

Lawrence Berkeley National Laboratory

Recent Work

Title

ENERGY VARIATION OF THE PHASE RULE IN ALPHA PARTICLE SCATTERING

Permalink

<https://escholarship.org/uc/item/5tz6k365>

Authors

Meriwether, J.R.
Nercy, A. Bussiere de
Harvey, B.G.
et al.

Publication Date

1964-06-01

University of California
Ernest O. Lawrence
Radiation Laboratory

ENERGY VARIATION OF THE PHASE RULE IN
ALPHA PARTICLE SCATTERING

TWO-WEEK LOAN COPY

*This is a Library Circulating Copy
which may be borrowed for two weeks.
For a personal retention copy, call
Tech. Info. Division, Ext. 5545*

Berkeley, California

DISCLAIMER

This document was prepared as an account of work sponsored by the United States Government. While this document is believed to contain correct information, neither the United States Government nor any agency thereof, nor the Regents of the University of California, nor any of their employees, makes any warranty, express or implied, or assumes any legal responsibility for the accuracy, completeness, or usefulness of any information, apparatus, product, or process disclosed, or represents that its use would not infringe privately owned rights. Reference herein to any specific commercial product, process, or service by its trade name, trademark, manufacturer, or otherwise, does not necessarily constitute or imply its endorsement, recommendation, or favoring by the United States Government or any agency thereof, or the Regents of the University of California. The views and opinions of authors expressed herein do not necessarily state or reflect those of the United States Government or any agency thereof or the Regents of the University of California.

Rept. sub. for pub. in
Physics Letters.

UCRL-11484

UNIVERSITY OF CALIFORNIA
Lawrence Radiation Laboratory
Berkeley, California
AEC Contract No. W-7405-eng-48

ENERGY VARIATION OF THE PHASE RULE IN ALPHA PARTICLE SCATTERING

J. R. Meriwether, A. Bussière de Nercy, B. G. Harvey and D. J. Horen

June 1964

ENERGY VARIATION OF THE PHASE RULE IN ALPHA PARTICLE SCATTERING

J. R. Meriwether, A. Bussière de Nercy,[†] B. G. Harvey,Lawrence Radiation Laboratory
University of California
Berkeley, California

and

D. J. Horen

Naval Radiological Defense Research Laboratory,
San Francisco, California

June 1964

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 model¹ 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 Ni⁵⁸, 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 Ni⁶² 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 Ni⁶² 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 others⁵ 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.

The authors would like to thank Jeannette Mahoney for considerable assistance in reducing the data.

This work was performed under the auspices of the U.S. Atomic Energy Commission and BUSHIPS.

FOOTNOTE AND REFERENCES

[†] NATO Fellow, on leave from Laboratoire de Physique Nucleaire, Orsay, (S. et O.), France.

1. S. I. Drozdov, J. Exptl. Theoret. Phys. (USSR) 36, 1875 (1959) [translation; Soviet Phys. JETP 9, 1335 (1959)]; J. S. Blair, Phys. Rev. 115, 928 (1959); J. S. Blair, D. Sharp and L. Willets, Phys. Rev. 125, 1625 (1961); J. S. Blair, Proceedings of the Conference on Direct Interactions and Nuclear Reaction Mechanisms, Padua, Italy, September 3-8, 1962 (Gordon and Breach Science Publishers, New York, 1963), p. 669
2. R. Beurtey, P. Catillon, R. Chaminade, M. Crut, H. Faraggi, A. Papineau, J. Saudinos and J. Thirion, Compt. Rend. 252, 1756 (1961); H. Broek, T. Braid, J. Yntema and B. Zeidman, Nucl. Phys. 38, 305 (1962); Phys. Rev. 126, 1514 (1962).
3. B. Buck, Phys. Rev. 127, 940 (1962).
4. H. Faraggi and J. Saudinos, Nuclear Spectroscopy with Direct Reactions, Paper C-7, Argonne National Laboratory Report ANL-6848, March, (1964).
5. G. Bruge, J. C. Faivre, M. Barloutaud, H. Faraggi and J. Saudinos, Phys. Letters 7, 203 (1963).

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.

