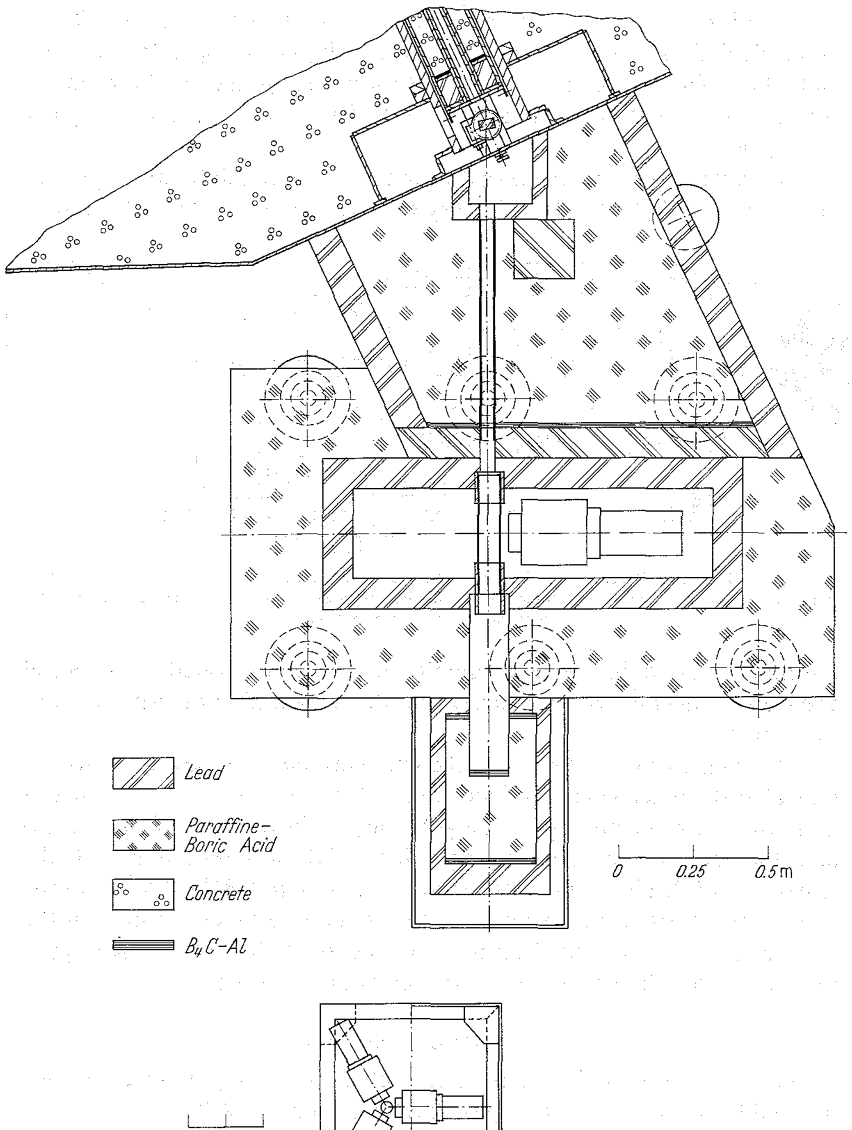
[15] GROSHEV, L. V., A. M. DEMIDOV, V. N. LUTSENKO, and V. I. PELEKHOV: Atlas of γ-ray spectra from radiative capture of thermal neutrons. Oxford 1959.



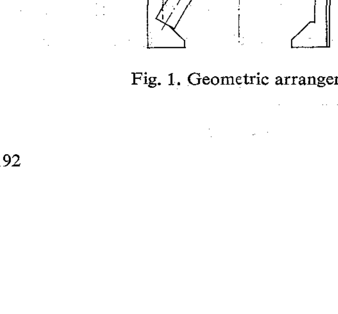


Fig. 1. Geometric arrangement

2.3. Apparatus

A lithium-drifted germanium detector with a sensitive area of 4.0 cm^2 and a depletion depth of 5 mm operated at liquid nitrogen temperature and 600 V bias voltage is used for precision measurements of the singles spectra. A typical resolution is 6.7 keV FWHM for the Cs^{137} γ-ray photopeak.

