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LEVELS OF ^{32}S EXCITED IN THE ^{28}Si (α, γ) ^{32}S AND ^{31}P(p, γ) ^{32}S REACTIONS

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Synopsis

Alpha-particle emitting levels of ^{32}S, in the $E_x = 9-10$ MeV region, were studied by means of (α, γ) and (p, γ) reactions. In the ^{28}Si$(\alpha, \gamma)^{32}$S reaction, with α particles in the 2.0–3.3 MeV range, four resonances were observed, at E_α = 2.618, 2.878, 2.904 and 3.162 MeV. The latter three correspond to ^{31}P$(p, \gamma)^{32}$S resonances at $E_p =$ = 618.9, 642.1 and 875.5 keV.

The spins and parities of the four resonant states, as determined by angular distribution and correlation measurements, are 1^-, 2^+, 1^- and 2^+, respectively. The (α, γ) and (p, γ) yields were also measured. From corresponding (α, γ) and (p, γ) resonance energies a Q value of 1919 $\pm$ 4 keV is found for the ^{31}P$(p, \alpha)^{28}$Si reaction.

1. *Introduction.* In a previous paper on the ^{24}Mg$(\alpha, \gamma)^{28}$Si reaction [1], it was shown that useful information may be obtained by the study of (α, γ) reactions on even-even nuclei in the $2s-1d$ shell. The object of the present investigation was to study the ^{32}S levels in the region of 9–10 MeV by the same method. The compound nucleus in this region only decays by α_0, p_0 and γ emission, so that by studying the same level by means of (α, γ), (p, γ) and (p, α) reactions both total and partial widths can be determined. Moreover, the resonance parameters, like spin and parity, can be determined in several independent ways, so that cross checks on these determinations are possible. During the course of the experiment it became desirable to obtain more information from the ^{31}P$(p, \gamma)^{32}$S and ^{31}P$(p, \alpha)^{28}$Si reactions. The latter reaction was investigated, simultaneously with this work, by Kuperus, Glaudemans and Endt [2]. The (α, γ) and (p, γ) reactions will be dealt with in this paper.

Preliminary results of the work reported here were mentioned in the review article of Endt and van der Leun [3].

2. *The* ^{28}Si$(\alpha, \gamma)^{32}$S *reaction.* 2.1. The yield curve. Targets of natural silicon, evaporated from tantalum boats onto copper backings, were bombarded with an ≈ 6 μA He$^+$ beam from a 3 MV Van de Graaff generator. The He$^+$ energy was determined by measuring the field of a 90° deflecting

magnet by means of a nuclear magnetic resonance fluxmeter. The small deviation from proportionality between the fluxmeter frequency and the average field of the deflecting magnet at high fields [1]) was taken into account by using three calibration points, namely the 992.0 ± 0.5 keV ^{27}Al(p, γ)^{28}Si resonance [4]) and the 2437.4 ± 1.0 and 3199.8 ± 1.0 keV ^{24}Mg(α, γ)^{28}Si resonances [5]).

Gamma rays were detected with a 10 by 10 cm NaI crystal placed very close to the target at 55° to the beam direction. Pulses were counted in two channels covering the peak region of the γ_0 and γ_1 spectra, respectively. Because of the intense background of low energy γ-rays (mainly produced by neutrons from the ^{13}C(α, n)^{16}O reaction) it was not thought worthwhile to measure the yield in lower channels. Any strong ^{28}Si(α, γ)^{32}S resonance decaying chiefly to higher levels would rather be detected by the sum pulses coming in the γ_0 and γ_1 channels than by a channel set at lower γ-energy.

