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FRAGMENTATION OF THE OCTUPOLE STRENGTH IN $^{205}Tl(p,p')^{205}Tl$[†]

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In addition to the octupole transitions to the apparent weak-coupling doublet [$3s_{1/2}^{-1}$, $Pb^{206}3^-$] at 2.62-2.71 MeV, three other strong octupole transitions to nearby states are observed in the inelastic scattering of 20 MeV protons from ^{205}Tl. Two of these extra states, at 3.21 and 3.26 MeV, may arise from the [$2d_{3/2}^{-1}$, $Pb^{206}3^-$] configuration. It is not likely that the other transition (2.48 MeV) can be described by the simple weak-coupling model.

— — —

The study [1] of isobaric analog resonances in the $^{205}Tl(p,p')^{205}Tl$ reaction revealed a doublet at an excitation energy near 2.65 MeV in ^{205}Tl. Its position, resonant structure, and absolute cross section indicated that it arises from the weak coupling of a $3s_{1/2}$ proton hole to the 3^- state at 2.65 MeV in Pb^{206}. Although such weak-coupling multiplets are well known [2] in other nuclei in this region, its appearance in ^{205}Tl is surprising since the low-lying states in this nucleus are not well described by the weak-coupling model.

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In fact, an intermediate coupling calculation [3] which gives reasonable agreement with experimental spectroscopic factors suggests that the ground-state of ^{205}Tl is quite mixed. It is expected to closely resemble ^{203}Tl, for which the following wave function was calculated [3]:

$$\psi_{g.s.} = 0.88\,[3s_{1/2}^{-1},\ ^{206}\text{Pb}\ 0^+] - 0.38\,[2d_{3/2}^{-1},\ ^{206}\text{Pb}\ 2^+]$$

$$+ 0.24\,[2d_{5/2}^{-1},\ ^{206}\text{Pb}\ 2^+] + \cdots$$

We have studied the inelastic scattering of protons near 20 MeV to investigate weak coupling in ^{205}Tl, and also to confirm the existence of several states observed [4] in the ^{208}Pb(p,α)^{205}Tl reaction. Angular distributions were taken over the range 27° - 150° for both ^{205}Tl and ^{206}Pb. The ratios of the absolute cross sections for ^{205}Tl and ^{206}Pb are accurate to about ±7%, although the individual absolute cross sections have errors of about ±15%. The energy resolution in four Si(Li) detectors was about 25 keV. The targets were thin evaporated metallic foils with isotopic enrichment (98.8% for ^{205}Tl, 97.2% for ^{206}Pb).

Angular distributions for the 0.803-(2^+), 2.648-(3^-), 1.684-(4^+), and 3.776-MeV (5^-) states in ^{206}Pb are shown in Fig. 1. The spins have been assigned previously [5]. The curves are macroscopic-model DWBA calculations with optical parameters determined from the elastic scattering cross section and strengths determined by normalization to the experimental data. Note that the angular distributions are quite characteristic of the transferred angular momentum (L).

Angular distributions for five states at excitation energies of 2.48, 2.62, 2.71, 3.21, and 3.26 MeV in ^{205}Tl are illustrated in Fig. 2. The solid

line has the shape of a smooth curve drawn through the data points for the 2.65-MeV (3^-) state in ^{206}Pb. This curve matches the ^{205}Tl angular distributions very well in every case, and allows the assignment of L = 3 (spin $5/2^-$ or $7/2^-$) to each of these levels. Other levels excited in the (p,p') reaction will be discussed in a later publication [4]. Several of these appear to be additional L = 3 transitions, but their cross sections are small and a definite spin assignment cannot be made. However, of special interest is a level at 0.92 MeV which was observed also in the ^{208}Pb(p,α)^{205}Tl reaction [4] but not in the ^{206}Pb(t,α)^{205}Tl reaction [6] or the ^{205}Tl(γ,γ')^{205}Tl reaction [7]. Comparison with the ^{206}Pb results gives a distinct L = 4 distribution (spin $7/2^+$ or $9/2^+$), with a strength equal to 45% of the 1.69 MeV level in ^{206}Pb.

