PROTON RADIATIVE CAPTURE BY NUCLEI ^{54}Cr

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The paper presents experimental results from proton capture reaction by nuclei ^{54}Cr, namely, partial cross-sections and radiative strength functions (RSF) simulated in the framework of a statistical model and new phenomenological approaches to the description of the RSF developed by Sirotkin and Plujko. The measurements were performed in NSC KIPT using a Van de Graaf accelerator for 4.5 MeV. The RSFs were determined so as to achieve the best agreement between the measured and the calculated cross-sections for fixed global parameters of the statistical model. As was found, the RSF is influenced by the excitation energy and final state properties of nuclei, contrary to Brink's hypothesis that denies the relationship between the RSF and the nuclear structure.

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As was exhibited in a previous papers [1,2] experimental investigations, bound with study of partial cross-sections (PCS) radiative capture of protons by medium-heavy nuclei (40 < A < 70), are rather fruitful as alongside with the traditional spectroscopic information (cross-sections, scheme of levels, the spins of states) allow to receive the information on an absolute value and energy dependence of a radiative strength function [3]. It is necessary to mark that the behavior RSF can be explored with the help of this method in the field of energies of γ-quantums below than nucleon escape threshold for which practically there are not alternative source of the information. The knowledge behavior RSF in this energy region, alongside with value these data in the various practical appendices, allows to make deductions about applicability of various modern theoretical models [4,5] for calculation E1-RSF at energy of γ-quantums below maximum of a giant dipole resonance (GDR)

The purpose of the present paper is the study of a radiative capture of protons by nuclei ^{54}Cr within the framework of statistical model with usage for calculation RSF of the various modern theoretical approaches. At study of PCS of reaction ^{54}Cr(p,γ)^{55}Mn in work [2] it was not possible to describe transitions to all apparent low-lying states of ^{55}Mn. In the subsequent works [1,6] was exhibited that the uprating of calculation data about PCS in relation to experimental data is bound with to usage in quality E1-RSF of an extrapolating a Lorenzian in explored region of energies of γ-quantums.

The measurements were fulfilled in NSC KIPT using a Van de Graaf accelerator for 4.5 MeV in an interval of energy of protons from 1.5 up to 2.5 MeV. The enriched target ^{54}Cr (~70%) by width 0.42 μm was made by a method of an electrolytic deposition on a golden substrate by width 100 μm. The cool-off of a target by water having immediate contact to a substrate has allowed to use a current of a beam of protons up to 10 μA without damage of a target at long-lived exposures. The spectra of high-energy γ-rays corresponding to primary transitions were measured by a binary spectrometer consisting of a Ge(Li) detector of volume 63 cm^3 surrounded by a four section annular NaI(Tl) detector. For calibration of efficiency of a pair γ-spectrometer were used γ-rays from reaction ^{27}Al(p,γ)^{28}Si and standard source γ-radiation.

We measured the partial cross-sections by using targets whose thickness was such that proton-energy losses satisfied the condition $D_\lambda << E_p < D_0$, where D_0 is the spacing between low-lying levels of final nuclei and D_λ is spacing between the levels of the compound nucleus through which the reaction occurs. Presetting the level of accuracy to which the PCS are determined, we can choose the interval of averaging for E_p in such way that fluctuations of the widths, together with other errors, do not exceed the admissible uncertainty. This can be ensured either by increasing the target thickness or by adding successively spectra measured for different energies with the energy shift that corresponds to the target thickness.

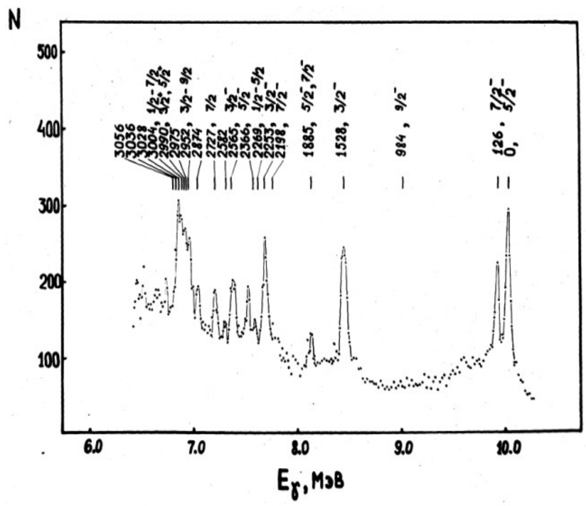

Fig. 1. *γ-spectrum from the ^{54}Cr(p,γ)^{55}Mn reaction*

The averaged pair γ-spectrum for reaction ^{54}Cr(p,γ) ^{55}Mn obtained as a result of addition of individual γ-spectrums on an interval of an average 175 keV and relevant to energy of protons E_p = 1.89 MeV is shown in Fig. 1. At a spectrum there are intensive transitions to all low-lying states of ^{55}Mn and also lines relevant

