RELATIVE SPECTROSCOPIC FACTORS OF 3S PROTON HOLES IN ^{206}Pb AND ^{208}Pb

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The question whether spectroscopic factors close to unity [with a (2j+1) weighting] exist and can be measured absolutely is basic for the validity of many-body theories of nuclei. If the answer were positive it would support the conventional shell-model picture of nuclei. The theory of Fermi liquids, however, predicts about 30% reduction of the occupancy of normally completely filled orbits close to the Fermi surface due to short range correlations, tensor correlations and long-range correlations[1,2]. Configuration mixing can cause additional fragmentation.

The amount of ground-state correlations in nuclei is crucial for the interpretation of a variety of present-day nuclear structure problems, e.g. the quenching of the transverse electron scattering response function,[3] the missing strength in the medium energy charge exchange reaction (p,n)[4] and the related questions concerning the role of non-nucleonic (e.g. Δ) degrees of freedom.[5] Experimental approaches to the problem comprise DWBA analyses of transfer reactions using radial wave functions of the bound state nucleon from electron scattering experiments combined with sum rules limits,[6,7] sub-Coulomb heavy ion transfer reactons,[8] DWIA analyses of (e,e'p) reactions[9] and the quenching of electron scattering cross sections.[1] None of these methods alone are sufficiently accurate. It is hoped that combining all of them might lead to absolute spectroscopic factors.

Recent experimental observations from various different sources have brought forth suggestive evidence of a substantial depletion of shell-model states near the Fermi-surface in the lead region.[1] The experimental information consists mainly of i) the charge density difference between ^{206}Pb and ^{205}Tl, (Ref. 10), which is consistent with a 30% depletion of the $3s_{1/2}$ proton orbit and ii) the quenching of the elastic magnetic response function of ^{207}Pb and ^{205}Tl (Ref. 11). One would like to connect these observations to the $3s_{1/2}$ proton occupancy in the doubly-magic nucleus ^{208}Pb, which presumably constitutes the best candidate for a truly closed shell-nucleus.

To this purpose we performed a high-resolution study of the proton knockout reaction (e,e'p) on both ^{206}Pb and ^{208}Pb with the linear electron accelerator MEA at NIKHEF-K in Amsterdam at incident energies of 410 and 350 MeV. Using two high-resolution magnetic spectrometers in a dispersion matching mode, a missing energy resolution of 130 keV was obtained. The ^{206}Pb (99.7%) and ^{208}Pb(97.0%) targets were rotated in the 20 μA beam to avoid melting. Data were taken in parallel kinematics, i.e. the proton with initial momentum p_m is knocked out parallel to the momentum transfer q_{eff} with an energy kept constant in three ranges of missing momentum p_m, 15 ± Δp, 100 ± Δp and 200 ± Δp MeV/c with Δp = 25 MeV/c. Figure 1 shows the spectral function of ^{208}Pb(e,e'p)^{207}Pb for these three different values of p_m. The characteristic selectivity for ℓ=0 ($3s_{1/2}$) knockout is evident. In all data, the energy resolution was sufficient to separate the $1/2^+$ ground state from the first excited $3/2^+$ state at E_x = 0.21 (0.35) MeV in ^{205}Tl(^{207}Tl).

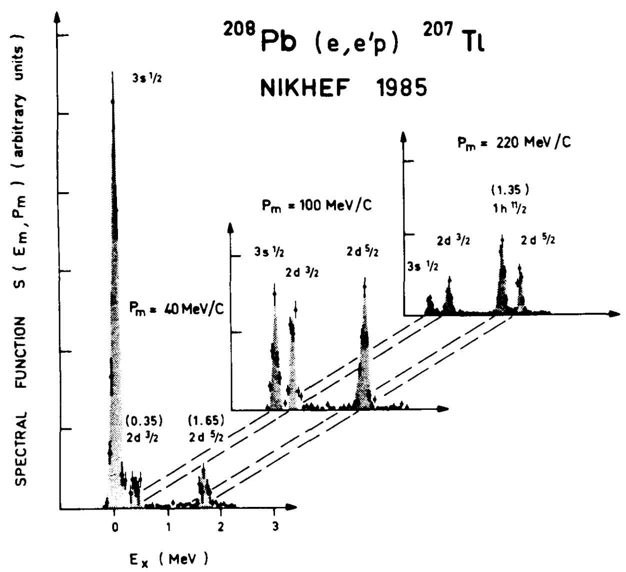

Figure 1. Spectral function of ^{208}Pb(e,e'p)^{207}Tl for three different values p_m of the transferred momentum.