The existence of so many L = 3 transitions appears to contradict the description of the 2.62 - 2.71 MeV doublet as a pure $3s_{1/2}$ hole coupled weakly to the 3^- state in ^{206}Pb. If the ground state of ^{205}Tl were simply [$3s_{1/2}^{-1}$, ^{206}Pb 0^+], this would certainly be true. However, it is possible that the extra transitions are transitions from other configurations in the ^{205}Tl ground state to relatively pure weak-coupling excited states.

For the 3.21 - 3.26 MeV states, this explanation is plausible. The weak-coupling model predicts a quadruplet of states near 3.05 MeV with the configurations [$2d_{3/2}^{-1}$, ^{206}Pb 3^-]. Such a multiplet has been observed at approximately this energy in ^{207}Tl via the (t,p) reaction [8] on ^{205}Tl, but this reaction has not been carried out on ^{203}Tl. The $5/2^-$ and $7/2^-$ states of this configuration could be excited in the (p,p') reaction via an L = 3 transition from the [$2d_{3/2}^{-1}$, ^{206}Pb 2^+] component in the ^{205}Tl ground state. In a pure phonon description of the ^{206}Pb states, this would be a second-order process; the strong

excitation of the 3.26-MeV state would thus imply an enhanced B(E3) [^{206}Pb $3^- \rightarrow$ ^{206}Pb 2^+].

The 2.48 MeV state is less likely to be a pure weak-coupling state. Of expected nearby states, only the $[1h_{11/2}^{-1}, {}^{206}\text{Pb}\ 2^+]_{7/2^-}$ configuration has the proper spin; its zero-order energy is 2.28 MeV. The excitation of this configuration from the calculated ground state should be weak.

Another explanation for these strong L = 3 transitions, of course, is the possible admixture of the $[3s_{1/2}^{-1}, {}^{206}\text{Pb}\ 3^-]$ component in $5/2^-$ or $7/2^-$ states whose dominant structure may be unrelated to the 3^- state in ^{206}Pb. This is especially likely for the 2.48-MeV state which lies close to the 2.62 - 2.71 MeV doublet. The summed cross section for the doublet is 55 ± 5% of the cross section for the 3^- state in ^{206}Pb; a value of 60-70% was obtained by Solf *et al.* [1]. Their value is almost consistent with a weak-coupling description of this doublet, since the probability of the $[3s_{1/2}^{-1}, {}^{206}\text{Pb}\ 0^+]$ component in the ground state is about 75%. Our value of 55% is probably too small to be consistent with this description; however if the 2.48 MeV state is included in the sum, our ratio becomes 67%. The measured ratio of the cross sections for the two states of the ^{205}Tl doublet at the 60° maximum is 0.85 ± 0.06, whereas the weak-coupling prediction is 0.75, the value obtained in ref. 1.

If the $[3s_{1/2}^{-1}, {}^{206}\text{Pb}\ 3^-]$ component is present in the 2.48, 3.21 or 3.26 MeV states, the (p,p') cross sections to these states should resonate at the same incident energies as the 2.62 - 2.71 MeV doublet. Experiments are currently being conducted at Rutgers to observe such resonance structure which was not found in the earlier work [1].

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FIGURE CAPTIONS

Fig. 1. Differential cross sections for excitation of several low lying states in ^{206}Pb from proton inelastic scattering. The curves are DWBA calculations.

Fig. 2. Differential cross sections for excitation of several low lying states in ^{205}Tl from proton inelastic scattering showing L = 3 angular distributions. The same curve has been drawn through all five distributions; it has the shape of a smooth curve drawn through the data points for the 2.65 MeV (3^-) state in ^{206}Pb.

