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Isomeric Cross-Section Ratios for Reactions Producing the Isomeric Pairs ^{69}Zn and ^{69}Zn^{m}, ^{71}Zn and ^{71}Zn^{m}.

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Summary. — Absolute cross-sections and isomeric cross-section ratios were measured for the following reactions in which the ^{69}Zn and ^{69}Zn^{m}, ^{71}Zn and ^{71}Zn^{m} isomeric pairs are produced: ^{69}Ga(n, p), ^{71}Ga(n, p), ^{72}Ge(n, α) and ^{74}Ge(n, α). These experimental values are interpreted in terms of the spin dependence of the nuclear level density. Isomeric ratios were compared with calculations based on different nuclear models. Calculations with a shifted Fermi gas model require a moment of inertia smaller than the rigid body; in general a reasonable fit is obtained with independent-pairing and superconductor models.

1. - Introduction.

During the last few years, the experimental and theoretical aspects of nuclear reactions in which isomers are produced became of considerable interest. In fact, information about the spin dependence of the nuclear level density and the nuclear moment of inertia can be obtained from isomeric cross-section ratios.

HUIZENGA and VANDENBOSCH (¹) have shown that, in compound nuclear reactions, the relative cross-section for the formation of a residual nucleus in its ground state and an isomeric state may be used to deduce information about the distribution of angular momentum of the excited states.

In this work, absolute cross-sections and isomeric ratios σ_m/σ_g (where σ_m and σ_g are the cross-sections for the production of the high-spin and low-spin

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(¹) J. R. HUIZENGA and R. VANDENBOSCH: *Phys. Rev.*, **120**, 1305 (1960); R. VANDENBOSCH and J. R. HUIZENGA: *Phys. Rev.*, **120**, 1313 (1960).

isomers of the residual nucleus), for the isomeric pairs ^{69}Zn and ^{69}Zn^m, ^{71}Zn and ^{71}Zn^m were determined from the reactions ^{69}Ga(n, p), ^{71}Ga(n, p), ^{72}Ge(n, α) and ^{74}Ge(n, α) respectively.

Previous results of cross-section ratios for these isomeric pairs from the reactions (n, p) and (n, α) were reported by LEVKOVSKII (²).

More recently a determination for ^{69}Ga(n, p) and ^{72}Ge(n, α) reactions was made by KOLAR, STROHAL and CINDRO (³). Unfortunately, their work seems to be based on the interpretation of unreliable experimental results. Indeed the 3.9 h ^{71}Zn^m, was masked by the other isomers, though certainly present in the decay of chemically separated zinc.

More recently WOOD, COOK, GOODGAME and FINK (⁴) have reported a careful determination of the cross-section for the metastable states only in ^{69}Zn^m and ^{71}Zn^m obtained from Ge(n, α) reactions.

In the present paper, we report some new experimental results. These results have been compared with previous results and with theoretical predictions from various nuclear models.

2. – Experimental procedure.

Samples of the target materials either in the form of the elements Ga and Ge or simple compounds Ga_2O_3 and $Ga(NO_3)_3$ were irradiated with (14.5 ± 0.2) MeV neutrons. The spread in the neutron energy at the target is actually ± 0.15 MeV for about 70% of the neutrons.

The incident neutron flux is determined by monitoring the outgoing α-particles with a solid-state detector placed at 90° with respect to the deuteron beam.

Metal foils were used as targets whenever possible. If foils were unavailable uniform layers in powdered form were used. The target thicknesses were generally of the order of (100 ÷ 200) mg/cm².

After irradiation, each target underwent chemical separation to remove undesirable activities.

The gallium targets were dissolved in hot HCl solution containing standardized Zn carrier; $Ga(OH)_3$ was extracted by adding NH_3 and then filtering. The solution containing ^{69}Zn and ^{69}Zn^m, ^{71}Zn and ^{71}Zn and ^{66}Cu was examined

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(²) V. N. LEVKOVSKII: *Žurn. Èksp. Teor. Fiz.*, **31**, 360 (1956); *Sov. Phys. JETP*, **4**, 291 (1957); *Žurn. Èksp. Teor. Fiz.*, **33**, 1520 (1957); *Sov. Phys. JETP*, **6**, 1174 (1958).

(³) Z. KOLAR, P. STROHAL and N. CINDRO: *Journ. Inorg. Nucl. Chem.*, **27**, 2471 (1965).