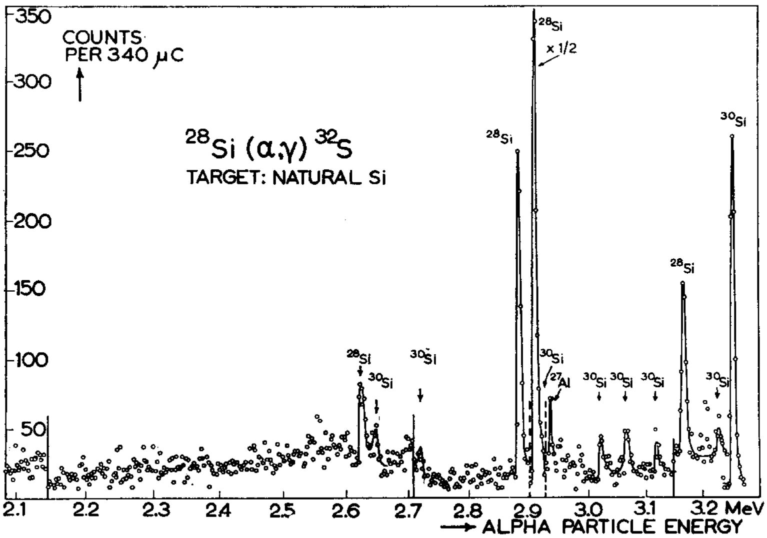

Fig. 1. Resonance curve of the ^{28}Si(α, γ)^{32}S reaction. The γ rays are detected with a NaI crystal (10 cm long and 10 cm in diameter) placed as close to the target as possible at 55° to the beam. The discriminator channel is set to accept pulses from ground state transitions (or sumpulses from cascades to the ground state) only. The breaks in the curve at 2.15, 2.71, 3.15 and 3.24 MeV correspond to adjustments of the channel setting.

As shown in fig. 1, where the yield in the γ_0 channel is displayed, several distinct resonances are observed. Of these, the four resonances at 2.618, 2.878, 2.904 and 3.165 MeV can be ascribed to the ^{28}Si(α, γ)^{32}S reaction with certainty. This is evident from the γ-ray spectra at these resonances (see next section). Although natural silicon only contains 3 percent ^{30}Si, some ^{30}Si(α, γ)^{34}S resonances are also observed. These resonances were also seen using enriched ^{30}Si targets with much higher absolute but roughly the same relative yields [6].

The weak resonance at 2.932 MeV was not observed in runs with other silicon targets and therefore must be due to target impurity. Comparison of the energy and the γ-spectrum of this resonance with results recently obtained in this laboratory by bombarding ^{27}Al targets with He^{+} ions, shows that this is a ^{27}Al(α, γ)^{31}P resonance. The existence of a very weak resonance at 2.193 MeV, observed in one of the first runs and ascribed to ^{28}Si(α, γ)^{32}S in ref. 3, could not be confirmed. This resonance is also thought to stem from target impurity.

2.2. Spectra and absolute yields. At the four ^{28}Si resonances single γ spectra were recorded using a 400-channel RIDL analyzer. Absolute yields were measured using thick Si and SiO_2 targets. The result are summarized in table I, columns 3, 4 and 5. The excitation energies in column 2 were calculated using a Q value of 6946 keV [7].

At all resonances the main decay is to the ground state and/or the 2.24 MeV first excited state of ^{32}S. Transitions to higher levels would be difficult to observe, due to the higher background at lower γ energies. Only at the 3.162 MeV resonance, transitions to higher levels are clearly present. Some γ—γ coincidence spectra were taken at this resonance. In coincidence with a 6—9 MeV channel only a 2.24 MeV line was found, undoubtedly the second γ ray of a $(r)\rightarrow(1)\rightarrow(0)$ cascade. In coincidence with a 4–6 MeV channel, the same line was found and also a 2.51 $\pm$ 0.05 MeV line. Furthermore, there are several γ rays in the 4–5.5 MeV region which could not be analysed in a unique way. Probably the 4.70 MeV level is excited, which decays to both the ground and first excited states [3]. This would require γ rays of 5.01, 4.70, 2.46 and 2.24 MeV with relative intensities which are consistent with the measured spectra.

Spectra taken at the 3.249 MeV resonance show a strong 10.7 MeV line, confirming that this is indeed the same ^{30}Si resonance as found by Van der Leun and Wiechers [6].

