QUANTUM CHARACTERISTICS OF THE 6.847-Mev LEVEL OF P^{30} *OBSERVED IN THE REACTION* $Si^{29}(p, \gamma)P^{30}$

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Resonance at an energy of 1330 kev was investigated in the reaction $Si^{29}(p, \gamma)P^{30}$. The magnetically separated isotope Si^{29} was used as a target and a γ-spectrometer with a NaI(Tl) crystal of 70 mm diameter and 50 mm height was used for the measurements. Quantum characteristics $J^{\pi} = 2^{+}$ and $T = 1$ were obtained for the P^{30} 6.847-Mev resonance level on the basis of measurements of the γ-ray spectra and of the angular distributions. A scheme is proposed for the γ-transitions from the given resonance level.

INTRODUCTION

THE first researches on the reaction $Si^{29}(p, \gamma)P^{30}$ ($Q = 5.562$ Mev) using targets made of magnetically separated Si^{29} were carried out in 1954 by Endt, Kluyver, and Van der Leun.[1] By magnetic analysis of the α particles from the reaction $S^{32}(d, \alpha)P^{30}$ ($Q = 4.887$ Mev), Endt and Paris[2] observed that P^{30} has not one 0.688-Mev level as indicated by Endt et al,[1] but two closely-lying levels with energies 0.684 and 0.706 Mev. Van der Leun and Endt[3] again investigated the γ spectra in the $Si^{29}(p, \gamma)P^{30}$ reaction at resonant energies $E_p = 326$, 414, 696, and 729 kev, and determine the spins and parities and also the isobaric spins of certain low-lying and resonant levels of P^{30}.

In the present investigation we continue the study of the $Si^{29}(p, \gamma)P^{30}$ reaction at higher bombarding-proton energies and measure the spectra and angular distribution of the γ rays for one of the observed resonances ($E_p = 1330$ kev).

APPARATUS, METHOD, AND PROCEDURE OF MEASUREMENTS

The source of the bombarding protons was the 4-Mev electrostatic generator of the Physico-Technical Institute of the Ukranian Academy of Sciences, which was described earlier.[4]

The isotopic target was prepared directly in an electromagnetic separator, by "hammering" the Si^{29} ions into a tantalum base.[5] The energy losses in the target used in these experiments were approximately 5 kev for 1.3-Mev protons.

To measure the spectra of the γ rays we used a NaI(Tl) crystal 70 mm in diameter and 50 mm

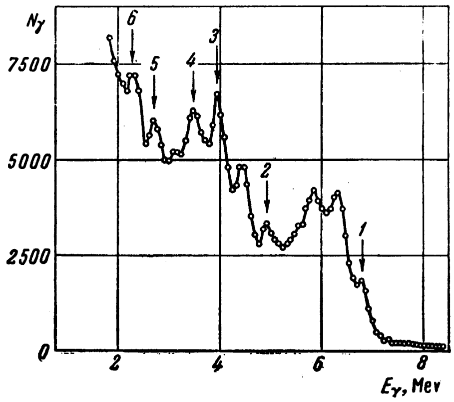

FIG. 1. Hard part of the γ-ray spectrum for the resonance at $E_p = 1330$ kev in the reaction $Si^{29}(p, \gamma)P^{30}$.

high, mounted on an FÉU-43 photomultiplier. The preamplifier was placed next to the photomultiplier and was connected to the main amplifier through a long cable, the output of the main amplifier being fed to a 100-channel AI-100-1 pulse-height analyzer. The crystal with the photomultiplier could be rotated about the center of the target, and the angles to the proton beam could be set at values from 0 to 145°, right or left.

In the measurement of the angular distribution of the γ rays, the target was mounted such that its normal made an angle of 30° with the direction of the proton beam. Consequently, for angles less than 90°, a correction was introduced for the absorption of γ rays in the tantalum base. The correction for absorption did not exceed 5% with a 3% average.

The measured angular distribution of the γ rays was processed by the least-squares method and the coefficient A_2 in the angular distribution

Table I.

No.	γ lines observed in the spectrum, Mev	Level of P^{30} nucleus		Energy of γ transition and relative intensity*
		initial	final	
1	6.84±0.08	6,847	0	6.847; 70%
2	4.90±0.08	6.847	1.97	4.877; 10%
3	3.90±0.08	6.847	2.94	3,907; 15%
4	3.50±0.08	4.18	0.684	3.496; 5%
5	2.70±0.08	6.847	4.18	2,667
6	2.25±0.08	2.94	0.684	2.256
7	1.97±0.08	1.97	0	1.97
8	1.65±0.08	4.18	2.54	1.64
9	1.45±0.08	2.94	1.45	1,49
10	0,68±0.05	0,684	0	0,684

*The sum of all the transitions from the resonant level is taken to be 100 percent.

was corrected for the finite angle subtended by the crystal.

EXPERIMENTAL RESULTS

The relative γ-ray yield due to proton capture was measured at 90° to the proton beam. Two γ resonances belonging to this reaction were observed at E_p values of 1308 and 1330 kev.

Figure 1 shows the hard part of the γ-ray spectrum, measured for the 1330-kev resonance. All the observed γ lines and the corresponding γ transitions between the P^{30} levels are listed in Table I.

The angular distribution for the γ transition from the 6.847-Mev resonant level to the ground state of P^{30} (γ line 1) is shown in Fig. 2. As can be seen from the figure, the angular distribution has good symmetry relative to the 90° angle. We can therefore assume that at the 1330-kev resonance this γ-ray angular distribution is due to the capture of protons with one value of the orbital momentum l^p.

