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Recently, the use of elastic and inelastic alpha particle scattering data to obtain nuclear spectroscopic information has been the subject of a number of theoretical and experimental investigations. Initial application of the Drozdov-Blair-Sharp-Wilets diffraction model[1] to extract information pertaining to spins, parities and reduced radiative transition probabilities of excited states was relatively successful. Among other things, this model predicts that for the inelastic scattering of alpha particles, the angular distributions corresponding to odd values of the angular momentum transfer L should be in phase with the elastic angular distribution, while those for even angular momentum transfer should be out of phase. Considerable evidence has been accumulated in support of this model as regards excitations of the first 2+ and 3- states in even-even nuclei, which are believed to arise from single quadrupole and octupole oscillations, respectively. However, several groups have observed that the angular distributions for the alpha groups leading to excitation of the second 2+ and first 4+ levels in medium weight even-even nuclei, which are assumed to arise from two-phonon excitation, are in some cases out of phase with the elastic group and in other cases in phase.[2]

Blair has indicated that expanding the diffraction model to second order in the deformation could reproduce the "in phase" characteristic.[1] Recent coupled channel calculations by Buck have shown that the two-phonon states can be excited either by a direct two-phonon mechanism or by a multiple process.[3] This author found that, for the scattering of 43-MeV alpha particles by Ni^{58}, the magnitude of the direct and multiple processes for excitation of the 4+ level are comparable.[3] Furthermore, the angular distributions for the two processes, although shifted slightly in opposite directions, were nearly in phase with that for excitation of the first 2+ level. However, as the result of destructive interference, the combined effect of the two excitation mechanisms resulted in an angular distribution which was out of phase with that arising from excitation of the first 2+ level. To fit the experimental data, Buck found it necessary to multiply the predicted contribution from the direct process by a factor of 1.5, and suggested this might be attributable to a contamination of the 4+ level with a single 4+ phonon component.

Most measurements to date have been made with alpha particles of energy less than about 48 MeV. The results for scattering of 44 MeV alpha particles by several even-even isotopes of iron, nickel and zinc have been summarized by Faraggi and Saudinos.[4] This summary shows variations in the phase relationships for excitation of supposed two-phonon levels within the same elements, and sometimes within a given isotope. Hence, it was not clear whether the deviations from the phase rules as predicted by the diffraction model arise from nuclear model effects, or are due in some way to the reaction mechanism. It was thought that measurements of the angular distributions as a function of the incident alpha particle energy might shed some light on these questions.

Utilizing the Berkeley 88-inch variable energy cyclotron, angular distributions for the scattering of 25-, 33-, 50-, 85- and 100- MeV alpha particles by thin Ni^{62} targets have been measured. The particle detectors were of the lithium-drifted silicon type, varying in thickness from 0.020 inch to about 0.140 inch, and gave overall resolutions from 65 keV at 25 MeV to 300 keV at 100 MeV. Angular distributions for scattering to the ground, 1.17-MeV (first 2+), and combined 2.303- and 2.336- MeV (second 2+ and first 4+, respectively) states in Ni^{62} are shown in Fig. 1 for three incident alpha particle energies, 33, 50, and 100 MeV. In addition to the data obtained in this work, the results of others[5] are available for 44 MeV. The data show: 1) the angular distribution resulting from excitation of the first 2+ level is out of phase with the elastic distribution over the incident alpha particle energy range of 25-100 MeV. 2) The angular distribution for the combined excitation of the second 2+ and first 4+ levels is about one-quarter cycle out of phase with the elastic distribution at 25 MeV and is in phase at 100 MeV; there appears to be a smooth variation from out-of-phase to in-phase as one increases the incident alpha particle energy.

Comparison of the data, at small angles in the center of mass system, with the diffraction model for incident alpha particle energies of 50 MeV, indicates that the angular momentum transfer involved in excitation of the doublet at 2.3 MeV is L = 4, which would imply that the main contribution arises from excitation of the 4+ level. Complications could arise from the presence of an unresolved 2+ component if its phase were opposite from the phase of the 4+ component and if the relative cross sections for L = 2 and L = 4 varied strongly as a function of bombarding energy. The variation of phase of the angular distribution of a pure L = 4 excitation cannot be explained by the diffraction model. Whether or not a coupled channel analysis could explain this phenomenon is not yet clear as the variation of the relative magnitudes of the direct and multiple processes as a function of energy was not discussed in the paper by Buck.[3]

The results reported here clearly indicate the need for additional alpha particle scattering measurements, as well as further coupled channel calculations, as a function of energy of the incident alpha particles.

