STUDY OF THE BACK-ANGLE ANOMALY IN ELASTIC α-^{40}Ca SCATTERING.

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The elastic scattering of α-particles from ^{40}Ca up to about 50 MeV reveals a strong backward rise of the angular distributions exceeding the back-angle cross-sections of neighbouring nuclei[1]. Various attempts have been made to get a conclusive explanation of this effect. Recently, rather good fits have been obtained within the framework of an optical folding model[2], but this description provides little insight into the microscopic structure of the α-nucleus interaction.

Since the back-angle region of the α-^{40}Ca angular distributions is fairly well fitted by the square of a single Legendre Polynomial it is obvious that one partial wave is predominating within the scattering amplitude. This supports an interpretation in terms of resonances of the α-^{40}Ca-system, which, by their specific ℓ-dependence, can be regarded to be of quasimolecular type.

By using the Resonating Group Method (RGM) in connection with the Generator Coordinate Method (GCM) it has been possible to describe the α-^{40}Ca-system on a completely microscopic basis, but restricted to the elastic channel only[3]. As a main result, the phase shifts calculated in this way reveal resonances forming a rotational band in close accordance to the experimental observations (fig.1).

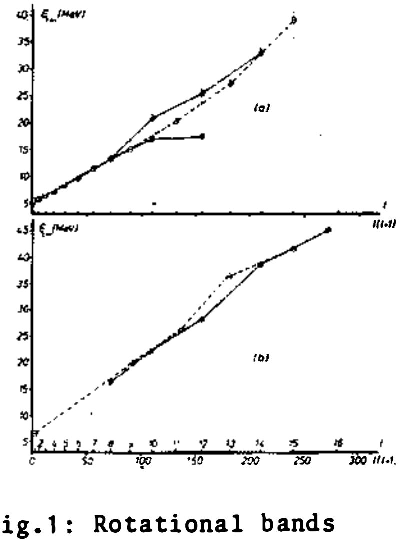

Fig.1: Rotational bands
a) theory ; b) experiment

It might be expected that the angular distributions at resonance energies display a back-angle structure of P_{ℓ}^{2}-type which is only scaled up in account of the omission of absorption. Due to the strong interference of lower partial waves, which are not damped by any absorption, the back-angle distributions do not show this simple structure.

In order to arrive at a more realistic description of the experimental data, an inclusion of inelastic reaction effects seems to be necessary. Assuming that inelastic scattering proceeds via the formation of a compound nucleus only, a semi-microscopic absorptive potential has been derived and introduced into the RGM-equation. Hence, energy- and angular momentum dependencies are determined by the level density formula[4], whereas the radial dependence has been assumed to be proportional to the non-local overlap-kernel of the RGM. This leaves only one free parameter which has been adjusted to the experimental data at a fixed energy. By this concept, the microscopic character of the RGM seems to be most consistently preserved.

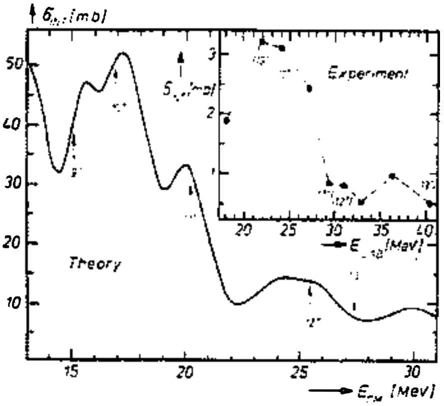

Fig.2: Back-angle integrated excitation function. The maxima coincide with best P_ℓ^2-structure for back-angles. The arrows mark the resonance positions of the pure elastic calculation taken from ref.[3].

Solving the RGM-equation including the absorptive part, angular distributions have been obtained in the energy-range up to E_{CM}=30 MeV. Integration of the theoretical cross-sections within the back angle region leads to an excitation function with distinct maxima (fig.2) indicating the existence of well pronounced resonances. The energy-range, that has been chosen, includes resonances from ℓ=9 to ℓ=13. As a main result the angular distributions at these maxima reveal a prominent P_ℓ^2-structure at backward angles.

