PICKUP REACTIONS ON F^{19}, P^{31}, *AND* S^{32} *NUCLEI*

G. E. VELYUKHOV, A. N. PROKOF'EV, and S. V. STARODUBTSEV

Leningrad Physico-Technical Institute, Academy of Sciences, U.S.S.R.

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A telescope consisting of two proportional counters and a scintillation counter was employed to study the energy and angular distributions of deuterons from the reactions $F^{19}(n, d)O^{18}$, $P^{31}(n, d)Si^{30}$, $S^{32}(n, d)P^{31}$, and $Ne^{20}(n, d)F^{19}$. The cross sections and angular distributions for transitions to the ground states of the O^{18}, Si^{30}, and P^{31} nuclei are derived. The total cross section for the reaction $Ne^{20}(n, d)F^{19}$ is estimated. The reduced transition widths are computed from Butler's theory.

In our previous work[1] we pointed out that O^{18} and Si^{30} have the same differential cross sections for the reactions $F^{19}(n, d)O^{18}$ and $P^{31}(n, d)Si^{30}$ in transitions to the ground state if the incident neutron energy is 14.1 Mev. If it is assumed that this equality is connected with the fact that, according to the nuclear shell model, the last proton of F^{19} is in the same state as that of P^{31}, then analogous transitions can be expected in the reactions $Ne^{20}(n, d)F^{19}$ and $S^{32}(n, d)P^{31}$, because there the last protons are in the state $2S_{1/2}$. In connection with this it was of interest to conduct simultaneous investigations of (n, d) reactions on F^{19}, P^{31}, and S^{32}, because the comparison of reduced widths in this case could give relative characteristics of the wave properties of the nuclear surface.

We developed a method which is new compared to that[1] used before, and which improved the resolution of the deuteron groups. We carried out the investigation with the help of a telescope composed of two proportional counters and a scintillation counter. The proportional counters measured the ionization energy loss dE/dx, and the scintillation counter measured the energy of the deuterons. The separation of the deuteron groups was achieved with an electronic system which was based on the fact that $EdE/dx \sim M^{0.8}Z^2E^{0.2}$, i.e., it is only weakly dependent on the energy of the particle and depends almost linearly on its mass.

In the investigation of the reaction $S^{32}(n, d)P^{31}$ we used a target of a natural mixture of the isotopes of sulfur. We obtained the energy spectrum of the deuterons (Fig. 1) and their angular distribution. In the energy spectrum is observed a strong group of deuterons corresponding to the transition to the ground state of P^{31}. From an analysis of the line shape corresponding to this transition it is clear that, in addition to the transition to the ground state, transitions also take place to the first excited state of P^{31}; however, their intensity is too weak to permit a quantitative estimate. From the form of the angular distribution it follows that proton capture takes place from the S state. The differential cross section for the angle $\theta = 0^0$ (in the laboratory system) is $(20.4 \pm 1.5) \times 10^{-27}\,cm^2/sr$; the Q-value for this reaction is (-7.7 ± 0.1) Mev.

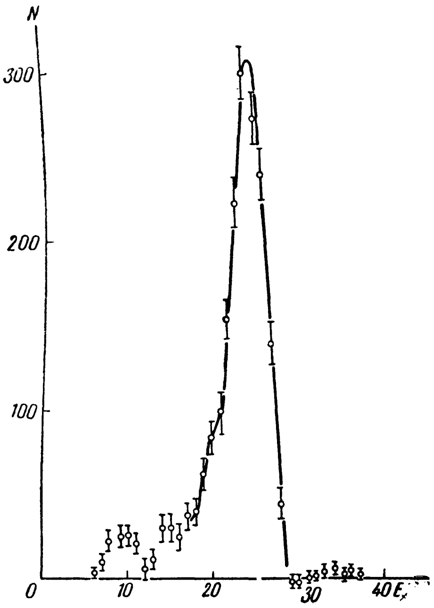

FIG. 1. Energy spectrum of deuterons from the reaction $S^{32}(n, d)P^{31}$ at the angle $\theta = 0°$ (in the laboratory system); E is the channel number.

