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INVESTIGATIONS ON GAMMA-TRANSITIONS IN THE /2s1d/ SHELL

I.Berkes, I.Demeter, I.Dézsi, Ilona Fodor, L.Keszthelyi
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The attraction of the study of the /2s1d/ shell nuclei for nuclear spectroscopy is twofold, first, the coupling within an individual nucleus in this range is usually neither pure /LS/ nor pure /jj/ and various intermediate coupling schemes are encountered from nucleus to nucleus, second, that the nuclei in the central region are deformed and they exhibit collective nuclear properties. These points of interest have stimulated also at our group a number of experimental investigations of the excited levels in /2s1d/ shell nuclei, such as Ne^{20}, Mg^{24}, Al^{27}, Si^{28} and S^{32}.

An already long established method for getting some information on nuclear structure is the analysis of the gamma-radiation emitted by the excited nucleus. This information, however, can be used for inferring the nature of the transition, only with the knowledge of its multipolarity, lifetime and decay scheme, the knowledge of multipolarity implying frequently also the knowledge of the spin and parity assignments to the initial and final states of the nucleus. In other words, one has to determine the energy, multipolarity and partial level width of the individual decays. To obtain some approximate orientation on the level structure, these partial level widths have then to be compared with the Weisskopf-estimate predicted from the extreme single particle transition approach.

Let us consider, for instance, the nucleus Ne^{20}! The levels at 13,196 MeV and at 13,511 MeV have equally spin and parity 1^+. Now, the experimental results obtained at our Laboratory and by other authors as well, show for the 13,196 MeV level a broad level width of alpha-transition and a low probability of proton scattering and /p, gamma/ reaction /1/, /2/, /3/, while for the 13,511 MeV level gamma-decay is more favoured, than in the former case, and so is the probability of proton scattering too; on the other hand, alpha-decay is less probable. /The partial level width of gamma-transition is, for instance, $0{,}8.10^{-2}$ W.u. at the 13,196 MeV level and 7.10^{-2} W.u. at the 13,511 MeV level/. One attempts to interpret this interesting observation qualitatively by assuming a cluster configuration of the excited levels in Ne^{20}. The nucleus is assumed to spend the time at both levels mostly, say, an a O^{16} + alpha cluster state with a temporary onset of F^{19} + p /single particle/ states.

The elastic proton scattering as well as the M1 radiation are favoured by the F^{19} + p state, thus the probability of the onset of the two kinds of states may explain the different transition probabilities.

Although both levels in question, having spin and parity 1^+, may decay by M1 transition either to the 0^+ ground state or to the 2^+ first excited level in Ne^{20}, the reduced level width of the transition to the first excited level is for the 13,511 MeV level 350 times, for the 13,196 MeV level as the lowest limit, more than 6 times that of the transition to the ground state. This state of things cannot be accounted for by any selection rule following from the configurations of the shell model assumed to have /jj/ coupling /3/. On the other hand, the F^{19}/d,n/ Ne^{20} reaction cross section at the first excited level in Ne^{20} is from 6 to 10 times that of the neighbouring levels /1/. This suggests that even the first excited level in Ne^{20} may be of the F^{19} + p type and since there is a higher probability of transition between states of similar configuration, this would explain the strange behaviour of Ne^{20} /4/. Yet, it is still questionable whether the assumption of this, or any other nucleon-association is an approach capable of yielding results in quantitative agreement with the experimental observations.

The average structure of the /2s1d/ shell can be inferred from the complete set of a great number of available data. The information available to date on the gamma-transitions is presented in a tabulated form in the Appendix. /Fig.1/ /As compared with the compilation of A.M.Lane /5/ recent data have been added, while some, not unambiguous experimental values have been omitted./ The available data can be used for plotting the frequency distribution of the reduced level widths for the E1, M1 and E2 type radiations /Fig.2 and 3/.

Let us now compare these distribution curves with a similar analysis carried out by Wilkinson for the /1p/ shell /6/, /7/.

Defining the expectation value of the transition probability as

$$|\overline{M^{\bullet}}|^2 = \frac{\sum_i E_i \log |M_i|^2}{\sum_i E_i}$$

where E_i is the number of examples. In Table 1. we have listed for comparison the values both for the /1p/ and for the /2s1d/ shell:

Table 1.

Radiation type	/1p/ shell		/2s1d/ shell	
	examples	$\overline{\lvert M\rvert^2}$	examples	$\overline{\lvert M\rvert^2}$
E 1	68	0,055	18	0,003
M 1	43	0,15	55	0,055
E 2	13	5	25	3,3

Average reduced level widths for E1, M1 and E2 transitions.

It is striking that in the /2s1d/ shell magnetic and electric dipole radiations seem to be 3 and 20 times as strongly forbidden, respectively, as in the /1p/ shell. It is also interesting to note that, though the data on the /1p/-shell were reported three years earlier, about four times as much data are available for E1 transition in the /1p/ as for the /2s1d/ shell. This can be explained partly by that the excited states have rather often /s, d/ configuration in which electric dipole transitions are forbidden by the parity selection rule, partly by that, owing to the higher number of nucleons in the /2s1d/ shell, residual interactions are likely to produce nucleon clusters slowing down the dipole radiation favoured by single particle transitions. The same accelerating effect is observed for the E2 radiation as in the /1p/ shell, the reason for this may lie also here in the collective nuclear properties.

The known configurations in the /1p/ shell have been used by Wilkinson for estimating the distribution function to be expected from the single particle model and this was compared with the experimental histogram. Unfortunately, in lack of a satisfactory approach of the configurations in the /2s1d/ shell, this method cannot be used presently.

For the disintegrations considered up to present, a complete set of the required experimental data is available. In most cases, however, owing both to experimental difficulties and evaluation problems /e.g. a given angular correlation may occur for several spin and parity values in the case of different mixing parameters/, only a few data can be determined. Nevertheless, even a restricted number of data may suggest interesting qualitative interpretations.