(⁴) R. E. WOOD, W. S. COOK, J. R. GOODGAME and R. W. FINK: *Phys. Rev.*, **154**, 1108 (1967).

with a liquid Geiger counter. In a second set of experiments ZnS was precipitated by adding thioacetamide and filtering onto a filter paper disk and then examined by means of an end-window counter (≈ 1.2 mg/cm^2).

In a set of experiments performed to measure the 2.45 min ^{71}Zn activity, the Ga(NO$_3$)$_3$ target was dissolved in hot 5 M NaOH basic solution to which Zn and KCN carriers had been added. The CN$^-$ ions have been added to complex Cu; ZnS was precipitated with H$_2$S onto a Büchner and abundantly washed.

The germanium oxide targets were dissolved in hot aqua regia to which Zn and Ga were previously added. By adding NH$_3$, gallium was precipitated from basic solution as Ga(OH)$_3$. After precipitation, thioacetamide was added, and, since GeCl is volatile, a final precipitate of white ZnS was obtained. In another set of gallium irradiations, the 13.8 h metastable state ^{69}Zn^m cross-section was determined by absolute β-counting, without previous chemical separation. The metastable-state activity was used to obtain the ^{69}Zn and ^{71}Zn^m cross-sections.

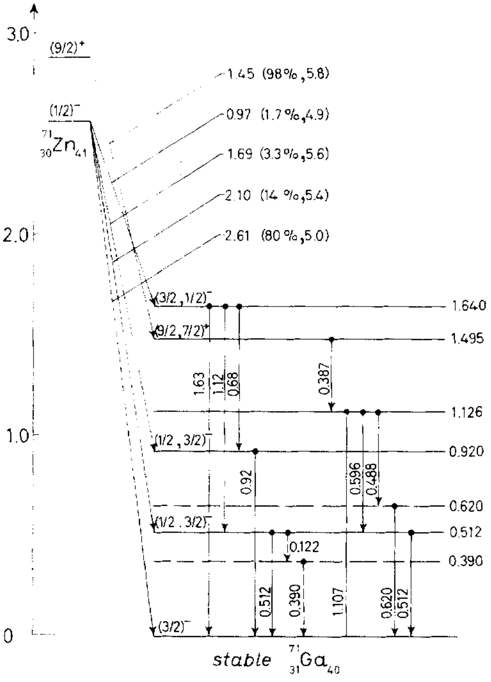

Fig. 1. – Decay scheme for ^{71}Zn and ^{71}Zn^m.

A 7.6 cm × 7.6 cm NaI(Tl) crystal scintillator coupled with a 512-channel pulse-height analyser was used for gamma counting.

The photopeak efficiencies used in the calculation of the absolute disintegration rates were from ref. (5). Samples were counted in a shielded box to reduce background radiation.

Decay curves were analysed by least-squares methods; corrections for self-absorption (6) were made.

The various measurements were compared to the measurements on the ^{27}Al(n, α)^{24}Na reaction whose cross-section value is (114 ± 6) mb.

The half-lives and level schemes were from Nuclear Data Sheets (7).

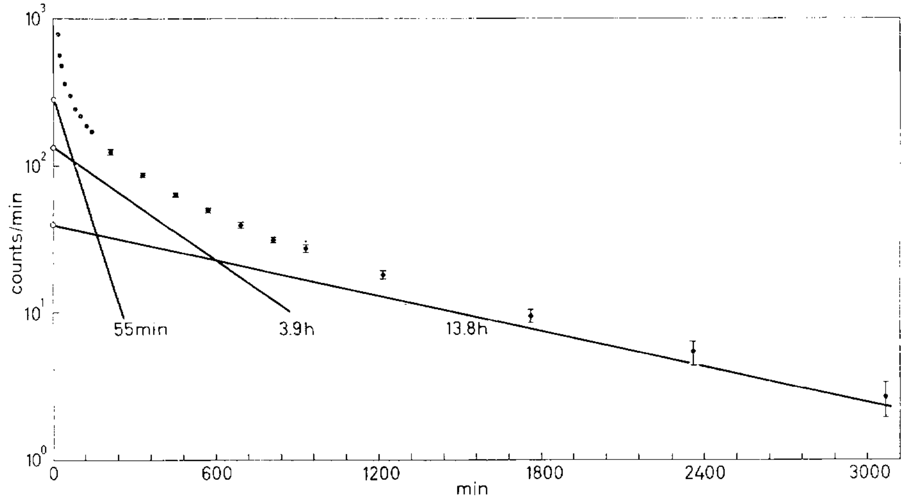

Fig. 2. – Decay curve of Zn measured by β-counting. The components are assigned to be due to 13.8 h ^{69}Zn^m, 3.9 h ^{71}Zn^m and 55 min ^{69}Zn. There is evidence of the 5.2 min ^{66}Cu component.