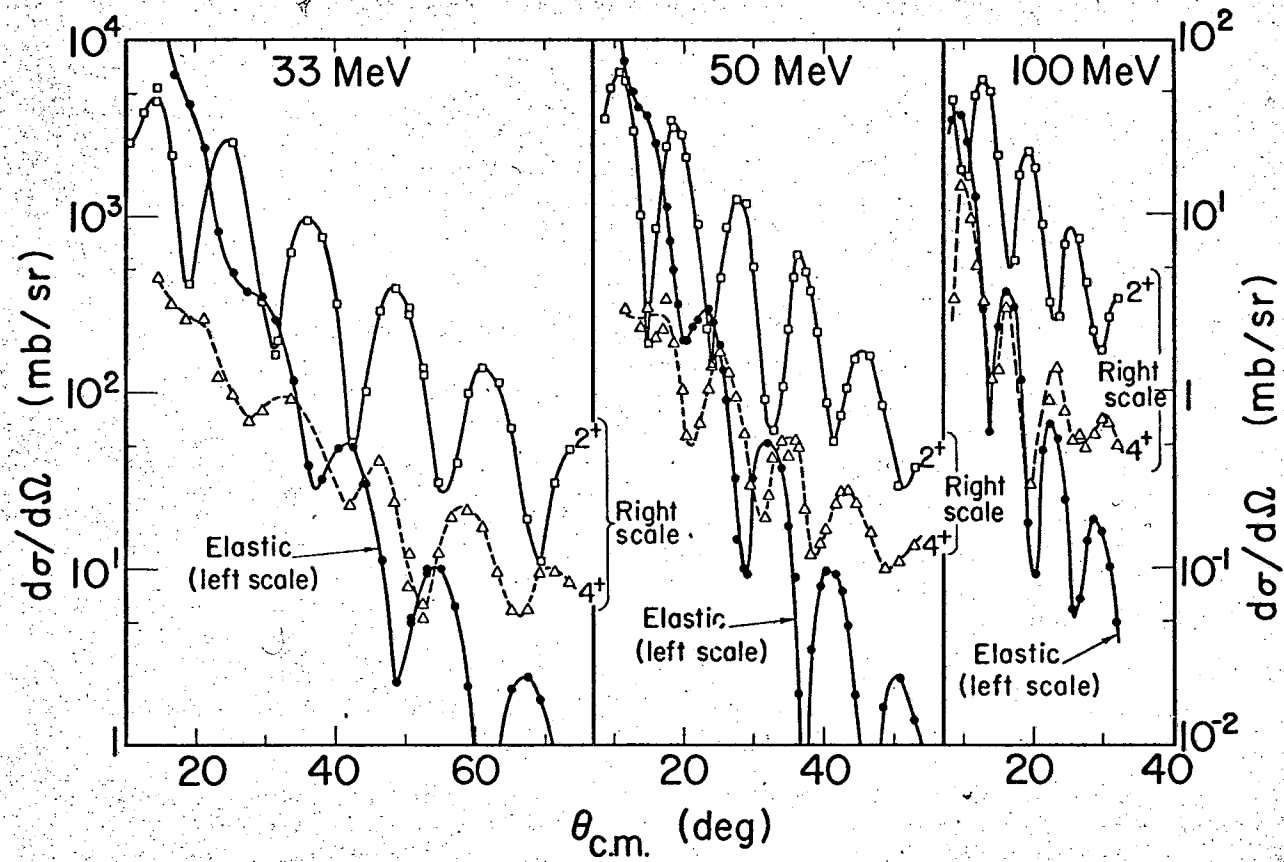


Fig. 1.

MUB-3137

UCRL-11484

This report was prepared as an account of Government sponsored work. Neither the United States, nor the Commission, nor any person acting on behalf of the Commission:

- A. Makes any warranty or representation, expressed or implied, with respect to the accuracy, completeness, or usefulness of the information contained in this report, or that the use of any information, apparatus, method, or process disclosed in this report may not infringe privately owned rights; or
- B. Assumes any liabilities with respect to the use of, or for damages resulting from the use of any information, apparatus, method, or process disclosed in this report.

As used in the above, "person acting on behalf of the Commission" includes any employee or contractor of the Commission, or employee of such contractor, to the extent that such employee or contractor of the Commission, or employee of such contractor prepares, disseminates, or provides access to, any information pursuant to his employment or contract with the Commission, or his employment with such contractor.

