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NEUTRON TOTAL ELASTIC SCATTERING CROSS SECTION MEASUREMENT ON ^{16}O

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Abstract: Total cross section measurement of elastically scattered neutrons on ^{16}O was done in the neutron energy range between 14 and 19 MeV. Liquid oxygen target in an annular-sphere geometry was used. A resonance structure at 17.3 MeV incident neutron energy was found, corresponding to the resonance of the same height and width as in total neutron cross section. A resonant amplitude of the single particle type superimposed on the optical potential scattering amplitude was assumed and the analysis gave an assignment of $s_{1/2}$ for the state at 20.4 MeV excitation energy in ^{17}O.

1. Introduction

The elastic scattering of protons and neutrons on ^{12}C and ^{14}N established the existence of resonance structures at high excitation energies in the corresponding compound nuclei. For ^{13}N and ^{13}C the resonances were found around 16 and 23 MeV[1, 2], and for ^{15}N around 16 MeV of the excitation energy[3]. No strong resonance structures were found in the other nonelastic channels at these energies[2, 3]. Total cross section measurement of neutrons on ^{16}O showed resonance structures in the energy range between 14 and 20 MeV of the incident neutron energy[4]. This experiment was made to see if some of these resonances are of the same elastic scattering type.

2. Experimental arrangement

The experiment was done with a 4 MeV Van de Graaff accelerator of the University of Texas and with the 1.5 MeV Cocroft-Walton accelerator of the »Boris Kidrič« Institute in Beograd. As neutron source a ZrT target about 1 mg/cm^2 in thickness was used with 5 μA of deuteron beam. The experimental arrangement was very similar to one described in paper[1, 2]. The geometry is shown in Fig. 1.

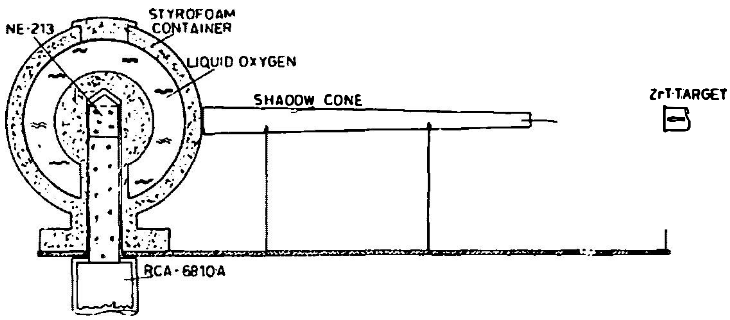

Fig. 1 — Experimental arrangement.

The neutron detector was an encapsulated NE 213 liquid scintillator (Nuclear Enterprises) of 2.5 cm in diameter and 2.5 cm long, mounted on a 12 cm long lucite light guide, and a RCA 6810 A photomultiplier; this was connected to a neutron-gamma ray discriminator circuit. The liquid scintillator is more suitable than stilbene for low temperature measurements as the latter is very sensitive to the temperature changes. The scatterer consisted of a spherical shell of liquid oxygen of 15 cm o. d. and 9 cm i. d. contained in a double walled styrofoam container as shown in Fig. 1. A 2.5 cm hole at one end at the styrofoam container allowed the liquid scintillator on the lucite light guide to be placed in the center of the shell. To keep the temperature of the detector constant the air was permanently blown in the container hole. The level of the liquid oxygen was kept as constant as possible by refilling the container before each measurement to the well defined mark. The liquid oxygen was obtained by circulating the oxygen gas through a liquid nitrogen trap. The shadow cone of 30 cm length made out of brass was supported by thin rods from an aluminium arm which could be rotated about a vertical axis passing through the tritium target.

The neutron energy change was obtained by varying the angle of emission of neutrons relative to the incident deuteron beam, as well as by changing the incident deuteron energy.

For each neutron energy measurements were made with the three geometrical arrangements shown in Fig. 2. The geometry (A), without a shadow cone and scatterer, determines the number of neutrons reaching the detector directly from the target; the geometry (B), with the shadow cone shielding the detector from the direct neutron beam determines the background; the geometry (C), with the scatterer and the shielded detector determines the number of elastically scattered neutrons.

The proton recoil spectra for each measurement were taken and printed on Nuclear Data 512 channel analyser and then analysed. From each recoil spectrum an equal end part corresponding to 6 MeV of neutron energy was taken into account. In this way the inelastically scattered neutrons were eliminated, as the first excited state of ^{16}O lies at 6.05 MeV[5].