From the ^{69}Zn and ^{69}Zn^m decay scheme, the 13.9 h ^{69}Zn^m is observed to decay exclusively by isomeric transition to the 55 min β^--emitting ^{69}Zn ground state, therefore the entire decay sequence can be followed by observing the β^--decay with the β counter.

The conversion electrons from the 13.9 h isomeric transition ($\alpha_T = 0.06$, ref. (8)) were detected by the end-window Geiger counter. In the computations,

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(5) C. E. Crouthamel: *Applied γ-Ray Spectrometry* (London, 1960).

(6) C. Oldano and A. Pasquarelli: *Nucl. Instr.*, **36**, 192 (1965).

(7) K. Way, *et al.*: *Nuclear Data Sheets* (National Academy of Sciences, National Research Council, 1963).

(8) F. Demichelis and C. Oldano: *Nuovo Cimento*, **51** B, 341 (1967).

we have assumed that the Geiger counter has the same efficiency for the conversion electrons as for β-rays having the same average energy (⁹).

The decay scheme of ^{71}Zn and ^{71}Zn^{m} is shown in Fig. 1.

Figure 2 shows the β-decay curve of the ^{69}Zn and ^{71}Zn isomeric pair. The curve was analysed by a least-squares method assuming half-lives of 13.9 h, 3.9 h and 55 min, respectively.

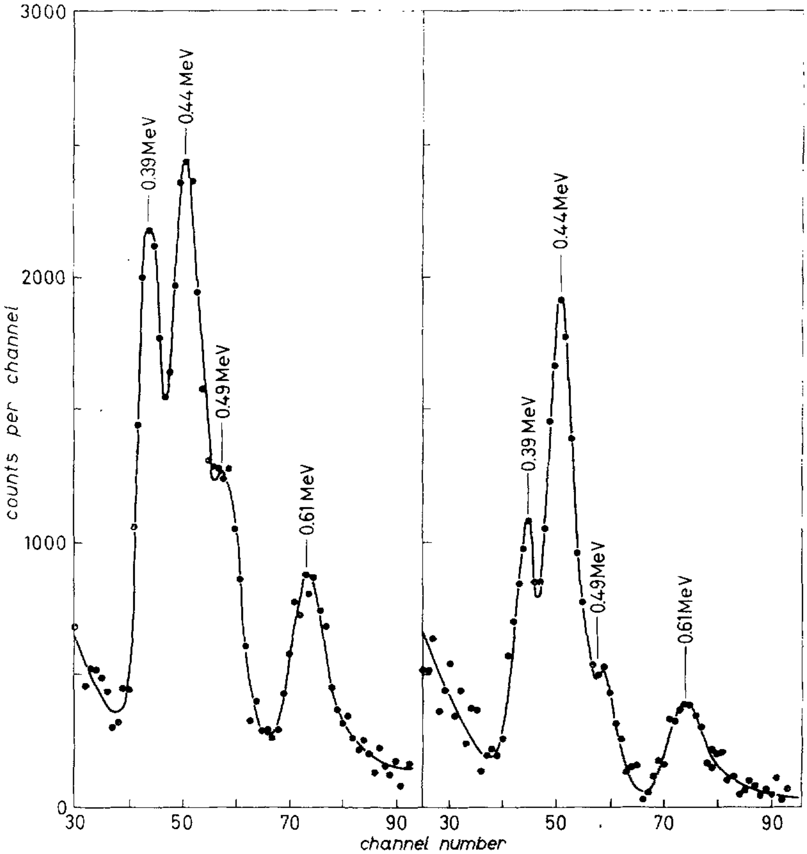

Fig. 3. – Gamma-ray spectrum from a zinc simple. The curves correspond to the spectra observed 2.5 h and 7.7 h after the end of the irradiation. The 0.44 MeV gamma-ray is assigned to be due to 13.8 h ^{69}Zn^{m}, the other gamma-rays are assigned to be due to 3.8 h ^{71}Zn^{m}.

The gamma-ray pulse-height spectrum for a typical sample is shown in Fig. 3. The intensity of the photopeaks was observed several different times after irradiation for each sample.

(⁹) B. P. BAYHURST and R. J. PRESTWOOD: *Nucleonics*, **17**, 82 (1959).

3. – Results.

The experimental results are reported in Table I. The absolute cross-sections are accurate to about 15%; the errors for the isomeric ratios are less than 20%.

