

Lawrence Berkeley National Laboratory

Recent Work

Title

RELATION BETWEEN THE OPTICAL POTENTIAL FOR SPHERICAL AND DEFORMED NUCLEI

Permalink

<https://escholarship.org/uc/item/8q449830>

Authors

Glendenning, Norman K.

Hendrie, D.L.

Jarvis, O.N.

Publication Date

1967-11-01

University of California
Ernest O. Lawrence
Radiation Laboratory

RELATION BETWEEN THE OPTICAL POTENTIAL
FOR SPHERICAL AND DEFORMED NUCLEI

Norman K. Glendenning, D. L. Hendrie, and O. N. Jarvis

November 1967

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*

UCRL-17935
c. 2

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.

to be submitted to Phys. Letters

UCRL-17935

UNIVERSITY OF CALIFORNIA

Lawrence Radiation Laboratory
Berkeley, California

AEC Contract No. W-7405-eng-48

RELATION BETWEEN THE OPTICAL POTENTIAL FOR SPHERICAL AND DEFORMED NUCLEI

Norman K. Glendenning, D. L. Hendrie, and O. N. Jarvis

November 1967

RELATION BETWEEN THE OPTICAL POTENTIAL FOR
SPHERICAL AND DEFORMED NUCLEI*

Norman K. Glendenning, D. L. Hendrie, and O. N. Jarvis[†]

Lawrence Radiation Laboratory
University of California
Berkeley, California

November 1967

ABSTRACT

It is shown that when the contribution of the strong collective states to the optical potential is removed by treating them explicitly through solution of the coupled equations describing the scattering, the resulting optical potential is valid for both spherical and deformed nuclei over a broad mass range in the rare earth region. In a search for the nuclear shape in the deformed region, this has the very important effect of removing the optical parameters from the list of free parameters.

* Work performed under the auspices of the U. S. Atomic Energy Commission.

[†] Permanent address: AERE, Harwell, Berkshire, England.

The elastic scattering cross sections of spherical and deformed nuclei are qualitatively different even for such close neighbors as ^{148}Sm (spherical) and ^{154}Sm (deformed). This is illustrated for 50-MeV alpha particles¹⁾ in fig. 1. The slope is steeper and the amplitude of the oscillations smaller for the deformed nuclei. This difference reflects the stronger coupling to the excited states in the deformed nucleus. As a convenient measure of the coupling to the 2^+ state one can use the reduced transition probability $B(E2)$, which is about five times larger for ^{154}Sm than ^{148}Sm . The optical potential that reproduces the elastic scattering accordingly must be, and is, quite different in the two cases. The optical parameters for the elastic scattering are shown in Table 1 (first and last lines) and the solid curves in fig. 1 are the corresponding cross sections.

Table 1

Optical model parameters corresponding to Woods-Saxon shape and a uniform charge distribution with a correct quadrupole moment

	<u>V</u>	<u>W</u>	<u>r</u>	<u>a</u>
^{148}Sm elastic only	65.5	29.8	1.427	.671
Coupled channels	65.9	27.3	1.440	.637
^{154}Sm elastic only	34.6	29.4	1.404	.819

Conceptually, the optical potential was introduced to reduce an infinite-channel problem to a one-channel problem (the usual optical model for elastic scattering) or a few-channel problem (the optical model and coupling between a few low-lying levels). By construction it carries implicitly the effects of all the eliminated channels on those that are treated explicitly²⁾. The eliminated channels include the intrinsic excitations which are present in all nuclei, as well as rotations in the case of deformed nuclei. It is mainly the rotations which give rise to the difference in the elastic optical potentials, as we now show.