The experimentally obtained angular γ-ray distribution for the 6.847-Mev γ line, reduced by the least-squares method and corrected for the finite solid angle subtended by the crystal, had the form

$$W_{\text{exp.}}(\theta) = 1 - (0{,}485 \pm 0{,}015)\cos^2\theta. \quad (1)$$

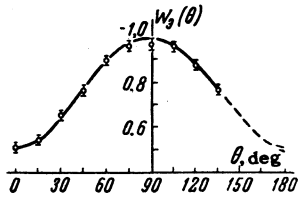

FIG. 2. Experimental angular distribution of the γ rays for the γ transition from the 6.847-Mev level to the ground state of P^{30} [see (1)].

This value was compared with all the theoretical angular distributions possible for γ transitions to the level with spin 1. From Table II it is easy to see that this comparison makes it possible to assign to the 6.847-Mev resonant level only one spin value, namely 2. The parity still remains indeterminate, however, since the coefficient A_2 in the experimentally-obtained angular distribution can correspond either to one of the calculated angular distributions (– 0.50), or to multipole mixtures ($M_1 + E_2$), or to channel-spin mixtures ($J_c = 1$ and 0).

GAMMA-TRANSITION SCHEME FOR P^{30} AND DISCUSSION OF THE RESULTS

The analysis of the measurement results in a proposed γ-transition level scheme for the 6.847-Mev level of P^{30} is shown in Fig. 3. From an examination of this scheme we can draw certain conclusions concerning the parity of the 6.847-Mev resonant level and its isobaric spin T. For the given resonant level, generally speaking, there exist four possible estimates of the quantum characteristics, namely: 2^+, T = 0; 2^+, T = 1; 2^-, T = 0 and 2^-, T = 1. Recognizing, however, that the direct transition to the ground state of P^{30} from the resonant level is a dipole transition and is the most intense of all other γ transitions, and that E1 and M1 transitions with ΔT = 0 are apparently forbidden by the selection rules in T, we must assign to the 6.847-Mev resonant level a value of T = 1. It remains therefore to examine two possible estimates: 2^+, T = 1 and 2^-, T = 1.

The γ transitions to the ground state and the intermediate levels should be classified as M1 and E2 in the former case and E1 and M2 in the latter case. But since the probability of observing M2

Table II.

Spin of initial state								
0			1			2		
l_p	J_c	A_2	l_p	J_c	A_2	l_p	J_c	A_2
0	0	0	0	1	0	2	0	–0.60
1	1	0	2	1	+0.43	2	1	–0.33
			1	0	+1.00	1	1	–0.45
			1	1	–0.33	3	1	–0.50

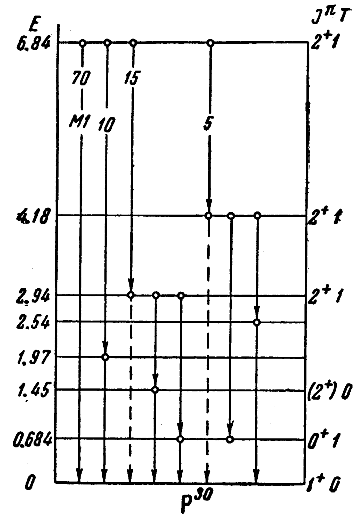

FIG. 3. γ-transition scheme in P^{30} from the 6.847-Mev resonant level.

transitions in parallel with an E1 transition is negligibly small compared with the probability of observing the corresponding M1 and E2 transitions, a positive parity of the resonant level is the more probable. Thus, the resonant level must be assigned values 2^+ and T = 1.

Since the value $A_2 = -0.485 \pm 0.015$ obtained in the experimental angular distribution differs appreciably from the calculated values (− 0.60 and − 0.33), it is of interest to discuss possible mixtures of multipoles and channel spins.

For the multipole mixture M1 + E2 we can obtain good agreement with experiment if we add to the pure M1 transition [with angular distribution $W(\theta) = 1 - 0.60\cos^2\theta$] an E2 transition mixture with coefficient $\delta = (2|E2|1)/(2|M1|1) = 0.1$ or $\delta^2 = 0.01$.

For the mixture in channel spin, the coefficient in the angular distribution of the γ rays is given by the relation

$$A_2 = -(0.60 + 0.33)/(1 + t),$$

where t is the channel-spin mixture coefficient.

It is of interest in this case to compare with experiment the values of the coefficient t, predicted by the theory for two limiting cases of jj and ls couplings. The analysis shows that in the case of an ls coupling there is no agreement with experiment, since the theoretically predicted values of t_{ls} are 0 and ∞, i.e., there are no channel spin mixtures for the ls coupling. In the case of jj coupling, t_{jj} has two values[6], ⅔ and 3.

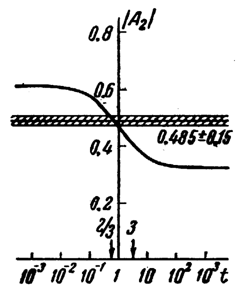

FIG. 4. The coefficient A_2 in the angular distribution of the γ rays for a channel-spin mixture as a function of the mixture coefficient t. The hatched strip corresponds to the experimental value of A_2 (with the error in its determination). The arrows indicate the values of t_{jj} predicted by the theory.

Figure 4 shows a comparison of the theoretical values of t for the jj coupling with the experimentally obtained value based on measurement of the angular distribution of the γ rays. As can be seen from the plots of A_2 vs. t, only one of the values predicted by the theory for the jj coupling is in good agreement with the experimental value $A_2 = -0.485 \pm 0.015$.

[1] Endt, Kluyver, and Van der Leun. Phys. Rev. 95, 580 (1954).

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[5] M. I. Guseva, ibid, No 5, 112 (1957).

[6] Nuclear Reactions, **1**, edited by P. M. Endt and M. Demeur, Amsterdam (1959), p. 312.

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