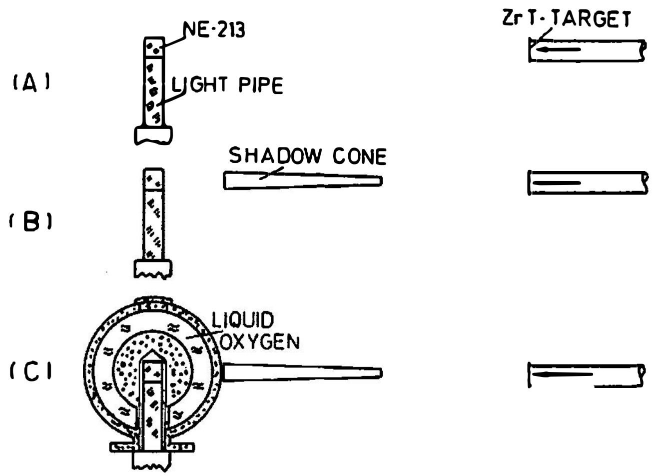

Fig. 2 — Geometry for the total elastic scattering cross section measurements.

The quantity C—B, the fraction of the neutrons scattered from the scatterer sphere shell, is proportional to the total elastic scattering cross section; only a small part of the total solid angle of the sphere, the part which is shielded with the shadow cone in the front and back scattering angles, is not taken into account.

The ratio (C—B)/(A—B) was determined with the statistical accuracy of 3 % in about 10 to 15 independent measurements for each point.

3. *Results*

In Fig. 3 the ratio (C—B)/(A—B) is plotted against the incident neutron energy. The broad peak shows up at 17.3 MeV with a width of about 700 keV. The energy resolution of the incident neutron beam, depending on the angle subtended by the sphere at the source, on the target thickness, and on the neutron emission angles is indicated in the same figure.

The absolute scale in barns was obtained by normalysing the ratio curve to the 14 MeV data[6].

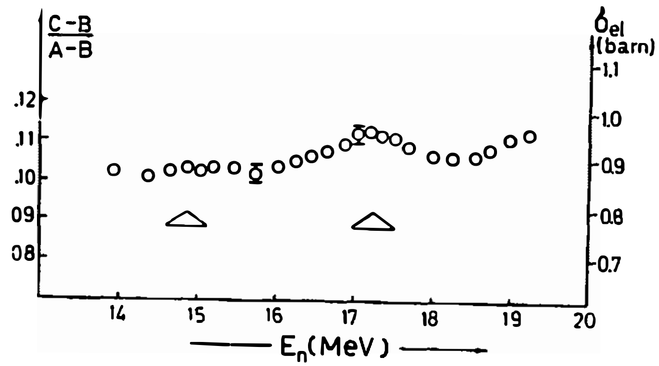

Fig. 3 — Measured cross section for neutrons scattered elastically from oxygen in the energy range between 14 and 19.5 MeV. The triangles indicate the energy resolution and the statistical error.

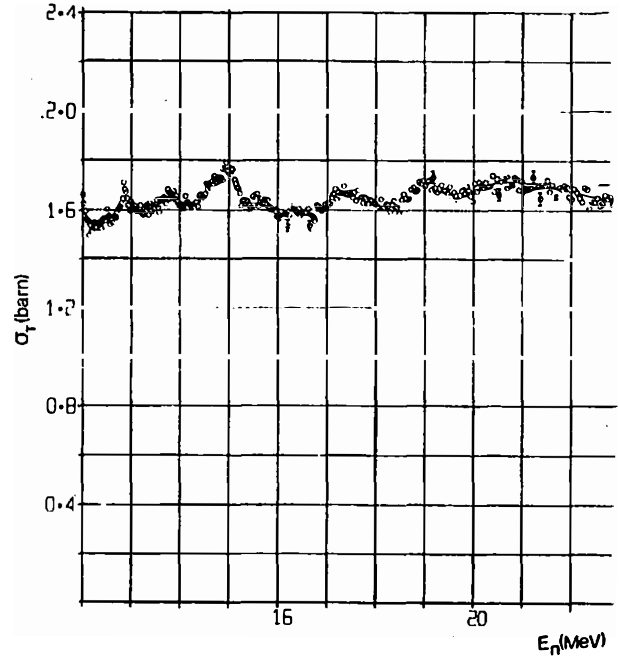

Fig. 4 — Total neutron cross section on ^{16}O in the energy range between 12 and 22 MeV.

