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ELASTIC AND INELASTIC PROTON SCATTERING FROM ^{46}Ti and ^{48}Ti

H. J. ERRAMUSPE

Synchrocyclotron Laboratory, Comisión Nacional de Energía Atómica, Buenos Aires, Argentina †

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Abstract: The dynamic deformation parameters β were measured for the separated isotopes ^{46}Ti and ^{48}Ti. Use has been made of Buck's coupled channel formalism for proton scattering. We obtain $\beta = 0.28$ for ^{46}Ti and $\beta = 0.26$ for ^{48}Ti.

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NUCLEAR REACTIONS ^{46,48}Ti(p, p′), $E = 14.5$ MeV; measured $\sigma(E_{p'}, \theta)$. Deduced nuclear deformation, reduced transition probability B(E2), mass transport (B_2) and restoring force (C_2) parameters. Enriched targets.

1. Introduction

Coulomb excitation has been one of the main sources to investigate collective effects and nuclear deformabilities in a broad range of nuclei. Nevertheless, some inconsistencies have remained and this is the case for the nuclei ^{46}Ti and ^{48}Ti. Since the available data have been obtained via the Coulomb excitation process, it is advisable to extract the desired information in an independent way. It is feasible to study simultaneously elastic and inelastic proton scattering processes by the introduction of the coupled differential-equation formalism due to Buck ^{1}), which includes the consideration of charged incident particles and spin-orbit effects and takes into account the rotational and the vibrational models.

Buck has carried out a study over a range of nuclei including ^{48}Ti. For this nucleus, however, the experimental data available ^{2}) correspond only to a target of natural Ti. It has been the purpose of this work to study separated isotopes and to improve the precision of the experimental data. The analysis has been also extended to ^{46}Ti.

2. Experimental methods

The experiment was performed using the external 14.5 MeV proton beam ^{3}) facilities of the Columbia University Pupin 91 cm cyclotron. The angular distributions were measured with a scattering chamber described elsewhere ^{4}). Particle detection was made with the use of Si (Li-drifted) solid-state detectors. An ion protector system was installed to avoid detector damage. Resolutions of the order of 100 keV

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were obtained. The energy spread of the beam was measured, and a value of 60 keV was obtained.

Spectra at 40°, 80°, 120°, 130° and 140° (lab angles) are shown in figs. 1 and 2. Detector collimators were used defining a solid angle of the order of 10^{-4} and a semi-angle at the centre of 22′.

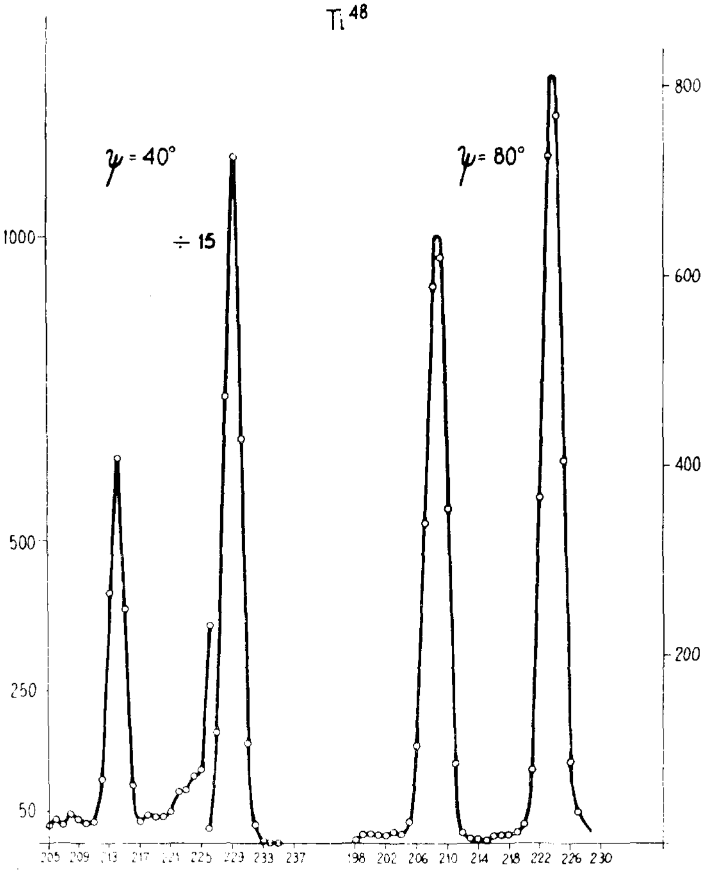

Fig. 1. Spectra at 40° and 80° (lab angles).

