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INELASTIC SCATTERING OF 14 MeV NEUTRONS BY IRON NUCLEI

Lychageen A.A., Lunev V.P., Zhuravlev B.V., Salnikov O.A., Titarenko N.N.

Institute of Physics and Power Engineering, Obninsk, USSR.

Abstract: Double differential neutron emission spectra from iron have been measured by time of flight method with a time resolution about 0.45 ns/m. The direct contribution to the neutron emission spectra have been calculated using DWBA and CC theory. Contributions from statistical and direct reactions are found to reproduce well the experimental data.

A number of the works/1-2/ deal with a theoretical description of inelastically-scattered neutron spectra. The availability of experimental data obtained with high time resolution/4,5/ was encouraging their more detailed theoretical analysis /3/. Regardless the structural features of the two references beihg in an agreement, however, they disagree by the absolute value at certain angles. That is the reason of the authors' rerunning of the earlier experiment with an aim to obtain higher resolution and more detailed analysis of the results.

The timo-of-flight spectrometers used for the measurements, the features of their procedure and experimental data processing are described in Ref, /8/. A path length was 7.1 m (90^o), a neutron detection threshold 1 MeV, time resolution for all angles was as high as 0.45 ns. An iron sample of natural isotope composition had a hollow cylinder form with an outer diameter 45 mm, inner diameter 35 mm, height 55 mm. The neutron detection efficiency from the threshold up to 6 MeV was determined by comparihg the measured spectra of Cf^{252} spontaneous fission with Maxwell distrubution with a temperature 1.42 MeV. In addition the neutron detection efficiency in an energy range 3.5 to 12 MeV was measured by hydrogen scattering. The resulting efficiency was extrapolated up to the energy 14 MeV, where the efficiency value was obtained through the target yield measurement. A correction for attenuation and multiple scattering of neutrons in the sample was calculated by the Monte Carlo method according to Ref. /9/. The absolute value of cross-sections was determined by normalization on scattering cross-section on hydrogen, carbon and on Al(n,α) reaction cross-section.

The figure shows double-differential cross-sections of inelastic neutron scattering on iron nuclei as compared with the data from Ref. /5/, which demonstrate a good agreement both by the absolute value and by the structure observed in the spectra. The spectra calculated by the present representation authors' averaged by the real experimental resolution are included in this figure as well. The inelastic scattering cross-sections have been represented as a sum of two independent scattering processes - the direct and equilibrium ones. The equilibrium component has been calculated in frame of the Hauser-Feshbach model (H-F) with a code SMT-80 /10/. The contribution of direct transitions has been calculated in the first order of Born distorted waves approximation (DWBA) With a code BAP-82 /11/ and coupled channels approximation (CC) with a code ECIS--79 /12/. The parameters of neutron optical potential for all theoretical models employed have been determined