Coincidence spectra are taken using two or three scintillation spectrometers with 4″ ∅ × 5″ NaI(Tl) crystals mounted on XP-1040 photo-

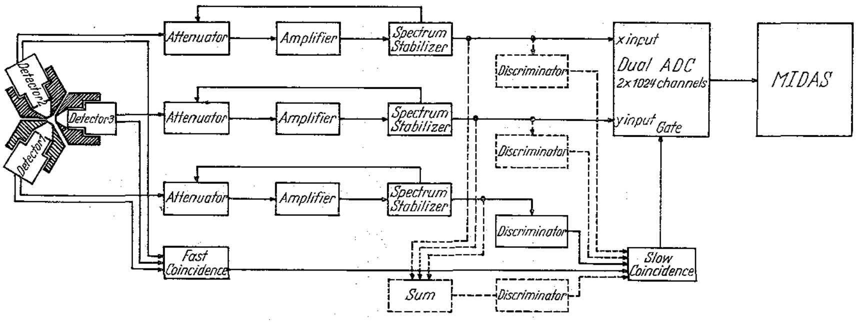


Fig. 2. Block diagram of the electronic circuitry. Solid lines show ordinary triple coincidence arrangement. Broken lines indicate configurations for sum coincidence measurements and window setting in the *X* and *Y* channel for deadtime reduction

multipliers. Shifts in the pulse amplitude are compensated by a special stabilizing system[16] comprehending both the scintillation detector and the amplifier.

The coincidence system is of the conventional fast-slow type, with a typical fast coincidence resolving time of 15 ns. Recording of data is done by a 1024 channel pulse-height analyzer in the case of the Ge(Li) detector and by a 2 × 1024 channel dual ADC in connection with the Karlsruhe Multiple Input Data Acquisition System (MIDAS)[17, 18] in the case of the NaI(Tl) measurements. Fig. 2 shows a block diagram of the coincidence arrangement. Further refinements of the coincidence apparatus involving the use of Ge(Li) detectors are in progress.

2.4. Data Processing

Most of the Ge(Li) spectra (cf. Sect. 3) are not presented in their original form. In the energy region between 1000 and 2300 keV the background spectrum shows the very prominent peaks from the H(n, γ)D reaction, so background had to be subtracted (in other regions background shows a fairly smooth behaviour; those spectra are, in fact,

[16] TAMM, U.: Submitted to Nucl. Instr. and Meth.
[17] KRÜGER, G., and G. DIMMLER: KFK-242 (1964).
[18] KRÜGER, G.: Atomwirtschaft **10**, 118 (1965).

shown without background correction, and marked peaks from the background are labelled "background").

In order to minimize the influence of shifts in the analyzer system (not included in the stabilizing loop) most of the spectra are taken initially at an energy scale of 0.9 to 1.4 keV per channel, and contents of two or more adjacent channels are added afterwards. This reduction of channel numbers proves especially advisable in the higher energy regions where peak width and/or statistics are such that a loss of information does not occur.

Where statistics remains poor, a smoothing procedure is finally used that replaces the contents of each channel by the average over that channel and the two neighbouring ones.

For calibration of the Ge(Li) spectra use is made of the annihilation peak and of the gamma lines from the reactions $H(n, \gamma)D$ and $C^{12}(n, \gamma)C^{13}$.

NaI(Tl) coincidence spectra are taken with a special MIDAS subroutine the principle of which can shortly be reviewed as follows. Regardless of the special electronic configuration (see Fig. 2) the ADC is set busy whenever the slow coincidence unit gives an output pulse. The two (usually 8 bit) digital pulse-height informations (denoted as X and Y) are then recorded together on magnetic tape and stored independently each in one part of a random access memory playing the part of two one-dimensional pulse height analyzers. The resulting spectra are called X and Y projection spectrum, respectively, and can be visualized, reset, punched out, read back etc. during the measurement. This proves especially useful for calibration purposes, shift detection and decisions whether to stop or to continue the particular experiment. The sorting of events stored on magnetic tape is then done not in "full resolution", e.g. in a 256×256 channel matrix (which would require too many random access memory locations or too many runs of the magnetic tape and which would have to be followed by a subsequent summing up of different spectra), but one of the axes is subdivided into a number of "groups" covering one region of interest each, the channel limits being suitably chosen from the corresponding projection spectrum. They will later on be called "MIDAS window", the term "electronic window" referring to the energy setting of the discriminator of detector 3.

In order to compare the resultant spectra with each other they are then normalized and, if necessary, smoothed before being plotted. As not all of the peaks are prominent it turned out very useful to integrate over the same regions of all (normalized) coincidence spectra of one run and to compare the results of this integration for adjacent spectra in X and Y direction to decide whether or not two γ-rays are coincident. This is done by a special IBM-7074 program.

