Proc. Sixth Int. Symp. Polar. Phenom. in Nucl. Phys., Osaka, 1985
J. Phys. Soc. Jpn. 55 (1986) Suppl. p. 570-571

1.8 Tensor Operators in the Nucleon-Nucleus Spin-Spin Interaction*

H. Ohnishi**, T. L. McAbee and W. J. Thompson
Department of Physics and Astronomy
University of North Carolina, Chapel Hill, NC 27514 USA

A class of tensor operators which occur in the nucleon-nucleus spin-spin interaction is discussed. New terms are introduced and shown to be non-negligible compared to the usual central and second-rank tensor interactions. Operators that have been discussed previously[1] are shown to be special cases of the generalized tensor operator presented here.

Although the presence of a spin-spin term in the nucleon-nucleus optical was postulated many years ago,[2] experimental verification of such interactions has been difficult, with large uncertainties in all measurements made to date.[3-5] Our work is motivated by experiments at Triangle Universities Nuclear Laboratory to measure spin-spin total cross sections for fast polarized neutrons incident on brute-force-polarized nuclei.

Until now, only two interactions have been considered,[3,6] central $\mathbf{I}\cdot\mathbf{S}_p$ or tensor $\mathbf{S}_{12}$. We construct generalized nucleon-nucleus spin-spin tensor operators $\mathbf{S}_{ik}$ defined by

$$\mathbf{S}_{ik} = N \left[\mathbf{I}^i \times \mathbf{S}_p \right]^k \cdot \left[\hat{\mathbf{r}} \right]^k, \tag{1}$$

where $\mathbf{I}$ is the target spin operator, $\mathbf{S}_p$ is the projectile spin operator, and $\mathbf{r}$ is the relative vector between nucleon projectile and target nucleus. The target spin is coupled to itself i times to form a rank-i operator stretched in target-spin space, with $i \leqslant 2I$. This target operator is then coupled to the maximal rank-1 nucleon-spin operator $\mathbf{S}_p$ ($S_p = 1/2$) to form a rank-k operator. Thus $k = i,\ i\pm1$. For rotational invariance of $\mathbf{S}_{ik}$ the rank of the operator formed from $\hat{\mathbf{r}}$ must also be k. Time-reversal invariance of $\mathbf{S}_{ik}$ requires that i be odd, while parity invariance restricts k to be even, so that $k = i\pm1$ only. The $\mathbf{S}_{ik}$ operators are a special case of those defined by Petrovich <u>et al.</u>[7] with the projectile restricted to be a nucleon.

In Eq. (1) the normalization N is chosen so that $\mathbf{S}_{ik}$ is a unit operator in the vector-model limit. In terms of reduced matrix elements and 3-j coefficients,

$$N = \left[\hat{k}\, \gamma_k\, S_p\, \hat{I} \langle I \| I^i \| I \rangle \begin{pmatrix} i & k & 1 \\ 0 & 0 & 0 \end{pmatrix} \begin{pmatrix} I & I & i \\ I & -I & 0 \end{pmatrix} \right]^{-1}, \tag{2}$$

with $\hat{k} \equiv [2k+1]^{1/2}$ and γ_k given by

$$\gamma_k = \left[2^k (k!)^2/(2k)! \right]^{1/2}. \tag{3}$$

This factor arises from the relation

$$\left[\hat{\mathbf{r}} \right]^k = \gamma_k\, \mathbf{C}_k(\hat{\mathbf{r}}) , \tag{4}$$

where $\mathbf{C}_k(\hat{\mathbf{r}})$ is the renormalized spherical harmonic operator. Since

$k \leq 2I+1$, and magnetically-polarized targets often have high spin (such as I=5/2 for ^{27}Al and I=9/2 for ^{93}Nb), the dependence of observables on spin-orientation angles is expected to be correspondingly complicated in the presence of interactions constructed from $\mathbf{S}_{ik}$.

The central and rank-2 tensor operators described by Hussein and Sherif[6] are special cases of $\mathbf{S}_{ik}$, namely the central spin-spin interaction

$$S_{10} = \mathbf{I} \cdot \mathbf{S}_p \,/\, IS_p \;, \tag{5}$$

and the (second-rank) tensor interaction

$$S_{12} = \tfrac{1}{2}\left[3(\mathbf{I} \cdot \hat{\mathbf{r}})(\mathbf{S}_p \cdot \hat{\mathbf{r}}) - \mathbf{I} \cdot \mathbf{S}_p\right] / \, IS_p \;. \tag{6}$$

Thus $\mathbf{S}_{ik}$ differs only in normalization from the conventional spin-spin operators. Operators of rank $i > 1$ in the target spin do not have simple forms in terms of $\mathbf{I}$, $\mathbf{S}_p$ and $\mathbf{r}$.

We have investigated higher-rank operators by using the folding-model approach, in which the nucleon-nucleus spin-spin potential is obtained by folding an effective nucleon-nucleon interaction with the target valence-nucleon density. The nucleon-nucleon central spin-spin interaction contributes to all operators $\mathbf{S}_{ik}$. For example, for target spins of 3/2 and greater the resulting folded potential for $\mathbf{S}_{32}$ has contributions from the same multipole order as for $\mathbf{S}_{12}$, and hence the same radial form factor. Thus if the valence-nucleon spin is parallel to the orbital angular momentum ($I = \ell_t + 1/2$), the strength of the $\mathbf{S}_{32}$ potential is 3/2 that for $\mathbf{S}_{12}$. This example emphasizes the importance of such higher-rank tensors to the spin-spin interaction. Although the central spin-spin term is the dominant nucleon-nucleon operator contributing to $\mathbf{S}_{ik}$, the nucleon-nucleon tensor and spin-orbit interactions also contribute.

Currently, we are considering various contributions to interactions involving $\mathbf{S}_{ik}$ in the context of the folding model and a DWBA treatment of the spin-spin interaction. A more extensive description of the formalism presented here will be given elsewhere.[8]

*Research supported in part by the US Department of Energy, Contract No. DE-AS05-76ER02408.

**Present and permanent address, Dept. of Physics, Hosei University, Tokyo, Japan

1) G. R. Satchler, Particles and Nuclei **1** (1971) 397
2) H. Feshbach, Annu. Rev. Nucl. Sci. **8** (1958) 49
3) K. Nagamine et al., Nucl. Phys. **A145** (1970) 203
4) W. Heeringa et al., Phys. Rev. **C16** (1977) 1389
5) T. R. Fisher, Phys. Lett. **35B** (1971) 573
6) A. H. Hussein and H. S. Sherif, Phys. Rev. **C8** (1973) 518
7) F. Petrovich et al., Nucl. Phys. **A425** (1984) 609
8) H. Ohnishi, T. L. McAbee, W. J. Thompson, to be published