To discuss conveniently the difference between the two cases, we introduce Feshbach's³⁾ expression for the optical potential:

$$U_{el} = \langle 0|V|0\rangle + \sum_C \langle 0|V|C\rangle \frac{1}{E-E_C+i\epsilon} \langle C|V|0\rangle \quad (1)$$

where the sum C is over all the omitted channels, or in the case of the elastic optical potential, over all channels save the elastic. Except for those states which couple strongly to the ground state, such as collective levels, the sum will be dominated by the region of high level density in the nucleus. We can think of breaking the sum up into two parts, therefore, consisting of the sum over the low-lying collective states, and the sum over all others

$$U_{el} = U_s + \sum_{\text{Collective}} \langle 0|V|C\rangle \frac{1}{E-E_C+i\epsilon} \langle C|V|0\rangle \quad (2)$$

The sum over non-collective states U_s is now dominated by the high excitation region of the nucleus because of the high level density there. Since the level density at high excitations should be independent of the deformed nature of the ground state, this part should be essentially the same for all nuclei in a broad range of mass; the subscript s then denotes its smooth behavior. The more enhanced the collective states are, the larger the second term will be and hence the more the elastic optical potential will deviate from the smooth behavior we attribute to U_s .

We can easily test this division of the optical potential into a part which is peculiar to each nucleus due to the particular nature of its collective states, and a part which is slowly varying from nucleus to nucleus. This can be done by solving the coupled system comprising the elastic and collective channels. Once the collective channels are treated explicitly, they no longer contribute to the effective interaction. In other words, the second term of eq. 2 is removed from the optical potential of the coupled system. We search empirically for a parameterization of the remaining interaction.

As an example of a deformed nucleus we choose ^{154}Sm which we treat as a rigid rotor and include explicitly the levels of the ground state rotational band up to and including the 6^+ state⁴⁾. We treat explicitly the collective vibrational 2^+ state in the spherical ^{148}Sm nucleus, employing the macroscopic description. After a search for the potential parameters we find that a single potential gives rise to the excellent agreement shown in fig. 2. In fact the same potential can be used, with only minor adjustments, from the spherical ^{148}Sm throughout the deformed region up to ^{178}Hf .

We identify this potential as U_s . It is given on the second line of Table 1. We note that it is quite similar to the elastic potential U_{el} for the spherical nucleus. This is understood in view of our discussion following eq. 2 and the weaker collectivity of the spherical nucleus. They differ in W and a in just the way expected.

This understanding of the optical potential has two important consequences. We are interested in determining the nuclear shape in the deformed region by analysis of inelastic alpha scattering through a solution of the coupled system⁵⁾. Whereas it may have been assumed that the parameters of the problem include the optical parameters as well as the shape parameters β_2, β_4, \dots , we have been shown that the former are essentially determined by the scattering on a neighboring spherical nucleus, and that the same potential can be used throughout the deformed region with only very slight adjustments.

A second consequence concerns the search for systematics in elastic optical potentials. It is clear that whenever strong collective states exist, the elastic potential will be anomalous. Only when the contribution of the collective states to the optical potential are removed will the systematics appear, since it is U_s that is smoothly behaved.

References

1. The experimental results are due to B. G. Harvey, D. L. Hendrie, O. N. Jarvis, H. H. Duham, J. Saudinos, J. Valentin, and J. Mahoney. Similar systematic differences have been found in proton scatterings by P. Stoler, M. Slagowitz, M. Makofske, and T. Kruse, Phys. Rev. 155, 1334 (1967).
2. For a fuller discussion of this see N. K. Glendenning, UCRL-17503 (1967), to be published in the Proceedings of the International School of Physics 'Enrico Fermi', Course XL, Academic Press, New York (1967).
3. H. Feshbach, Annals of Physics (New York) 19, 287 (1967).
4. For details see ref. 2.
5. See the companion paper by D. L. Hendrie, N. K. Glendenning, B. G. Harvey, O. N. Jarvis, H. H. Duham, J. Saudinos, and J. Mahoney, UCRL-17890.