3. Results and Discussion

3.1. Singles Spectra

Some of the Ge(Li) singles spectra are shown in Figs. 3 and 4, and Table 1 gives the corresponding γ-ray energies. The uncertainties quoted include both statistical and systematical errors (mainly due to erroneous calibration). For the medium-energy part of the spectra where full-energy peak and double-escape peak are of comparable intensity particular

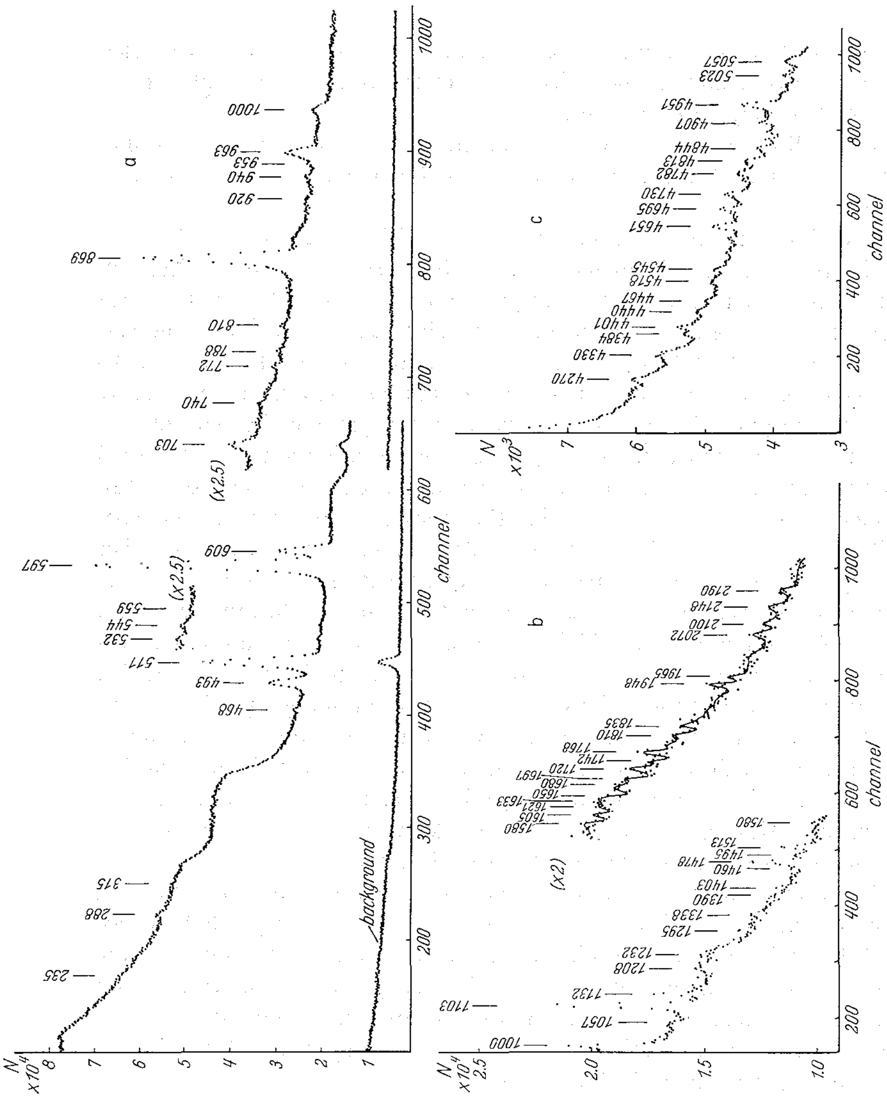


Fig. 3. Singles gamma-ray spectra from the reaction $Ge^{73}(n, \gamma)Ge^{74}$ taken with a Ge(Li) detector. *a* Energy range from 200 to 1100 keV, background shown below. *b* Energy range from 1000 to 2300 keV, background subtracted, contents of two adjacent channels added. *c* Energy range from 3200 to 4100 keV, without background correction, contents of three adjacent channels added, spectrum smoothed. All peaks are assumed to be double escape peaks and are labelled with the gamma-ray energy

care is taken as to the interpretation. Some weak lines, however, cannot be assigned unambiguously. Compared to the preliminary results[14] both statistics and resolution have been considerably improved. Therefore, several lines given in that report now appear as doublets or triplets. It is important to realize that this may also occur for the present results. If a peak which is now assumed to correspond to a single gamma ray turns out to be a closely spaced doublet or triplet, the energy listed in Table 1 refers only to the centroid.

