THE $J \rightarrow J$ RULE FOR M1 TRANSITIONS IN ^{38}Ar

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Received 17 August 1967

The γ decay of resonances in the ^{37}Cl(p,γ)^{38}Ar reaction in the E_p = 1-2 MeV region has been investigated with a Ge(Li) counter. Mean lives of 11 bound states are found from γ-ray Doppler shift measurements. The J^{π} values of resonances and three bound states are obtained from γ-ray angular-distribution and polarization measurements. The E_p = 1732 keV, $J^{\pi} = 4^-$, resonance can be regarded as the analogue of ^{38}Cl(3). The enhancement of $J \rightarrow J$ M1 transitions, formerly observed for $5^- \rightarrow 5^-$, has also been observed for $3^- \rightarrow 3^-$ and $4^- \rightarrow 4^-$ transitions.

Strongly enhanced $J^{\pi} = 5^- \rightarrow 5^-$ (as compared to $5^- \rightarrow 4^-$) M1 transitions between states in the $d_{\frac{3}{2}}{}^3f_{\frac{7}{2}}$ configuration in ^{38}Ar have been found and explained by Erné et al. [1]. It was found that the E_p = 1089 and 1093 keV, $J^{\pi} = 5^-$, ^{37}Cl(p,γ)^{38}Ar resonances can be regarded as the split analogue of ^{38}Cl(1). The analogue of ^{38}Cl(2), with $J^{\pi} = 3^-$, has been shown by Bošnjaković et al. [2] to be split into at least seven components, centered around E_p = 1140 keV, as observed with the ^{37}Cl(p,α)^{34}S reaction.

The purpose of the present note is to report on the γ decay of the strongest of these 3^- components, at E_p = 1138 keV, and on that of the analogue of ^{38}Cl(3), with $J^{\pi} = 4^-$, which was located at E_p = 1732 keV. It will be shown that these two resonances provide striking examples of $J \rightarrow J$ enhancement. Part of this investigation was the determination of lifetimes and of J^{π} values of ^{38}Ar levels. The γ decay of the two 5^- resonances was reinvestigated.

Protons were accelerated with a 3 MeV Van de Graaff generator. Gamma radiation was detected with a 20 cm^3 Ge(Li) counter, coupled to a 4096-channel Laben analyser. The target material was Ba^{37}Cl$_2$ evaporated onto directly water-cooled tantalum backings.

The branchings of the E_p = 1138 and 1732 keV resonances, and the average branchings of the E_p = 1089 and 1093 keV resonances (the γ decay of those resonances is almost identical) are given in fig. 1.

The unraveling of the complex γ-ray spectra was greatly helped by a preceding determination (to be published elsewhere) of the accurate excitation energies (errors 0.14 - 2.0 keV) of 21 ^{38}Ar bound states and of the Q value of the ^{37}Cl(p,γ)^{38}Ar reaction (error 1.1 keV).

Doppler shifts were measured of all stronger γ rays observed at the resonances mentioned above and at the E_p = 1136, 1142, 1262 and 1320 keV resonances, by taking spectra at $\theta = 0^{\circ}$ and 140°. From the observed shifts, mean lives (or lower limits) were obtained of nine ^{38}Ar levels (fig. 1), by applying the slowing-down theory developed by Lindhard et al. [3] and elaborated by Blaugrund [4].

Angular distributions were measured of all γ rays at the E_p = 1089 ($J^{\pi} = 5^-$), 1138 and 1732

Table 1
Angular distribution coefficients A_2 and polarizations P of γ-rays from the ^{37}Cl(p,γ)^{38}Ar reaction.

E_{γ} (MeV)	Transition (E_x in MeV)	A_2^*	P
	E_p = 1089 keV resonance		
4.70	11.30 → 6.60	-0.30 ± 0.10	
	E_p = 1138 keV resonance		
9.18	11.35 → 2.17	-0.30 ± 0.02	
6.47	11.35 → 4.88	+0.24 ± 0.07	-0.15 ± 0.07
2.71	4.88 → 2.17	+0.04 ± 0.15	
1.07	4.88 → 3.81	+0.40 ± 0.12	-0.18 ± 0.05
	E_p = 1732 keV resonance		
7.34	11.93 → 4.59	+0.14 ± 0.04	
5.72	11.93 → 6.21	+0.28 ± 0.03	-0.65 ± 0.30
5.33	11.93 → 6.60	+0.31 ± 0.02	-0.35 ± 0.18
2.12	6.60 → 4.48	+0.22 ± 0.03	
1.73	6.21 → 4.48	-0.03 ± 0.04	

* The angular distribution is written as $1 + A_2P_2(\cos\theta)$. All A_4 coefficients are zero within the experimental error.

