SOME NEUTRON SPECTRUM MEASUREMENTS THE THERMAL TOTAL NEUTRON CROSS SECTION FOR MOLYBDENUM AT ROOM TEMPERATURE

By

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THESIS

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S U M M A R Y

This thesis describes the author's work in the measurement of the total neutron cross-section of molybdenum in the energy range from 2.2 eV to 0.0022eV at room temperature.

The measurements were performed using two time - of - flight spectrometers installed in front of two of the horizontal channels of the ET-RR-1 reactor. One of the spectrometers has its mechanical chopper with pertinax 160 mm in diameter and having a straight slit 1x25 mm^2 while the other spectrometer has a rotor of the same dimensions but with a cigar - shaped slit, in order to increase the transmission for neutron energies below 5 meV. The rotation rate of the rotors can be controlled in the range 800-3600 r.p.m. within the accuracy of 0.14 %. ^{3}He gas filled neutron detectors were used during the measurements. The calibration of the spectrometer time scale was done using the γ -ray pulse emitted from the reactor and transmitted through the rotor slit. Molybdenum is considered as one of the important materials in the reactor design; since it is a fission product nucleus, also its thermal neutron cross-section data at neutron

energies > 0.01 eV appear rather scattered over a wide
range. Moreover, in the region where coherent elastic
scattering is significant, the only available data
does not clearly show any resolved Bragg peaks. Thus it
seems useful to study the thermal total neutron cross -
section for this element, for the precise determination
of its thermal absorption coherent, incoherent and in-
elastic scattering cross- section.

The measurement samples used were prepared using
a reactore grade molybdenum in the form of metal sheets.
Spectroscopic analysis of the used element was carried
out for accurate determination of impurities. The analy-
sis show that the total amount of impurities is very
small (50 ppm.) which gives negligible effect on the
measured cross-section. X-ray analysis has also been
carried out to determine the crystalline structure of
the molybdenum sample used. This analysis shows that
the molybdenum structure is in confirmation with the
body centre cubic structure.

The measurements of the total neutron cross-
section of molybdenum were carried out in three regions
to obtain suitable counting rates, taking into account

the effect to background ratio as well as the counting
rates. In the first run, the measurements were performed
in the energy range from 2.2 eV to 0.01 eV. At neutron
energies below 0.04 eV the measured cross-section behaviour was found to fluctuate near a constant value (o_t =
6.09 ±0.63)b. In the second run the measurements were
performed in the energy range from 0.02 eV to 0.005 eV.
At neutron energies below 0.04 eV, the observed behaviour
of the cross-section shows sharp cut- offs at neutron
wavelengths corresponding to double interplaner distances
of molybdenum crystal structure.

In the third run, the measurements were performed in
the energy range from 0.005 eV to 0.0022eV. The measurements in this range were performed at room temperature.
A Be block, 20 cm thick, was used in this run to remove
neutrons of energies higher than 0.005 eV; consequently
increasing the effect to background ratio. The contribution of known close and far -away resonance upon the
cross - section value in the thermal region have been
calculated using the single level Breit - Wigner formula.
The values of both the potential scattering cross - section and effective nuclear radius R'were determined for
the cross - section.

From the data analysis, the potential scattering amplitude value was found to be in good agreement with that calculated according to optical model with the following parameters: V_o = 42 MeV., and the ratio of the imaginary to the real component of the potential

= 0.05 and R' = 1.48 $A^{\frac{1}{3}}$.

The coherent scattering amplitudes as well as the coherent scattering cross - sections of molybdenum were determined using the values of the Bragg cut-offs observed in the total cross-section measured at low neutron energies. The resulting values are in good agreement with those obtained using neutron diffraction methods. The measured total neutron cross-section of Mo beyond the cut-off wavelength, at room temperature, provides information about the incoherent scattering cross-section of molybdenum. The one phonon annihilation process was estimated also at long neutron wavelengths and its contribution to the total cross-section at room temperature was found to be very small, since the Debye temperature for Mo is relatively small and can be neglected compared to the absorption and incoherent scattering cross-section.

During the course of this work, the following
papers were prepared:-

1) Measurement of the total neutron cross - section of
   molybdenum in the energy range from 2.2 eV to 3 meV.
   By M. Salama and M. Mazhar.