2.3. Angular distributions and correlations. By angular distribution and correlation measurements a unique spin and parity assignment of the four resonant states was obtained. The experimental equipment, as well as the method followed, were the same as described in ref. 1. Also, like in the ^{24}Mg(α, γ)^{28}Si reaction, the possible spins and parities are limited to 0^{+}, 1^{-}, 2^{+}, 3^{-} and 4^{+}. Since the same spin sequences are involved, the same forms of angular distributions and correlations are possible as in ref. 1. We only briefly repeat the arrangement of the different geometries used when measuring γ—γ angular correlations. In geometries I and V the angular distribution of the first gamma of a cascade (γ_1) is measured in coincidence with the second gamma (γ_2) detected in a counter fixed at 90° to the beam. In geometries II and VI the roles of γ_1 and γ_2 are interchanged as compared to geometries I and VI. The angle between the planes through the beam and the axes of the respective counters is 180° in geometries I and II, and 90° in geometries V and VI.

The 2.618 MeV *resonance.* This resonance mainly decays through an $(r)\rightarrow(1)\rightarrow(0)$ cascade. The angular correlation of this cascade measured in geometries II, V and VI is in good agreement with an unmixed $1^- \xrightarrow{E1} 2^+ \xrightarrow{E2} 0^+$ transition (see fig. 2). Resonance spins 0, 2 and 4 are excluded by the

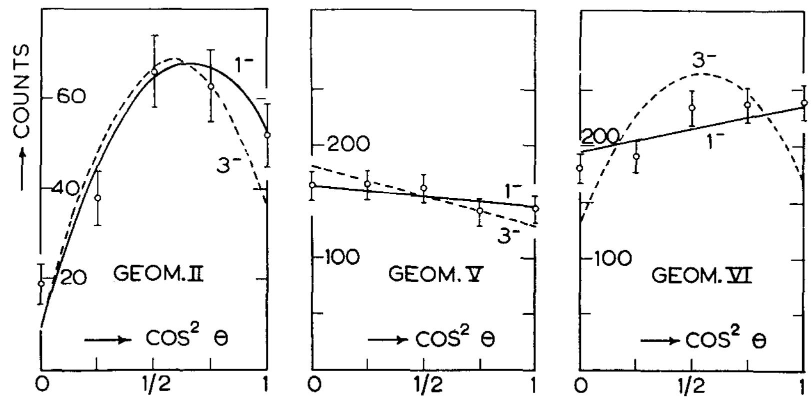

Fig. 2. Angular correlations at the 2.618 MeV $^{28}Si(\alpha, \gamma)^{32}S$ resonance of the cascade through $^{32}S(1)$, measured in geometries II, V and VI. Solid curves correspond to the theoretical expressions for a spin sequence 1-2-0, dashed curves to 3-2-0. For both γ_1 is considered to be pure dipole radiation. The rotating counter was placed at 10 cm from the target, the fixed counter at 10 cm in geometry II and at 5 cm in geometries V and VI. Both counters were 10 × 10 cm NaI crystals.

strongly negative $P_4(\cos\vartheta)$ coefficient in geometry II. The possibility $J^\pi = 3^-$ can be excluded on the basis of the combined results of geometries II, V and VI. Even if $M2/E1$ mixing is considered possible, the best fit for $J = 3$ is obtained for $x = 0$. This fit which is drawn as a dashed line in fig. 2 is bad enough to discard $J = 3$ as a possible solution, as shown through a χ^2 goodness-of-fit test.

The 2.878 *and* 2.904 *MeV resonances.* These two resonances mainly decay to the ground state. The ground state angular distributions (see fig. 3) yield unique 2^+ and 1^- assignments, respectively.

The 3.162 *MeV* resonance. At this resonance, which has a very weak ground-state transition and a strong transition to the first excited state, angular distributions of γ_0 and γ_1 and angular correlations of the $(r)\rightarrow(1)\rightarrow$

$\rightarrow$(0) cascade in geometries I and II were measured simultaneously (see fig. 4). The γ_0 angular distribution is very similar to the theoretical $2^+ \rightarrow 0^+$ distribution but shows a systematic deviation from theory. This