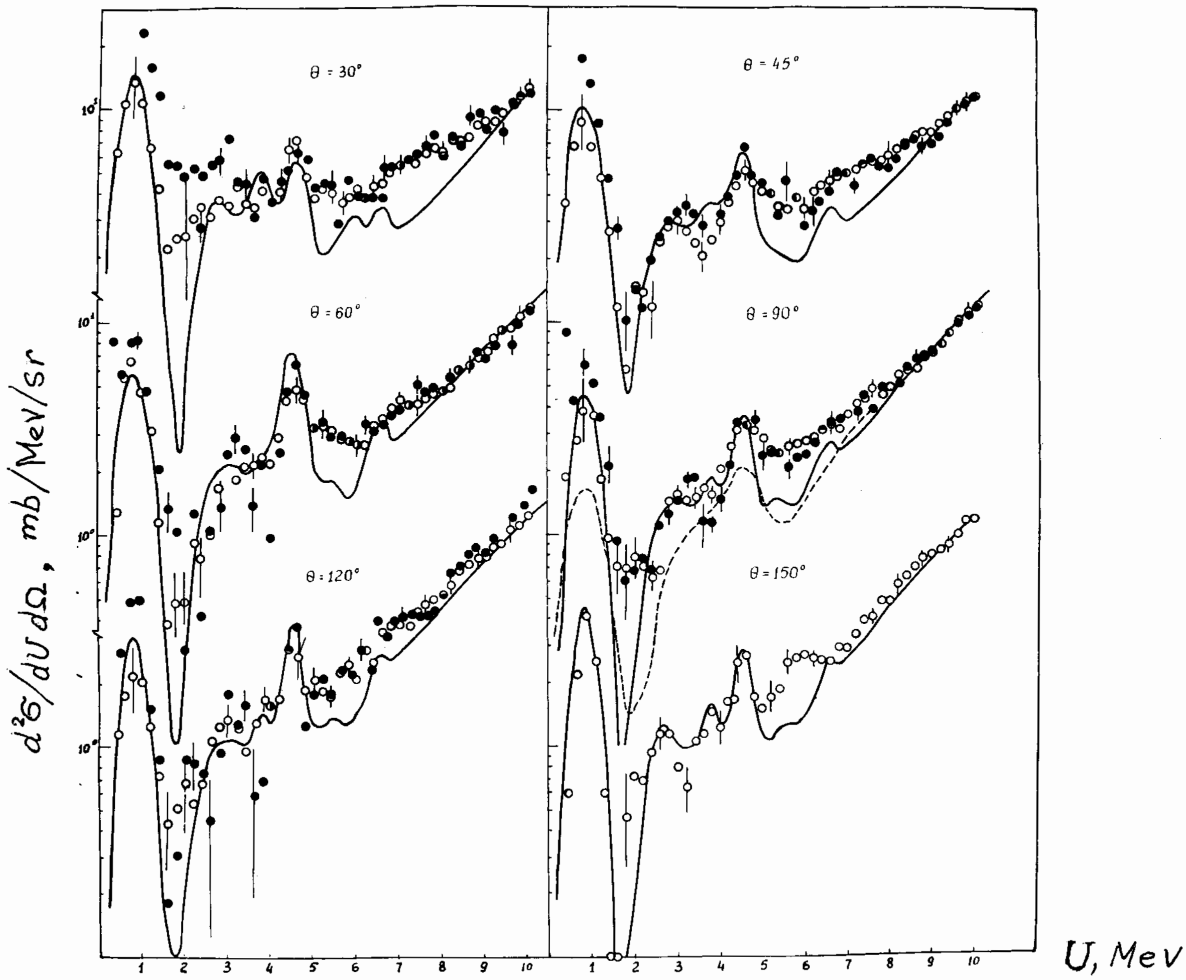

Fig. Comparison of experimental and calculated double-differential inelastic scattering cross-sections. ○ – present work data, ● – data of Ref /5/ , —— – CC + HF calculation, - - - – DWBA + HF calculation.

according to Rapaport et al. global systematic /13/ .

The calculations in frame of the statistical model for neutron, proton and alpha - channels have taken into account all known discrete states of residual nuclei (46 states for ^{56}Fe, 12 - for ^{56}Mn, 14 - for ^{53}Cr). A nucleus excitation region above the discret states with the known characteristics (5 MeV) have been described by the level density in the back-shifted fermi gas model Dilg et al. systematic parameters /14/ .

The required information on the parameters of dunamical deformation for each direct transition of ^{56}Fe even - even nucleus was based on the available data on inelastic scattering of protons in ^{56}Fe / 6 /. For DWBA calculation (see the figure for the angle 90°) the direct transitions with an excitation of 27 vibrational single-phonon states of the target-nucleus were adopted. In CC calculation also took into account 10 two-phonon states $\{2_1^+ \otimes 2_1^+\}$, $\{2_1^+ \otimes 3_1^-\}$, $\{3_1^- \otimes 3_1^-\}$. The imaginary part of the optical potential was chosen so as to yield the best description of experimental data on excitation of strong-collective states 2_1^+ and 3_1^- for ^{56}Fe nucleus for incident neutron energies from 11 to 26 MeV 15 and for the energy 14 MeV it was W_{SF}=6.4 MeV.

In the figure you can see, that the experimental data for all the angles are well reproduced in the calculation for energy ranges coresponding to strong - collective states 2_1^+ and 3_1^- with the energies 0.845 MeV and 4.51 MeV. In the excitation energy range from 1 MeV to 2

MeV the disagreement of experimental data and calculated ones can be due to the isotopic composition of the sample. The disagreement in the excitation energy range above 5 MeV may well be caused by two reasons:

a) a lack of reliable experimental data on the structure of states in the energy range,

b) an employment of global systematics of level density parameters, which can underge significant modifications when considering specific nuclei.

Hence, the (n,n') reaction analysis demonstrates, that the energy of incident neutrons 14 MeV in the whole we can have the experimental data to be qualitatively and quantitatively described virtually over the whole nuclear excitation energy range under investigation making use only of the direct and equilibrium mechanisms of the reaction. In this case the coupled-channels method enables the inelastic scattering process to be better described in the low-energy part of the nuclear excitation spectrum. In addition more detailed consideration should be given to the equilibrium part of the spectrum taking into account the collective enhancement of level density.

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