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Competition of Two-Step Sequential Transfer Processes with Direct Process in the Reaction $^{208}Pb(d,\alpha)^{206}Tl(0^-,g.s.)$ and a Complete Experiment of the Transition

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Reaction mechanism of (d,α) and/or (α,d) reaction has been discussed recently.[1] In addition to the direct one-step (d,α) process, it has pointed out that there exist two-step processes and the contribution of the D state of the α particle. In this report we take the case of reaction $^{208}Pb(d,\alpha)^{206}Tl(0^-_{gs},(\pi s_{1/2})^{-1}(\nu p_{1/2})^{-1})$ and present the evidence of strong sequential two-step processes in the (d,α) reaction.

We measured the cross section, vector- (iT_{11}) and tensor analyzing powers (T_{20}, T_{21} T_{22}) of this reaction at E_d = 21.5 MeV. The data were analyzed in terms of the full finite range (FR) first- and second-order distorted wave Born approximation (DWBA). This reaction is explained in terms of the sequential transfer $(d,t)(t,\alpha)$ and $(d,{}^3He)({}^3He,\alpha)$ two-step processes in addition to a (d,α) one-step process by taking account of α particle D-state. The one-step (d,α) process is generated by the deuteron-deuteron cluster interaction. The D-state admixture is chosen so that the parameter ρ, the asymptotic ratio of the S- and D-state wave function is -0.38[2]. The absolute value of the one-step cross section was normalized so that the total theoretical cross sections obtained from a coherent sum of the one- and two-step transition amplitudes reproduce the experimental (d,α) cross sections. The strength of each of the one-nucleon transfer reactions [3,4] in the sequential transfer two-step processes is determined by comparing the experimental cross sections of each of the one-nucleon transfer reactions with the corresponding FR DWBA cross sections (Fig. 1). The intensity of the two-step processes is as large as that of the one-step process so that the constructive interference between the one- and two-step transition amplitudes play an essential role in reproducing not only the observed analyzing powers but also the experimental cross section (Fig. 2). The D-state effect is minor.

This reaction has a special spin-and-parity sequence of $1^+ + 0^+ \rightarrow 0^+ + 0^-$. We can express the transition matrix M for this reaction as $M = [\langle 00|M|10\rangle\ \langle 00|M|00\rangle\ \langle 00|M|-10\rangle] \equiv [A\quad B\quad C]$, where the notations α, β, γ and δ in the matrix element $\langle\gamma\delta|M|\alpha\beta\rangle$ denote the magnetic quantum numbers of the particles d, ^{208}Pb, α and ^{206}Tl respectively. According to the Bohr's theorem[5], the transition matrix element $C = -A$. Therefore, this transition can be described by A and B. So we obtained the relations for the analyzing powers, $A_{yy} = -(T_{20} + \sqrt{6}\,T_{22})/\sqrt{2} = 1$, and $|iT_{11}|^2 + |T_{20}|^2/2 + |T_{21}|^2 + |T_{22}| = 1$, then we can calculate the T_{22} and the absolute value of T_{21} only by using measured values of the iT_{11} and T_{20}. Each of the analyzing powers is described by using the transition matrix elements A and B as $iT_{11} = \sqrt{6}\,\mathrm{Im}(AB^*)/I_0$, $T_{20} = \sqrt{2}\,(|A|^2 - |B|^2)/I_0$, $T_{21} = -\sqrt{6}\,\mathrm{Re}(AB^*)/I_0$, and $T_{22} = -\sqrt{3}\,|A|^2/I_0 < 0$, where $I_0 = 2|A|^2 + |B|^2 = 3\sigma_0$, and σ_0 is the unpolarized cross section. We put $A = |A|\,e^{i\alpha}$, and $B = |B|\,e^{i\beta}$. Then they become $A = [\sigma_0(T_{20}/\sqrt{2} + 1)]^{1/2}$, $B = [\sigma_0(1 - \sqrt{2}T_{20})]^{1/2}$, $\sin(\alpha-\beta) = \sqrt{3}\,iT_{11} / \sqrt{2}\,(1 - T_{20}/\sqrt{2} - T_{20}^2)^{1/2}$ and $\tan(\alpha-\beta) = -iT_{11}/T_{21}$. Thus all the transition matrix elements A and B are completely determined by the present experiment.