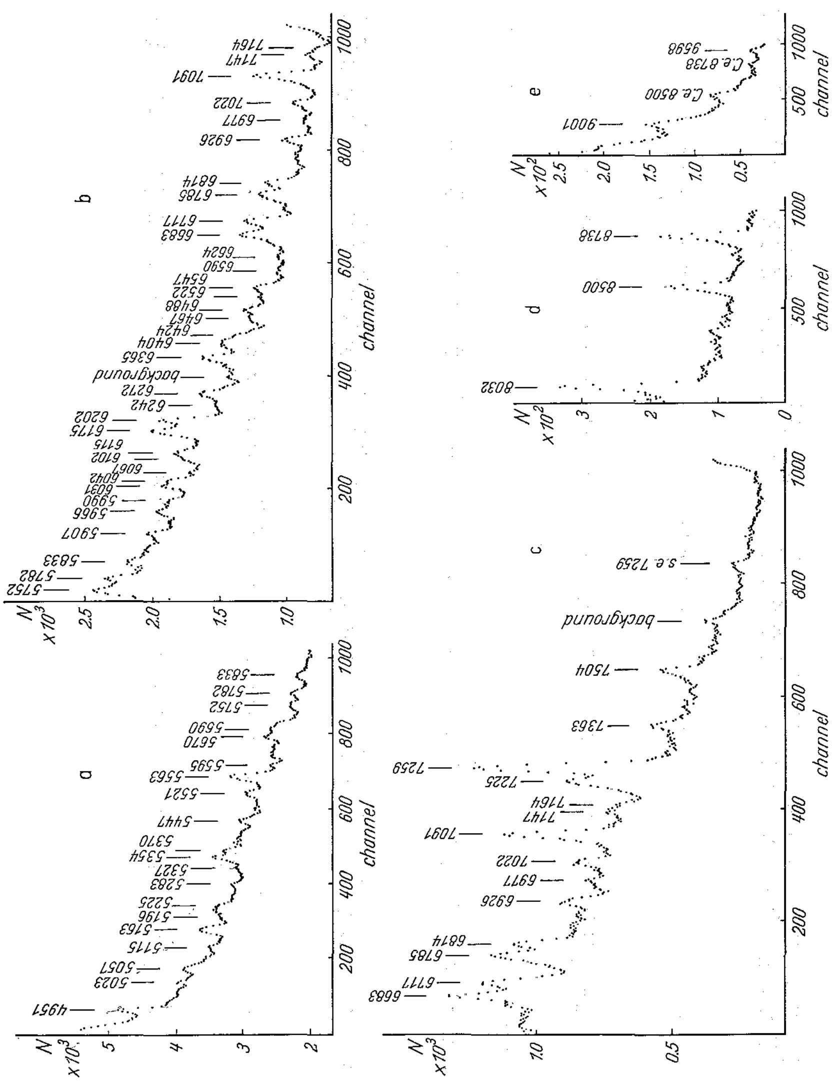


Fig. 4. Singles gamma-ray spectra from the reaction $Ge^{73}(n, \gamma)\,Ge^{74}$ taken with a Ge(Li) detector. *a* Energy range from 3900 to 4800 keV, contents of three adjacent channels added. *b* Energy range from 4700 to 6100 keV, contents of two adjacent channels added. *c* Energy range from 5600 to 7000 keV, contents of two adjacent channels added. *d* Energy range from 7000 to 7900 keV, contents of six adjacent channels added. *e* Energy range from 7900 to 8600 keV, contents of ten adjacent channels added. All spectra smoothed and without background correction. Peaks are labelled with the gamma ary energy. Where background is not smooth peaks are labelled "background". For some prominent gamma rays Compton edges or single-escape peaks can be distinguished and are labelled C.e. or s.e., respectively

Table 1. *Gamma rays from thermal neutron capture in 86.1% enriched Ge^{73} observed with a Ge (Li) detector*

Line Number	Energy E_γ/keV	Error ΔE_γ/keV	Class[a]	Line Number	Energy E_γ/keV	Error ΔE_γ/keV	Class[a]
1	235	5	B	48	1933	7	B[b]
2	288	4	A	49	1948	5	A
3	315	4	A	50	1965	7	B[b]
4	468	3	A	51	2072	5	A[b]
5	493	2	A	52	2100	10	B[b]
6	532	2	A	53	2148	5	A[b]
7	544	3	B	54	2190	10	B[b c]
8	559	3	B	55	2265	7	B[b]
9	597	1	A	56	2280	7	B[b]
10	609	1	A	57	2318	7	B[b]
11	703	2	A	58	2337	7	B[b]
12	740	3	A	59	2357	7	B[b]
13	772	2	A	60	2375	7	B[b]
14	788	3	A[b]	61	2395	10	B[b]
15	810	3	A	62	2416	7	B[b]
16	869	1	A	63	2451	7	B[b]
17	920	2	A[b]	64	2466	7	B[b]
18	940	2	A	65	2483	7	B[b]
19	953	3	B	66	2655	10	B[b]
20	963	1	A	67	2690	10	B[b]
21	1000	2	A	68	2710	10	B[b]
22	1057	3	A[b]	69	2757	10	B[b]
23	1103	2	A	70	2793	10	B[b c]
24	1132	3	A	71	2852	10	B[b]
25	1208	5	A[d]	72	2868	10	B[b]
26	1232	5	B	73	2900	10	B[b]
27	1295	4	A[b]	74	4270	5	A
28	1338	4	A	75	4330	10	A
29	1390	5	A[b]	76	4384	7	B
30	1403	5	A[b]	77	4401	7	A
31	1445	7	B[b]	78	4440	8	B
32	1460	7	B[b]	79	4467	8	B
33	1478	3	A	80	4518	10	B
34	1495	4	A	81	4545	10	B
35	1513	4	A	82	4651	5	A
36	1580	7	A	83	4695	7	A
37	1605	7	B[b]	84	4730	7	A
38	1621	7	B[b]	85	4782	8	A
39	1633	7	A[b]	86	4813	10	A
40	1650	7	B[b]	87	4844	10	A
41	1680	7	B[b]	88	4907	8	A
42	1697	7	B	89	4951	5	A
43	1720	7	A[d]	90	5023	8	A
44	1742	7	B	91	5057	7	A
45	1768	6	A[b]	92	5115	8	B
46	1810	7	A[b]	93	5163	5	A
47	1835	7	B[b]	94	5196	10	B

