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THE ISOBARIC ANALOGUE STATE IN ^{31}P OF THE 3.13 MeV LEVEL IN ^{31}Si

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Synopsis

The differential cross section for elastic scattering of protons on ^{30}Si was measured with surface barrier counters at four angles. The $E_p = 2187$ keV resonance known from ^{30}Si$(p, \gamma)^{31}$P was observed in the ^{30}Si$(p, p)^{30}$Si reaction and the parity, the proton width and the reduced proton width were determined. A confirmation of the f-wave character was obtained. The resonance level in ^{31}P was identified as the analogue state of the 3.13 MeV level in ^{31}Si. The observed reduced width is in accord with this assumption.

1. *Introduction.* The spins, parities and spectroscopic factors of the lower levels of ^{31}Si are well known from investigations of the ^{29}Si$(t, p)^{31}$Si and ^{30}Si$(d, p)^{31}$Si reactions[1) 2)]. The 6.38 and 7.15 MeV levels of ^{31}P have been identified as the analogues of the ground state and the first excited state of ^{31}Si respectively[3)]. The analogue state of ^{31}Si(3.13) with $J^\pi = (5/2, 7/2)^-$ is expected at an excitation energy of about 9.5 MeV in ^{31}P. In the ^{30}Si$(p, \gamma)^{31}$P reaction a resonance at $E_p = 2187$ keV with an excitation energy in ^{31}P of 9.42 MeV has been observed and $J^\pi = 7/2^-$ has been determined from angular correlation and polarization measurements[4)]. In a low-resolution investigation of the ^{30}Si$(p, p)^{30}$Si reaction this resonance was observed as an f-wave resonance at about the same energy[5)]. In fig. 1 some details of the level schemes of ^{31}Si and ^{31}P are given after correction for Coulomb displacement.

Because at $E_p = 2187$ keV only the channels for proton and gamma decay are open and as Γ_γ is much smaller than Γ_p, one can approximate Γ_p by the total width Γ. The elastic proton scattering experiment on ^{30}Si is then an ideal tool to determine the reduced proton width of the resonance level. The $E_p = 2187$ keV resonance in the ^{30}Si$(p, p)^{30}$Si reaction was the subject of this experiment.

2. *Experimental.* Protons were accelerated with a 3 MeV electrostatic generator and magnetically deflected over 90°. More details about the equipment have been described in a previous paper[6)]. The energy distri-

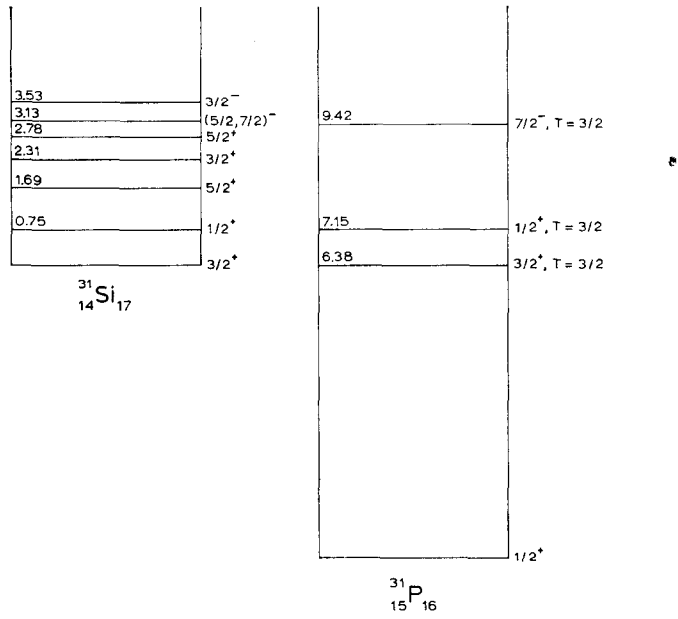

Fig. 1. Some details of the level schemes of ^{31}Si and ^{31}P after correction for the Coulomb displacement.

bution of the analysed proton beam at $E_p = 2$ MeV has a full width at half maximum of at most 250 eV. With a target thickness of 900 eV the elastic proton yield curve was measured at four angles, viz. $\theta_1 = 90.0°$, $\theta_2 = 125.3°$, $\theta_3 = 140.8°$ and $\theta_4 = 149.5°$ (C.M.), simultaneously with the γ-ray yield curve. The target was prepared in the same way as described earlier[6]).

3. *Analysis of the data.* The measured resonance shape can be fitted only assuming f-wave scattering; at θ_1 and θ_3 the interference term between the resonance and Rutherford amplitudes vanishes. The differential cross section at these angles after subtracting the Rutherford contribution can be analysed in a relatively simple way as a Breit-Wigner curve, giving information about the total width Γ and the resonance energy E_0. After this first step the complete analysis at four angles was accomplished with the theoretical formulas of Blatt and Biedenharn in the way described previously[6]).

