acta phys. slov. 43 (1993), No. 1, 16–20

THE CORE-POLARIZATION EFFECT ON THE 2p PROTON HOLE STATES OF ^{207}Tl

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The shell-model strengths of the $2p_{1/2}$ and $2p_{3/2}$ proton states in ^{207}Tl have been obtained by coupling the vibrational states of the ^{208}Pb with the proton hole states of ^{207}Tl within the Hole-Core Coupling model scheme. Theoretical results have been discussed in the light of the recent experimental results on ^{207}Tl. The broad based fragmented patterns of the $2p_{1/2}$ and $2p_{3/2}$ hole states of ^{207}Tl have also been discussed within the other existing theoretical models.

I. INTRODUCTION

In recent years various experimental information has been obtained to know the nature of the deep-lying proton or neutron states as well as the high-lying unbound proton or neutron states in the odd A+1 or A-1 nuclei around the Fermi level of the ^{208}Pb nucleus [1,2]. These results invariably indicate that the proton or neutron states of ^{208}Pb are not perfect shell model states. In order to explain the structures of these shell model states within the particle vibration coupling model all the vibrational states including the ones arising from the giant resonances are essential to frame the Hamiltonian matrices. The success of the present model rests particularly on the investigation of the structures of the high spin unbound states of the ^{209}Pb [3] and the discussion on the loss of the shell-model identity of the $2f_{7/2}$ neutron hole states of ^{207}Pb (2). There we have discussed the demerits of the results on the Quasi-Particle Phonon coupling model and the model based on the Hartre Fock, self consistent field with the vibrational states from the random Phase approximation method [2].

In the present paper we want to investigate the two deep-lying proton $2p$ hole states within the frame work of the hole-core vibrational coupling model. It is observed from the experimental distribution pattern of these two deep hole states in the ^{207}Tl [1,4] that the spreading of the hole strength continues up to 18.5 MeV excitation energy and it maintains uniform distribution pattern within 9.5 to 13.5 MeV. In order to explain this experimental results we have included $3s_{1/2}$, $2d_{3/2}$, $2d_{5/2}$, $1g_{7/2}$, $1g_{9/2}$, $1h_{11/2}$, $1f_{5/2}$, $2p_{1/2}$ and $2p_{3/2}$ proton orbitals and $3^-_1, 2^+, 4^+, 6^+, 8^+, 5^-_1, 5^-_2, \bar{1^-}$ and $\bar{2^+}$ vibrational states of ^{208}Pb in our hole-core vibrational coupling model. The dash over 1^- and 2^+ states indicate the vibrational states arising from the giant resonances in ^{208}Pb.

II. HOLE-CORE COUPLING MODEL

The salient features of the above model have been explained in detail in [5]. The total Hamiltonian of the physical system has been diagonalised by writing the wave function for the $J = j_1$ spin state as,

$$\Psi_J = \sum a_{\lambda j_2} \,|\, n_\lambda;\ \lambda j_2,\ j_1\rangle \tag{1}$$

where j_2 and λ are the angular momenta of the hole state and the vibrational state respectively. Vectorially we have,

$$\lambda + \mathbf{j_2} = \mathbf{j_1}. \tag{2}$$

The interaction Hamiltonian H_{int} in this basis (eq.1) has been formulated in terms of the λ-mode vibrational amplitude $\langle\alpha_\lambda\rangle$ (2).

III. RESULTS AND DISCUSSION

The zero order shell-model energies of the $3s_{1/2}$, $2d_{3/2}$, $2d_{5/2}$, $1g_{7/2}$, $1g_{9/2}$, $1h_{11/2}$, $1f_{5/2}$, $2p_{1/2}$ and $2p_{3/2}$ proton states have been obtained by solving the Schrödinger equation with the Saxon-Wood potential whose form is given in [6]. The potential parameters and the energies of the proton states have been depicted in Table 1.

Table 1

The energies of the proton hole states of the ^{208}Pb.

V_0 = 64.366 MeV; r_0 = 1.1843 fm; a_0 = 0.64 fm; V_s = 32.383 MeV; r_s = 1.1343 fm; a_s = 0.785 fm; r_c = 1.1843 fm.

nlj_2:	$3s_{1/2}$	$2d_{3/2}$	$1d_{5/2}$	$1g_{7/2}$	$1g_{9/2}$	$2p_{1/2}$	$2p_{3/2}$	$1f_{5/2}$	$1f_{7/2}$	$1h_{11/2}$
E (MeV):	0.00	0.41	1.69	4.00	9.15	8.78	9.73	12.80	14.38	1.28

The calculated results for the $1/2^-$ and $3/2^-$ states have been shown in Table 2. Quantitatively, the experimental results show that the fragmentation of both $2p$ proton states should lie within 3.8 to 14.5 MeV energy region. Our results (Table 2) show that almost all the $2p_{1/2}$ proton states extend from 4.908 to 13.556 MeV. One strong fragment of the $2p_{1/2}$ state lies at the 9.957 MeV having 71 % of the full shell model strength. In case of the $2p_{3/2}$ state we have the fragments within 3.248 to 14.407 MeV. The broad fragmentation of the $3/2^-$ state over the

$1/2^-$ state is due to a large mixing of the vibrational configurations with the single hole state. As a result of which the $2p_{3/2}$ state gets deeply bound in comparison to the $2p_{1/2}$ state.

Table 2

The $2p_{1/2}$ and $2p_{3/2}$ states of the ^{207}Tl. E is the energy in MeV and $a^2_{oj_2}$ is the squared amplitude of the zero phonon coupled state.

$2p_{1/2}$		$2p_{3/2}$	
E(MeV)	$a^2_{oj_2}$	E(MeV)	$a^2_{oj_2}$
4.988	0.102	3.248	0.020
6.737	0.137	5.258	0.023
9.957	0.706	6.884	0.063
12.983	0.020	7.316	0.009
13.445	0.006	7.902	0.017
13.556	0.010	8.445	0.009
14.423	0.005	10.012	0.656
17.482	0.005	12.744	0.078
19.306	0.005	12.997	0.058
20.839	0.004	13.489	0.026
		13.576	0.012
		14.407	0.012
		17.720	0.005

Exp [1,4] : $2p$ state: Energy range 3.8 to 14.5 MeV; Sp. factor $= 0.62 \pm 0.04$.

The dilution of the shell-model strength of the high spin states in odd-A vibrational nuclei around the ^{208}Pb have been explained by the two theoretical approaches. The one is from the Quasi-Particle Phonon coupling model [7] and the other from the coupling of the particle states from the Hartree Fock self consistant field with the vibrational states from the RPA method (8). Both these models cannot properly explain the broad fragmented pattern of the high-spin shell-model states in the ^{209}Pb, the ^{209}Bi and the ^{207}Tl [3,8,9]. So the present theoretical result succeeds in obtaining the damping of the two deep $2p$ proton hole states of the ^{207}Tl.

Finally we suggest the high resolution pick-up reaction on the ^{208}Pb to establish broad based distribution of the $2p_{1/2}$ and $2p_{3/2}$ proton hole states of the ^{208}Pb.

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Received September 22nd, 1992
Accepted for publication October 16th, 1992