The lower levels in Mg^{24} are known to display a well defined rotational spectrum. Considering the decay schemes, the first six levels can be classed into two rotational band /Fig.4/. The highly excited levels in Mg^{24} produced in the Na^{23}/p,gamma/Mg^{24} reaction have been investigated by Glaudemans and Endt, further by Prosser et al. /9/, /10/. The main cascades in the disintegrations from the levels above 11,988 MeV excitation energy are of the $E_e \rightarrow 1{,}37 \rightarrow 0$ and $E_e \rightarrow 4{,}23 \genfrac{}{}{0pt}{}{\rightarrow 1{,}37 \rightarrow 0}{\rightarrow 0}$ type and the latter is much more intensive than would be expected from the single particle model. Prosser et al. observed even two levels decaying not to the 4,23 but to the 4,12 MeV level. In this case, however, the transitions to the 2^+ spin and parity first excited level were found to be poor /transition to the ground state did not occur at all/, therefore, the authors assumed the level spin to be 4.

The lowest known resonance for the Na^{23}/p,gamma/Mg^{24} reaction is at E_p = 250 keV proton energy. Up to present but the gamma-yield of this resonance, exciting the 11,933 MeV level, has been known. This resonance was investigated by our group with the use of the 1oo-2oo μA intensity ion current produced by the 8oo kV Cockcroft-Walton particle accelerator. The gamma-spectra were measured by 3x3" NaJ/Tl/ + Dumond 6363 photomultiplier and analysed on a 100-channel pulse height analyser. The high energy part of the pulse height spectrum is shown in Fig. 5/a, the low energy component in Fig. 5/b. It follows from the energy calibration that the decay of the 11,933 MeV level occurs mainly by transition to the 1,37 MeV first excitation level with a simultaneous but less intensive appearance of another cascade. The transition in this 15-20 % intensity cascade, however, is not to the 4,23 MeV but to the 4,12 MeV level. /In the meantime this decay scheme has been determined more accurately by Glaudemans and Endt /9/./ Here, the higher intensity $E_e \rightarrow 1{,}37 \rightarrow 0$ transition, however, does not suggest spin and parity 4^+ like in the case of the 12,640 and 13,053 MeV levels. We have found from angular distribution measurements that the angular distribution coefficients of the 10,5 MeV radiation can be described by the Legendre coefficients $a_2 = -0{,}19 \pm 0{,}02$ and $a_4 = 0{,}14 \pm 0{,}03$ while for the 7,75 MeV transition by $a_2 = -0{,}04 \pm 0{,}06$ and $a_4 = 0{,}05 \pm 0{,}13$. These coefficients imply the spin and parity of the 11,933 MeV level to be either 2^+ or 3^+.

Let us now compare the levels 11,933 MeV and 11,988 MeV! It is seen that either of the spin values 2 and 3 would allow M1 type transitions for both the 11,933→1,37 and the 11,933→4,23 decay. The intensity of the latter, however, if it can be detected at all, must be, according to our experiments, less than 1,5 %. The transition ratio 11,933→1,37 to 11,933→4,14 corresponds to the Weisskopf estimate. On the other hand, the transition from the 2^+ spin and parity, 11,988 MeV level to the 4,23 MeV level is of 30 % higher intensity than that to the 1,37 MeV level and such is the case, as it has been already mentioned, for several higher energy levels too. One may assume these levels to belong, for instance, to the rotational band K = 2 /Fig.4/ and this would explain for instance the abundant population of the 4,23 MeV /K = 2/ level. The 11,933 MeV level, on the other hand, may be of the K = 0 class, though it can be classed also as a single particle state.

Further conclusions could be drawn only if the multipolarity of the transitions as well as the absolute values of the partial level widths were known. Nevertheless we hope that above considerations are sufficient for attracting the interest of theoreticians dealing with light nuclei to some of the basic problems yet to be solved.