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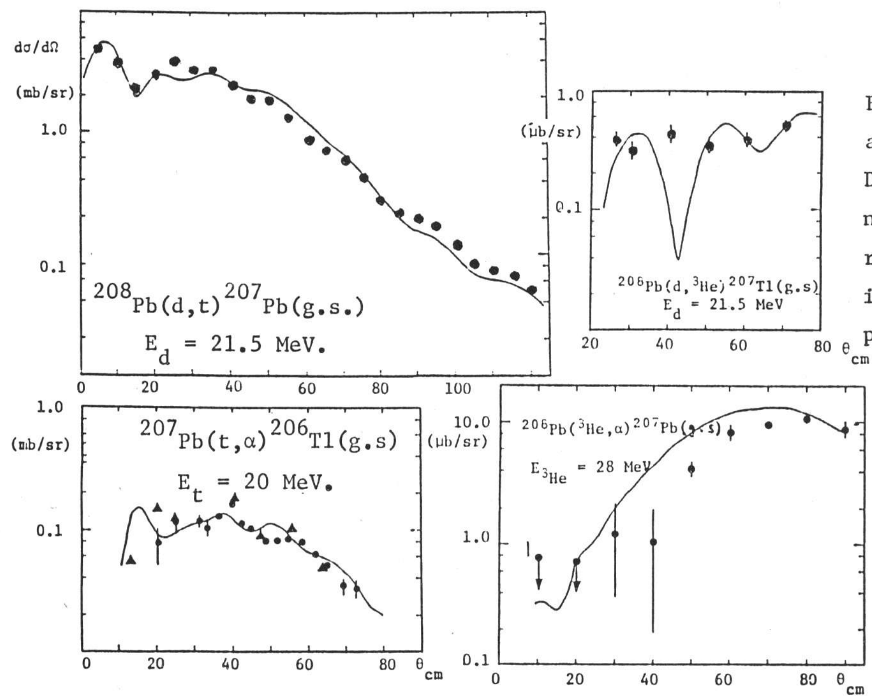

Fig. 1 Experimental and calculated (FR-DWBA) results of one-nucleon transfer reactions involved in the two-step processes of ^{208}Pb(d,α)^{206}Tl.

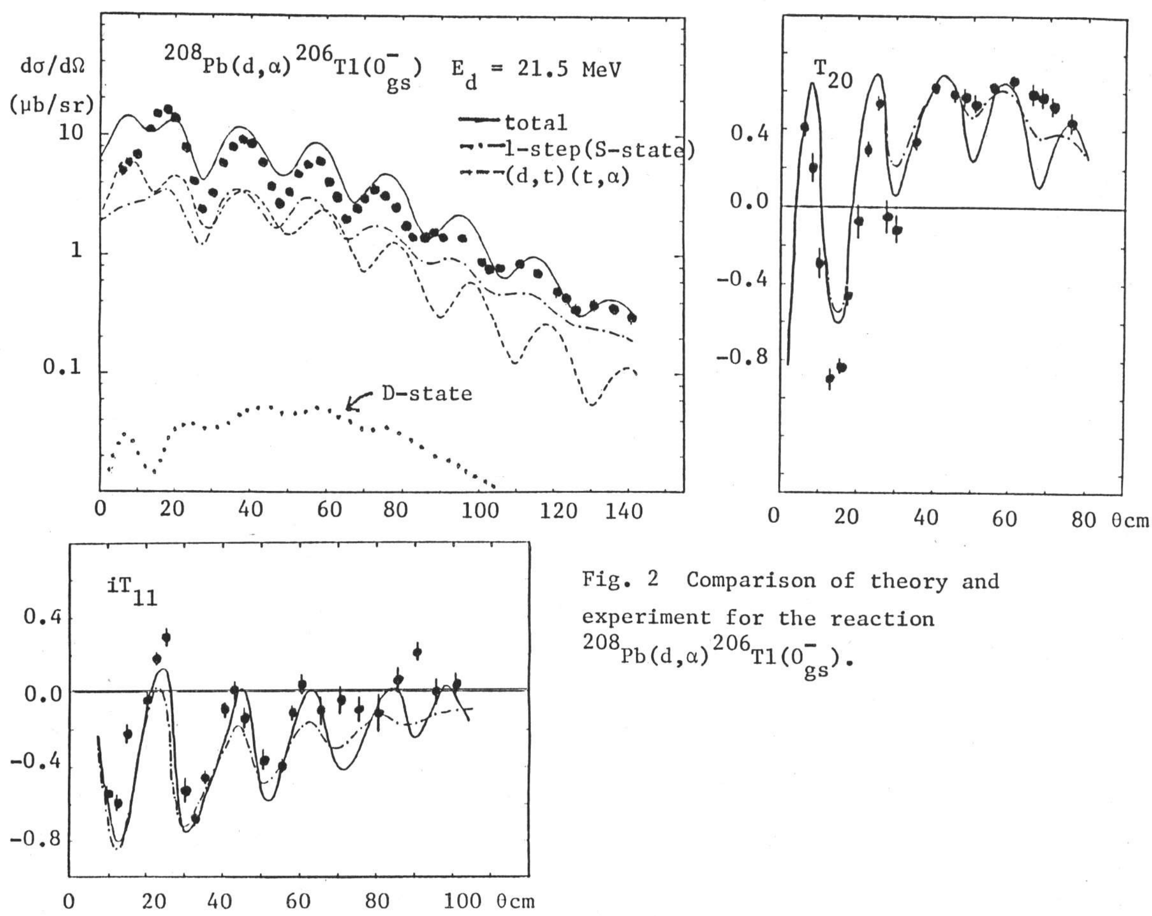

Fig. 2 Comparison of theory and experiment for the reaction ^{208}Pb(d,α)^{206}Tl(0^-_{gs}).