Table 1 (Continued)

Line Number	Energy E_γ/keV	Error ΔE_γ/keV	Class[a]	Line Number	Energy E_γ/keV	Error ΔE_γ/keV	Class[a]
95	5225	8	A	122	6404	12	A
96	5283	8	B	123	6424	12	A
97	5327	10	B	124	6467	12	A
98	5354	5	A	125	6488	8	A
99	5370	10	A	126	6522	12	B
100	5447	7	A	127	6547	10	A
101	5521	8	A	128	6590	12	B[c]
102	5563	5	A	129	6624	10	B
103	5595	8	A	130	6683	8	A
104	5670	8	A	131	6717	8	A
105	5690	10	A	132	6785	10	A[c]
106	5752	10	A	133	6814	10	A
107	5782	10	A	134	6926	8	A
108	5833	10	A	135	6977	12	B
109	5907	8	A	136	7022	8	A
110	5966	8	A	137	7091	8	A
111	5990	10	A	138	7147	10	A
112	6031	8	A	139	7164	10	A
113	6042	8	A	140	7225	8	A
114	6067	8	B	141	7259	8	A
115	6102	10	A	142	7363	8	A
116	6115	10	A	143	7504	8	A
117	6175	8	A	144	8032	10	A
118	6202	8	A	145	8500	10	A
119	6242	12	B	146	8738	10	A
120	6272	8	A	147	9001	12	A
121	6365	8	A	148	9598	15	A

[a] Classes: A certain line, B line not definitely established.
[b] Possibly double escape peak.
[c] Broad peak, possible doublet.
[d] Peak possibly due to incorrect background subtraction.

3.2. Coincidence Spectra

The coincidence configurations that proved most efficient for this particular case were the triple coincidence with electronic windows at 0.60 and 0.87 MeV and the double coincidence.

Only few of the resulting spectra are given for illustration (Fig. 5). As in all windows (whether electronic or "MIDAS") there are Compton contributions from higher-energy gamma lines, as pile-up cannot easily be accounted for, and because of the limited resolution of NaI(Tl) detectors the precise knowledge of the singles gamma-ray spectra is extremely important, and coincidence spectra are really significant together with the "neighbouring" spectra only. Coincidence measurements