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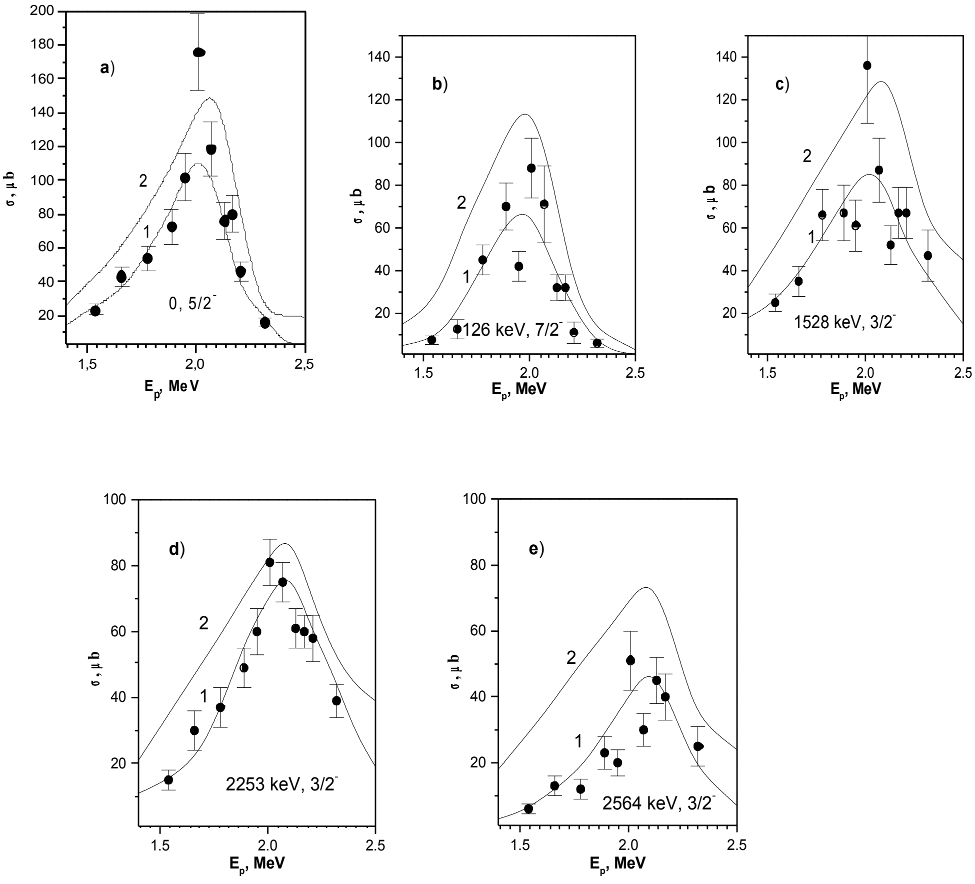

Fig. 2. *Partial cross-section for the $^{54}Cr(p,\gamma)^{55}Mn$ reaction*

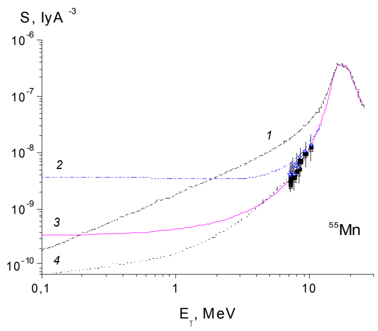

Fig. 3. *RSF in ^{55}Mn measured for the fixed excitation energy $E^*=9.8$ MeV, $\Delta E=0.5$ MeV. Curves: 1 - Lorenzian, 2 - [13], 3 - [4], 4 - [5]*

to γ-quantums from $^{52}Cr(p,\gamma)^{53}Mn$ reaction, that is explained by not enough cleanness of a used target. Besides there are transitions to groups of levels unsolvable at the given requirements of experiment.

The error in definition of PCS from a spectrum of γ-rays was defined mainly by experimental error, which consists of an error in definition of efficiency of a pair γ-spectrometer (~15%), statistical error (~7%), error in definition of width of a target (~5%) and error in definition of a charge produced on a target (~5%).