4. *Results and conclusions.* In fig. 2 the best fit to the experimental result is shown. The smooth curve is the theoretical curve for $J^\pi = 7/2^-$ and $\Gamma = 1.7$ keV. The cross section is given in units of the Rutherford contribution after subtraction of the background (see ref. 6). The bottom curve gives the γ-ray yield, measured simultaneously. For better presentation

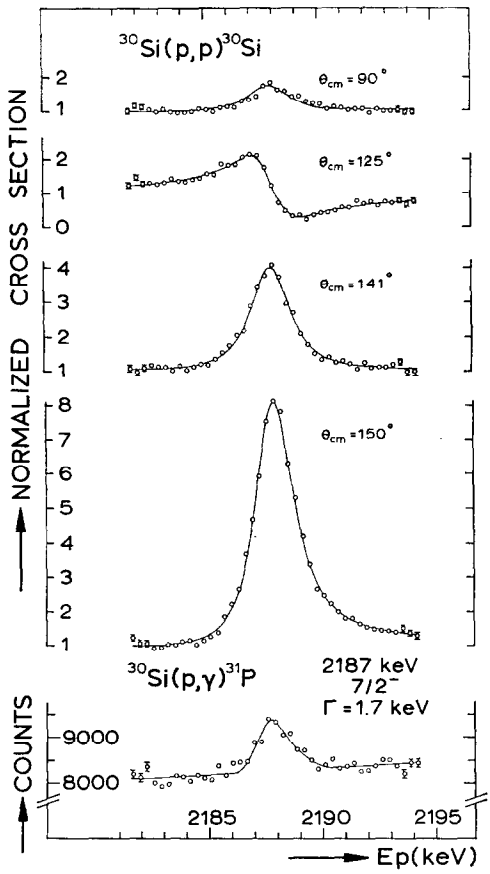

Fig. 2. Differential cross sections at four angles for elastic proton scattering on ^{30}Si in units of the Rutherford contribution, with background subtracted, at the E_p = = 2187 keV resonance. The smooth curve is the theoretical curve for $J^\pi = 7/2^-$ and $\Gamma = 1.7$ keV. The bottom curve gives the γ-ray yield, with suppressed zero.

the zero is suppressed. Although the $J^\pi = 7/2^-$ assignment gives the best fit, $J^\pi = 5/2^-$ cannot be excluded. The χ^2-calculations for both assignments state that the likelihood for $J^\pi = 5/2^-$ is a factor of 2 smaller than that for $J^\pi = 7/2^-$. From the total width, $\Gamma = 1.7 \pm 0.4$ keV, which closely approximates the proton width, the reduced proton width $\theta_p^2 = 0.37 \pm$ $\pm$ 0.09 is calculated, using $R = r_0(A^{\frac{1}{3}} + 1)$, with $r_0 = 1.20$ fm. Ref. 2 gives a total width $\Gamma = 1$ keV, in reasonable agreement with this experiment.

This value of θ_p^2 may be compared with the value computed from the spectroscopic factor for the 3.13 MeV level, $S_n = 0.83$, obtained[2]) from the ^{30}Si$(d, p)^{31}$Si reaction if $J = 7/2$. Using the appropriate isospin coupling factor one derives $\theta_p^2 = S_n/3 = 0.28$. This value is within the error in agreement with the result of the (p, p) experiment.

If ^{31}Si is considered as a ^{28}Si core with two neutrons bound in the $2s_{\frac{1}{2}}$ and one neutron in the $1d_{\frac{3}{2}}$ shell, a $7/2^-$ level can be explained by exciting the last neutron to the $1f_{\frac{7}{2}}$ shell. The levels at $E_x = 1.69$, 2.31, and 2.78 MeV in ^{31}Si are only weakly excited in the ^{30}Si$(d, p)^{31}$Si reaction[2]). Apparently they have little single-particle character, and consequently one can hardly expect to find their analogues in ^{31}P.

The results of this investigation, together with those of ref. 4, confirm the selection rule about the gamma decay of $T = 3/2$ levels mentioned in ref. 7, stating that the transition $J_i \rightarrow J_f = J_i$ is favoured by an order of magnitude over other transitions. In this case the excited state in ^{31}P with $J^\pi = 7/2^-$ decays more than 95 percent to a $7/2^-$ level at $E_x = 4.43$ MeV with isospin $T = 1/2$.

A similar favoured transition has been observed[8]) in ^{35}Cl, where the 7.54 MeV ($J^\pi = 7/2^-$, $T = 3/2$) level decays more than 80 percent to the 3.16 MeV ($J^\pi = 7/2^-$, $T = 1/2$) level.

As a result of this experiment the $E_p = 2187$ keV resonance, known from the (p, p) and (p, γ) reactions on ^{30}Si can be considered as the analogue state of the 3.13 MeV level in ^{31}Si with $J^\pi = 7/2^-$ and $T = 3/2$.

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