The 3s PROTON OCCUPANCY IN ^{206}Pb

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The experimental charge density difference between ^{206}Pb and ^{205}Tl measured by electron scattering has been interpreted by Cavedon et al.,[1] as evidence for 30% quenching of the single-particle $3s_{1/2}$ strength. It is however expected that the fragmentation of the $3s_{1/2}$ strength in ^{205}Tl plays an important role in the interpretation of the electron scattering data.[2] We have therefore undertaken a study of the ^{206}Pb($\vec{d}$,^{3}He)^{205}Tl reaction to extract spectroscopic strengths for the transitions in ^{205}Tl.

The ^{206}Pb($\vec{d}$,^{3}He)^{205}Tl reaction has been studied at E_d = 79.4 MeV using the QDDM magnetic spectrometer. Elastic scattering measurements of $\vec{d}$ + ^{206}Pb at 79.4 MeV and ^{3}He+^{205}Tl at E_{He}=78.4 MeV have also been made to obtain the appropriate optical potentials. Optical model analyses have been carried out using the code GOMFIL.[3] Different shapes have been used for the optical potential to obtain optimum fits to the elastic scattering data. Non-relativistic kinematics has been used throughout. The optical-model parameters are listed in Tables I and II. Analysis of the ^{206}Pb($\vec{d}$,^{3}He)^{205}Tl reaction data has been carried out to obtain the angular distributions of differential cross sections and analyzing powers for seventeen transitions; spin-parity assignments have been made for

Table I. Optical-Model Parameters for Deuteron Elastic Scattering from ^{206}Pb at 79.4 MeV

Set	Type	V (MeV)	r_0 (fm)	a_0 (fm)	W_S (MeV)	W_D (MeV)	r_w (fm)	a_w (fm)	V_{SO} (MeV)	r_{so} (fm)	a_{so} (fm)	W_{SO} (MeV)	r_{ws} (fm)	a_{ws} (fm)	r_c (fm)	Vol. Int. (MeV.fm^3)	σ_{reac} (mb)	χ^2/point
D1	WS	79.94	1.177	0.856	6.27	9.03	1.286	0.902	5.098	1.079	0.779	–	–	–	1.3	313.6	3006	46.13
D2	WS+ISO	80.67	1.174	0.861	5.93	9.52	1.298	0.846	5.174	1.072	0.712	-0.272	0.951	0.233	1.3	314.95	2947	19.35
D3	WS^2	87.38	1.317	0.625	7.046	7.662	1.282	0.990	5.832	1.062	0.791	–	–	–	1.3	305.99	3106	29.4
D4	WS^2+ISO	85.76	1.326	0.609	6.36	8.50	1.268	0.972	5.436	1.062	0.714	-0.320	0.937	0.280	1.3	308.1	3061	10.17

Table II. Optical-Model Parameters for ^{3}He Elastic Scattering from ^{205}Tl at 78.4 MeV

Set	Type	V (MeV)	r_0 (fm)	a_0 (fm)	W_S (MeV)	W_D (MeV)	r_w (fm)	a_w (fm)	r_c (fm)	Vol. Int. (MeV.fm^3)	σ_{reac} (mb)	χ^2/point
H1	WS(Shallow)	126.71	1.185	0.785	–	27.37	1.209	0.881	1.3	331.5	2813	2.35
H2	WS(deep)	160.89	1.183	0.738	–	30.60	1.169	0.928	1.3	412.7	2970	2.49
H3	WS(shallow)	134.57	1.133	0.860	15.83	–	1.57	0.767	1.3	318.0	2823	3.35
H4	WS(deep)	178.38	1.102	0.846	17.198	–	1.556	0.787	1.3	388.7	2850	3.3
H5	WS^2	138.45	1.319	0.601	0.0	26.72	1.182	0.951	1.3	326.15	2903	3.1

all the transitions. Table III lists the excitation energies and spin-parity assignments as compared to the previous values.[4]

DWBA calculations have been carried out using the exact finite range code FRUCK2.[5] The bound state form factor for ^{3}He has been obtained from a fit to data on elastic electron scattering.[6] Different combinations of optical potentials both in entrance and exit channels listed in Tables I and II have been used to generate the distorted waves. The bound state wave functions for the states in ^{205}Tl have been generated using the standard well-depth method and the parameters are listed in Table IV. The root-mean-square (RMS) radii obtained from this method are 5.377 fm, 5.528 fm, 5.490 fm, and 6.073 fm for the lowest $3s_{1/2}$, $2d_{3/2}$, $2d_{5/2}$, and $1h_{11/2}$ orbits, respectively. These values are in good agreement with the RMS radii obtained from Hartree-Fock (HF) calculations[7] employing the Skyrme