4. Discussion

Comparison between the total cross section data for the n + ^{16}O reaction[4] (Fig. 4) and the result of this measurement (Fig. 3) indicates that the resonance structure shows up at 17.3 MeV in both cross sections with about the same height of 0.1 b The cross sections for the other reactions which were measured at this energy show very small resonance peaks; so the

^{16}O (n, alpha) ^{12}C has a peak of $\leqslant$ 5 mb[7]; three alpha groups from the same reaction show an interference minimum of about 5 mb[7]; ^{16}O (n, p) ^{16}N shows also a resonance of less than 5 mb[8]. That was the reason to analyse the resonance at 17.3 MeV as a result of a single particle resonant state. A resonant amplitude was added to the optical potential scattering amplitude at this energy[2, 7].

Total elastic scattering was found by integrating so obtained differential cross section as given by[2]:

$$d\sigma_{\pm}/d\Omega = \left(Ae^{i\delta_A} + a\right)^2 + \left(Be^{i\delta_B} + b\right)^2$$

where $(Ae^{i\delta_A} + Be^{i\delta_B}B)$ is the optical potential scattering amplitude. All the parameters were obtained by using a computer program due to F. G. Perey, with a potential of the following form[10]: the real part of the potential 49.3 — 0.33 E_n (MeV), of Saxon-Woods form, with the nuclear radius equal to 1.25 $A^{1/3}$ fm, the difuseness being given by the parameter a = 0.65 fm; the imaginary part of the potential was a surface potential (the derivative of a Saxon-Woods potential), the depth being 5.57 MeV with a difuseness b = 0.70 fm, and the spin-orbit potential of the same general type, with a depth of 5.5 MeV and a difuseness of 0.65 fm.

a and b are resonance scattering amplitude[2]:

$$a(\theta) = i/2k \left((l+1)\left(1 - e^{2i\delta_l^+}\right) + b\left(1 - e^{2i\delta_l^-}\right)\right) P_l(\cos\theta).$$

$$b(\theta) = i/2k \left(e^{2i\delta_l^+} - e^{2i\delta_l^-}\right) P'_l(\cos\theta),$$

where the phases δ_l^+ and δ_l^- refer to two partial waves with $j = l \pm 1/2$.

The experimental and calculated total elastic cross sections for $l = 0$ and 1, for the 17.3 MeV resonance are given in the Table. The ratio Γ_n/Γ was estimated to be 0.7. No higher angular momenta are included for they give peak heights that would require far to low a value of Γ_n/Γ, to give agreement with the experiment.

Table

TOTAL ELASTIC SCATTERING CROSS SECTION IN mb FOR THE 17.3 MeV RESONANCE

Experimental	Calculated (Γ_n/Γ = 0,7)		
(from Fig. 3)	$l = 0, j = 1/2$	$l = 1, j = 1/2$	$l = 1, j = 3/2$
$\geqslant$ 100	150	195	390

The resonance therefore seems to be $j = 1/2^+$, $T = 1/2$. The strong resonance which shows at 15 MeV in total neutron cross section with a height of about 0.2 b has no counterpart in the elastic scattering cross section of more than 10 mb, although this resonance structure appears strongly in the (n, alpha)[5] and (n, p) cross sections[6].

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MERENJE TOTALNOG ELASTIČNOG PRESEKA ZA NEUTRONE NA ^{16}O

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Sadržaj

U energetskoj oblasti upadnih neutrona od 14 do 19 MeV izmeren je totalni elastični presek na ^{16}O. Korišćena je prstenasto-sferna geometrija, sa DT reakcijom kao izvorom monoenergetskih neutrona. Meta od tečnog kiseonika je formirana u stirofomskoj šupljoj sferi sa neutronskim detektorom smeštenim u sredini sfere. Kod registracije neutronskih impulsa korišćeno je neutronsko-gama diskriminaciono kolo.

Nađena je rezonanca na energiji od 17.3 MeV, amplitude 0.1 b, sa poluširinom od oko 700 keV. Totalni presek[4] pokazuje na toj energiji rezonancu približno iste amplitude i širine. Zato je kod analize te rezonance pretpostavljena jednočestična rezonantna amplituda superponirana na amplitudi rasejanja optičkog potencijala. Data je oznaka za stanje ^{17}O na 20.43 MeV energije pobude kao $s_{1/2}$.