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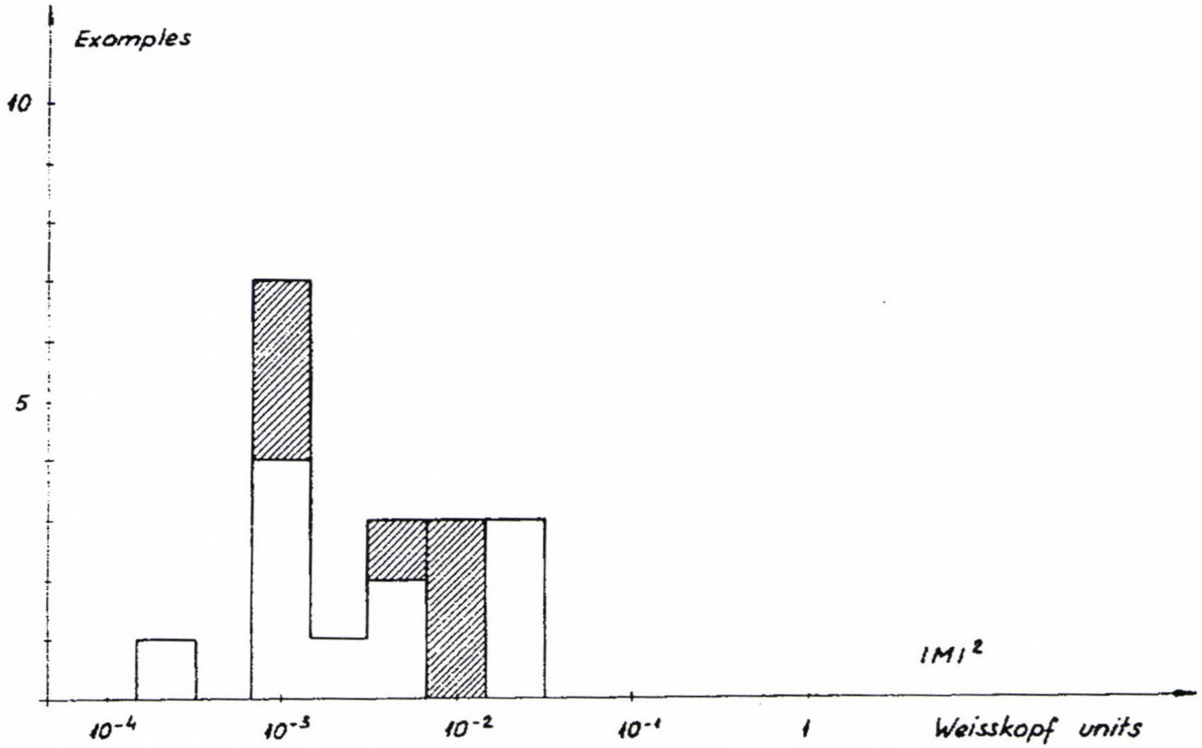
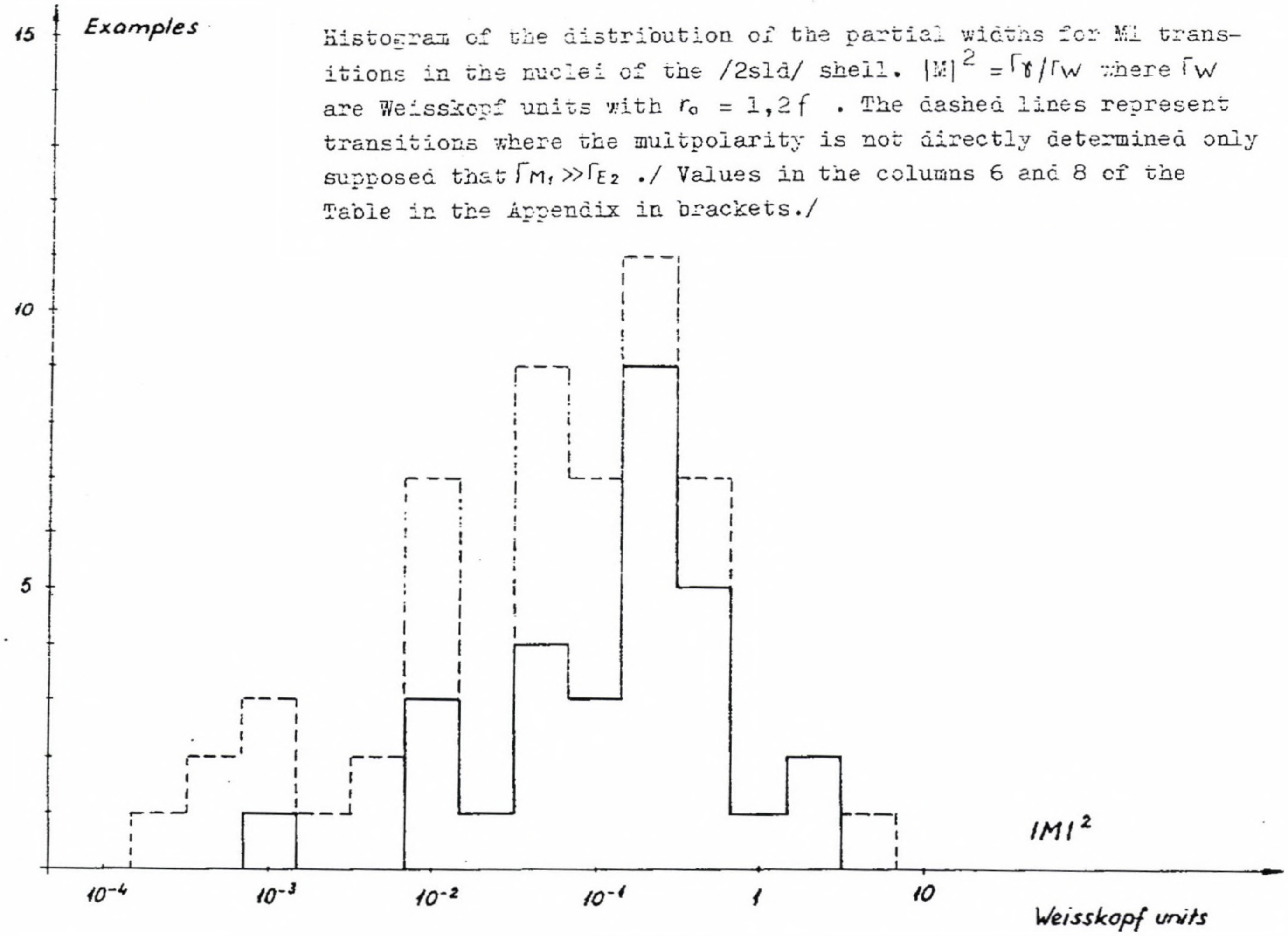


Fig. 1.

Histogram of the distribution of the partial widths for E1 transitions in the nuclei of the /2s1d/ shell. $|M|^2 = \Gamma_\gamma / \Gamma_W$, where Γ_W are Weisskopf units with $r_0 = 1{,}2\,f$. The shaded area represents transitions that may violate the isotopic spin selection rule.



Histogram of the distribution of the partial widths for M1 transitions in the nuclei of the /2s1d/ shell. $|M|^2 = \Gamma_\gamma / \Gamma_W$ where Γ_W are Weisskopf units with $r_0 = 1{,}2f$. The dashed lines represent transitions where the multpolarity is not directly determined only supposed that $\Gamma_{M_1} \gg \Gamma_{E_2}$ ./ Values in the columns 6 and 8 of the Table in the Appendix in brackets./

Fig. 2.