   Atomkernenergie/ Kerntechnik Bl.39 (1981)Lfg. 3,207.

2) New measurements for the total neutron cross-section
   of molybdenum in the energy range from 2.2 to 0.04 eV.
   By M. Salama and M. Mazhar.
   Atomkernenergie/ Kerntchnick Bd. 40 (1982) Lf 9.4,290.

3) Analysis of the total neutron cross - section of
   molybdenum measured at room temperature and at
   wavelength neutrons beyond λ_c.
   By M. Salama and M.S. Mazhar. Under publication,
   in Atomkernenergie - Kerntechnick Journal.

INTRODUCTION

1- I N T R O D U C T I O N

Slow neutrons are used mainly in an increasing
number of original applications which lead attentively
to the importance of studying the interaction of neutrons
with matter. Slow neutrons have gained also a great
importance as a tool for research and application at
present time. The low energy and relatively long wave-
length of such neutrons govern their interaction with
matter. Since the wavelength of slow neutrons is of the
same order as the interatomic distances in crystals,
therefore the optical effects are quite marked [1,2].

In pure nuclear physics research, slow neutrons
play an important role, since they can be used in the
investigation of atomic structure of different materials,
at the time when the application of X-rays or electrons
seems inconvenient or impossible as in diffraction studies
of hydrogenous compounds and alloys of elements with
neighbouring atomic numbers.

Information about the vibrational frequency
spectrum of the crystal lattice and phonon dispersion
curves can be gained from neutron scattering data of

different solids [3] . Moreover, slow neutrons give
valuable information about the motion of atoms (or mole-
cules) in liquids, also about the diffusion mechanism.
Magnetic dynamics of crystals can be investigated
successfully using slow neutrons. Slow neutrons have
been successfully used also in the determination of
nuclear scattering amplitudes for different isotopes.
Moreover, slow neutrons are also important and essen-
tial as iniators and perpetuators of nuclear chain
reactions in most types of reactors [4] .

The probability of interaction between a given
nucleus and an incident neutron is conventionally re-
presented by the nuclear cross-section. A great deal
of work has been performed in connection with the
determination of nuclear cross-sections for neutron
reactions but much still remains to be done as the
subject has practical and theoretical significance.

The study of nuclear cross - section for neutron
reactions attracted a considerable attention, as it
was thought with some justification that the information
would contribute to a better understanding of complexi-
ties of nuclear structure [5] .

Neutrons interact with matter in two ways. First, there is a nuclear interaction between neutrons and the ambient nuclei. Secondly, although the neutron is electrically neutral as a whole, there is an electro-magnetic interaction because the neutron has a magnetic dipole moment [6].

The leading interaction process is the nuclear reaction. Such reaction may proceed either through the formation of excited nucleus followed by its decay along one of the possible channels, or without the formation of an intermediate nucleus when the neutron is scattered directly by the nuclear force field. The decay channels of the intermediate nucleus may be elastic and inelastic scattering emission of γ -rays (radiative capture of neutrons by the nucleus); emission of charged particles [(n,p) and (n, α) reactions] and nuclear fission [6].

In the thermal neutron energy range, there is no nuclear inelastic scattering. Also, neutron capture followed by fission occur for some few heavy isotopes, while reactions involving the emission of charged particles occur only in few light isotopes. Therefore as we are interested in the thermal energy range, we can pay attention

only to two decay channels namely radiative capture and resonance elastic scattering. Potential elastic scattering has to be taken into consideration which may proceed without the formation of an intermediate nucleus [7] . Interference between potential and resonance elastic scattering may occur. In the thermal energy range and for neutron energies of few electron volts, the scattering cross-section component has a form characteristic of potential scattering, i.e. it is independent of neutron energy, nevertheless, this is not true, the potential scattering will not be pure and there will be a certain contribution to resonance scattering [8] .

For neutrons with energies of about 10^{-4} eV up to 10^{-1} eV, we are interested in the phenomenon of neutron optics such as reflection and diffraction where there is much discussion of the coherent and incoherent cross-section. Since in this region the wavelength of thermal neutrons is of the same order of magnitude as the interatomic distances in crystals, therefore the optical effects are quite marked [1,9] .

The coherent cross - section is the cross section when the scattering centre, participate in the process in