In the study of the reaction on F^{19}, a target of the fluorocarbon $4(CF_2 = CF_2)$ was used. The energy spectrum of the deuterons and their angular distribution were obtained. From the angular dis-

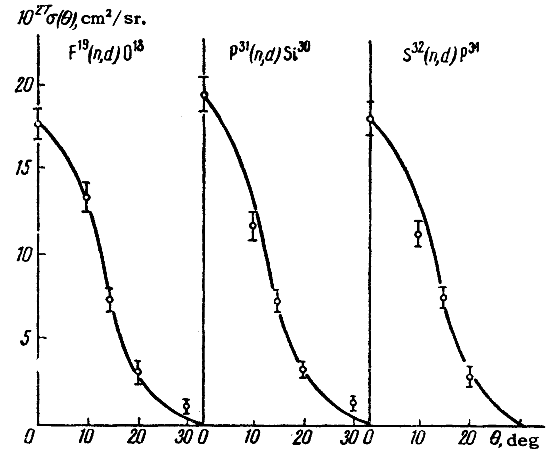

FIG. 2. Angular distribution of deuterons corresponding to transitions to the ground state in (n, d) reactions, in the center-of-mass system.

tribution it follows that a proton with $l_p = 0$ is captured in the transition to the ground state of O^{18}. The differential cross section for the same transition at the angle $\theta = 0^0$ (in the laboratory system) equals $(21.4 \pm 1.1) \times 10^{-27}\,cm^2/sr$, and the Q-value equals (-5.9 ± 0.3) Mev.

In the study of the reaction on P^{31}, the target was prepared by deposition of red phosphorus on a tantalum backing. The transition to the ground state of the nucleus Si^{30} was observed, and an angular distribution was obtained for this. The transition corresponds to $l_p = 0$. The differential cross section of the reaction for the transition to the ground state of Si^{30} at $\theta = 0^0$ (in the laboratory system) is $(21.8 \pm 1.2) \times 10^{-27}\,cm^2/sr$; the Q-value is (-5.2 ± 0.2) Mev.

The angular distribution of deuterons corresponding to transitions to the ground state of the final nuclei in the reactions $F^{19}(n, d)O^{18}$, $P^{31}(n, d)Si^{30}$, and $S^{32}(n, d)P^{31}$ (Fig. 2) were analysed on the basis of Butler's theory.[2] For the normalization of the theoretical values of the differential cross sections at the angle $\theta = 0^0$ we used the following values of the reduced transition widths (i.e., the quantities $\theta^2 = 2\mu_0 r_0 \gamma^2/3\hbar^2$)

$F^{19}(n, d)O^{18}$:

$\theta^2 = 0.011$ (0,012 according to reference 3),

$P^{31}(n, d)Si^{30}$: $\theta^2 = 0{,}012$,

$S^{32}(n, d)P^{31}$: $\theta^2 = 0{,}011$

(the measurement errors amounted to 15% in all cases).

Thus it appears that the differential cross section and the reduced width of the transition to the ground state of the nucleus in the reaction $S^{32}(n, d)P^{31}$ coincide, within the limits of experimental error, with the values of these quantities in the reactions $F^{19}(n, d)O^{18}$ and $P^{31}(n, d)Si^{30}$. The theoretical angular distributions fit the experimental results for the same interaction radius $r = 5.1 \times 10^{-13}$ cm.

Evidently this agreement is connected with the fact that in all three cases the proton is captured from the same state. If the reduced width is interpreted as the probability of the presence of the proton on the nuclear surface, then it follows that the contribution of S waves to the state of the last proton in the nuclei F^{19}, P^{31}, and S^{32} is identical.

However, a somewhat different point of view may be taken: since the nucleus S^{32} contains two protons in a $2S_{1/2}$ state, one would expect the probability of the presence of the proton on the nuclear surface to increase. Because this is not observed, it is necessary to find reasons for the lower probability of capture of a proton by the neutron. One of these reasons may be the increase of binding energy of the proton in S^{32} in comparison with P^{31} (S^{32} is an even-even nucleus). This assumption could be verified by investigating the reaction $Ne^{20}(n, d)F^{19}$, since Ne^{20} also contains two protons in the state $2S_{1/2}$ and has a proton binding energy greater than in S^{32}. We conducted such an investigation by the method described above, but because of bad conditions (high negative Q-value for the reaction and a gas target) we were able only to estimate the upper limit of the cross section of the reaction $Ne^{20}(n, d)F^{19}$ for the transition to the ground state of F^{19}. This estimate was $5 \times 10^{-27}\,cm^2/sr$.

At present we are continuing the study of this reaction by another method. According to our preliminary data, the estimate given is at least five times too high.

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111