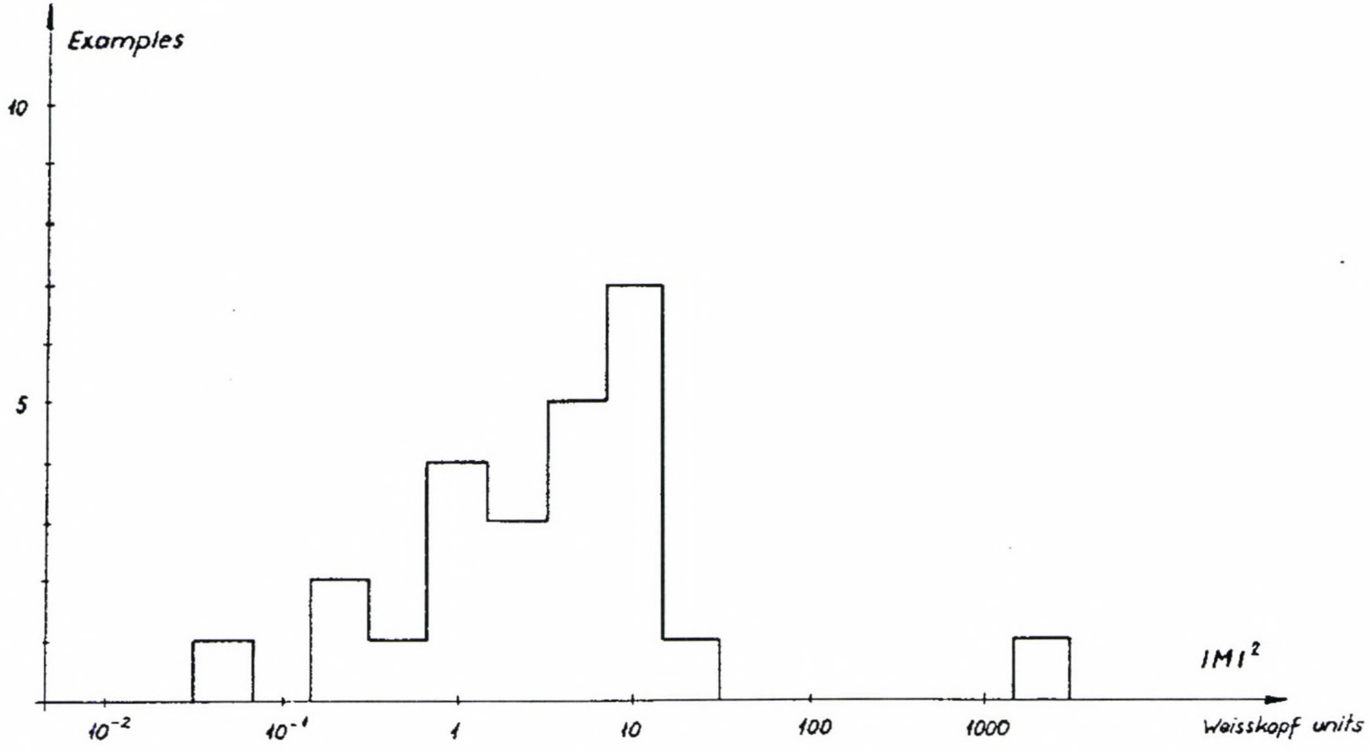


Fig. 3.

Histogram of the distribution of the partial widths for E2 transitions in the nuclei of the /2s1d/ shell. $|M|^2 = \Gamma_\gamma / \Gamma_W$, where Γ_W are Weisskopf units with $r_0 = 1{,}2 f$.