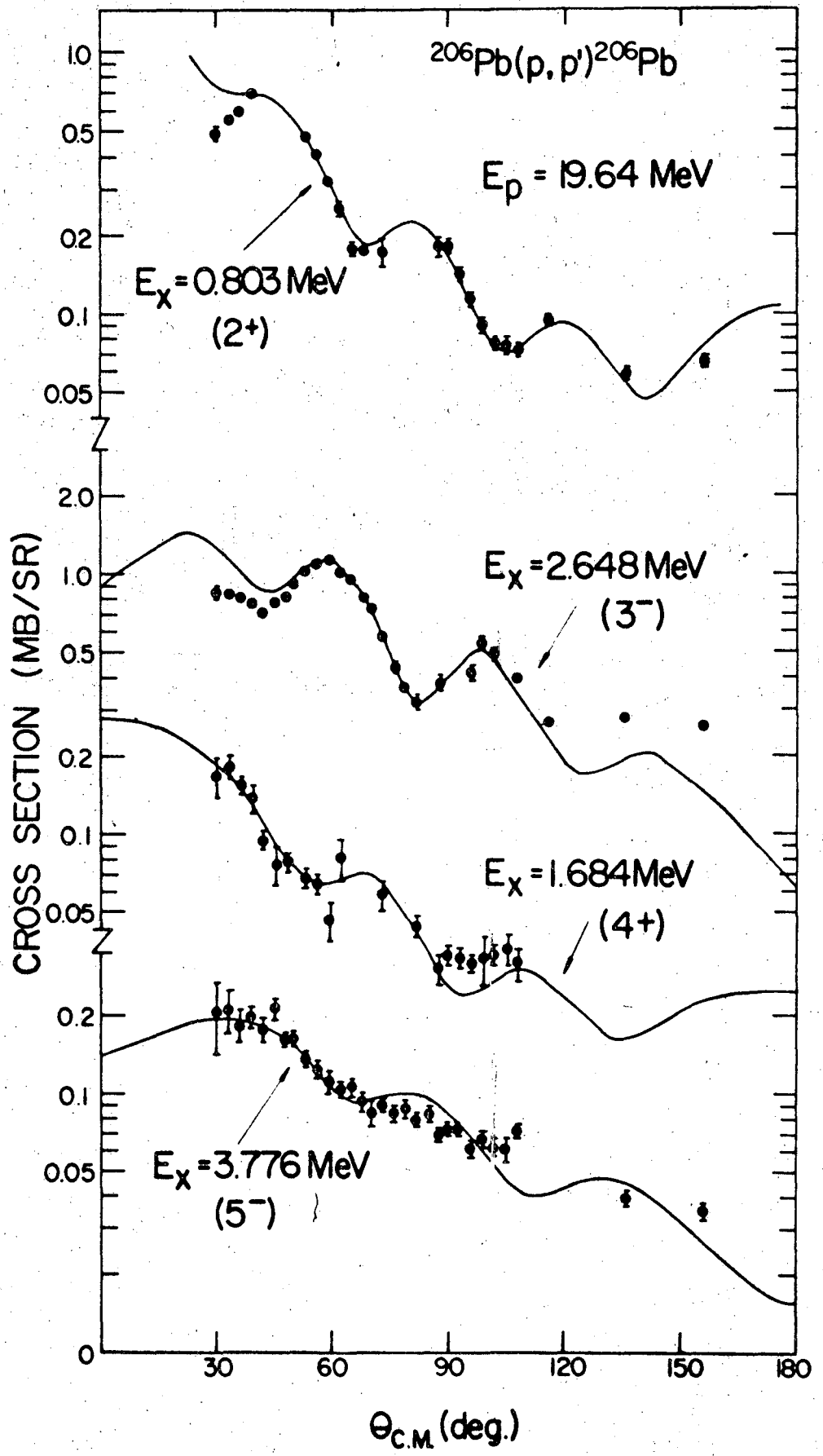
$^{206}Pb(p, p')^{206}Pb$
E_p = 19.64 MeV
E_x = 0.803 MeV
(2+)
E_x = 2.648 MeV
(3⁻)
E_x = 1.684 MeV
(4+)
E_x = 3.776 MeV
(5⁻)
CROSS SECTION (MB/SR)
$\theta_{c.m.}$ (deg.)
1.0
0.5
0.2
0.1
0.05
2.0
0
30
60
90
120
150
180

