Intermediate structure and the cross section of the reaction $Fe^{54}(\gamma,n)$ for high-energy neutrons and their spectra

S. S. Verbitskiĭ, B. S. Ratner, and A. N. Sergievskiĭ

Nuclear Research Institute, USSR Academy of Sciences

(Submitted March 23, 1976)
Pis'ma Zh. Eksp. Teor. Fiz. **23**, No. 9, 538–542 (5 May 1976)

The cross section of the reaction $Fe^{54}(\gamma, n)$ was investigated at different energies of the registered neutrons, and the energy spectra of the neutrons were measured. A connection is established between the intermediate structure and the neutron energy.

PACS numbers: 25.20.+y

The pre-equilibrium nuclear decay, with which the existence of the intermediate structures seems to be connected, leads to predominate emission of high-energy neutrons.[1] There are therefore grounds for expecting the structure and the cross section of the (γ, n) reaction due to the emission of the high-energy component of the neutron spectrum to become manifest most distinctly.

We have investigated the yield of the (γ, n) reaction for the nucleus Fe^{54} at different values of the minimum energy of the registered neutrons, and also

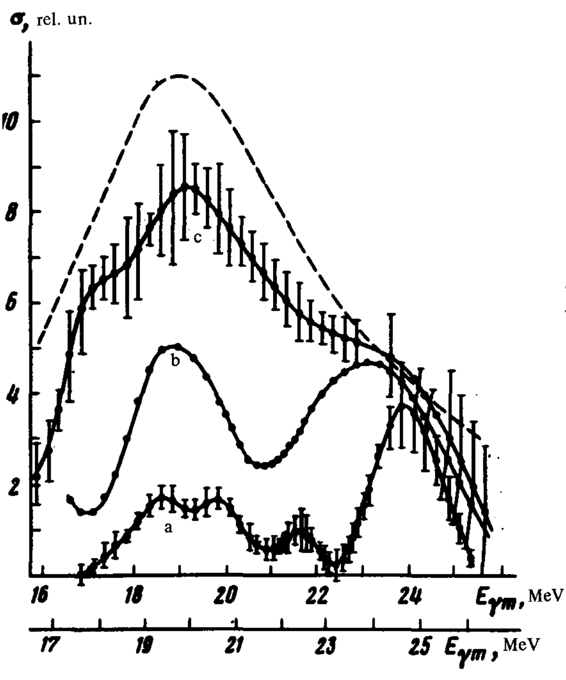


FIG. 1. Cross section of the reaction $Fe^{54}(\gamma, n)Fe^{53}$. The threshold for the neutron registration was: a) 3.7 MeV, b) 3.2 MeV, c) 0.9 MeV. Dashed curve—cross section of the reaction $Fe^{54}(\gamma, n)$ from[4].

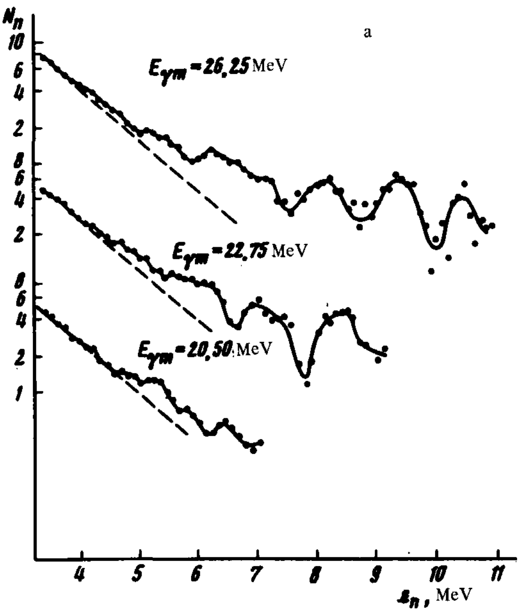
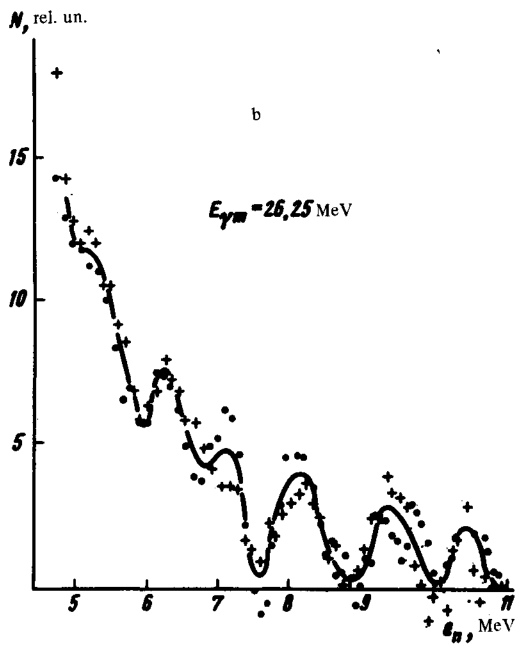


FIG. 2. Energy spectra of photo neutrons from the $Fe^{54}(\gamma, n)$ reaction.



measured the energy spectra of the neutrons for several values of the end-poi energy $E_{\gamma m}$ of the bremsstrahlung of the 35-MeV synchrotron of our institute.