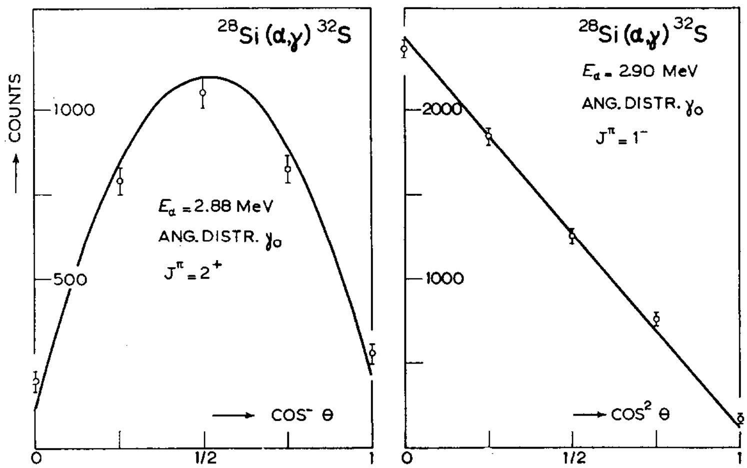

Fig. 3. Angular distributions of γ_0 at the 2.878 and 2.904 MeV ^{28}Si(α, γ)^{32}S resonances measured with a 10 × 10 cm NaI crystal at 10 cm from the target. The curves correspond to the theoretical expressions for $J^\pi = 2^+$ and 1^-, respectively.

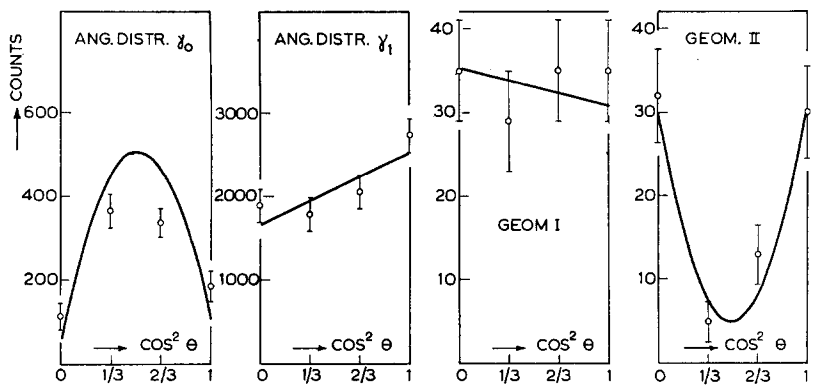

Fig. 4. Angular distributions of γ_0 and γ_1, and angular correlations of the cascade (r) $\rightarrow$ (1) $\rightarrow$ (0) in geometries I and II, as measured at the 3.162 MeV ^{28}Si(α, γ)^{32}S resonance. The curves correspond to the theoretical expressions for resonance spin 2^+ and $E2/M1$ amplitude ratio of γ_1 $x = +0.10$. Two 10 × 10 cm NaI crystals were used, both at 10 cm from the target.

deviation can be explained by a contribution of sum pulses from the (r)$\rightarrow$ $\rightarrow$(1)$\rightarrow$(0) cascade. The measured angular distribution, however, is in complete disagreement with resonance spin 1^- (compare fig. 3). The 2^+ assignment is confirmed by the angular distribution of γ_1 and the angular correlations. Least-squares analysis yields a good for fir resonance spin 2 for a value $x = 0.10 \pm 0.08$ of the $E2/M1$ amplitude ratio of γ_1.

3. *The* $^{31}P(p, \gamma)^{32}S$ *reaction.* 3.1. Resonance curve. The ^{32}S states obtained in the (α, γ) reaction also may be formed by proton bombardment of ^{31}P. The (p, γ) resonances corresponding to the (α, γ) resonances listed in, table I would be expected at proton energies of 386, 621, 644 and 877 keV all $\pm$ 5 keV, when using a $^{31}P(p, \alpha)^{28}Si$ Q value of 1916.8 ± 2.8 keV [7]). Of these, only a resonance at $E_p = 641.3 \pm 0.8$ keV [8]) was known at the start of the present experiment.