Table III. Energy Levels of ^{205}Tl

Nuclear Data Sheets (Ref. 4)		Our Experiment $^{206}Pb(\vec{d},{}^3He)^{205}Tl$	
E_x(keV)	J^π	E_x(keV)	J^π
0.0	$1/2^+$	0.0	$1/2^+$
203.75	$3/2^+$	202 ± 5	$3/2^+$
619.42	$5/2^+$	618 ± 5	$5/2^+$
1140.75	$3/2^+$	1139 ± 5	$3/2^+$
1218.98	$1/2^+$	1217 ± 5	$1/2^+$
1340.3	$3/2^+$	1340 ± 5	$3/2^+$
1433.79	$(1/2^+)$	1435 ± 15	$1/2^+$
1484.05	$11/2^-$	1486 ± 5	$11/2^-$
1574.03	$(3/2^+)$	1579 ± 15	$5/2^+$
1866.4	$(5/2^+)$	1844 ± 10	$5/2^+$
1951	$(5/2^+)$	1949 ± 10	$5/2^+$
2002.46	$(3/2^+)$		
		2035 ± 10	$5/2^+$
		2098 ± 10	$5/2^+$
2124.54	(5/2+)	2434 ± 15	$5/2^+$
2488.48	$(5/2^-)$		
		2498 ± 15	$11/2^-$
2583	--		
		2607 ± 15	$11/2^-$
		2756 ± 15	$5/2^+$

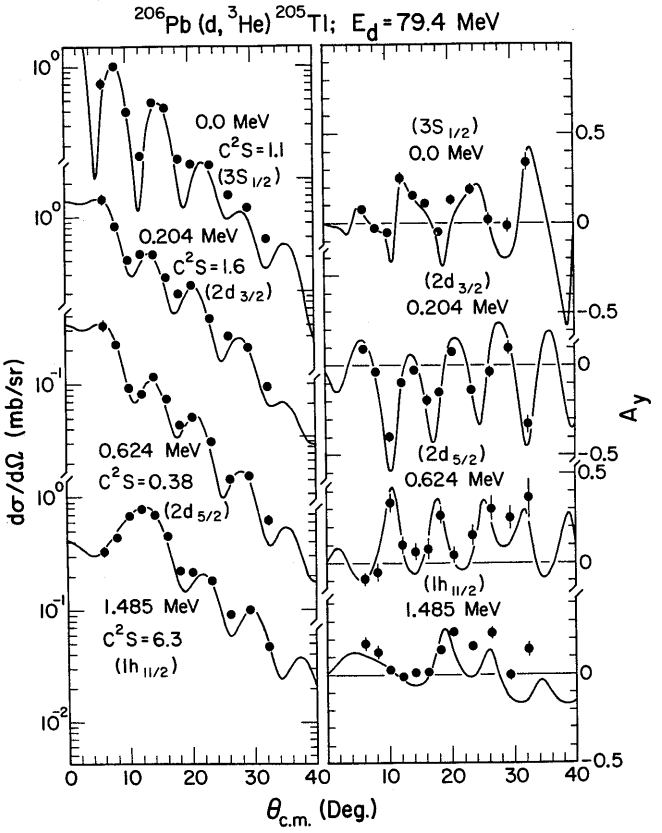

Figure 1. Comparison of differential cross-section and analyzing-power measurements for the transitions to the 0.0-MeV (ℓ= 0), 0.202-MeV (ℓ = 2), 0.618-MeV (ℓ = 2), and 1.486-MeV (ℓ = 5) states of ^{205}Tl with exact finite range DWBA calculations.

interaction SGII from Van Giai and Sagawa.[8] The combination of potentials used here are D2 for deuterons and and H2 for ^{3}He. Non-locality parameters of 0.54 and 0.25 have been used for deuterons and ^{3}He respectively As is evident from the figure the DWBA fits to the experimental data are quite good. The spectroscopic strengths for the $3s_{1/2}$ (ℓ=0) transitions deduced from this experiment are listed in Table IV and are compared with the values from other related experiments.