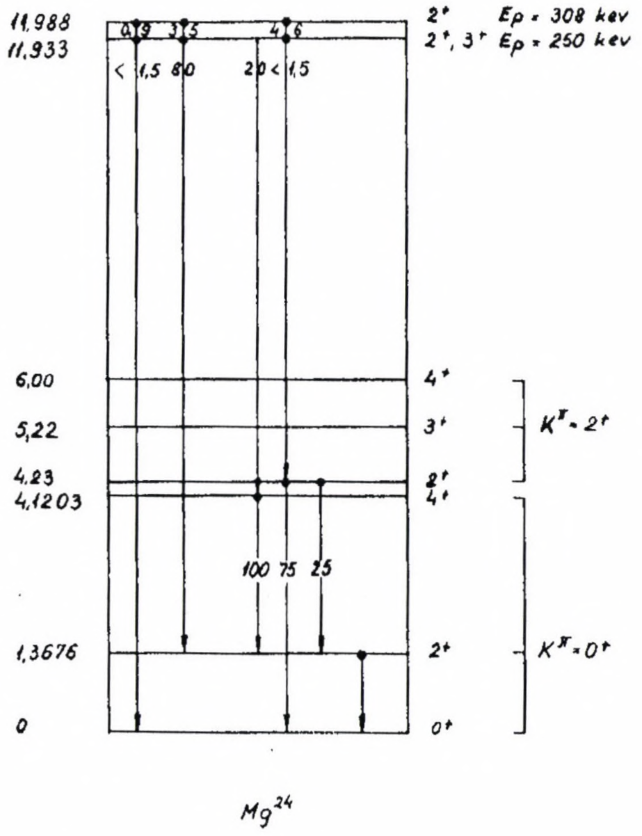
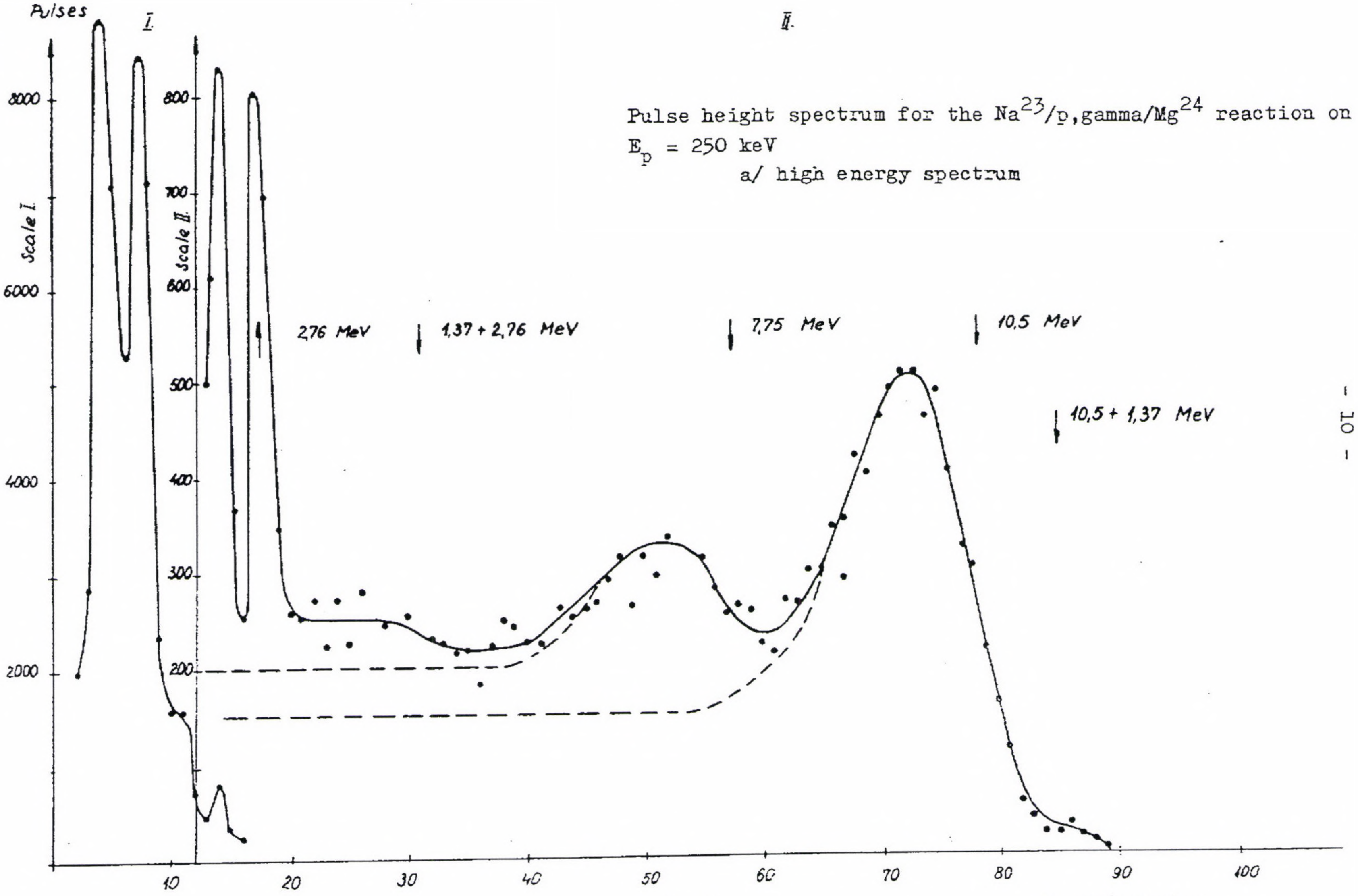


Fig. 4.

Level scheme of Mg^{24} reported by /8/.



Pulse height spectrum for the $Na^{23}/p,gamma/Mg^{24}$ reaction on E_p = 250 keV
a/ high energy spectrum