A search for the other resonances was made taking yield curves in the regions where the resonances were expected. Use was made of the Utrecht cascade generator for $E_p < 650$ keV and of the Van de Graaff generator for $E_p > 630$ keV. In the last case the H_2^+ beam was used. The targets were prepared by evaporating Zn_3P_2 onto copper backings. The γ detectors were 10×10 cm NaI crystals. The relevant parts of the yield curve are given in fig. 5. New, weak, resonances were found at $E_p = 618.9 \pm 1.0$ and 875.5 ± 1.4 keV. No resonance could be detected in the region around 386 keV. The energies of the new resonances were determined using the values given by Kuperus *e.a.*[8]) for previously known $^{31}P(p, \gamma)^{32}S$ resonances as a calibration. They were corrected upwards by 0.12% for a change in the $^{27}Al(p, \gamma)^{28}Si$ calibration energy from 990.8 keV to 992.0 keV [4]). Close to the new 875.5 keV resonance, a known $^{19}F(p, \alpha\gamma)^{16}O$ resonance at $E_p = 872.4 \pm 0.4$ keV [4]) was observed, the fluorine occurring as a contaminant on the target. The new resonance is shifted upwards by about 3 keV with respect to the fluorine resonance.

Note: The energies of several $^{31}P(p, \gamma)^{32}S$ resonances have also been determined by Andersen *e.a.*[9]). For the resonance at 812 keV they find $E_p = 812.8 \pm 0.5$ keV in good agreement with the value 812.2 ± 1.0 keV as given by Kuperus. (Both values are corrected for the change in calibration mentioned). Using the latter value for calibration we observe a resonance at 895.8 ± 1.1 keV, which agrees poorly with the (corrected) value 893.1 ± 0.5 keV as given by Andersen *e.a.*

3.2. Spectra. The single γ-ray spectrum of the weak 618.9 keV resonance shows transitions to the ground state and to the first excited state of ^{32}S. The latter transition, however, is largely obscured by the 7.12 MeV γ-ray from the $^{19}F(p, \alpha\gamma)^{16}O$ reaction.

The 642.1 keV resonance mainly decays to the ground state. Other γ-rays observed are 5.18 ± 0.05 (10%), 4.27 ± 0.05 (10%), 2.76 ± 0.05 (3%) and 2.24 ± 0.03 MeV (9%). The values in brackets give the intensities in fractions of the γ_0 intensity. No transition from the resonant level to the first excited state is observed: $\gamma_1 < 3\%$. The 5.18 and 4.27 MeV transitions probably form a cascade $(r) \to 4.29 \to (0)$. The interpretation of the other lines would require a more comprehensive study.

At the 875.5 keV resonance again the spectrum is largely obscured by lines from the ^{19}F(p, $\alpha\gamma$)^{16}O reaction. However, γ_0 and γ_1 transitions are distinguishable.

3.3. Angular distribution. At the 642.1 keV resonance the angular distribution of the ground-state transition has been measured. After correction for finite solid angle this measurement yielded $W(\vartheta) = 1-(0.273 \pm \pm 0.015)$ $P_2(\cos\vartheta)$. No appreciable $P_4(\cos\vartheta)$ term was observed. This result uniquely determines the resonance spin as $J = 1$. For $J = 2$ one would expect a positive $P_2(\cos\vartheta)$ coefficient. The strong transition to the 0^+ ground state excludes $J = 3$ or higher. The parity does not follow from this measurement, but follows from the fact that this resonance also decays by α-particle emission to the 0^+ ^{28}Si ground state [2]). This requires natural parity, so $J^\pi = 1^-$. The 1^- state may be formed via 0^+ and 1^+ channel spins with $l_p = 1$ in both cases. The intensity ratio of the 1^+ and 0^+ channels as derived from the angular distribution measurement is 0.94 ± 0.04. This is in good agreement with the value 0.85 ± 0.07 found from the (p, α) reaction [2]).

The other two resonances were considered too weak for angular distribution measurements.

