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INELASTIC SCATTERING OF 18.9-Mev NUCLEONS FROM THE 9.6-Mev STATE OF C^{12}

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Recently it has been suggested[1] that the 9.6-Mev state of C^{12} has spin and parity $J^\pi = 3^-$ and not 1^- as previously supposed.[2] This Letter reports a new analysis of Peelle's[3] 18.9-Mev inelastic proton scattering data, which definitely favors 3^- for the 9.6-Mev state. The calculation uses a direct volume interaction with spin-dependent distorted waves.[4]

Peelle's[3] analysis of his data is based upon the direct surface interaction theory, which predicts a $j_K{}^2(kR)$ angular distribution. Using an interaction radius $R = 3.3$ fermis, he found a best fit for $K = 1$ giving $J^\pi = 0^-$, 1^-, or 2^-. The same theory applied to inelastic scattering from the 4.4-Mev 2^+ state of C^{12} gave very poor agreement with experiment.

Levinson and Banerjee[5] showed that the direct-surface-interaction theory is probably inadequate for a nucleus as small as C, and Robson and Robson[4] found spin-orbit effects to be important for 12-Mev nucleons inelastically scattered from the 4.4-Mev level of C^{12}. Thus it was considered essential to take both these effects into account before using Peelle's data to determine the spin and parity of the 9.6-Mev state. In the following, only $J^\pi = 1^-$ or 3^- are considered because there exists a reasonable amount of evidence[1] for eliminating other values.

The distorting potential is taken to be the usual Woods-Saxon optical potential plus a Thomas-Fermi spin-orbit potential,[6]

$$V_D(r) = -(V + iW)f(r) + (V_S + iW_S)\left(\frac{\hbar}{m_\pi c}\right)^2 \frac{1}{r}\frac{df}{dr}\vec{\sigma}\cdot\vec{L},$$

$$f(r) = \{1 + \exp[(r - R)/a]\}^{-1}. \qquad (1)$$

The values of V, W, V_S, and W_S used are 45, 12,

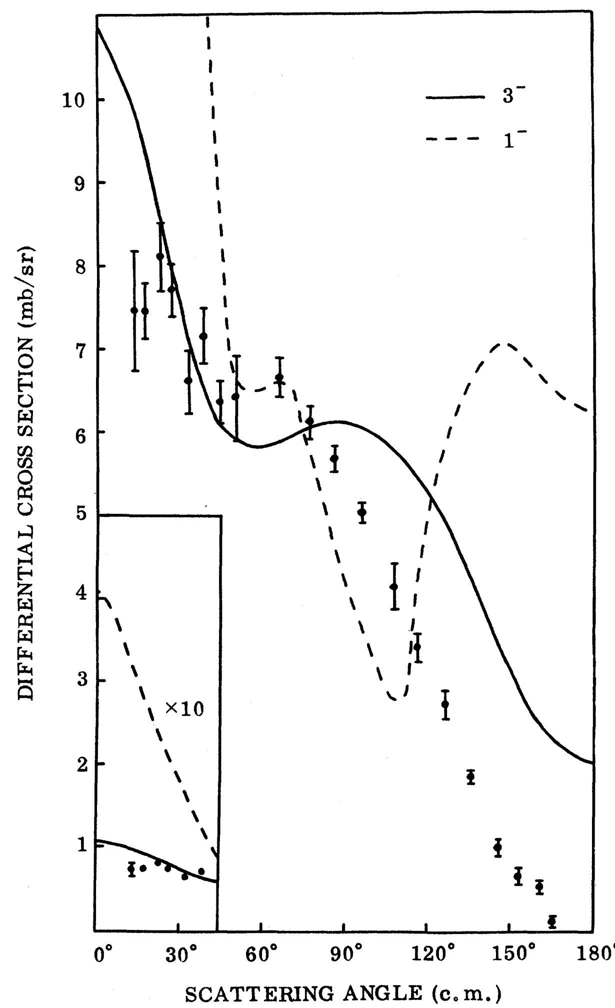

FIG. 1. Inelastic nucleon scattering from the 9.6-Mev state of C^{12}. The points are the experimental results of Peelle for 18.9-Mev protons. The theoretical curves are for 18.9-Mev neutrons. The normalization is arbitrary and both curves are fitted at 75°.

15, and -4 Mev for the incident energy of 18.9 Mev and 45, 8, 17, and -4 Mev for the emergent energy of 9.3 Mev, with $a = 0.4$ fermi and $R = 2.75$ fermis in both cases.

The direct-interaction two-body potential is assumed to be zero ranged and spin independent, and all forms of exchange are neglected.

Following Barker et al.,[1] the C^{12} ground state is taken as

$$\psi_0 = \psi(1s^4\, 1p^8[4,4]000, 0), \tag{2}$$

where the numbers following the configuration are values of $[\lambda]TSL, J$. The 9.6-Mev state is taken as

$$\psi_3 = \psi((1s^4\, 1p^7[4,3]\tfrac{1}{2}\tfrac{1}{2}1, 1d)003, 3) \tag{3}$$

for $J^\pi = 3^-$, and

$$\psi_1 = \sum_{i=1}^{3} \alpha_i \psi_{1i} \tag{4}$$

for $J^\pi = 1^-$, where

$$\psi_{11} = \psi((1s^4\, 1p^7[4,3]\tfrac{1}{2}\tfrac{1}{2}1, 2s)001, 1), \tag{4a}$$

$$\psi_{12} = \psi((1s^4\, 1p^7[4,3]\tfrac{1}{2}\tfrac{1}{2}1, 1d)001, 1), \tag{4b}$$

$$\psi_{13} = \psi((1s^3[3]\tfrac{1}{2}\tfrac{1}{2}0, 1p^9[441]\tfrac{1}{2}\tfrac{1}{2}1)001, 1). \tag{4c}$$

For the Elliott and Flowers interaction, Barker et al.[1] found $\alpha_1 = 0.916$, $\alpha_2 = -0.399$, and $\alpha_3 = -0.028$. For simplicity, the values used in the present calculation are $\alpha_1 = 0.869$, $\alpha_2 = -0.494$, and $\alpha_3 = 0$. The $1p$, $1d$, and $2s$ wave functions are taken for an ideal harmonic oscillator with length parameter $b = 2.0$ fermis, obtained by fitting the $1p$ harmonic-oscillator wave function to the $1p$ square-well solution of the Schrödinger equation for a radius $R = 3.66$ fermis, which gives a reasonable fit to the 4.4-Mev data.[4]

Figure 1 shows the result of the calculation. It is seen that the theoretical curve for the 3^- assumption is a much better fit than for the 1^- assumption (both curves are normalized at 75°). Greater emphasis should perhaps be placed on fitting the scattering for angles $\theta < 90°$, since other processes like heavy-particle stripping[7] may become important for $\theta > 90°$. On account of the very lengthy calculations involved, no attempt was made to vary the parameters, which were selected by a consideration of the elastic scattering and inelastic scattering from the 4.4-Mev state data.[4,8]

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