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Fast-neutron total cross section of Mg, Cl, K, Ca, $5.0 \div 8.5$ MeV

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SEZIONE II

(Fisica, chimica, geologia, paleontologia e mineralogia)

Fisica. — *Fast–neutron total cross section of* Mg, Cl, K, Ca, $5.0 \div 8.5$ MeV. Nota di UMBERTO FASOLI, DOMENICO TONIOLO e GUIDO ZAGO, presentata (*) dal Socio A. ROSTAGNI.

RIASSUNTO. — Sono state misurate, nell'intervallo di energia da 5.0 a 8.5 MeV, le sezioni d'urto di neutroni sugli elementi naturali Mg, Cl, K, Ca, con una dispersione dell'energia di circa 30 keV e accuratezza statistica migliore di 2%. La misura sul Ca è stata eseguita anche da 1.5 a 5.0 MeV. Le fluttuazioni osservate hanno caratteristiche interpretabili in termini statistici.

In a previous paper [1] we presented the results of a measurement of the neutron total cross sections of Na, Al, Si, P, S, in the energy interval $5.0 \div 8.5$ MeV. The measurement has been performed with an energy resolution of 30–40 keV and a statistical accuracy of 1–2%, in order to investigate the problem of the fluctuations of fast neutron cross sections.

Since then, other Authors have studied the same problem. Carlson and Barschall [2] measured the total neutron cross section of 18 elements from Mg to Bi, with an energy spread of 20 to 50 keV in the energy range between 4.5 and 7.5 MeV, which was extended up to 14 MeV for some elements. Glasgow and Foster [3] performed, with moderate energy resolution, a systematic measurement on 92 elements in the range 2.5–15 MeV. They also made an accurate comparison with many (24) other previous measurements including ours, and found good agreement between some of their results and similar ones obtained at Wisconsin, Los Alamos, Harwell and Padova. This agreement was considered as supporting all their results.

The presence of strong fluctuations renders the measured cross section values largely dependent on the experimental neutron energy spread [1]. It is therefore important, when one needs accurate cross section values, to use small energy spreads. Therefore, we considered worthwhile extending our measurement [1], with the same energy resolution of about 30 keV, to other elements. In this paper, we present the results relative to the natural elements Mg, Cl, K, Ca. With the elements previously reported [1] all natural elements having $11 < Z < 20$ have been studied with the only exception of Argon.

(*) Nella seduta dell'8 aprile 1972.

The measurement has been performed, as in References [1] by means of the transmission method. Neutrons were used which were produced at 0° by the p, t and d, d reactions in thin gaseous targets, at the 5.5 MeV Van de Graaff accelerator of Padova. The neutron detector, located 3 m from the neutron source and 2 m from the sample, was a plastic scintillator NE 102A, 5 cm wide and 2.5 cm thick, seen by a 56AVP photomultiplier. The time-of-flight technique has been used, by pulsing the beam at few nanoseconds at the frequency of 3 Mhz, to reduce the neutron and gamma rays background.

The energies of the neutrons were calculated from the known proton and deuteron energies, taking into account the energy lost in the target. The uncertainty on the neutron energy, mainly due to the uncertainty on the thickness of the 1 μm Nickel foil closing the target, is evaluated to be around 10 ÷ 20 keV.

The neutron energy spread has been evaluated to be 30 ÷ 40 keV, the main contribution being due to the finite target thickness.

The data were taken in steps of 25 keV, in the interval 5.0 ÷ 8.5 MeV; for Ca the measurement was extended also to the interval 1.5 ÷ 5.0 MeV. The counting statistics were such as to allow statistical errors between 1 and 2 %. The data were corrected for the background, measured by means of a long iron shadow bar, the correction being less than 2 %. The correction for the dead time of the electronics had an average value of 2 %. No correction was carried out for the in-scattering effect, because it was negligible.

The sample used had the following characteristics:

Magnesium: cylinder of metal, chemical purity 99.5 %, diameter 2.5 cm, length 8.8 cm, number of atoms per square centimeter in the axis direction, $n = 3.780 \cdot 10^{23}$ cm^{-2}.

Potassium: cylinder of metal, purity 99.9 %, diameter 2.5 cm, length 19.11 cm, $n = 2.532 \cdot 10^{23}$ cm^{-2}, contained in a very light aluminium can to avoid oxidation.

Calcium: cylinder of metal (purity better than 99 %), diameter 2.5 cm, length 15 cm, $n = 3.446 \cdot 10^{23}$ cm^{-2}, contained in a very light aluminium can.

Chlorine: cylinder of KCl, purity 99.7 %, in very fine powder, pressed in a light aluminium can equal to the one used for K, $n = 2.532 \cdot 10^{23}$ cm^{-2}. The chlorine data have been obtained by subtracting the potassium contribution from the measurement of the transmission through KCl.

In fig. 1 the measured cross sections are graphically presented versus energy. The Cl and K points are each the average of three contiguous values. The numerical values have been sent to " ENEA, Neutron Data Compilation Centre ", Paris. The agreement with the Authors of References [2] and [3] is good if one takes into account the different energy resolutions.

The general behaviour of the fluctuations of the elements studied here is not different from those quoted before. These new data therefore confirm the conclusions previously reported [1, 2, 3].