Fig. 1

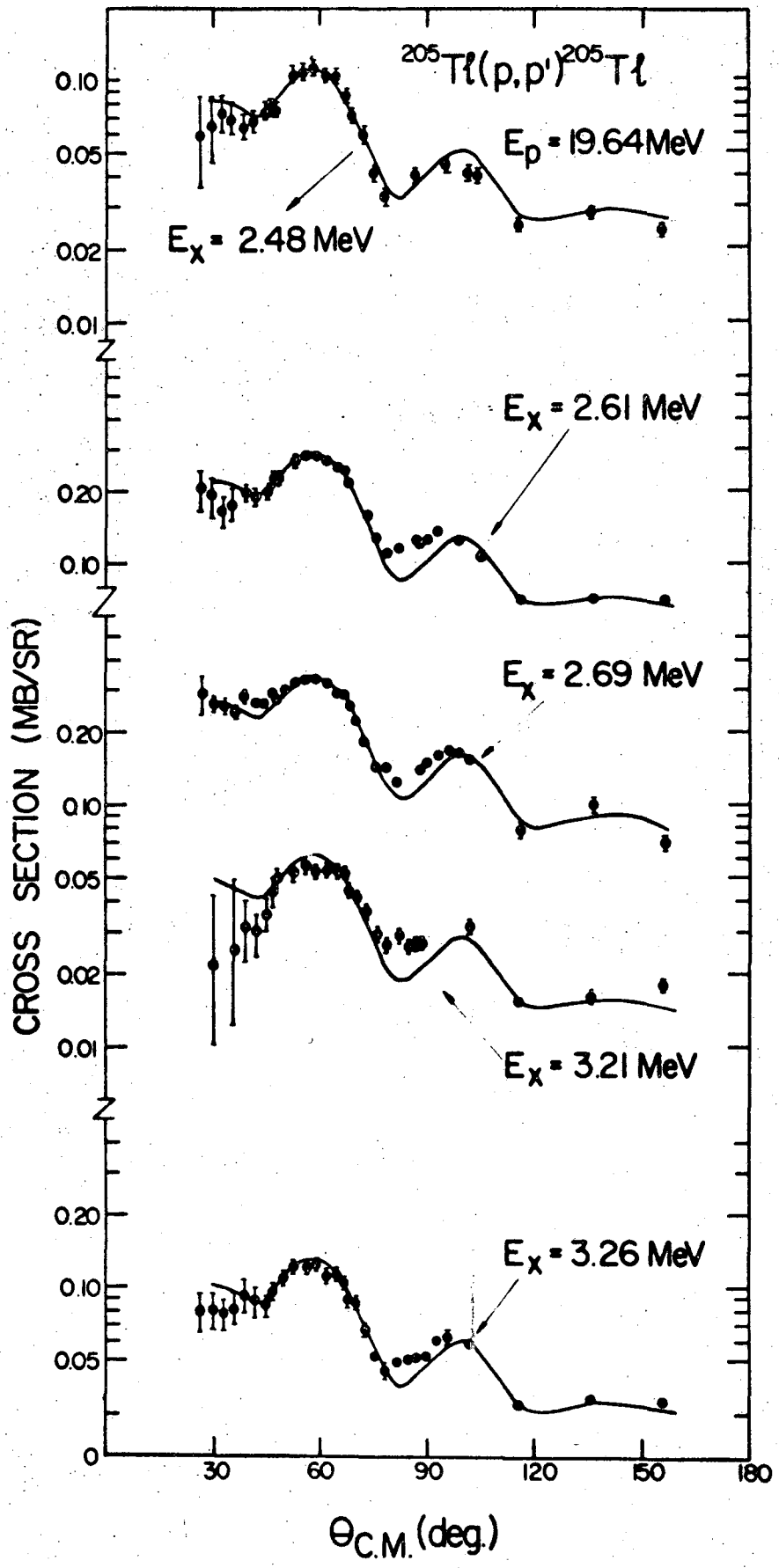
$^{205}Tl(p,p')^{205}Tl$
E_p = 19.64MeV
E_x = 2.48 MeV
E_x = 2.61 MeV
E_x = 2.69 MeV
E_x = 3.21 MeV
E_x = 3.26 MeV
CROSS SECTION (MB/SR)
$\Theta_{C.M.}$ (deg.)
0.10
0.05
0.02
0.01
0.20
0.10
0.05
0.02
0.01
0.20
0.10
0.05
0
30
60
90
120
150
180

Fig. 2

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