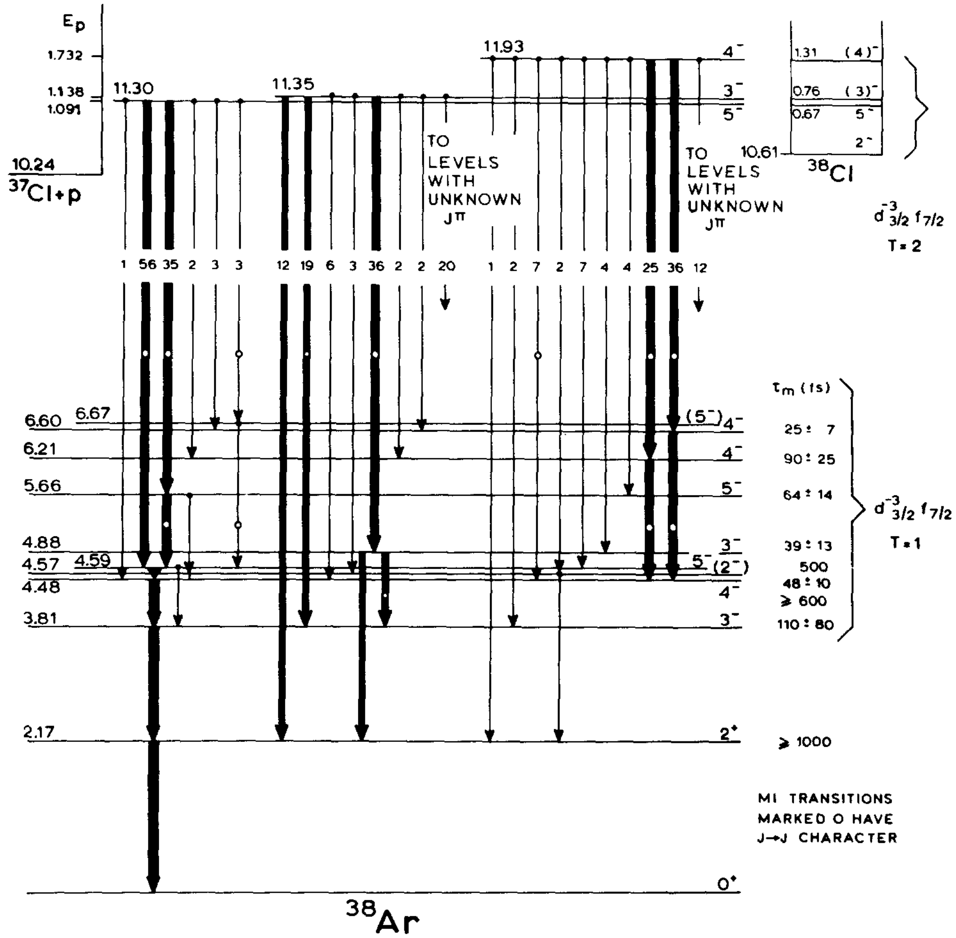

Fig. 1. Gamma decay of $J^\pi = 3^-$, 4^- and 5^- analogue states in ^{38}Ar. The branching of the E_x = 11.30 MeV level as given here is actually the average of the (almost identical) branchings of the E_p = 1089 and 1093 keV resonances. The E_p = 1138 keV resonance is the strongest of the seven components into which the 3^- analogue is split. The $J \rightarrow J$ transitions are seen to be strongly enhanced as compared to $J \rightarrow J \pm 1$. The 4.88 MeV level decays 50%, the 5.66 MeV level 90% through a $J \rightarrow J$ transition.