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FOOTNOTE AND REFERENCES

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FIGURE CAPTION

Figure 1. Angular distributions of alpha particles, with incident energies of 33, 50 and 100 MeV, scattered by the ground 1.17-MeV (2+) and combined 2.303- and 2.336-MeV (second 2+ and first 4+, respectively) states in Ni 62.

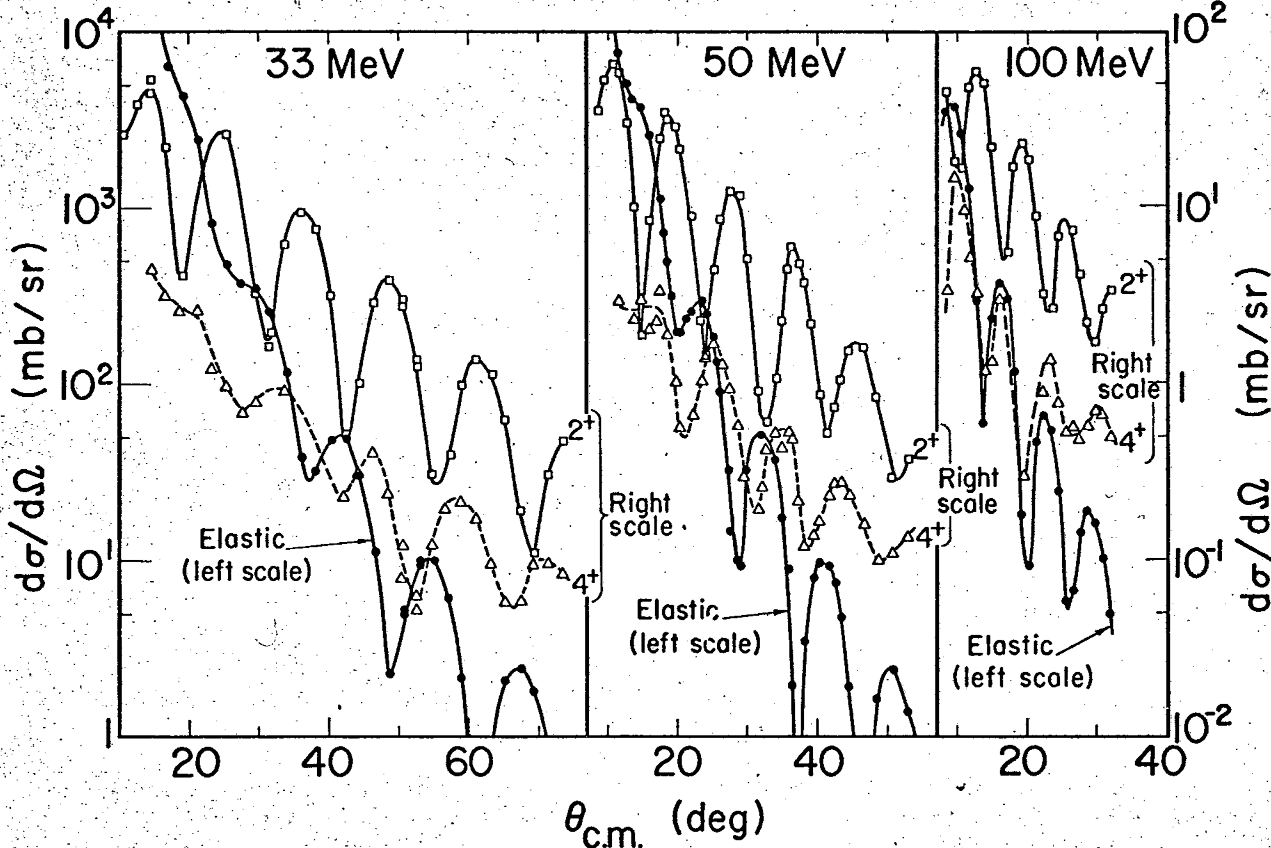

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Fig. 1.