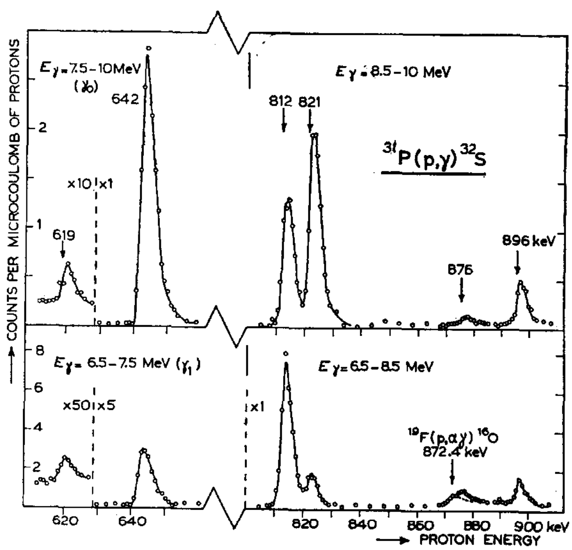

Fig. 5. Resonance curves of the ^{31}P(p, γ)^{32}S reaction, showing the new 619 and 876 keV resonances. The upper and lower curves give the yields in different discriminator channels, corresponding to the γ_0 and γ_1 peaks in the γ spectrum. The γ rays are detected with a 10×10 cm NaI crystal placed about 1 cm from the target, at 55° to the beam.

3.4. Yield measurements. The absolute yield at the 642 keV res nance was measured using a thick Zn_3P_2 target. At the 619 and 876 ke resonances the strength was determined by comparing the area under t resonance curve with that of the 642 keV resonance using the target fig. 5. Apart from changes in efficiency of the crystal and the discriminat channel, the resonance strengths $(2J + 1)\ \Gamma_p\Gamma_\gamma/\Gamma$ are then proportion

TABLE I

Resonances in the $^{28}Si(\alpha, \gamma)^{32}S$ reaction					
1 E_α(MeV)	2 E_x(MeV) (Q=6.946 MeV)	3 Observed γ transitions	4 $\Gamma\gamma_0/\Gamma\gamma_0$	5 $(2J+1)\Gamma_\alpha\Gamma_\gamma/\Gamma$(eV) *)	6 J^π
2.618	9.236	γ_1, 2.24	<0.1	0.3	1^-
2.878	9.464	γ_0, γ_1, 2.24	1.5	0.4	2^+
2.904	9.487	γ_0	>5	0.7	1^-
3.162	9.713	γ_0, γ_1, 4–5.5†) 2.51, 2.24	0.15	0.2**)	2^+
all ± 4 keV					

*) Only γ_0 and γ_1 are included in the yields.
**) At this resonance the total strength is ≈ 0.3 eV.
†) see text.

to $E_p^{3/2}$ times this area when the yield is plotted versus fluxmeter frequenc Only the γ_0 and γ_1 yields were measured directly. At the 642 keV resonan the total yield was obtained by assuming other transitions to have a tot intensity of 20% of γ_0; at the 876 keV resonance the branching obtain from the (α, γ) work was used (see section 4). Results are summarized table II. The lower limit at 386 keV was derived from the resonance curv

TABLE II

$^{31}P(p, \gamma)^{32}S$ resonances, corresponding to $^{28}Si(\alpha, \gamma)^{32}S$ resonances of table I						
E_p(keV)	E_x(keV) (Q=8862.6 keV)	J	$(2J+1)(\Gamma_{\gamma0}+\Gamma_{\gamma1})$ $\times\ \Gamma_p/\Gamma_\gamma$ (eV)	$(2J+1)\Gamma_p\Gamma_\gamma/\Gamma$ (eV)	Observed γ transitions	Correspon (α, γ) resor (MeV
386			<0.00015	<0.00015	none	2.618
618.9±1.0	9462		0.003	0.003	γ_0, γ_1	2.878
642.1±1.0	9485	1	0.19	0.23	γ_0; see text	2.904
875.5±1.4	9711		0.02	0.03	γ_0, γ_1	3.162

To connect our yield measurements to those of others authors we al measured the γ_0 or γ_1 yields, relative to the 642 keV resonance, at the 44 540, 812 and 820 keV resonances. Results are presented in table III. Tl agreement of our results with those of Chagnon and Treado [10]) and tho of Ter Veld and Brinkman [11]) is reasonable, but the values of Paul *e.a.*[1] are a factor of two to three higher.