TABLE I. – *Experimental isomeric cross-section.*

Reaction	Half-life	Spin	LEVKOVSKII (2) σ_m/σ_g	KOLAR *et al.* (3) σ_m/σ_g	WOOD *et al.* (4) σ_m (mb)	Present work			
						σ_m/σ_g	σ_m (mb)	σ_g (mb)	
$^{69}Ga(n, p)^{69}Zn^m$	13.9 h	$\frac{9}{2}^+$	0.5	0.95 ± 0.2		1.2 ± 0.2	21 ± 3		
$^{69}Ga(n, p)^{69}Zn$	55 min	$\frac{1}{2}^-$						17 ± 4	
$^{71}Ga(n, p)^{71}Zn^m$	3.9 h	$\frac{9}{2}^+$	0.66			> 2.5	12 ± 4		
$^{71}Ga(n, p)^{71}Zn$	2.45 min	$\frac{1}{2}^-$						< 4	
$^{72}Ge(n, \alpha)^{69}Zn^m$	13.9 h	$\frac{9}{2}^+$	1	0.79 ± 0.2	7.61 ± 0.76	1.2 ± 0.2			$^{71}Zn^m/^{69}Zn^m$ 0.36 ± 0.06
$^{72}Ge(n, \alpha)^{69}Zn$	55 min	$\frac{1}{2}^-$							
$^{74}Ge(n, \alpha)^{71}Zn^m$	3.9 h	$\frac{9}{2}^+$	0.33		3.32 ± 0.33				
$^{74}Ge(n, \alpha)^{71}Zn$	2.45 min	$\frac{1}{2}^-$							

Our absolute cross-section for $^{69}Zn^m$ does not agree with the value of (42 ± 3) mb at 15 MeV reported by BORMANN (10). This discrepancy may be accounted for by the presence of 14.22 h ^{72}Ga from the $^{71}Ga(n, \gamma)^{72}Ga$ reaction in Bormann's work.

The present ^{69}Zn ratio from the (n, p) reaction is in disagreement with that of Levkovskii. Since this author reported only the ratio and not the individual isomeric cross-sections, the reason for the disagreement is not easily found. The present ^{69}Zn ratio from the (n, α) reaction is consistent with those reported by KOLAR *et al.* and by LEVKOVSKII.

Moreover, the $^{71}Zn^m$ $^{69}Zn^m$ ratio from Ge(n, α) is in good agreement with Wood's results.

Finally we report only a maximum value of the ^{71}Zn cross-section from the

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(10) M. BORMANN: *Zeits. Phys.*, **166**, 477 (1962).

(n, p) reaction and consequently only a minimum value for the isomeric ratio. The present ratio, however, is in disagreement with the experimental value of Levkovskii.

4. – Statistical model calculations.

In the present experiments we have used the method of Huizenga and Vandenbosch to analyse the two isomeric pairs. We shall describe calculations based on the predictions of various theoretical models. These models and their application to isomeric ratio calculations have been thoroughly discussed previously ([1,11,12]).

The form for the nuclear level density expression used in the present work is

$$\varrho(J) = \varrho(0)(2J+1)\exp\left[\frac{-J(J+1)}{2\sigma^2}\right], \tag{1}$$

where $\varrho(J)$ is the density of levels of spin J. The density of levels of spin zero, $\varrho(0)$, contains most of the excitation energy dependence of the nuclear level density. The spin cut-off parameter σ characterizes the angular momentum distribution of levels and is defined by

$$\sigma^2 = gt\langle m^2\rangle, \tag{2}$$

where t is the thermodynamic temperature, g the single-particle level density and $\langle m^2\rangle$ the mean-square value of the magnetic quantum number of individual nucleons ([13]). The parameter g can be expressed in terms of the level density parameter a by

$$a = \tfrac{1}{2}\pi g^2 . \tag{3}$$

For a simple Fermi gas ([11])

$$\sigma^2 = ct = \frac{\mathscr{I}t}{\hbar^2} . \tag{4}$$

([11]) T. Ericson: *Nucl. Phys.*, **6**, 62 (1958); D. W. Lang and K. J. Le Couteur: *Nucl. Phys.*, **14**, 21 (1959).

([12]) A. Bohr, B. R. Mottelson and D. Pines: *Phys. Rev.*, **110**, 936 (1958); D. W. Lang: *Nucl. Phys.*, **42**, 353 (1963); H. K. Vonach, R. Vandenbosch and J. R. Huizenga: *Nucl. Phys.*, **60**, 70 (1964); R. Vandenbosch, L. Haskin and J. C. Norman: *Phys. Rev.*, **137**, B 1134 (1965).