The target was 281 grams of metallic iron enriched with the isotope Fe^{54} to 93%.[1] The neutrons were registered with a spectrometer consisting of two stilbene single crystals measuring 50×50 mm[2] and a KhR1020 photomultiplie

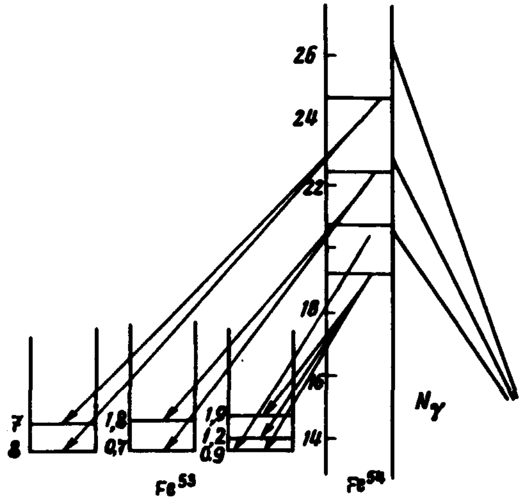


FIG. 3. Decay of resonant states of the Fe^{54} nucleus.

'o distinguish the neutrons from the γ background we used a modification of a reviously described scheme[2] based on the time when the zero is crossed. 'he gain of the spectrometric channel was stabilized with the aid of a light lash from a thyratron. The spectrometer made it possible to work at a beam uration 30 μsec, without decreasing the beam intensity, when the detector was rotected with a 5-cm layer of lead.

To calibrate the spectrometer we used neutrons from a PoBe source and eutrons from the reaction $O^{12}(\gamma, n)O^{16}$. The neutron background amounted to . 6% of the effect at $E_{\gamma m} = 22.5$ MeV.

Position of the peak in the energy spectrum of the neutrons ϵ_m, MeV			Position of Fe^{54} resonance	Position of Fe^{53} levels $E = E_R - \bar{\epsilon}_m - \epsilon_{no}$, MeV		
$E_{\gamma m}$ = 20.5 MeV	$E_{\gamma m}$ = 22.75 MeV	$E_{\gamma m}$ = 26.25 MeV	E_R, MeV			
4,1	4,1	4,1	19,5	–	1,9	–
4.7	4,7	4,6	19,5	–	–	1,2
5,3	5,1	5,2	19,5	0,7	–	–
6,4	6,1	6,2	20,7	0,9	–	–
–	7,0	7,2	22,5	–	1,8	–
–	8,4	8,1	22,5	0,7	–	–
–	–	9,5	24,8	–	1,7	–
–	–	10,5	24,8	0,8	–	–
				Average		
				0,8	1,8	1,2

ϵ_{no} —is the neutron binding energy 13.6 MeV.

The yield curves of the $Fe^{54}(\gamma, n)$ reaction were measured from the threshold to $E_{\gamma m} = 26.25$ MeV for minimum neutron energy values ϵ_{min} equal to 3.7, 2.2, and 0.9 MeV in steps of 0.1—0.25 MeV. The threshold for the registration of the $(\gamma, 2n)$ reaction is 27.8, 26.3, and 25.3 MeV, respectively.

The obtained yield curves were processed with a BÉSM-6 computer by the statistical regularization method.[3] The cross section errors were determined in the following manner: The yield was determined from the cross-section curve and was subjected several times to a random perturbation in accordance with the mean-squared errors of the measured yield curve. The cross section was then calculated from each of the curves and its mean-squared error was determined.

An examination of the cross-section curves (Fig. 1) shows that the smooth component of the cross section increases as the spectrum of the registered neutrons softens, thus confirming the assumption made concerning the connection between the structure and the neutron energy. The contribution of the intermediate structure is much larger for the region of high excitation ($E_\gamma = 24$—25 MeV) than for the region of the maximum of the giant resonance ($E_\gamma = 19$—20 MeV). This indicates that the excited states of the Fe^{54} nuclei decay in different manners. The energy spectra of the photoneutrons, measured at $E_{\gamma m} = 20.5$, 22.75, and 26.25 MeV for $\epsilon_{min} = 2.2$ MeV are shown in Fig. 2a.

The spectra at $E_{\gamma m} = 26.25$ MeV were obtained in two independent measurements (Fig. 2b). The exponentially decreasing region in all the energy spectra corresponds to a final-nucleus temperature T equal to 1.1 MeV and is due mainly to evaporation neutrons. The energy corresponding to the kinks and to the peaks in the spectra remains unchanged within limits of errors on going from one spectrum to another. Comparison of the positions of the maxima in the cross section of the (γ, n) reaction with the energies of the peaks in the energy spectra (Fig. 3) makes it possible to establish the positions and the levels of the final nucleus Fe^{53} to which the decay takes place (see the table). It appears that all the resonances include a decay to an Fe^{53} state with $E = 0.8$ MeV. It can be assumed that the maximum in the cross section of $E = 24.8$ MeV corresponds to excitation of the dipole state $T = T_0 + 1$, as indicated by the interval between this maximum and the lower ones, which is close to the magnitude of the isospin spreading of the giant resonance. In this case it becomes necessary to assume an appreciable mixing of the states with $T = T_0$ and $T = T_0 + 1$ with respect to isospin. The connection observed in this study between the intermediate structure and the emission of energetic photoneutrons can be easily interpreted on the basis of the representation of the decay doorway states of the particle-hole type, but its reconciliation with the model of collective correlations calls for a special analysis.

1)Obtained by us from the State Depository of Stable Isotopes.

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