Target thicknesses were measured by the gravimetric technique. The targets were obtained from Oak Ridge National Laboratory. The ^{46}Ti target was enriched to 77.1 %, the remaining Ti being almost pure ^{48}Ti. The thickness was 3.93 mg/cm^2. The ^{48}Ti target was 99.4 % pure and 3.59 mg/cm^2 thick. The uniformity was better than 1 %. Total charge collection was verified.

Due to the good resolution of the detector and to the fact that the first excited levels are at 0.885 MeV for ^{46}Ti [ref. [9]] and at 0.983 MeV for ^{48}Ti [ref. [5]], the runs were taken for fixed-target, normal-beam-direction angles. With this procedure practically the same target area was exposed to the beam in the whole angular distribution. At the beginning, a fixed monitor was used to check the reproducibility of the positions of the targets.

Statistical, geometric, charge collection, dead-time, background and target thickness errors were taken into consideration.

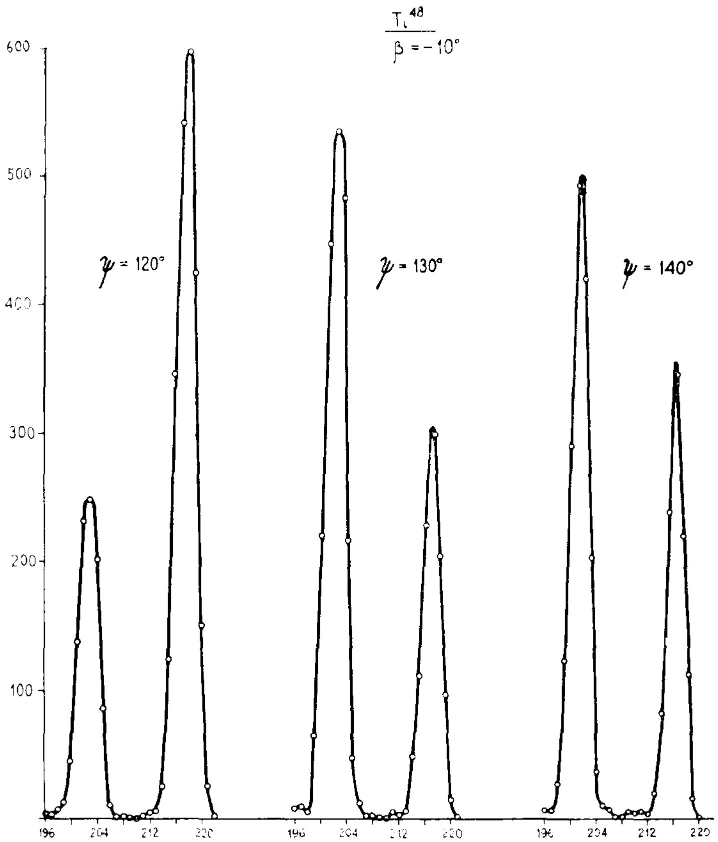

Fig. 2. Spectra at 120°, 130° and 140° (lab angles). Here β denotes the target, normal-beam direction angle.

Target and observation angle errors can be estimated to be less than ±0.2°. Generally, the statistical errors were kept less than 1 % for the elastic cross sections and less than 2 % for the inelastic ones, unless small cross sections forced larger errors. The background errors were estimated by taking extreme background subtraction curves, averaging and taking as error the deviation from the average value. These errors were significant only for 20° and 25° angles.

3. Results and discussion

The computer calculations were made by using a code due to Buck. Perey's parameters [6]) were used for both nuclei; $r_S = r_D = 1.25$ fm; $a_S = 0.65$ fm; $a_D = 0.47$ fm; $V_{S.O.} = 8.0$ MeV. For the meaning of the symbols, the reader is referred to ref. [3]). After several trials the imaginary potential was fixed equal to 11 MeV. The best fit for ^{48}Ti was obtained for $V_S = 47.4$ MeV and $\beta = 0.26$. This result is coincident with that of Buck [1]). The angular distributions and the theoretical fits are shown in fig. 3. An important fact to be observed is that the angular distribution has been followed until 20°. The increasing experimental difficulties for forward angles are well illustrated in fig. 4, where the increasing uncertainty for background subtraction is also shown in two different scales in order to display this effect. This situation is reflected in larger errors for the corresponding cross section at 20° and 25°.