Figure Captions

- Fig. 1. The elastic scattering of 50-MeV alpha particles from samarium isotopes which span the spherical ($A=148$) to deformed ($A=154$) region. Note the systematic trend to weaker oscillations and steeper slope of the envelope of maxima with increasing collectivity. Solid lines are elastic optical model calculations of the cross section. The data is from ref. 1.
- Fig. 2. Elastic and inelastic scattering of 50-MeV alpha particles by the spherical ^{148}Sm and deformed ^{154}Sm nucleus. Solid curves are coupled-channel calculations of cross sections based on a vibrational description of 148 and a rotational description of 154. In each case the same optical potential was used (Table 1) even though the elastic cross sections are different. Shape parameters β_λ for each nucleus are indicated on the figure.

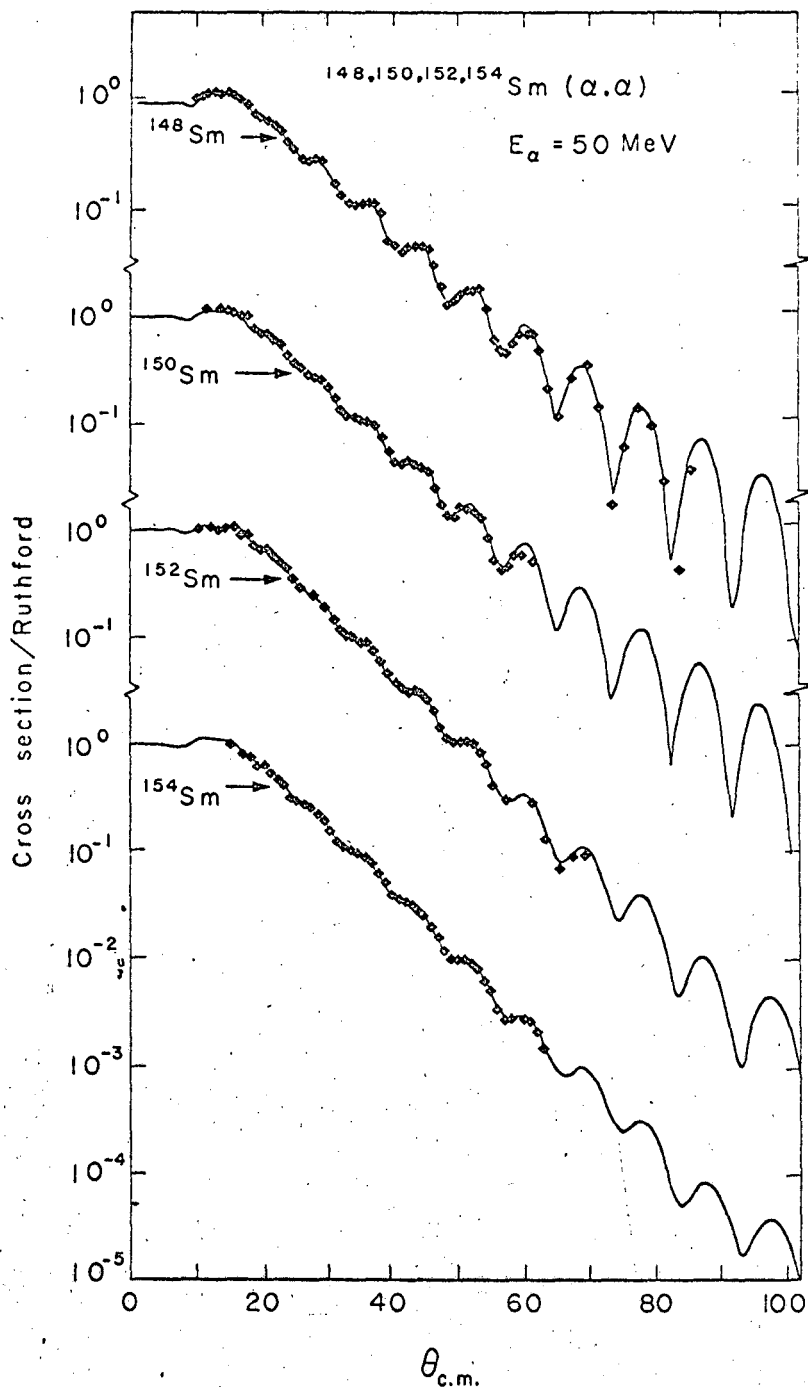
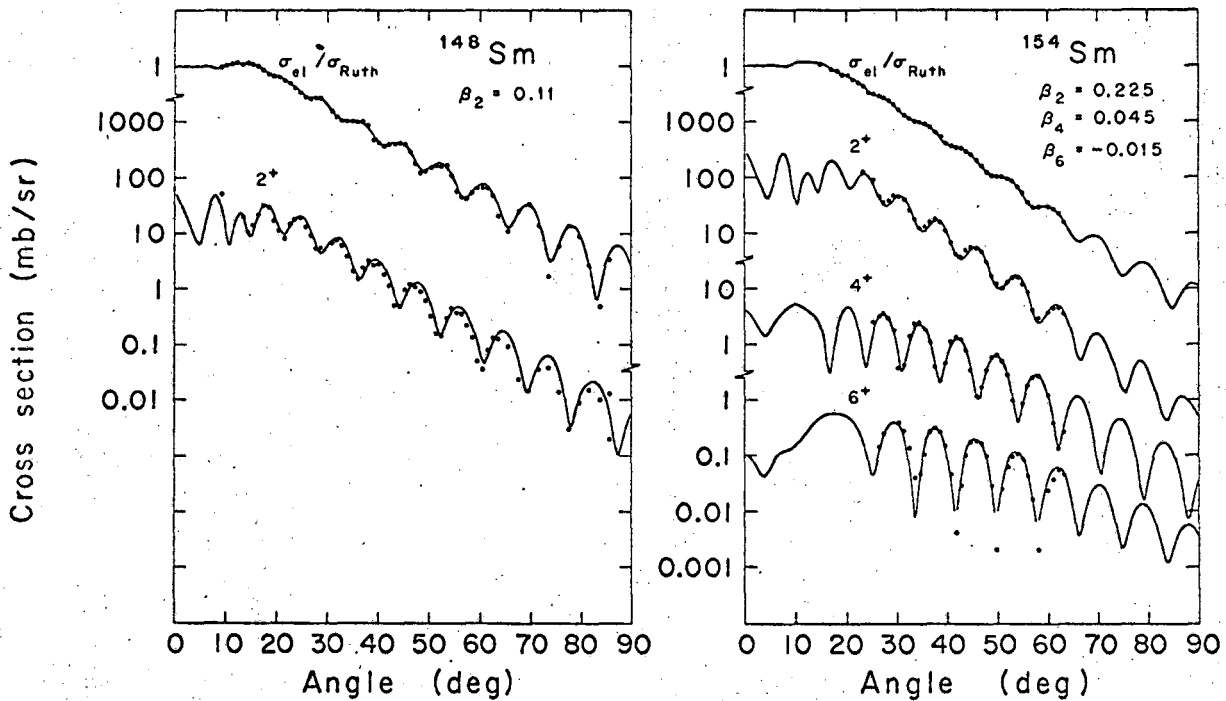


Figure 1.

XBL672-885

The elastic scattering of 50-MeV alpha particles from samarium isotopes which span the spherical ($A=148$) to deformed ($A=154$) region. Note the systematic trend to weaker oscillations and steeper slope of the envelope of maxima with increasing collectivity. Solid lines are elastic optical model calculations of the cross section. The data is from ref. 1.



XBL6710-5466

Figure 2.

Elastic and inelastic scattering of 50-MeV alpha particles by the spherical ^{148}Sm and deformed ^{154}Sm nucleus. Solid curves are coupled-channel calculations of cross sections based on a vibrational description of 148 and a rotational description of 154 . In each case the same optical potential was used (Table 1) even though the elastic cross sections are different. Shape parameters β_λ for each nucleus are indicated on the figure.

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.

