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A Method for Measuring the Polarization of Nuclear Reaction Products

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Abstract. A method for measuring the polarization of nuclear reaction products ist proposed in which the reverse reaction is used for analysis.

In recent years experiments in which polarized neutrons or protons of intermediate energy were used have given valuable information about nuclear structure. While polarized neutrons or protons are produced in many nuclear reactions, it is often difficult to measure the degree of polarization of such particles. The usual procedure has been to scatter the particles from a nucleus near an energy corresponding to an excited state of the compound nucleus.[1]) If the resonance parameters of the state are known, it is then possible to calculate the polarization of the incident particles from a measurement of the left-right asymmetry in the scattering.

There are, however, only very few resonances for which the parameters are sufficiently accurately known to carry out the calculations reliably. The higher the energy of the particles, the more phase shifts have to be considered, and small errors even in the non-resonant phase shifts may introduce appreciable errors in the calculated polarizations.

The most unambiguous way of analyzing the degree of polarization would be to perform a double scattering experiment[2]). Enough polarization for such experiments is to be expected only in the neighborhood of a resonance, and as a consequence, the polarization will vary rapidly with energy. Because of the energy loss of the particles in elastic collisions the polarizations in the two scattering processes will not be the same so that even in a double scattering experiment the phase shifts have to be known. For neutrons double scattering experiments are impractical because of shielding and intensity difficulties.

The purpose of this note is to mention a method which avoids these difficulties and which is applicable to some sources of polarized particles. The method is most easily explained by considering a specific example, *i. e.*, the production of neutrons in the reaction

$C^{13} + \alpha \rightarrow O^{17} \rightarrow O^{16} + n + 2{\cdot}2$ MeV. It is proposed to analyze the polarization of the neutrons by observing the reverse reaction $O^{16} + n \rightarrow C^{13} + \alpha$. Over a wide range of energies of the bombarding α-particles it is possible to choose an angle of emission of the neutrons with respect to the incident α-particles such that the compound nucleus O^{17} is formed at the same energy of excitation in the first reaction as in the reverse reaction. If in both reactions the same center-of-mass angle between the neutron and the α-particle is chosen, a measurement of the leftright asymmetry of the α-particles emitted in the (n, α) reaction will determine the polarization of the neutrons, since this asymmetry depends only on the square of the polarization[3]). No knowledge of any resonance parameters is needed.

If the polarization of particles $\boldsymbol{d}$ produced in a reaction $\boldsymbol{a} + \boldsymbol{b} \rightarrow \boldsymbol{c} \rightarrow \boldsymbol{d} + \boldsymbol{e}$ is to be studied, the proper angle Θ in the laboratory system between the incident particles of energy E_a and the direction of emission of $\boldsymbol{d}$ is given by

$$\cos \Theta = \frac{E_a(m_b + m_e) + Q(m_c + m_e)}{2\sqrt{\frac{m_a m_e}{m_d}}\sqrt{E_a}\sqrt{E_a m_b + Q m_c}},$$

where Q is the reaction energy. The experiment is possible if $0 < \cos \Theta < 1$.

For the $C^{13}(\alpha, n)$ reaction this condition is satisfied for α-particle energies greater than $1/3\, Q$. At $E = 1/3\, Q$, the reaction product O^{16} is formed at rest in the laboratory system and the neutrons which have the proper energy are emitted in the forward direction and are not polarized. As the energy of the α-particles is increased, the proper angle of observation will also increase.

This method could be applied to other types of reactions provided both the bombarded and the product nucleus are available in sufficient quantity. While the proposed experiment may be difficult to perform because counting rates will be low, it involves one less successive nuclear interaction than a double scattering experiment and the intensity difficulties should, therefore, be far smaller.

References.

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