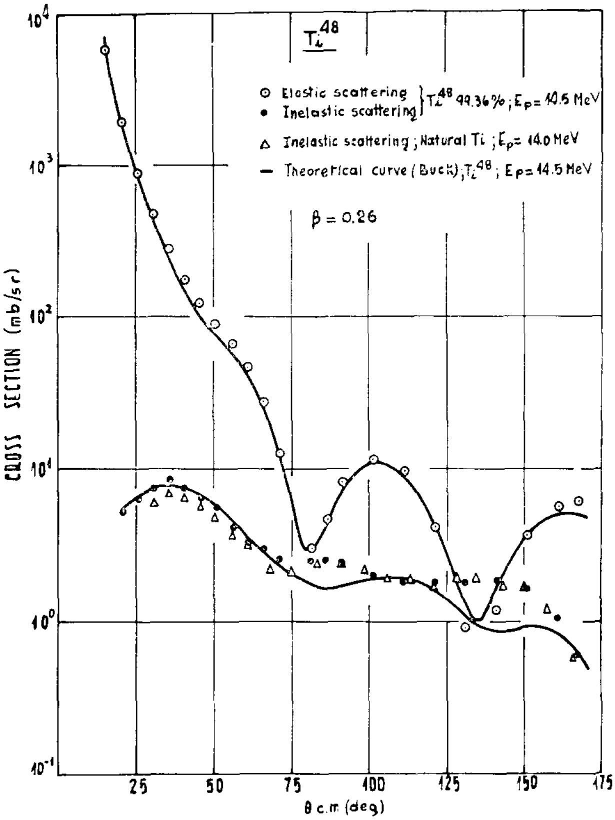

Fig. 3. Elastic and inelastic proton scattering from ^{48}Ti. Open circles-elastic scattering, full circles-inelastic scattering, triangles- results from ref. [2]), full line-theoretical curve for parameters given in the text.

After some trials to obtain the best fit for ^{46}Ti, the imaginary potential was fixed according to its known trend [6]) and from the previous value obtained for ^{48}Ti. We used $W_D = 9.5$ MeV.

After several not too successful trials to get the best simultaneous fits for the elastic and inelastic scattering, use was made of the formula $V_S = V_0 + C(N-Z/A)$ for the real part of the potential. As an indirect test of the value of the coefficient C, it is worth emphasizing that it was extracted from the result of ref. [3]). With the potential depth V_S obtained for ^{48}Ti and with the above expression, $V_S = 46.5$ MeV for ^{46}Ti. Finally, this value turned out to be the best one to get a good fit, as is illustrated in fig. 5. The nuclear deformation parameter turned out to be $\beta = 0.28$.