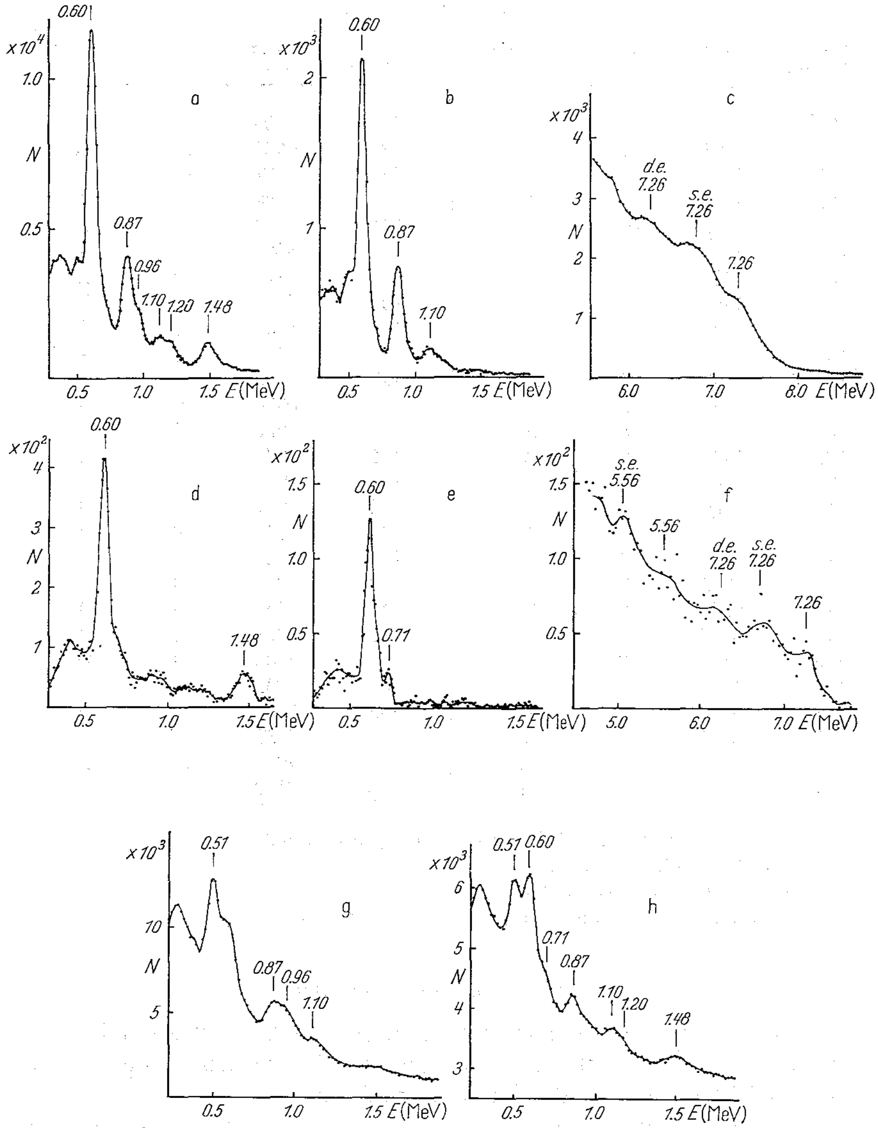


Fig. 5. NaI(Tl) coincidence spectra from the reaction $Ge^{73}(n, \gamma)Ge^{74}$. *a* Double coincidence spectrum, MIDAS window (7.05–7.30) MeV. *b* Double coincidence spectrum, MIDAS window (8.50–8.75) MeV. *c* Double coincidence spectrum, MIDAS window (1.43–1.54) MeV. *d* Triple coincidence spectrum, MIDAS window (7.09–7.42) MeV, electronic window at 0.87 MeV. *e* Triple coincidence spectrum, MIDAS window (8.00–8.32) MeV, electronic window at 0.87 MeV. *f* Triple coincidence spectrum, MIDAS window (1.45–1.52) MeV, electronic window at 0.87 MeV. *g* Triple coincidence spectrum, MIDAS window (0.57–0.64) MeV, electronic window at 0.60 MeV. *h* Triple coincidence spectrum, MIDAS window (0.81–0.91) MeV, electronic window at 0.60 MeV. Spectra are not normalized

are therefore summarized in Tables 2 and 3 for the triple coincidences with the electronic window of detector 3 (Fig. 2) set to 0.60 and 0.87 MeV, respectively, and in Table 4 for the double coincidences. For convenience only those relationships are included in Table 4 that cannot be deduced from Tables 2 and 3.

Table 2. *Summary of triple coincidence measurements* with electronic window at 0.60 MeV*

MIDAS window location MeV	Coincident γ-ray energies MeV 0.49	0.60	0.71	0.87	0.96	1.00	1.10	1.20	1.48	7.26	8.03	8.74
0.49		(+)				(+)						
0.60	(+)			((+))	+	+	((+))					
0.71				+								
0.87		((+))	+	((+))			((+))	((+))	+	+	+	+
0.96		+										
1.00		+										
1.10							(+)					
1.20												
1.48				+								
7.26				+								
8.03				+								
8.74				+								

* Single and double parentheses indicate decreasing certainty.

Table 3. *Summary of triple coincidence measurements* with electronic window at 0.87 MeV*

MIDAS window location MeV	Coincident γ-ray energies MeV 0.49	0.60	0.71	0.87	1.48	7.26	7.50	8.03
0.49								
0.60			+			+		+
0.71		+		((+))				
0.87		((+))	((+))					
1.48						+		
7.26		+			+			
7.50	(+)	(+)	(+)					
8.03		+	+					

* Single and double parentheses indicate decreasing certainty.

Because of the effects mentioned above not all of the coincidence relations of the tables are established unambiguously: + indicates that a coincidence is certain, (+) indicates that a coincidence is probable, and ((+)) is to say that the coincidence peak is possibly due to contributions from other lines or that more than one γ-ray are covered by the window

Table 4. *Summary of double coincidence relationships* that cannot be deduced from Tables 2 and 3*

MIDAS window location MeV	Coincident γ-ray energies MeV						
	0.60	0.87	0.96	1.00	1.10	1.20	1.48
7.26	+	+					+
7.50				(+)			
8.03			+			(+)	
8.50	+				+		
8.74	+	+					
9.00	+					+	

* Parentheses indicate less certain coincidences.

setting and probably only one of them is in coincidence. The parentheses so stand for decreasing certainty.

It may be noted that Tables 2, 3 and 4 are not strictly symmetric with respect to the diagonal. This is due to different energy scales and window settings in the X and Y axis or to additional "electronic" discriminators in the X or Y branch.