([13]) T. D. Newton: *Can. Journ. Phys.*, **34**, 804 (1956); T. Ericson: *Adv. Phys.*, **9**, 425 (1960).

The quantity $c\hbar^2$ can be interpreted as a moment of inertia. It is sometimes convenient to compare $\mathscr{J}$ with the rigid-body moment of inertia $\mathscr{J}_2$ given by

$$\mathscr{J}_r = \tfrac{2}{5} M R^2 A \,, \tag{5}$$

where M is a nucleon mass, A the mass number and R the nuclear radius. A value of the radius parameter of $r_0 = 1.2$ fm was taken in the present calculations. The relationship between the nuclear temperature T and the excitation energy U is approximatively given by

$$U \simeq aT^2 - 4T \,. \tag{6}$$

Calculations of the expected isomeric cross-section ratios have been carried out using the formalism described previously (^{1}).

The first step of calculation is the determination of the angular momentum distribution of the compound nucleus produced in the reaction

$$\sigma(J_c, E) = \pi \lambda\!\!\!^{-2} \sum_{S=|I-s|}^{I+s} \; \sum_{l=|J_c-S|}^{J_c+S} \frac{2J+1}{(2s+1)(2I+1)} \, T_l(E) \,, \tag{7}$$

where J_c is the angular momentum of the compound nucleus formed by capturing the incoming projectile of energy E and spin s by the target nucleus of spin I.

The transmission coefficients for the incoming neutrons were calculated using the usual formulae.

The next step is the calculation of the angular-momentum distribution in the residual nucleus following particle emission. The probability that the initial compound nucleus of spin J_c will become a residual nucleus of spin J_f by emission of a particle is given by

$$P(J_f)_{J_c} \propto \varrho(J_f) \sum_{S=|J_f-s'|}^{J_f+s'} \; \sum_{l'=|J_c-S|}^{J_c+S} T'_{l'}(E) \,, \tag{8}$$

where s' is the intrinsic spin of the emitted particle, $T'_l(E)$ is the transmission coefficient for an alpha-particle or proton with angular momentum l' and energy E, and

$$\varrho(J_f) \propto (2J_f + 1) \exp\left[-(J_f + \tfrac{1}{2})^2/2\sigma^2\right] . \tag{9}$$

It has been assumed that the particles carry off an average energy; the Coulomb barrier energy is a reasonable approximation for the average energy of the emitted charged particles. The calculations of Feshbach *et al.* (^{14}) have been used for the charged particles.