4. *Comparison of* (p, γ), (p, α) *and* (α, γ) *results.* 4.1. Resonance ene gies. From the close agreement between the excitation energies of tl

(α, γ) and (p, γ) resonances listed in tables I and II, it seems reasonable to assume that these relate to the same resonance levels. The excitation energies were calculated with the aid of Everlings mass tables [7]). Once this relationship between (α, γ) and (p, γ) resonances is established, one can

TABLE III

Comparison of yield measurements of ^{31}P$(p, \gamma)^{32}$S resonances by different authors. (All strengths in eV).

Resonance energy (keV)	Measured quantity	Present work	Other authors (a)	(b)	(c)
440	$(2J+1)(\Gamma_p/\Gamma) \times \Gamma_{\gamma 0}$	0.042	0.067	0.052	
540	$(2J+1)(\Gamma_p/\Gamma) \times \Gamma_{\gamma 1}$	0.25	0.25		
812	$(2J+1)(\Gamma_p/\Gamma) \times \Gamma_{\gamma 1}$	0.5			1.8
820	$(2J+1)(\Gamma_p/\Gamma) \times \Gamma_{\gamma 0}$	0.17			0.36

(a) Chagnon and Treado, ref. 10.
(b) Ter Veld and Brinkman, ref. 11.
(c) Paul *et al.*, ref. 12.

determine the ^{31}P$(p, \alpha)^{27}$Si Q value from the corresponding resonance energies, independent from the mass tables. From our measuremments one finds $Q = 1919 \pm 4$ keV, while Everling *e.a.* give 1916.8 ± 2.8 keV[7]). This good agreement is in contrast with the result of the analogous case ^{27}Al$(p, \alpha)^{24}$Mg, where a discrepancy of 7 keV was found by similar methods [5]) [1]).

4.2. Spectra, spins and parities. Further evidence for the assumption, made above, that the same levels are excited in the alpha and proton work follows from the comparison of spectra, spins and parities obtained in the different reactions. Within the accuracy of observation the results of the ^{28}Si$(\alpha, \gamma)^{32}$S and ^{31}P$(p, \gamma)^{32}$S reactions agree, as may be seen from tables 1 and 2. The ^{31}P$(p, \alpha)^{32}$S reaction, furthermore, yields $J^\pi = (2^+, 3^-)$ and $J^\pi = 1^-$ for the $E_p = 619$ and 642 keV resonances respectively [2]). The most impressive check is thus obtained at the 9487 keV level for which $J = 1$ is found by three different methods, and, moreover, the proton channel mixing as determined in two different ways (see section 3) is the same. For the 9.464 MeV level the (α, γ) and (p, α) work yields $J^\pi = 2^+$ and $J^\pi = 2^+, 3^-$ respectively. For the other two levels there is only the (α, γ) spin determination.

4.3. Partial widths. The 9.236 MeV level is only observed in the (α, γ) reaction ($E_\alpha = 2.618$ MeV). For this level $\Gamma_\alpha \Gamma_\gamma / \Gamma = 0.1$ eV, $\Gamma_p \Gamma_\gamma / \Gamma < 5 \times 10^{-5}$ eV (tables 1 and 2) and $\Gamma_p \Gamma_\alpha / \Gamma < 0.01$ eV (ref. 2). This leads to $\Gamma_p < 0.01$ eV, $\Gamma_\alpha > 0.1$ eV, $\Gamma_\gamma > 0.1$ eV and $\Gamma_{\text{total}} > 0.4$ eV, or (using $R = 1.45(A^{\frac{1}{3}} + m^{\frac{1}{3}}) \times 10^{-13}$ cm) $\vartheta_p^2 < 0.02$ and $\vartheta_\alpha^2 > 6 \times 10^{-4}$. The nonobservation of this resonance in (p, γ) and (p, α) reactions thus does n require exceptionally low or high values for the reduced widths.

The 9.464 and 9.487 MeV levels are observed in (α, γ), (p, γ) and $(p,$ reactions. Their partial widths as derived from the combined yields a already discussed in ref. 2).