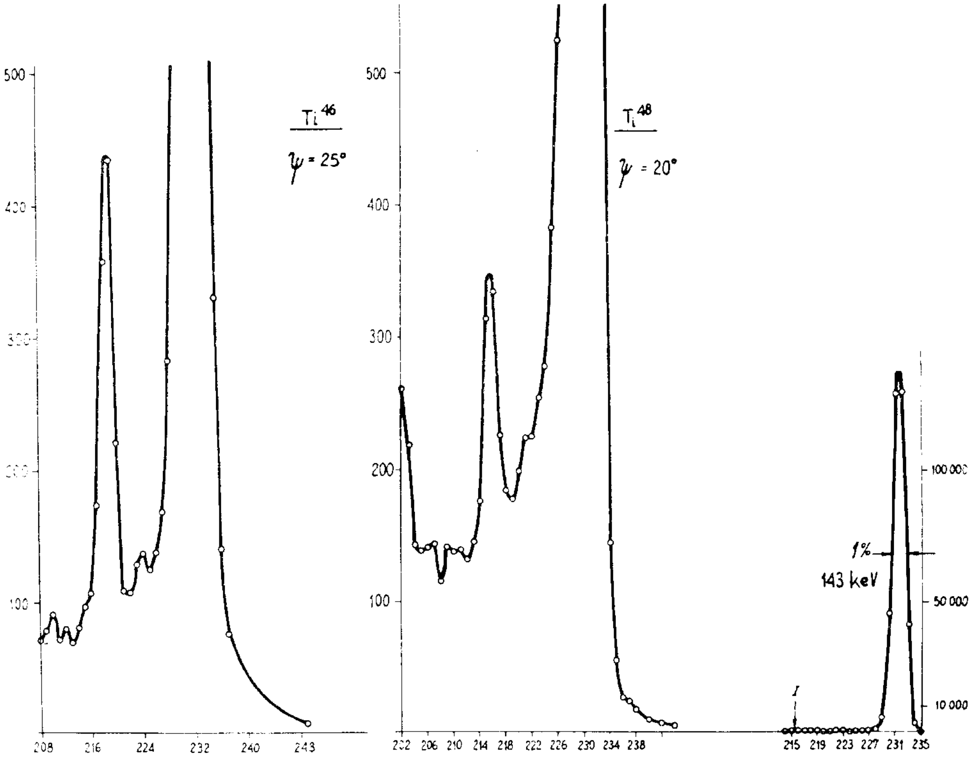

Fig. 4. Proton spectra for $\psi = 20°$ and $\psi = 25°$ (lab angles). On the right of the figure, two different scales have been used. A resolution of 1 % for the elastic peak is shown.

The elastic fit can be considered very good. The inelastic one shows the same type of discrepancies as for ^{48}Ti in the regions 75°–100° and 130°–160°.

These values have the advantage of being independent of any model [1]).

Since 14.5 MeV protons were used for this experiment, compound scattering effects can be neglected. At this energy we are several MeV above the threshold for the (p, n) reaction, which constitutes a preferential channel for compound nucleus de-excitation [7]).

With the aid of the parameters just determined, a brief study of the collective properties of these nuclei can be made. Using the expressions of ref. [8]), the results shown in table 1 are obtained.

The results show that ^{46}Ti has a stronger tendency to deformation than ^{48}Ti. This is in agreement with the fact that the former is farther from a neutron closed shell than the latter.

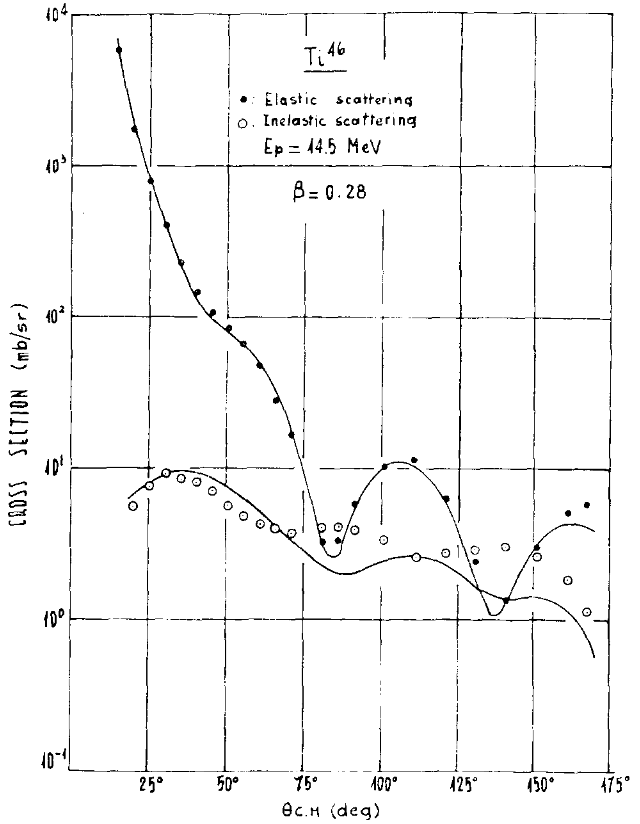

Fig. 5. Elastic and inelastic proton scattering from ^{46}Ti. Full circles – elastic scattering, open circles – inelastic scattering, full line – theoretical curve for parameters given in the text.

TABLE 1

Collective parameters for the nuclei ^{46}Ti and ^{48}Ti obtained from 14.5 MeV (p, p′) results

Nucleus	B(E2: 0 → 2) $e^2 10^{-48}$ cm^4	B_2/B_2(irrot)	C_2 (MeV)	C_2(irrot) (MeV)
^{46}Ti	0.0738	15	28	47
^{48}Ti	0.0673	14	36	49

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