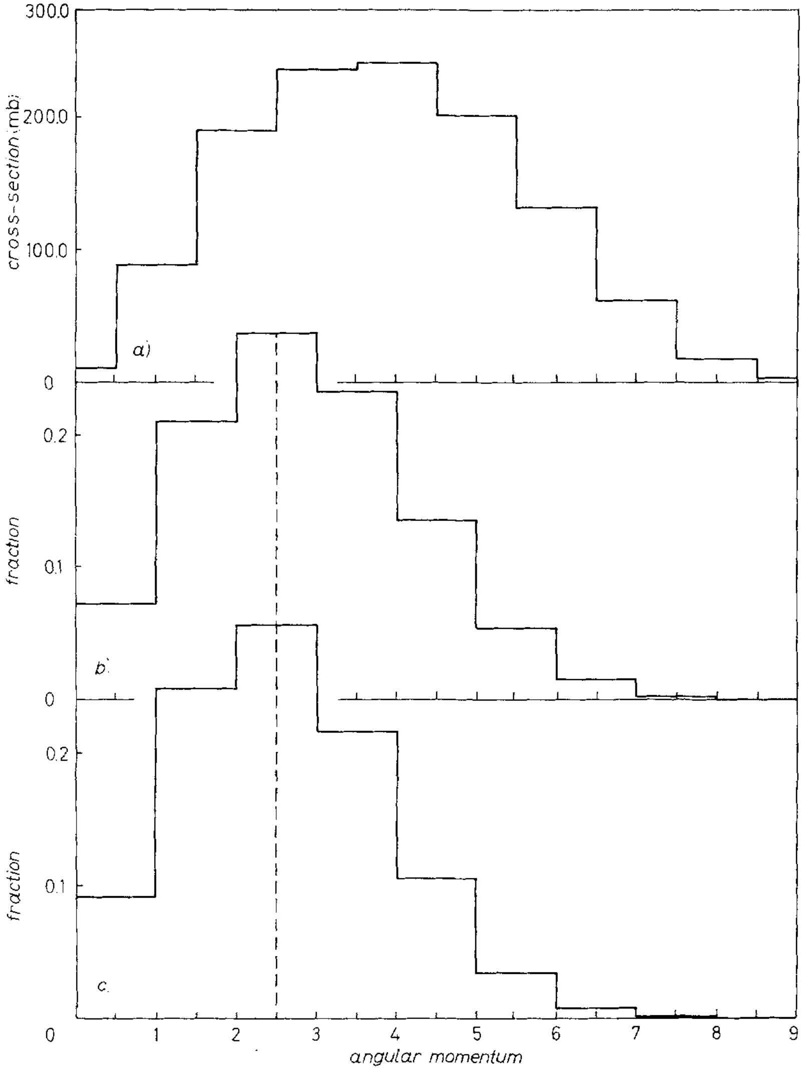

Fig. 4. – Distribution of angular momentum at several stages of the calculation for the ^{69}Ga(n, p) ^{69}Zn-^{69}Zn^{m} reaction using the spin cut-off parameter $\sigma = 2$. *a*) the cross-section of the compound nucleus, *b*) the distribution following the emission of the proton and *c*) the distribution obtained after the emission of one dipole gamma-ray.

(^{14}) H. Feshbach, M. M. Shapiro and V. F. Weisskopf: Atomic Energy Commission Report NYO-3077 (1953) unpublished.

The spin distribution in the residual nuclei following particle emission when only a single-particle type of average energy need be considered in order to determine the distribution leading to the isomeric ratio is

$$P(J_f) = \sum_{J_c} P(J_c)P(J_f)_{J_c}\,, \tag{10}$$

where $P(J_c) = \sigma(J_c, E)\Big/\sum_{J_c=0}^{\infty}\sigma(J_c, E)$ is the probability of spin J_c in the total spin distribution of the compound nuclei.

After the last particle is emitted, the final stage of de-excitation takes place by emission of one γ-ray or a cascade of gamma-rays. The number ν and energy spectrum of the gamma-rays emitted have been discussed in previous works (^{11}). Gamma-ray cascade cut-off energy limits of 1 and 2 MeV were used. Isomeric ratios were calculated from the distributions just preceding the final gamma emission.

The calculations of isomeric ratios discussed in this report were carried out with an IBM 7040 using a program written by HAFNER, HUIZENGA and VANDENBOSCH (^{15}). Figure 4 shows the distribution in angular momentum at several stages of calculations for the ^{69}Ga(n, p)^{69}Zn reaction using the spin cut-off parameter $\sigma = 2$.

TABLE II. – *Calculated isomeric ratios.*

Reaction	σ	σ_m/σ_g				
		$\nu = 0$	$\nu = 1$	$\nu = 2$	$\nu = 3$	$\nu = 4$
^{69}Ga(n, p)^{69}Zn	2	1.375	1.052	0.835	0.688	0.582
	3	2.498	2.332	2.191	2.071	1.972
^{71}Ga(n, p)^{71}Zn	1	0.138	0.0358	0.013	0.0080	0.0069
	2	1.434	1.092	0.862	0.706	0.600
	3	2.551	2.377	2.229	2.104	1.999
^{72}Ge(n, α)^{69}Zn	2	0.744	0.627	0.546	0.491	0.452
	3	1.851	1.793	1.762	1.699	1.662
^{74}Ge(n, α)^{71}Zn	1	0.038	0.013	0.0081	0.0068	0.0066
	2	0.748	0.630	0.549	0.492	0.453
	3	1.866	1.804	1.753	1.708	1.669

(^{15}) W. L. HAFNER jr., J. R. HUIZENGA and R. VANDENBOSCH: Argonne National Laboratory, Report ANL 6662, unpublished.

Curve *a*) shows the distribution in angular momentum of the compound nucleus prior to the proton emission, curve *b*) the distribution following the proton emission and curve *c*) the distribution obtained after the emission of one dipole gamma-ray. The final population is then determined by dividing this distribution at $J=\frac{1}{2}(I_m+I_g)=\frac{5}{2}$, where I_m and I_g are the angular momenta of the metastable and ground state, respectively.

States with $J>\frac{5}{2}$ are assumed to populate the higher-spin isomer ($I_m=\frac{9}{2}$) and states with $J<\frac{5}{2}$ to populate the lower-spin isomer ($I_g=\frac{1}{2}$). Half-states with $J=\frac{5}{2}$ are presumed to decay to each isomer.