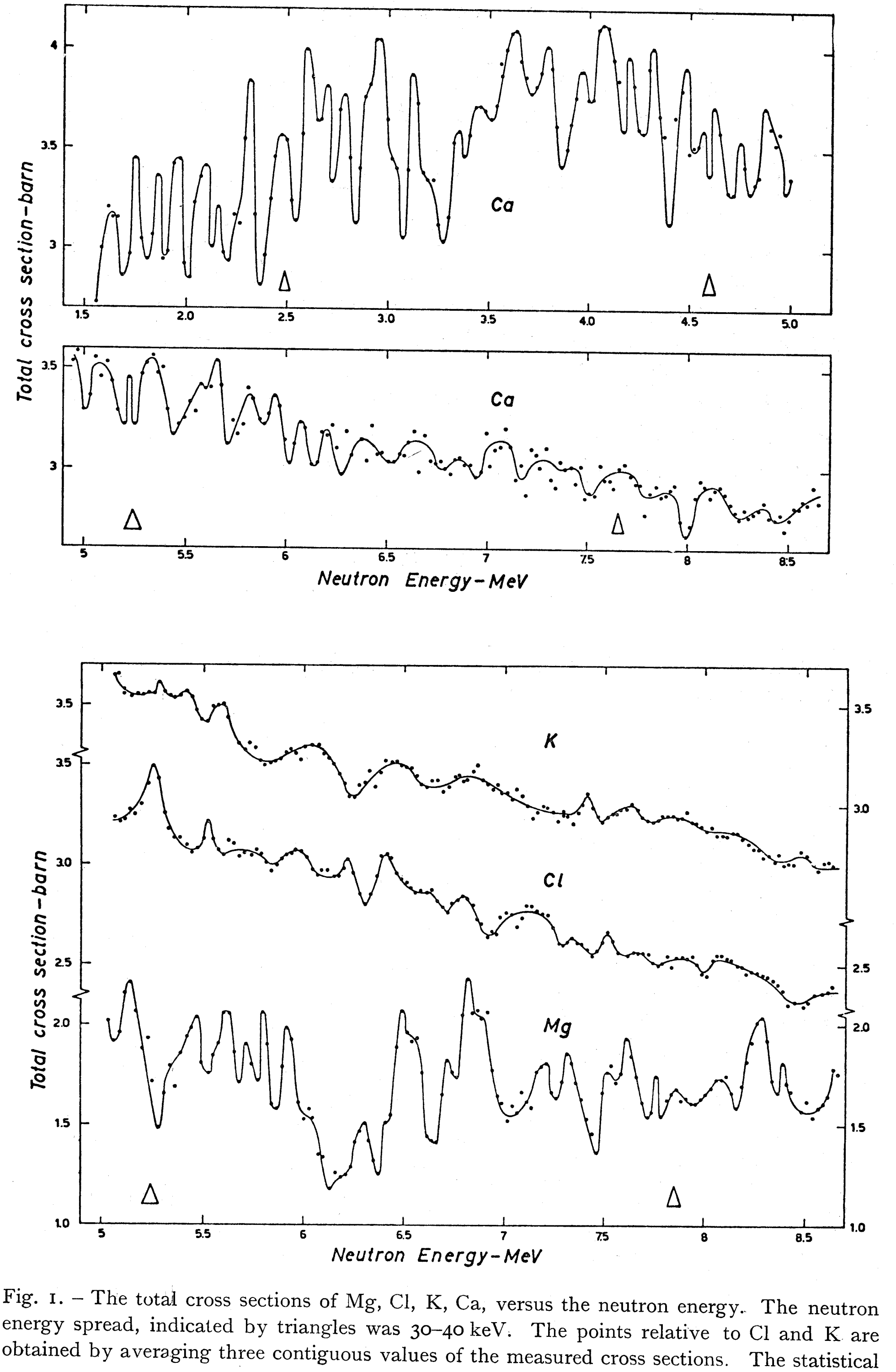

Fig. 1. – The total cross sections of Mg, Cl, K, Ca, versus the neutron energy. The neutron energy spread, indicated by triangles was 30–40 keV. The points relative to Cl and K are obtained by averaging three contiguous values of the measured cross sections. The statistical errors are 1–2%.

We want to emphasize here two final remarks which seem to present a peculiar evidence.

(*i*) When the fluctuations are large, the optical model is able to reproduce the gross behaviour of the cross sections, only when they are averaged on very wide energy intervals.

(*ii*) Assuming a statistical origin for the fluctuations the variance around their average value, as expressed by Ericson [4], should depend on the weighting factor $1/[2\,(2\,I + 2)]^2$ where I is the ground spin of the target nucleus. Limiting our remarks to the elements investigated by us, having $11 < Z < 20$, we note that Mg, Si, S, Ca have spin zero, P spin 1/2, Na, Cl, K spin 3/2, Al spin 5/2, taking the spin value of the most abundant nucleide for the polysotopics natural elements. From the figures presented here and in our previous work [1], it is evident that the elements showing larger fluctuations are Mg, Si, S, Ca. Therefore, our results favour the assumption of the statistical nature of the fluctuations.

References

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[4] T. Ericson, « Ann. Phys. (N.Y.) », *23*, 390 (1963).