3.3. Level Scheme

Fig. 6 shows the level scheme of Ge^{74}. It is based on the assumption that gamma rays with energies >5.8 MeV correspond to primary transitions from the capturing state. Most of the higher-energy levels have not been observed before. The diagram only contains levels that are populated in the $Ge^{73}(n, \gamma)Ge^{74}$ reaction: states even well-established from other reactions have been omitted. Apart the high-energy transitions from the capturing state and except the 1850 keV γ-ray the position of which is suggested by other authors no gammas have been included that do not fit the level energies (or one another) within ± 4 keV. Coincidence relationships well established by coincidence measurements are indicated by dots. Some gamma rays that did not show marked coincidence relations fit the energy difference between more than one pair of levels. This is indicated in Fig. 6 by an interrogation mark behind the transition energy. Dashed lines represent γ-rays that are not definitely assured. The observed energy levels are summarized in Table 5.

The collective nature of the 2^+ state at 597 keV seems to be well established. As for the 2^+ and 4^+ states at 1206 and 1466 keV, respectively, there is strong evidence for these states to belong to the two-phonon quadrupole vibrational triplet; the third level (0^+) of this triplet was recently found at 1486 keV by DARCEY[11] from the reaction $Ge^{72}(t, p)Ge^{74}$. In the (n, γ) reaction this level is not fed directly with appreciable inten-

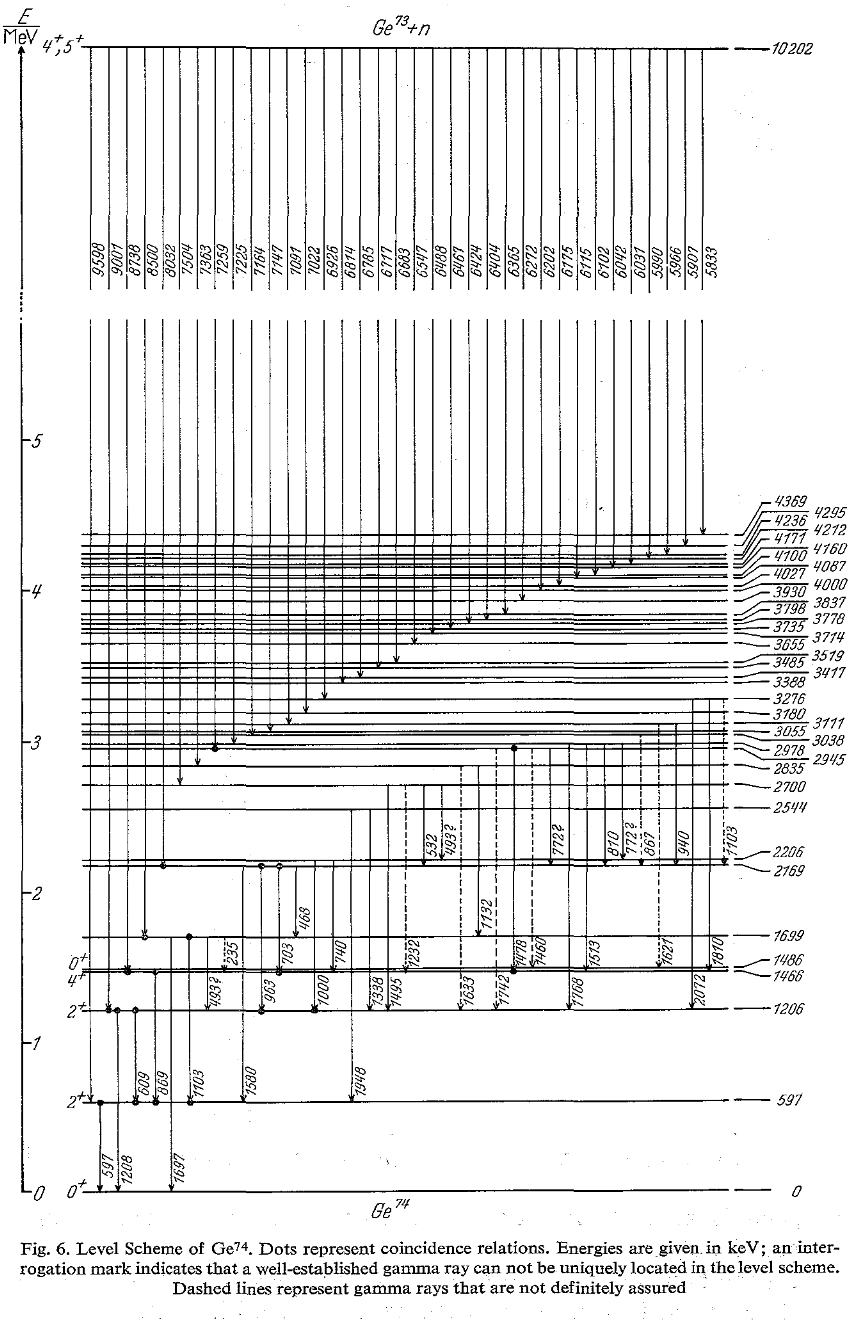


Fig. 6. Level Scheme of Ge^{74}. Dots represent coincidence relations. Energies are given in keV; an interrogation mark indicates that a well-established gamma ray can not be uniquely located in the level scheme. Dashed lines represent gamma rays that are not definitely assured

