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ANOMALOUS ^{one}M-1 STRENGTHS AND DOORWAY STATES
IN NEUTRON CAPTURE*

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ABSTRACT: Recent experiments concerning the anomalous ratio of M-1 and E-1 strengths in ^{36}Cl and ^{57}Fe are interpreted as strong evidence for doorway state reaction mechanisms in neutron capture.

Recently several striking exceptions to the rule of random decay for compound nucleus resonances were pointed out for $^{35}\text{Cl}(n,\gamma)$, ^{36}Cl and $^{56}\text{Fe}(n,\gamma)^{57}\text{Fe}$.^{1,2} In these cases the spectra of high energy γ rays deexciting neighboring $\ell=0$ and $\ell=1$ resonances were quite similar, and the E-1 and M-1 strengths were moreover of the same size.

In ref. 1 there was no attempt to analyze the observed data by subdividing the transitions into groups according to the ℓ -values of the final single particle states. The purpose of this note is to indicate that when this is done, the data are suggestive of the strong influence of 3-quasiparticle doorway states in neutron capture.

For the case of ^{35}Cl , capture in the 2^- 398 eV resonance was compared to capture at thermal, dominated by a 2^+ bound level; in ^{56}Fe , capture in the 1167 eV $1/2^-$ resonance was compared to $1/2^+$ capture at thermal. We divide the final states of ^{36}Cl into three groups: $\ell_n=0$, $\ell_n=1$ and $\ell_n\geq 2$. For ^{56}Fe the final states can be divided into those with $j_n=1/2^-$ and $j_n=3/2^-$. Tables 1 and 2 show the transition strengths displayed in those groups.

By inspection it is apparent that for transitions where either $\Delta\ell_n=0$ or $\Delta j_n=0$, i.e. no change in the quantum numbers of the captured neutron, then $B(M1)>B(E1)$. (The $\Delta\ell_n=0$ group for ^{36}Cl shows a departure from this tendency, perhaps due to the presence of $\Delta j_n\neq 0$ components in the transitions with $\Delta\ell_n=0$.)

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In contrast to the above situation the more complex set of transitions with $\Delta l_n \neq 0$, to levels of ^{36}Cl with $l_n \geq 2$, show values of $B(E1)$ approximately equal to $B(M1)$; in ^{57}Fe the transitions with $\Delta j_n \neq 0$ show $B(E1)$ values which tend to be even larger than $B(M1)$. It is thus the more complex set of transitions that is responsible for the correlations and approximate equality of $E1$ and $M1$ strengths pointed out in ref. 1.

This behavior provides strong evidence for the presence of a semi-direct reaction mechanism caused by the coupling of a collective state to the neutron entrance channel. The fact that $B(E1) < B(M1)$ for the $\Delta l_n = 0$ and $\Delta j_n = 0$ transitions supports the concept of a $M-1$ giant resonance located more closely to the neutron binding energy than is the $E-1$ giant resonance.

It is significant that both target nuclides have two holes relative to a closed shell (^{35}Cl $N=18$ and ^{56}Fe $Z=26$). The doorway can be a simple 2-hole, 1 particle configuration, leading to the expectation that similar effects could be seen in other 2-neutron or 2-proton hole target nuclides.

Table 1 - ^{36}Cl

E_x	l	J^π	$I_Y(2^+)^{\dagger}$	$I_Y(2^-)^{\dagger}$
1163	0,2	1^+	10.0	0.4
1601	0	1^+	2.23	0.6
1958	0	2^+	8.1	14.4
2492	0	2^+	1.08	0.3
3331	1	$1,2^-$	0.53	1.9
3635	1	1^-	0.7	< 0.3
3962	1	$1,2^-$	0.65	1.6
0	2(0)	2^+	2.6	2.8
788	2	3^+	8.6	7.0
1951	3	3^-	4.6	4.2
2468	1,3	3^-	19.7	20.4
2676	2(0)	1^+	1.11	1.3
2863	2(0)	3^+	5.14	3.6
3599	1	3^-	3.53	2.8

$\dagger$ Intensities in photon/100 captures.

Table 2 - ^{57}Fe

E_x	ℓ	J^π	$I_\gamma(1/2^+)^{\dagger}$	$I_\gamma(1/2^-)^{\dagger}$
0	1	$1/2^-$	22.1	15.75
1263	1	$1/2^-$	0.64	11.3
2694	1	$1/2^-$	0.51	1.8
3182	1	$1/2^-$	0.61	1.8
14	1	$3/2^-$	27.2	30.9
3667	1	$3/2^-$	4.6	0.68
1625	1	$3/2^-$	8.1	1.11
1723	1	$3/2^-$	8.3	2.41
3368	1	$3/2^-$	0.37	0.42
3425	1	$3/2^-$	0.97	0.47

$\dagger$ Intensities in photons/100 captures.

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