Fig. 5/a

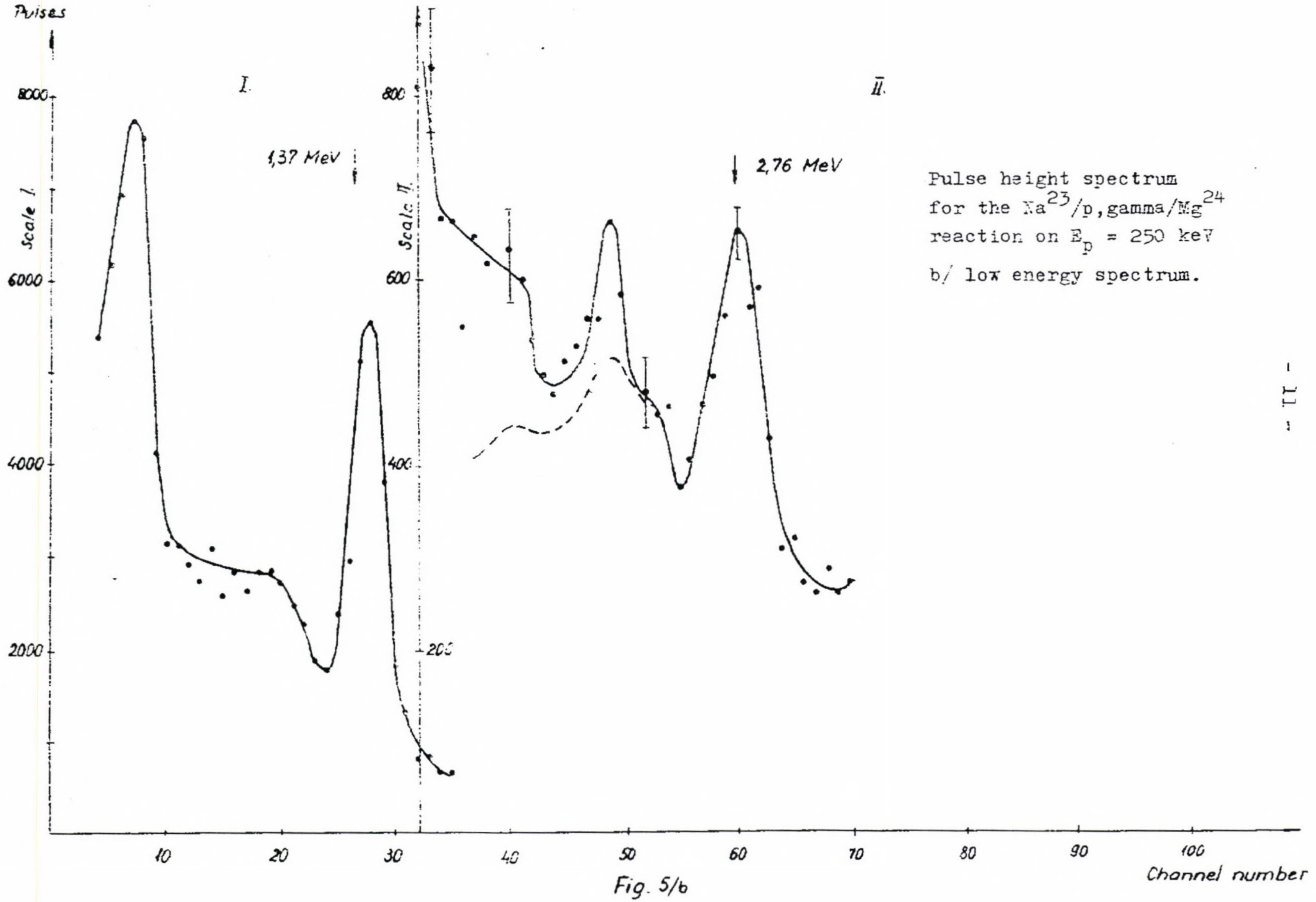


Fig. 5/b

Pulse height spectrum
for the Na^{23}/p,gamma/Mg^{24}
reaction on E_p = 250 keV
b/ low energy spectrum.

APPENDIX

APPENDIX

In the following appendix data available on the gamma-transitions in the /2s1d/ shell nuclei are summarized. The compilation 1-3 is given as reference for data taken from them. In listing the data we have been guided by following rules:

1/ Since the data listed are the partial level width of given transitions, the lifetimes are converted everywhere to level widths. The partial level widths are given only for higher intensity or highest energy radiations in known decay schemes. Upper limits of the level widths or transitions where the spin and parity of the initial or final state could not be assigned, are in general not listed.

2/ In the case when Γ_γ has been calculated from the yield of /p, γ / reactions with the use of $\Gamma p \gg \Gamma_\gamma$ i.e. $\Gamma p \approx \Gamma_t$ approximation, only the resonances at $E_p > 750$ keV are considered.

3/ For M1 type transitions where the type of radiation does not follow strictly from a selection rule or has not been experimentally confirmed, the data in the "Transition type" and $|M|^2$ columns are in brackets. In Fig.2 dashed lines are used for these plots.

4/ The values reported in the literature are subjected to criticism only if there is a great difference between various experimental results.

5/ The approximate cut-off date of this compilation is June 1, 1963.

Nucl.	E_i^{keV}	$I_i^{\pi i}$	E_f^{keV}	$I_f^{\pi f}$	Transition type	eV $\Gamma_{\gamma i\to f}$	Weisskopf units $\lvert M\rvert^2$	Ref
O^{17}	871± 4	$1/2^+$	0	$5/2^+$	E2	$(1,8\pm0,7).10^{-6}$	2	1
F^{17}	500± 3	$1/2^+$	0	$(5/2^+)$		$(1,5\pm0,4).10^{-6}$		1
O^{18}	1983	2^+	0	0^+	E2	$(1,2\pm0,2).10^{-4}$	2,5	Li 63
	3633	0^+	1983	2^+	E2	$(1,5\pm0,5).10^{-4}$	7,8	Li 63
	3921	2^+	1983	2^+	≥ 96%M1	$(3\pm1)\ .10^{-3}$	0,02	Li 63
F^{18}	940	(3^+)	0	1^+		$(3,8\pm0,6).10^{-4}$		Li 63
	1043	(0)	0	1^+		$2,2\ \ 10^{-3}$		3
	1085	(5^+)	940	(3^+)	E2	$(2,4\pm0,6).10^{-9}$	[illegible] 6	Li 63
	1700	1^+	0	1^+	(M1)	$(0,7\pm0,4).10^{-4}$	(10^{-3})	Li 63
			1043	0^+	M1	$(1,6\pm0,8).10^{-4}$	0,04	Li 63
	2104	(2^+)	0	1^+		$(2\ \pm0,6).10^{-4}$		
			940	(3^+)		$(2,3\pm0,7).10^{-4}$		Li 63
	2525	(3^+)	0	1^+		$(3\ \pm0,5).10^{-4}$		Li 63
			940	0^+		$(0,8\pm0,2).10^{-4}$		Li 63
O^{19}	96±11	$3/2^{\pm},5/2^+$	0	$5/2^+,3/2^+$	M1,E1	$(2,6\pm0,4).10^{-7}$		1
F^{19}	109,87±0,04	$1/2^-$	0	$1/2^+$	E1	$(4,5\pm1,1).10^{-7}$	$0,8.10^{-3}$	1
	198± 1	$(5/2^+)$	0	$1/2^+$	E2	$(3,7\pm0,7).10^{-9}$	4,6	1
	7700	$3/2^+$	0	$1/2^+$	M1	4,7	0,5	Ba 63
Ne^{19}	241± 4	$(5/2^+)$	0	$1/2^+$		$(2,5\pm0,2).10^{-8}$		1
Ne^{20}	1632± 4	2^+	0	0^+	E2	$(6\ \pm2,5).10^{-4}$	15	1
	≈9000	1^+	0	0^+	M1	7,1	0,5	Ba 63
	≈13000	1^+	0	0^+	M1	16,6	0,35	Ba 63
	13196	1^+	1632	2^+	(M1)	$0,28\pm0,06$	$(0,8.10^{-2})$	Be 63
	13332	1^+	0	0^+	M1	$0,05\pm0,02$	$1,2.10^{-3}$	Be 63
			1632	2^+	(M1)	$0,42\pm0,04$	$(1,4.10^{-2})$	Be 63
	13440	2^-	1632	2^+	E1	$12\ \pm1,5$	$1,5.10^{-2}$	Be 63
	13511	1^+	0	2^+	(M1)	$1,0\ \ 10^{-2}$	$(2\ .10^{-4})$	Ka 60
			1632	2^+	(M1)	2,2	$(6,7.10^{-2})$	1
	13703	2^-	1632	2^+	E1	$1,1\pm0,4$	$1,2.10^{-3}$	1
	14154	2^-	1632	2^+	E1	$4\ \pm0,7$	$4\ .10^{-3}$	1,Si54