Table 5. *Energy levels of* Ge^{74} *in keV*

YTHIER et al.[a]	EICHLER et al.[a]	DARCEY[b]	Present work[c]
600	598	599	597
1200	1200	1207	1206
1470	1470	1472	1466
		1486	1486
	1710		1699
	2180		2169
2200		2203	2206
	2530	2537	2544
		2575	
		2695	2700
		2835	2835
2950	2950		2945
			2978
			3038
	3050		3055
			3111
3150	3160		3180
			3276
3330	3330		
			3388
	3410		3417
			3485
			3519
	3570		
			3655
			3714
			3735
			3778
3800			3798
	3830		3837
			3930
			4000
			4027
4080			4087
			4100
			4160
			4171
			4212
			4236
			4295
			4369

[a] From β^- decay of Ga^{74}. — [b] From $Ge^{74}(p, p')\,Ge^{74}$. — [c] From $Ge^{73}(n, \gamma)\,Ge^{74}$.

sity, and the indirect population seems to be very weak, too. This favours the spin 0-assignment.

On the basis of the hitherto existing experimental data no definite conclusions can be drawn as to the nature of the higher-lying excited states. The level at 1699 keV seems to correspond to the 1.71 MeV state observed by EICHLER et al. in the decay of Ga^{74}. From energy considerations this level can hardly be collective in nature. Most probably, it is due to an intrinsic nuclear excitation. The 2169 keV level can obviously be identified with the level observed by EICHLER et al. at 2.18 MeV. The deexcitation of this level is consistent with EICHLER's data. While the 2169 keV state could be well established by a major number of coincidence spectra, the level at 2206 keV is only based on the observed 597 keV – 609 keV – 1000 keV coincidence relationship and the failure to observe coincidences of the 1000 keV gamma ray with other intense transitions such as the 869 keV and 1103 keV gamma lines. The absence of a 1103 keV – 1000 keV coincidence would preclude the 1000 keV gamma ray from corresponding to a transition between the excited states at 2700 keV and 1699 keV. Further coincidence studies would be valuable for verifying the existence of the 2206 keV level. Energetically both the 2169 keV and the 2206 keV level might belong to the three-phonon quadrupole vibrational quintuplet. If vibrational nuclear states are described in the harmonic and adiabatic approximation it can be shown that the matrix elements for $M1$ and $E2$ radiation vanish for $\Delta N > 1$ where N represents the number of phonons. Therefore, it is expected that the three-phonon states are mainly deexcited by transitions to the levels at 1206, 1466 and 1486 keV. Considering that the harmonic and adiabatic approximation gives only a rough estimate of transition probabilities (cf. the existence of a 1208 keV gamma-ray) the results obtained for the levels at 2169 and 2206 keV are not in contrast to this prediction.

From the (p, p') reaction Darcey observed a level at 2537 keV which seems to be identical with the 2544 keV excited state in Fig. 6. On account of the large cross section and the characteristic angular distribution he interpreted this level as the 3^- octupole vibrational state. It is striking that in the present (n, γ) investigation no primary transition proceeding to this energy range could be detected. A transition to a 3^- state should be clearly present in the capture spectrum, if only the selection rules in total angular momentum and parity are considered. On the other hand, a very strong primary transition is observed to a level at 2945 keV which, energetically, might be identical with the 2.95 MeV state proposed by YTHIER et al. and EICHLER et al. Both feeding and deexcitation are consistent with a spin and parity assignment 3^-. The previous authors report a strong 2.35 MeV gamma-ray deexciting this level to the state at 0.6 MeV. Such a strong gamma ray could not be found in the present investigation. This makes the identity of the levels doubtful.

In order to make more definite assignments as to the nature of the levels above 1.5 MeV further experimental information is required.

Additional experiments using refined techniques and including angular correlation studies, therefore, are in progress.

3.4. *Binding Energy*

The values of the binding energy of Ge^{74} reported so far are [19,20]

$$E_B = (10250 \pm 70)\ \text{keV},$$

$$E_B = (\ 9990 \pm 40)\ \text{keV},$$

and

$$E_B = (10140 \pm 70)\ \text{keV}.$$

The present investigation suggests

$$E_B = (10202 \pm 10)\ \text{keV}.$$

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[19] Nuclear Data Sheets, National Research Council, Washington 25, D.C., Sheet 59-4-67.

[20] WAY, K.: USAEC publication TID-5300 (1955).