The isomeric ratios calculated in this way are reported in Table II. They may be compared with the available experimental isomeric ratios reported in Table I.

The best agreement with experiments was obtained by setting $\sigma=2$ and $\nu=1$ for the ^{69}Ga(n, p)^{69}Zn-^{69}Zn^m reaction and $\sigma=\sim 2.5$ for the ^{72}Ge(n, α)·^{69}Zn-^{69}Zn^m reaction.

Analyses of isomeric cross-section ratios for the reactions in which the isomeric pair ^{71}Zn and ^{71}Zn^m is formed indicated a value for σ of approximately 1.5, according to the data of Levkovskii; a value for σ of approximately 3 is obtained taking into account the present result for the Ga(n, p) reaction.

5. – Discussion.

The calculated isomeric ratios for the shifted Fermi gas (16), the independent-pairing (11) and the superconductor (12) models for various values of the level density parameter *a* are compared with the experimental data. By making appropriate parameter choices, it is possible to obtain agreement with the experimental results. In the present calculations, *a* was treated as adjustable parameter.

Pairing energies $2\delta=3.16$ for ^{69}Zn and $2\delta=3.04$ for ^{71}Zn have been taken from the work of NEMIROVSKY and ADAMCHUK (17).

5·1. *Isomeric yields from the* ^{69}Ga(n, p)^{69}Zn^{69}-Zn^m *reaction.*

– The calculated isomeric ratios for the shifted Fermi gas, independent pairing and superconductor models for the value of $a=\frac{1}{8}A$, $a=\frac{1}{6}A$ and $a=\frac{1}{4}A$ are compared with experimental data.

The level density parameter value needed in the Fermi gas model to fit

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(16) K. J. LE COUTEUR and D. W. LANG: *Nucl. Phys.*, **13**, 32 (1959).

(17) P. E. NEMIROVSKY and YU. V. ADAMCHUK: *Nucl. Phys.*, **39**, 551 (1962).

experimental data is too large for the Fermi gas. If one assumes a value of the level density parameter $a = \frac{1}{8}A$, which is the more accepted value (12) in agreement with temperature measurements, a reduction of the rigid-body moment of inertia is required to fit the experimental isomeric ratios. From the $\sigma = 2$ and $a = \frac{1}{8}A$, one estimates $\mathscr{J}/\mathscr{J}_r = 0.28 \pm 0.03$. This corresponds to a moment of inertia which is appreciably less than the rigid-body value. The error on the $\mathscr{J}/\mathscr{J}_r$ ratio is deduced from the experimental one on the isomeric cross-section ratio.

On the other hand, a reduction of the moment of inertia was necessary for agreement with experimental results on several other isomeric pairs (18).

A reduction factor of $\mathscr{J}/\mathscr{J}_r = 0.35$ was observed (19) in neighbouring ^{69}Cu-^{69}Cu^m.

Comparison of the experimental data with the prediction of the independent-pairing model was made for the various level density parameters a. It is known that this model gives moments of inertia which are considerably less than the rigid-body values.

However with the accepted a-value given by $a = \frac{1}{8}A$, a smaller reduction of the moment of inertia is needed. To reproduce the experimental nuclear temperature using a rigid-body moment of inertia, a value of a larger than that given by $a = \frac{1}{8}A$ is required.

Calculations based on the superconductor model were performed for the above values of the level density parameter a. Among all the calculations performed on the ^{69}Ga(n, p)^{69}Zn-^{69}Zn^m, the superconductor model with $a = \frac{1}{4}A$ using a rigid-body moment of inertia gives a reasonable fit to the experimental data. The superconductor model requires usually large a-values to fit the experimental nuclear temperature (12).

For $a = \frac{1}{8}A$, a moment of inertia smaller than the rigid-body moment is needed in the calculations.

5'2. *Isomeric yield from the* ^{71}Ga(n, p)^{71}Zn-^{71}Zn^m *reaction.* – The experimental data of Levkovskii (2) are compared with results calculated with the various models. For a value of the level density parameter $a = \frac{1}{8}A$, the shifted Fermi gas model gives too large a moment of inertia. With this assumption, a ratio $\mathscr{J}/\mathscr{J}_r = \approx 0.31$ is indicated.

The superconductor model would fit the experimental data for $a = \frac{1}{4}A$ with a rigid-body moment of inertia.

On the contrary, accepted a value $\sigma = 3$ for the spin cut-off parameter, for a value of the level density $a = \frac{1}{8}A$ and a reduction factor of $\mathscr{J}/\mathscr{J}_r = 0.65$,

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(18) J. H. CARVER, G. E. COOTE and T. R. SHERWOOD: *Nucl. Phys.*, **37**, 449 (1962).