keV resonances, by taking spectra at $\theta = 0^\circ$, 35°, 55° and 90°. The linear polarization of the most prominent γ rays, emitted at 90°, was determined with a NaI Compton polarimeter [5]. The relevant results are presented in table 1. These data were analysed with a χ^2 grid search program, in which all continuous parameters (resonence statistical tensors and γ-ray mixing parameters) were varied in steps, for all possible J^π combinations. Possibilities involving γ-ray transition strengths of more that 10 W.u. were left out of consideration. It was found (as will be shown in detail in a forthcoming paper) that only assignments of $J^\pi = 3^-$ to the E_x = 4.89 and 11.35 MeV levels and of $J^\pi = 4^-$ to the E_x = 6.21, 6.60 11.93 MeV levels agreed with the measurements, while all other J^π possibilities led to χ^2 values above the 0.1% confidence limit. Probable asignments to the E_x = 4.57 and 6.67 MeV levels (see fig. 1) will not be discussed here.

All the odd-parity states found so far can be considered as having predominantly a $d_{\frac{3}{2}}^{-3} f_{\frac{7}{2}}$ configuration [6]. All $J \rightarrow J$ M1 transitions within this configuration, both for $T = 2 \rightarrow 1$ and $T = 1 \rightarrow 1$, are seen to be (fig. 1) about an order of magnitude stronger (with transition strengths between 0.1 and 0.4 W.u) than the $J \rightarrow J \pm 1$ transitions. It is hoped that the many states [6] within the $d_{\frac{3}{2}}^{-3} f_{\frac{7}{2}}$ configuration may be sorted by quantitative comparison of theoretical and measured transition probabilities.

We want to thank C. Alderliesten, M. J. N. Jacobs, Prof. H. Lindeman and P. de Wit for as-

sistance in different stages of this work.

This investigation was partly supported by the joint research program of the "Stichting voor Fundamenteel Onderzoek der Materie" and the "Nederlandse Organisatie voor Zuiver Wetenschappelijk Onderzoek".

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GROUND STATE SPIN OF ^{129}Te BY POLARIZATION MEASUREMENTS OF PROTONS SCATTERED VIA ANALOGUE RESONANCES

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Received 4 August 1967

Polarization measurements of protons elastically scattered from ^{128}Te have been made at bombarding energies spanning the ^{129}Te ground-state isobaric-analogue resonance at 7.95 MeV. Our measurements allow an unambiguous $d_{\frac{3}{2}}$ assignment for the ground state of ^{129}Te.

Robson et al. [1] have shown that a measurement of the polarization of protons elastically scattered from spin-zero targets over an isobaric-analogue resonance allows a unique assignment of the J value of that resonance. Recent work [2] has shown that this method is applicable even for resonances with partial widths as low as 5% of the total width. The best method of investigating polarization effects is obviously by the use of a polarized beam as reported by Veeser and Haeberli [2]. However, the present series of experiments indicates that with a properly designed double-scattering polarimeter laboratories without the complicated beam polarization facility can still undertake useful experiments. A detailed description of the polarimeter is to be published elsewhere [3].

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Part of the ^{128}Te(p,p$_0$) excitation function in shown in fig. 1. The lengths of the solid lines projecting downwards are proportional to the spectroscopic factors for the various neutron states seen in ^{128}Te(d,p)^{129}Te studies [4]. The solid curves beneath the excitation function are approximate shapes for s and d-wave resonances at 160^o. The boxed resonance at 7.95 MeV bombarding energy is identified as the analogue of the ground state of ^{129}Te which is known [4] to be a d-wave state. As the $d_{\frac{5}{2}}$ subshell has already been filled, all d states of appreciable strength in ^{128}Te are expected to be $d_{\frac{3}{2}}$ states. The analogue of the $h_{\frac{11}{2}}$ state is not seen because of the small penetrability for h-wave protons.

The shape of the polarization excitation curve over an energy region covering the 7.95 MeV resonance is shown in fig. 2. The data were taken at 140^o to the beam direction using a 10 keV ^{128}Te target on a thin carbon backing. The solid and broken cruves are the theoretical predictions of Robson et al. [1] for $d_{\frac{3}{2}}$ and $d_{\frac{5}{2}}$ resonances, respectively. The predictions are for a first