This feature is a marked characteristic of the experimental data and clearly supports the interpretation of the back-angle anomaly as due to α-^{40}Ca resonant states (fig.3). However, at forward and intermediate angles a sufficient agreement with the experimental data is not achieved. This failure is connected with the poor description of the nuclear surface by the harmonic oscillator shell model wave functions used.

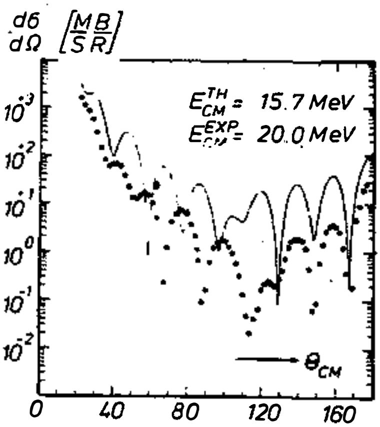

Fig.3: Angular distribution at E_{CM}=15.7 MeV (ℓ=9-resonance). The experimental data are taken from ref.$^{1)}$.

It turns out that the occurence of P_{ℓ}^{2}-structure does not coincide with the resonance positions that have been deduced by calculations without absorption. A detailed investigation of the behaviour of resonances in the presence of absorption has therefore been accomplished.

Various methods that have been applied to define resonances as well as their energy position lead to different results. A determination of resonances by use of the maxima of the transmission coefficients is most incomplete and even fails in the strong absorption limit. A more suitable method for getting more information about resonance features is supplied by the study of Argand diagrams.

In case of a counterclockwise Argand curve, resonances are defined as maxima of $\left|\frac{dS}{dE}\right|$, which describes the maximum "speed" of the Argand line. In fig.4 various curves of transmission coefficients and $\left|\frac{dS}{dE}\right|$ are shown for comparison. In the case of ℓ=11 and ℓ=13 the $\left|\frac{dS}{dE}\right|$-curves supply a second resonance that has not been observed in calculations without absorption.

In addition to the above methods poles of the scattering matrix S_l have been investigated by solving the RGM-equation for complex energies. The resonance positions obtained by this method are compared in table 1 to those determined by the previous methods.

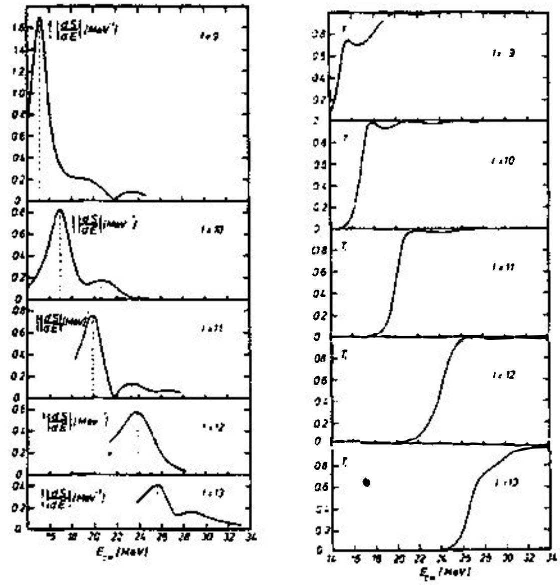

Fig.4: The $\frac{dS}{dE}$ -curves and transmission coefficients for l=9 - 13. The respective resonance positions are marked by dashed lines.

As a remarkable result one finds that P_l^2-structure of the angular distributions are intimately related to resonances of the respective partial waves. Hence, the experimentally observed back-angle anomaly can be interpreted as quasimolecular states of the α-^{40}Ca-system.

l	a)	b)	c)	d)	e)
9	15.1	15.62	15.58	15.1	15.7
10	16.9	17.12	17.01	17.0	18.0
11	20.2	21.46	21.1	19.9	21.5
12	25.4	26.37	25.6	23.8	27.0
13	27.3	30.93	27.1	28.5	--

Table 1: a) resonance positions from ref[3] (without absorption) b) poles of S_l (without absorption); c) poles of S_l (with absorption); d) maxima of $|\frac{dS}{dE}l|$; e) maxima of T_l

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