(19) J. H. CARVER and G. A. JONES: *Nucl. Phys.*, **19**, 184 (1960).

a good agreement between Fermi gas theory and our experimental data was obtained.

A reasonable fit can also be obtained for the superconductor model with $a=\frac{1}{8}A$. Thus our experimental result seems to be somewhere between the predictions of the various models.

5'3. *Isomeric yield from the* ^{74}Ge(n, α)^{69}Zn *reaction.* – The nuclear level density parameter a has been computed using the relationship $a=\frac{1}{10}A$. This choice is in agreement with several authors (^{20}). For $a=\frac{1}{10}A$, a value in agreement with the nuclear temperature, a reduction of the rigid-body moment of inertia of $\mathscr{I}/\mathscr{I}_r=0.53\pm0.04$ is needed in the shifted Fermi gas model.

The independent-pairing model calculations based on a rigid-body moment of inertia and value $a=\frac{1}{10}A$ give a good fit to experimental results.

A good fit is also obtained with the superconductor model for $a=\frac{1}{8}A$ using the rigid-body moment of inertia.

5'4. *Isomeric yield from the* ^{74}Ge(n, α)^{71}Zn *reaction.* – The experimental data are those of Levkovskii.

The calculated isomeric ratios for the shifted Fermi gas model for the values of $a=\frac{1}{10}A$ and $a=\frac{1}{8}A$ were compared with the experimental data. For $a=\frac{1}{10}A$, a moment of inertia smaller than the rigid-body moment is needed in the caluclations. A reduction of $\mathscr{I}/\mathscr{I}_r=\approx0.37$ is indicated.

Calculations based on the superconductor model were performed for $a=\frac{1}{10}A$ and $a=\frac{1}{8}A$. A reasonable fit with the superconductor model requires a level density parameter a which is too large. On the other hand, an a-value larger than $\frac{1}{8}A$ is difficult to justify. In view of this uncertainty, no definite conclusion can be drawn from this reaction.

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The calculations were performed on the FIAT IBM 7040 computer. The authors are indebted to the Staff of the Computer Center and to Dr. C. D'Urso and Dr. B. Gabutti for assistance with the computer calculations. The authors wish to express their thanks to Ing. N. Piccinini for the chemical separations.

(^{20}) D. G. Gardner and Y. W. Yu: *Nucl. Phys.*, **60**, 49 (1964); D. L. Allen: *Nucl. Phys.*, **24**, 274 (1961); I. Dostrowsky, Z. Fraenkel and G. Friedlander: *Phys. Rev.*, **116**, 683 (1959).

RIASSUNTO

Sono stati misurati sia i rapporti delle sezioni efficaci di isomeri sia le sezioni efficaci assolute per le seguenti reazioni nucleari: ^{69}Ga(n, p), ^{71}Ga(n, p), ^{72}Ge(n, α), ^{74}Ge(n, α), in cui vengono prodotti gli isomeri ^{69}Zn e ^{69}Zn^{m}, ^{71}Zn e ^{71}Zn^{m}. I risultati sono stati analizzati usando i calcoli statistici di Huizenga e Vandenbosch e confrontati con i calcoli basati sui vari modelli nucleari. In generale l'accordo tra teoria e dati sperimentali è soddisfacente. Nel modello del gas di Fermi l'accordo si ha solo con una riduzione del momento d'inerzia rispetto al valore relativo al corpo rigido.

Отношения изомерических поперечных сечений для реакций рождения изомерических пар ^{69}Zn, ^{69}Zn^{m} и ^{71}Zn, ^{71}Zn^{m}.

Резюме (*). — Были измерены абсолютные поперечные сечения и отношения изомерических сечений для следующих реакций, в которых рождаются изомерические пары ^{69}Zn и ^{69}Zn^{m}, ^{71}Zn и ^{71}Zn^{m}: ^{69}Ga(n,p), ^{71}Ga(n,p), ^{72}Ge(n,α) и ^{74}Ge(n,α). Эти экспериментальные величины интерпретируются в терминах спиновой зависимости плотности ядерных уровней. Изомерические отношения сравнивались с вычислениями, основанными на различных ядерных моделях. Вычисления с помощью модели Ферми-газа требуют момента инерции меньшего, чем момент твердого тела; вообще, разумная подгонка получается с моделями независимого спаривания и сверхпроводимости.

(*) *Переведено редакцией.*