The ratio of ground-state transition cross sections is shown in Fig. 2. Assuming equal spectroscopic factors $S_o(206) = S_o(208)$ the DWIA calculations using proton optical-model parameters from Schwandt et al.[12] yield the dashed curve. Adjusting the calculated curve to the data points results in $R_o = S_o(206)/S_o(208) = 0.69(3)$. In order to obtain the total $3s_{1/2}$ proton removal strength one has to sum over all states with non-vanishing ℓ=0 strength. Whereas in ^{208}Pb → ^{207}Tl the $3s_{1/2}$ strength is found exclusively in the ground state transition, appreciable $3s_{1/2}$ strength is observed in ^{206}Pb → ^{205}Tl feeding the $1/2^+$ states at 1.22 and 1.44 MeV. Adding up all strength

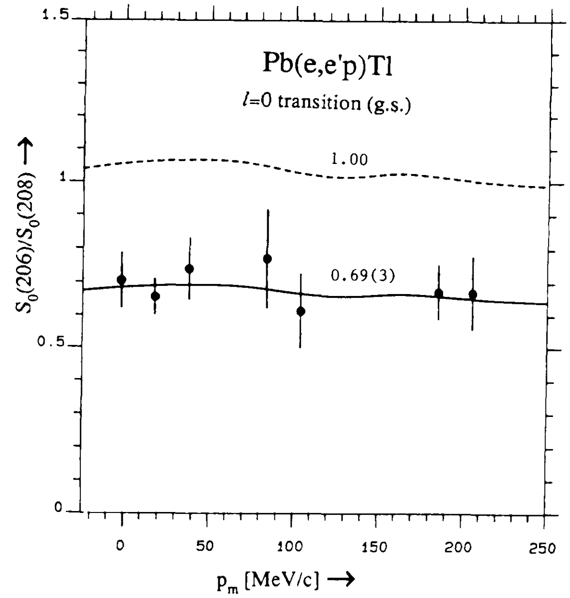

Figure 2. Ratio of spectroscopic factors for the transitions to the ground state of ^{205,207}Tl.

leads to a ratio of occupation numbers:

$$R = n(206)/n(208) \approx \Sigma\, S_i(106)/S_o(208) = 0.89(8).$$

In considering the ratio, the difficulties of the determination of absolute spectroscopic factors are avoided.

These (e,e'p) results can be compared with values from a recent (d,^{3}He) experiment[13] which yielded R_o = 0.77 ± 0.01 (stat.) ± 0.02 (syst.) and R = 0.93 ± 0.04. The (e,e'p) results are somewhat smaller than the (d,^{3}He) results. This is considered not to be overly surprising, since the $3s_{1/2}$ bound state wave function is sampled in quite different regions of r-space in the two reactions. There is, for example, the possibility that the standard prescription for the change of the geometry of the potential, in which the $3s_{1/2}$ proton is bound, in going from the open-shell nucleus ^{206}Pb to the closed-shell nucleus ^{208}Pb, is not adequate. If, for instance, the Woods-Saxon well radius R_o is increased by only 1% in ^{206}Pb, the results of the reanalysis show that R_o(e,e'p) = 0.69(3) and R_o(d,^{3}He) = 0.68(2).

In order to obtain absolute spectroscopic factors and from them occupation numbers, one has to apply sum rule limits to the spectroscopic data and to link them to the charge-density difference between ^{206}Pb and ^{205}Tl and the observed quenching of the elastic magnetic response function of ^{207}Pb and ^{205}Tl. Work on this combination is under way.

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