The method of the analysis of the PCS (p,γ)-reaction multiply was circumscribed by us in the previous papers [2,7] where the basic expressions for sections and RSF are given, and also the method of definition by experimental radiative strength function from data about PCS is circumscribed. Therefore here we give only basic parameters of models most influential in an end result.

The cross-section is calculated with the following Beechetti-Grenleess optical potential (in author's notation) [8]: ($V_0 = 54.0$, $V_{RS} = 56.9$, $W_0 = 8.8$, $W_S = 8.3$, $W_V = 0.$, $V_{S0} = 6.2$) MeV, ($r_{S0} = 1.01$, $a_{S0} = 0.75$, $r_R = 1.17$, $a_R = 0.75$, $r_D = 1.32$, $a_D = 0.57$) fm.

The level densities are from [9]: $\Delta = -1.51$, MeV, $a = 4.74$ MeV^{-1}. The moment of inertia is assumed equal to 0.5 of the solid state one.

Data on the GDR are given in [10]. It is a resonance with two maxima, each giving the contribution to the strength function for low energies, however, the role of the first is dominant. The single-particle estimates for M1-transitions are based on the systematic data on the factor $k_{M1} = (3.0\pm0.4)\times10^{-8}$ MeV^{-3} [11]. In addition to the single-particle estimates, we used the expression proposed by Sirotkin [12]:

$$S_\gamma^{E1}/S_\gamma^{M1} = 0.03A(E_\gamma^2 + (\pi T_f)^2)/Q_n^2 ,$$

where Q_n is the neutron binding energy. In Fig. 2 the experimental PCS are given. This cross-sections are relevant to direct transitions from states of a compound nucleus in a ground state 0 ($5/2^-$) and four low-lying excited states in nucleus ^{55}Mn: 126 keV ($7/2^-$), 1528 keV ($3/2^-$), 2253 keV ($3/2^-$), 2564 keV ($3/2^-$). The continuous curves are exhibit results of calculation of PCS within the framework of statistical model. The calculated cross-sections for fixed model parameters are in agreement with the model for RSF [4,5] (curve 1) but in disagreement with the Lorenzian (curve 2). The extrapolation of the Lorenzian results in cross-sections almost 1.5 times greater.

Fig. 3 shows RSFs for ^{55}Mn nuclei that were determined from the γ-spectrum measured for fixed proton energy. Experimental RSF values were obtained within various models for total radiation widths. Experimental data are located below the Lorenzian, being grouped around curves 3 and 4 in accordance with new models.

Summarizing we state that:

1) The partial cross-section for the proton capture reactions by ^{54}Cr are measured and described within the framework of a statistical model with a global set of parameters.

2) The radiative strength functions in nuclei ^{55}Mn were determined from the (p,γ) cross-sections measured using statistical averaging.

3) It is shown that Lorenzian is suitable for the description of RSF only in region of max GDR.

4) In the resonance region a good description of the RSF is achieved with the phenomenological approach of Kadmensky-Sirotkin-Plujko in which the dipole resonance widths (spread widths) depend on the γ-quantum energy and the temperature of a nucleus in the final state.

5) The RSF was found to depend on the excitation energy, which is in conflict with Brink's hypothesis declaring that the RSF is not sensitive to the structure of nuclei.

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РАДИАЦИОННЫЙ ЗАХВАТ ПРОТОНОВ ЯДРАМИ ^{54}Cr

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Определены парциальные сечения для γ-переходов в состояния 0(5/2$^-$), 126(7/2$^-$), 1528(3/2$^-$), 2253(3/2$^-$), 2564(3/2$^-$) кэВ ядра ^{55}Mn, образующегося в реакции захвата протонов. Измерения проводились на мишени ^{54}Cr толщиной 0,42 мкм в интервале энергии протонов 1,5…2,5 МэВ. Парциальные сечения проанализированы в рамках статистической модели. Отмечено важное значение выбора теоретической оценки для расчета радиационной силовой функции.

РАДІАЦІЙНЕ ЗАХОПЛЕННЯ ПРОТОНІВ ЯДРАМИ ^{54}Cr

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Визначено парціальні перерізи для γ-переходів у стани 0(5/2$^-$), 126(7/2$^-$), 1528(3/2$^-$), 2253(3/2$^-$), 2564(3/2$^-$) кеВ ядра ^{55}Mn, що утворюються в реакції захоплення протонів. Виміри проводилися на мішені ^{54}Cr товщиною 0,42 мкм в інтервалі енергії протонів 1,5…2,5 МеВ. Парціальні перерізи проаналізовано в рамках статистичної моделі. Відзначено важливе значення вибору теоретичної оцінки для розрахунку радіаційної силової функції.