Our results yield a $3s_{1/2}$ proton occupation number n(206)=1.34 in reasonable agreement with other results. If we use the ratio n(206)/n(208) = 0.84 from Ref. 9, we arrive at n(208)=1.6 which indicates depletion of the $3s_{1/2}$ strength by only 20% in ^{208}Pb and 33% in ^{206}Pb.

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1) J.M. Cavedon et al., Phys. Rev. Lett. 49, 978 (1982); B. Frois et al., Nucl. Phys. A396 409C (1983).

2) E.N.M. Quint et al., Phys. Rev. Lett. 57, 186 (1986) and private communication.

3) H. Leeb, Comuter code GOMFIL (unpublished).

Table. IV. Spectroscopic Strengths for the $3s_{1/2}$ Hole States in ^{205}Tl [a]

Ex (MeV)	C^2S			
	Our Experiment E_d=79.4 MeV	Electron Scattering (Ref. 10)	(e,e'p) (Ref. 2)	(d,^{3}He) E_d=52 MeV (Ref. 9)
0.0	1.10 ± 0.20	1.2 ± 0.3	1.10 ± 0.14	1.23 ± 0.25
1.22	0.18 ± 0.06	--	0.14 ± 0.10	0.20 ± 0.08
1.43	0.06 ± 0.04	--	--	0.08 ± 0.06
$\sum C^2S(3s_{1/2})$ =	1.34 ± 0.30		1.30 ± 0.24	1.49 ± 0.39

[a]Bound state parameters are r_0=1.2675 fm, a_0=0.81 fm, V_{s0}=6.0 MeV, r_{s0}=1.1 fm, and a_{s0}=0.65 fm (see Ref. 9); V_0 is adjusted to match the separation energy of the excited state.

4) M.R. Schmorak, Nuclear Data Sheets 45, 145 (1985).

5) P.D. Kunz, Computer code DWUCK5 and extended as FRUCK2 by J. R. Comfort (unpublished).

6) P.D. Kunz, Private communication.

7) B.A. Brown, Private communication.

8) N. Van Giai and H. Sagawa, Phys. Lett. 106B, 379 (1981).

9) P. Grabmayr et al., Phys. Lett. 164B, 15 (1985).

10) C.N. Papanicolas in Nuclear Structure at High Spin, Excitation, and Momentum Transfer, ed. H. Nann, A.I.P. Conf. Proc. No. 142, 110 (1986).

RADIAL FORM-FACTOR FOR TRANSFER REACTIONS AND THE SHELL-MODEL POTENTIAL

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The radial form factors for single-nucleon transfer reactions satisfy an inhomogeneous Schrodinger-like equation[1] that incorporates both mean-field and many-body aspects of the interaction responsible for transfer. Austern[2] and Rae[3] have proposed an approximation scheme that retains the simplicity of a one-body Schrodinger equation while accounting for the main many-body corrections. The method consists in introducing a shell-model (SM) potential for the motion of the transferred nucleon in the field of the core nucleus plus a surface-peaked potential to simulate the many-body corrections. The strength of the surface term is varied to reproduce the experimental separation energy of each final state. Winfield et al.[4] have recently applied this method to study (^{9}Be, ^{10}B) reactions.

The SM potentials available in literature yield varying predictions concerning the properties of single-nucleon orbits. As an example, the root-mean-square (RMS) radii[5-12] of the neutron hole states in ^{208}Pb are tabulated in Table I; the RMS radii vary widely. The DWBA cross section for transfer reactions, and hence the spectroscopic factor (viz., the normalization factor of the transfer form-factor), are known to depend sensitively on the RMS radii.

Attempts are being made to obtain SM potentials by making fits to more extensive data. The radial wave functions predicted by these potentials will be compared with those deduced from magnetic electron scattering[13] and will also be tested by their application to single-nucleon transfer reactions at intermediate energies.

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1) G.R. Satchler, Direct Nuclear Reactions, Clarendon Press, Oxford (1983), pp. 798-805.

2) N. Austern, Nucl. Phys. A292, 190 (1977).

3) W.D.M. Rae, D.Phil. thesis, Oxford 1976 (unpublished).

4) J.S. Winfield et al., Nucl. Phys. A437, 65 (1985).

5) E. Rost, Phys. Lett. 26B, 184 (1968).

6) C.J. Batty and G.W. Greenlees, Nucl. Phys. A133, 673 (1969).

7) P. Mukherjee et al., Phys. Rev. Lett. 44, 1391 (1980).

8) G. Bertsch, The Practitioner's Shell Model, North-Holland Publ. Co., Amsterdam (1972), p. 2.