Nucl.	E_i keV	$I_i^{\pi i}$	E_f keV	$I_f^{\pi f}$	Transition type	eV $\Gamma_{\gamma i \to f}$	Weisskopf units $\lvert M \rvert^2$	Ref.
Na^{22}	587± 4	1^+, 0	0	3^+, 0		$(1,7\pm0,1) \cdot 10^{-9}$		2
Na^{23}	439,2±0,8	$5/2^+$	0	$3/2^+$	(M1)	$(3,5\pm0,6) \cdot 10^{-4}$	(0,2)	2, Sw63
	4600	$3/2^+$	0	$3/2^+$	M1	0,43	0,22	Ba 63
	6100	$1/2^+$	0	$3/2^+$	M1	1,4	0,28	Ba 63
	9400	1/2	0	$3/2^+$		2,0±0,5		2, Mo60
Na^{24}	473± 3	1^+	0	4^+	(M3)	$(2,31\pm0,05) \cdot 10^{-14}$	(0,38)	2
Mg^{24}	1367,6±0,2	2^+	0	0^+	E2	$(3,8\pm0,6) \cdot 10^{-4}$	25	2
	≈10500		0	0^+	(M1)	≈ 100	(≈4)	3
	11000	1^+	0	0^+	M1	21	0,7	Ba 63
	12338	3^+	1370	2^+	(M1)	0,12	$(4,5 \cdot 10^{-3})$	Pr 62
			4230	2^+	(M1)	0,4	$(3,3 \cdot 10^{-2})$	Pr 62
	12532	1^+	0	0^+	M1	1,04	$3,4 \cdot 10^{-2}$	Pr 62
			4230	2^+	(M1)	0,41	$(3,4 \cdot 10^{-2})$	Pr 62
	12671	2^-	1370	2^+	E1	0,56	$8 \cdot 10^{-4}$	Pr 62
			4230	2^+	E1	2,4	$6 \cdot 10^{-3}$	Pr 62
	12809	2^+	0	0^+	E2	0,66	0,94	Pr 62
			1370	2^+	(M1)	0,24	$6,3 \cdot 10^{-3}$	Pr 62
	12819	1^+	0	0^+	M1	2,4	$6 \cdot 10^{-2}$	Pr 62
			4230	2^+	(M1)	1,6	$1,2 \cdot 10^{-1}$	Pr 62
	13033	3^+	4230	2^+	(M1)	2,1	(0,17)	Pr 62
	13053	4^+	4120	4^+	(M1)	7,5	(0,62)	Pr 62
	≈14000	1^+	0	0^+	M1	15,8	0,29	Ba 63
Mg^{25}	584± 4	$1/2^+$	0	$5/2^+$	E2	$(1,3\pm0,1) \cdot 10^{-7}$	0,65	2
	1611± 4	$(7/2)^+$	0	$5/2^+$	M1	$(2,7\pm0,7) \cdot 10^{-2}$	0,3	2
Al^{25}	455± 2	$1/2^+$	0	$5/2^+$	E2	$(2,4\pm0,1) \cdot 10^{-7}$	4	2
	3077±6	$3/2^-$	0	$5/2^+$	E1	$(1,4\pm0,3) \cdot 10^{-2}$	$7 \cdot 10^{-4}$	2
			455	$1/2^+$	E1	$(8,6\pm1,6) \cdot 10^{-2}$	$8 \cdot 10^{-3}$	2
	3720	$7/2^-$	0	$5/2^+$	E1	$(3,6\pm0,6) \cdot 10^{-3}$	$1,2 \cdot 10^{-4}$	2
			1810	$5/2^+$	E1	$(8,4\pm1,4) \cdot 10^{-3}$	$1,7 \cdot 10^{-3}$	2
	3840	$1/2^-$	455	$1/2^+$	E1	0,15±0,03	$6 \cdot 10^{-3}$	2