The 9.713 MeV level is excited by the (α, γ) and (p, γ) reactions (E_α = 3.162 MeV and E_p = 875.5 keV). The corresponding (p, α) resonanc might be the resonance observed by Freeman and Seed [13]) at E_p =

TABLE IV

Radiative widths in ^{32}S								
E_x(MeV)	Γ_γ(eV)	$\Gamma_{\gamma 0}$(eV)	type of γ_0	$\Gamma_{\gamma 0}$(eV)	type of γ_1	$\|M\|^2$(E2)	$\|M\|^2$(E1)	$\|M\|^2($
9.236	$\geqslant$0.1			$\geqslant$0.1	E1		$\geqslant 3.10^{-4}$	
9.464	0.08	0.06	E2	0.02	M1 *)	0.07		3.1
9.487	0.37	0.30	E1				3.10^{-4}	
9.713	$\geqslant$0.06	$\geqslant$0.01	E2	$\geqslant$0.05	M1	$\geqslant$0.01		$\geqslant$5.1

*) The E2/M1 mixing ratio of γ_1 for this level was not actually measured, but is assumed to be The value of $|M|^2$ (M1) for this level thus may be considered as an upper limit.

= 900 keV. Its yield, as estimated from their yield curve is nearly the san as for the 642 keV resonance, which has $(2J + 1)\ \Gamma_p \Gamma_\alpha/\Gamma = 5.4$ eV [1 Under these assumptions one gets $\Gamma_p = 1$ eV, $\Gamma_\alpha = 10$ eV and $\Gamma_\gamma = 0.06$ e $\vartheta_p^2 = 0.004$ and $\vartheta_\alpha^2 = 0.01$. This is, however, only a speculation and mo precise experiments on the 900 keV ^{36}P$(p, \alpha)^{32}$S resonance are necessar

The partial radiative widths for transitions deexciting the resonant stat are given in table IV, together with their strength in Weisskopf unit $|M|^2$ [14]). For the calculation of $|M|^2$ the conventional value $R = 1.5$ 10^{-13} cm for the nuclear radius was used. The values for the 9.236 and 9.7 MeV levels are lower limits. If $\Gamma p \ll \Gamma_\alpha$ and $\Gamma_\gamma \ll \Gamma_\alpha$, the true values w be close to these limits. As may be seen from the considerations given abov these conditions are very probably fulfilled.

5. *Discussion.* When the results of the ^{28}Si$(\alpha, \gamma)^{32}$S reaction are compar with those of the analogous ^{24}Mg$(\alpha, \gamma)^{28}$Si reaction [1]) two striking differenc are apparent. First, the number of resonances found in the ^{28}Si$(\alpha, \gamma)^{3}$ reaction is much lower. This difference may be explained partly by t higher Coulomb barrier, but mainly by the lower level density in the regi of excitation energy studied. In this region, corresponding to $E_\alpha = 2.0$ – 3.3 MeV, ($E_x(^{32}$S$) = 8.7 - 9.8$ MeV), there are ten levels known at pr sent of which four are found in the ^{28}Si$(\alpha, \gamma)^{32}$S reaction, and the remaini six only in the ^{31}P$(p, \gamma)^{32}$S reaction. In the comparable region of ^{28}Si(E_x = 11.78 – 12.74 MeV), 14 out of the 32 known levels are found in t ^{24}Mg$(\alpha, \gamma)^{28}$Si reaction, with $E_\alpha = 2.0 - 2.3$ MeV. Thus the fraction of t number of levels which is observed in the (α, γ) reaction seems to be t

same for both reactions. The levels which are not observed may have "unnatural" parity $(-)^{J+1}$, in which case they cannot be excited in the (α, γ) reaction due to the conservation of parity, or their (α, γ) yields are suppressed, either by the isotopic spin conservation rule, or by "accidental" low values of Γ_{α}.

The second difference is that three out of the four resonances decay predominantly by dipole γ radiation, while in the ^{24}Mg$(\alpha, \gamma)^{28}$Si reaction there is a strong preference for $E2$ transitions. This indicates that the $E1$ and $M1$ isotopic spin selection rules are less effective for ^{32}S than for ^{28}Si. Comparison of the transition strengths in ^{32}S with those in ^{34}S show, however, that there is still an appreciable suppression of dipole radiation in the self-conjugated nucleus ^{32}S, as compared to ^{34}S [6]).

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