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Abstract

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PHOTODISINTEGRATION OF Ne^{22}

In works (^{1}, ^{2}) devoted to the study of photonuclear reactions on Ne^{20}, it was found that photodisintegration of the nuclei of this neon isotope is accompanied by a considerable yield of complex reactions, such as $(\gamma, \alpha p)$, $(\gamma, \alpha n)$. The high yield of these reactions can be explained by the characteristic shell structure of the Ne^{20} nucleus, whose upper filled shell $2S_{1/2}$ corresponds to an α-particle configuration. In this connection, it is of interest to study the photodisintegration of the Ne^{22} nucleus, which has two additional neutrons as compared with Ne^{20}.

The study of the photodisintegration of Ne^{22} was carried out with the aid of a Wilson chamber placed in a constant magnetic field $H = 6700$ oersted. The mixture of neon isotopes filling the Wilson chamber contained 89% Ne^{22}, 10% Ne^{20}, and 1% Ne^{21}, and was irradiated with a bremsstrahlung γ-beam with maximum energy 90 MeV. The method of identification of photodisintegrations of various types, as well as of the measurements, is described in works (^{2}, ^{3}).

Table 1

Relative yields of neon photodisintegrations

Reaction	Ne^{20} threshold, MeV	Ne^{22} threshold, MeV	Ne^{20} yield, %	Ne^{22} yield, %
γ, p	12.9	15.3	39	22
γ, n	16.9	10.4	17	30
$\gamma, 2n$	(24.1)	(17.1)	–	–
γ, α	4.7	9.7	1	7
γ, pn	23.3	23.4	6	18
$\gamma, \alpha p$	16.9	25.6	22	1.5
$\gamma, \alpha n$	21.2	17.7	7.5	8.5
Other stars	–	–	7.5	13
Number of events			1928	1759

Fig. 1. Energy distribution of photoprotons of the (γ, p) reaction

Figure 1: Fig. 1. Energy distribution of photoprotons of the (γ, p) reaction

Fig. 2. Energy distribution of photoprotons of the (γ, pn) reaction

Figure 2: Fig. 2. Energy distribution of photoprotons of the (γ, pn) reaction

Reaction	Ne^{20} threshold, MeV	Ne^{22} threshold, MeV	Ne^{20} yield, %	Ne^{22} yield, %
$\int_0^{90} \sigma\, dE$, MeV·mb			430	440

The relative yields of the recorded photodisintegrations of various types are presented in Table 1. The relative yields of photodisintegrations of Ne^{20} (^{2}) are also given there. In addition, the table indicates the energy thresholds of the corresponding reactions for Ne^{22} and Ne^{20}. It should be noted that the reaction-yield figures given in the table were obtained as a result of allowance for background photodisintegrations, which include photodisintegrations of oxygen and carbon nuclei present in the vapors of the working liquid of the Wilson chamber. Moreover, since the investigations were carried out not with pure neon isotopes, in the case of Ne^{22} the reactions on Ne^{20} were background, and conversely.

The total integral cross section for absorption of γ-quanta for Ne^{22} was determined by comparison with the corresponding cross section for helium and was found to be

$$\int_0^{90} \sigma\, dE = 0.44\ \text{MeV} \cdot \text{b}.$$

This figure is in good agreement with the theoretical value of the integral cross section determined according to work (^{4}). The yield of photodisintegrations for Ne^{22} is characterized by the value 20 ± 3 mb/Q.

Figures 1 and 2 show the obtained energy distributions of protons belonging to the reactions (γ, p) and (γ, pn). Figures 2 and 3 show the angular distributions of the photoprotons of the above reactions. The points in these figures correspond to the experimental results, while the curves were obtained by the method of least squares and can be represented by the formulas $d\sigma/d\Omega = 0.29 + 0.11 \sin^2 \vartheta$ (Fig. 3) and $d\sigma/d\Omega = 0.22 + 0.07 \sin^2 \vartheta + 0.085 \cos \vartheta$ (Fig. 4).

Fig. 1. Energy distribution of photoprotons of the (γ, p) reaction

Fig. 3. Angular distribution of photoprotons (γ, p) with energies above 0.5 MeV

Figure 3: Fig. 3. Angular distribution of photoprotons (γ, p) with energies above 0.5 MeV

Fig. 4. Angular distribution of photoprotons (γ, pn) with energies above 0.5 MeV

Figure 4: Fig. 4. Angular distribution of photoprotons (γ, pn) with energies above 0.5 MeV

Fig. 2. Energy distribution of photoprotons of the (γ, pn) reaction

Fig. 3. Angular distribution of photoprotons (γ, p) with energies above 0.5 MeV

Fig. 4. Angular distribution of photoprotons (γ, pn) with energies above 0.5 MeV

It is characteristic that proton emission from Ne^{22} is accompanied in approximately 40% of cases by neutron emission; the relative yield of the (γ, pn) reaction for Ne^{20} is significantly smaller, despite the equality of the energy thresholds of these reactions for Ne^{22} and Ne^{20}. The energy distributions of the protons of the (γ, p) and (γ, pn) reactions on Ne^{22} are similar in shape, and in both cases there is a considerable number of protons with relatively high energies (above 10 MeV). The similarity of the energy distributions of photoprotons of the (γ, p) and (γ, pn) reactions can be understood if one assumes that in most cases in the (γ, pn) reaction a proton is emitted first, and then a neutron from the excited F^{21} nucleus. The angular distribution of the protons of the (γ, pn) reaction has a greater asymmetry, which apparently is caused by interference of $E1$ and $E2$ transitions. The presence of a significant asymmetry in the angular distribution of protons of the (γ, pn) reaction speaks in favor of the assumption made above concerning the sequence of nucleon emission in the (γ, pn) reaction. Indeed, if protons were emitted from excited Ne^{21} nuclei, their angular distribution would have to be close to isotropic even in the case where there is a sharply pronounced angular correlation between the neutron and the proton.

It should be noted that the energy threshold of the $(\gamma, 2n)$ reaction is considerably lower than the threshold of the (γ, np) reaction; therefore, in the case of the initial emission of a neutron, the emission of one more neutron is apparently more probable than that of a proton.

According to our estimates, the contribution of the quasi-deuteron mechanism to the yield of high-energy protons (above 14 MeV) cannot exceed 10%.

The yield of the (γ, α) reaction for Ne^{20} is extremely small, whereas for Ne^{22} it is almost an order of magnitude larger. This can be understood from the standpoint of the action of the isotopic-spin selection rules for dipole transitions, which in the case of Ne^{20} considerably raise the energy threshold of the reaction and reduce the number of possible channels of the (γ, α) reaction. Meanwhile, for Ne^{22} they impose no restrictions on the (γ, α) reaction.

The fact that the yield of the $(\gamma, \alpha p)$ reaction on Ne^{22} is extremely small in comparison with the yield on Ne^{20} cannot be explained solely by the high energy threshold of the indicated reaction, since the absorption cross section of γ-quanta with energies above 25 MeV is still sufficiently large. This is evident from the histograms shown in Figs. 1 and 2. Indeed, the yield of the (γ, pn) reaction, for example, for Ne^{22} is appreciable, although the energy threshold of this reaction is only ~ 2 MeV lower than the threshold of the $(\gamma, \alpha p)$ reaction.

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