Nucl.	E_i keV	$I_i^{\pi i}$	E_f keV	$I_f^{\pi f}$	Transition type	eV $\Gamma_{\gamma i \to f}$	Weisskopf units $\lvert M \rvert^2$	Ref.
Al^{25}			949	$3/2^+$	E1	$0,30 \pm 0,06$	2.10^{-2}	2
	3880	$5/2^+$	0	$5/2^+$	(M1)	$(4,6 \pm 0,8).10^{-4}$	(4.10^{-4})	2
			949	$3/2^+$	(M1)	$(3,8 \pm 0,6).10^{-3}$	(0,011)	2
	4220	$3/2^+$	455	$1/2^+$	(M1)	$0,18 \pm 0,03$	(0,15)	2
			949	$3/2^+$	(M1)	$0,14 \pm 0,03$	0,2	2
	4590	$5/2^+$	949	$3/2^+$	(M1)	$(3,9 \pm 0,8).10^{-2}$	(0,04)	2
Mg^{26}	1805 ± 10	2^+	0	0^+	E2	$(7,6 \pm 1,6).10^{-4}$	13	2
Al^{26}	$418 \pm 1,4$	3^+	0	5^+	E2	$(3,7 \pm 0,2).10^{-7}$	9,3	2
Al^{27}	842	$1/2^+$	0	$5/2^+$	E2	$(1,4 \pm 0,5).10^{-5}$	7	2
	1013	$3/2^+$	0	$5/2^+$	90%M1	$(2,3 \pm 1).\ 10^{-4}$	$1,2.10^{-2}$	2
	2212	$3/2^-$	0	$5/2^+$	E1	$1,5\ .\ 10^{-2}$	$2,5.10^{-3}$	Bo 62
	2976	3/2	0	$5/2^+$		10		Bo 62
	8965	$3/2^{(+)}$	0	$5/2^+$		$0,21 \pm 0,05$		Op 62
Al^{28}	$31,2 \pm 0,4$	2^+	0	3^+	(M1)	$(2,0 \pm 0,2).10^{-7}$	$(4,4.10^{-2})$	2
Si^{28}	1772 ± 5	2^+	0	0^+	E2	$(7,6 \pm 1,3).10^{-4}$	13	2
	11600	1^+	0	0^+	M1	47	1,56	3
	12067	2^+	0	0^+	E2	0,14	0,15	2, Sm 62
	12171	4^+	6270	3^+	(M1)	0,01	$(2,5.10^{-3})$	2, Sm 62
	12190	3^-	1772	2^+	E1	0,64	$1,2.10^{-3}$	2, Sm 62
	12235	2^+	1772	2^+	64%M1	0,44	$1,1.10^{-2}$	2, Sm 62
			9380	2^+	(M1)	0,32	0,65	2, Sm 62
	12445	2^+	0	0^+	E2	0,4	0,33	Sm 62
	12471	4^+	1772	2^+	E2	0,9	1,28	Sm 62
	12722	2^+	0	0^+	E2	1,5	1	Sm 62
Si^{29}	1277 ± 4	$3/2^+$	0	$1/2^+$	96%M1	$3\ .\ 10^{-3}$	0,1	Bo 62 Mc 61
	2425 ± 4	$3/2^+$	0	$1/2^+$	M1	$2,2.10^{-2}$	$7,8.10^{-2}$	Bo 62
P^{29}	4342	$3/2^-$	0	$1/2^+$	E1	$1,8 \pm 0,3$	3.10^{-2}	2
	4765	$1/2^+$	0	$1/2^+$	M1	$0,43 \pm 0,08$	0,22	2
P^{31}	1265 ± 3	$3/2^+$	0	$1/2^+$	94%M1	$1,5.10^{-3}$	0,6	2, Mc 61 Bo 62

Nucl.	E_i keV	$I_i^{\pi i}$	E_f keV	$I_f^{\pi f}$	Transition type	eV $\Gamma_{\gamma i \to f}$	Weisskopf units $\lvert M\rvert^2$	Ref.
P^{31}	2232	$5/2^+$	0	$1/2^+$	E2	10^{-3}	4	2, Bo 62
	3133	$3/2^+$	0	$1/2^+$	96%M1	$2,2.10^{-2}$	5.10^{-2}	2, Bo 62 Br 58
	3600	$3/2^+$	0	$1/2^+$	M1	0,29	0,25	Ba 63
	7886	$1/2^+$	0	$1/2^+$	M1	$1,52\pm0,12$	0,13	2
	7934	$3/2^+$	0	$1/2^+$	(M1)	$(6\pm1).\ 10^{-3}$	(5.10^{-4})	2
			1265	$1/2^+$	(M1)	$(8\pm1).\ 10^{-3}$	$(1,3.10^{-3})$	2
	8021	$5/2^+$	0	$1/2^+$	E2	$(5\pm1).\ 10^{-3}$	$3,3.10^{-2}$	2
	8038	$3/2^+$	0	$1/2^+$	(M1)	$0,14\pm0,01$	$(1,3.10^{-2})$	2
	8900	$3/2^+$	0	$1/2^+$	M1	4,0	0,26	Ba 63
S^{32}	2236	2^+	0	0^+	E2	$2\ \pm0,3.10^{-3}$	8	2, Ba 63
	5700	1^+	0	0^+	M1	0,76	0,20	Ba 63
	8500	1^+	0	0^+	M1	3,5	0,26	Ba 63
	10696	1^-	0	0^+	E1	12	$1,3.10^{-2}$	2, Pa 55
	10826	1^-	0	0^+	E1	8,7	10^{-2}	2, Pa 55
	10917	1^-	0	0^+	E1	1,3	$1,2.10^{-3}$	2, Pa 55
	11400	1^+	0	0^+	M1	14,2	0,40	Ba 63
Cl^{34}	143	3^+	0	0^+	M3	$(6,5\pm0,8).10^{-18}$	6,5	2
Cl^{35}	7230	$5/2^+$	0	$3/2^+$	99%M1	0,055	$8,3.10^{-3}$	2
			1220	$1/2^+$	E2	0,012	0,3	2
	7545	$7/2^-$	3163	$7/2^-$	(M1)	0,1	$(4,6.10^{-2})$	2
Cl^{38}	671 ± 3	$(5)^-$	0	2^-		$(4,5\pm1).10^{-16}$		2
A^{39}	1516 ± 9	$3/2^+$	0	$7/2^-$	(M2)	$(2,4\pm0,1).10^{-7}$	0,12	2
A^{40}	2130	0^+	1462	2^+	E2	$(1,4\pm0,3).10^{-3}$	1400	2, Wa 62
K^{40}	$29,7\pm0,7$	3^-	0	4^-	M1	$(1,2\pm0,1).10^{-7}$	3	2
Ca^{40}	$3730\ \pm\ 4$	3^-	0	0^+	E3	$(6,4\pm0,3).10^{-6}$	160	2
	9870	2^+	0	0^+	E2	$0,80\pm0,26$	1,7	Ra 62
	10300	2^+	0	0^+	E2	$3,6\ \pm0,24$	5	Ec 61

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