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DELAYED PROTONS FOLLOWING THE DECAY OF S^{29}

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Delayed protons have been observed following decay of the previously unreported S^{29}. The existence (i. e. particle stability) of S^{29} has been predicted by Baz [1], and its expected Q_{β^+} may be estimated using the semi-empirical formula of Jaenecke [2] for Coulomb energy differences. This formula yields an energy of 8. 2 ± 0. 5 MeV for the first $T = \frac{3}{2}$ level in Si^{29}. The lowest $T = \frac{3}{2}$ level in P^{29} should be at about this same energy if one assumes isobaric invariance, and the Q_{β^+} for S^{29} may be estimated at 13. 8 ± 0. 5 MeV.

Measurements were taken using a surface barrier silicon detector of area 200 mm^2 and 500 μ depletion depth (8 MeV for protons), mounted 6 cm from the thin target foil and inserted on a radial probe into the circulating proton beam of the McGill synchrocyclotron. Counting was performed between repetitive bursts, typically 30 msec long, of normal cyclotron operation. A clock-controlled counting period was initiated following a 100 msec delay which was long enough to allow dissipation of beam storage effects in the cyclotron. This period could be accurately divided into four equal intervals, enabling the spectrum to be stored sequentially in the four quadrants of a 256 channel analyzer. Thus fourpoint decay

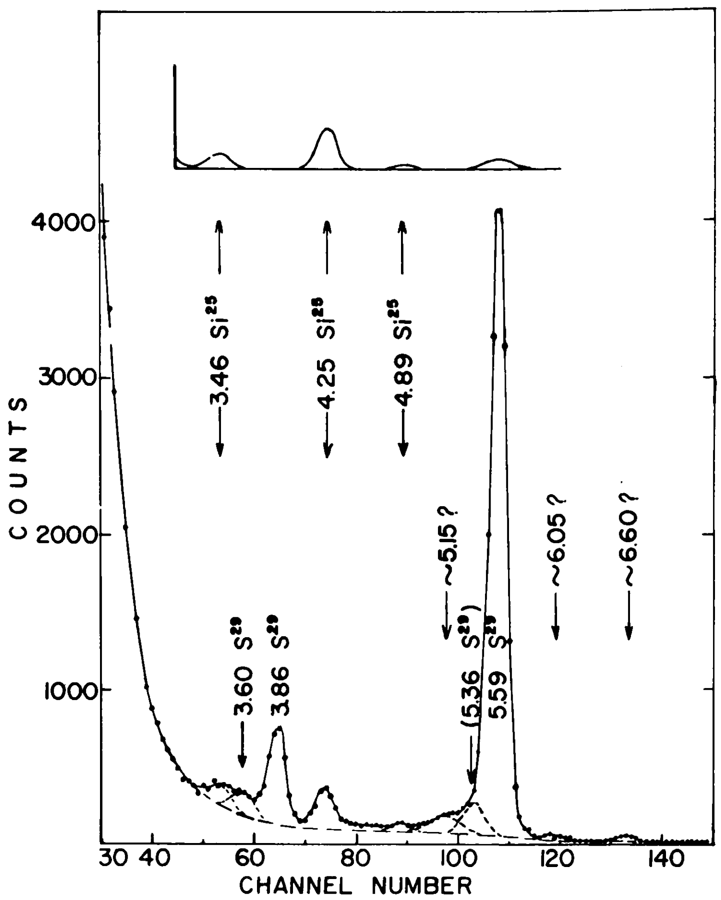

Fig. 1. Spectrum of delayed protons following the bombardment of sulfur. The energy of each proton peak is shown in MeV, corrected to centre-of-mass. The insert shows the delayed proton spectrum following the decay of Si^{25}, taken from reference 4; this spectrum has been normalized so that the peak height at 4.25 MeV is the same in both spectra. The peak marked (5.36 S^{29}) should be considered as less certain than the other S^{29} peaks.

curves for the peaks in the spectrum could be obtained.

Fig. 1 shows the delayed proton spectrum obtained following bombardment of a 1.5 mg/cm^2 sulfur target evaporated on a thin (200 μg/cm^2) gold backing. A phosphorus target [3] yielded similar peaks, but the counting rate obtained was not as great.

Yield curves for the most prominent peaks could be plotted for both targets by measuring their production as a function of the target radius in the cyclotron. Radial oscillations in the cyclotron beam make the actual bombarding energy at a given target radius less than the nominal cyclotron energy at that radius by an amount not well determined (2 to 5 MeV), but relative threshold measurements are accurate to better than 2 MeV.

Spectra taken at different incident proton energies indicated that the peak in channel 74 had a higher threshold than the large peak in channel 108. Both its energy and its measured threshold indicated that it was in fact following the decay of Si^{25}. The Si^{25} delayed proton spectrum [4] is shown as the insert in fig. 1. Other lines associated with Si^{25} could then be identified and are seen to appear in the main spectrum with the relative intensities expected. Of the remaining lines, four were attributed to the decay of S^{29} by the following argument. Since these lines did not appear following bombardment of silicon, the nuclide responsible for the activity must be an isotope of phosphorus or sulfur. (Clearly there is only a small contribution to the large peak in channel 108 from the Si^{25} peak at about the same energy.) Any isotope of phosphorus that can be a delayed proton precursor must have a production threshold from stable sulfur lower than that from phosphorus. In fact, however, the apparent production threshold from sulfur was 7 MeV greater than that from phosphorus, and was approximately 50 MeV. These results are compatible only with the reactions $S^{32}(p, d2n)S^{29}$ and $P^{31}(p, 3n)S^{29}$ whose calculated laboratory energy thresholds are (46.3 ± 0.5) MeV and (39.5 ± 0.5) MeV. The appearance of Si^{25} lines in the spectrum is attributed to the reaction $S^{32}(p, \alpha d2n)Si^{25}$ whose threshold, 55.8 ±0.5 MeV, is 9.5 MeV higher than the threshold for $S^{32}(p, d2n)S^{29}$; this difference compares favourably with the experimental difference of about 10 MeV.

The two high energy peaks (6.05 and 6.60 MeV) were not sufficiently above background to identify their source positively, while the peak in channel 97 did not behave in a consistent manner and has not yet been identified. The energies of the peaks shown in fig. 1 are corrected to centre-of-mass. Since this correction depends upon the source, the three peaks of uncertain origin are shown only with approximate energies.

Typical decay curves for the three main peaks are shown in fig. 2. The data for the 5.59 MeV peak has been corrected for the small Si^{25} peak (5.62 MeV). From such curves, the half life we adopt for S^{29} is 195 ± 8 msec. Incidentally, the 4.25 MeV peak is seen to have a half life consistent with its assignment to Si^{25} which has a measured half life of 225 msec [4].

The proposed decay scheme appears in fig. 3. The known level at 8.08 MeV [5] would result in proton peaks at 5.33 and 3.56 MeV, agreeing within experimental error with the observed peaks at 5.36 ± 0.10 and 3.60 ± 0.06 MeV. The peaks at 3.86 ± 0.04 and 5.59 ± 0.04 MeV fit the decay of a proposed new level at 8.36 ± 0.03 MeV.

The spin-parity of Al^{29} is $\frac{5}{2}^+$, as it is for all other nuclei with 13 odd nucleons, and consequently it is likely that S^{29}, its mirror, should have the same spin-parity. On this basis, the pos-

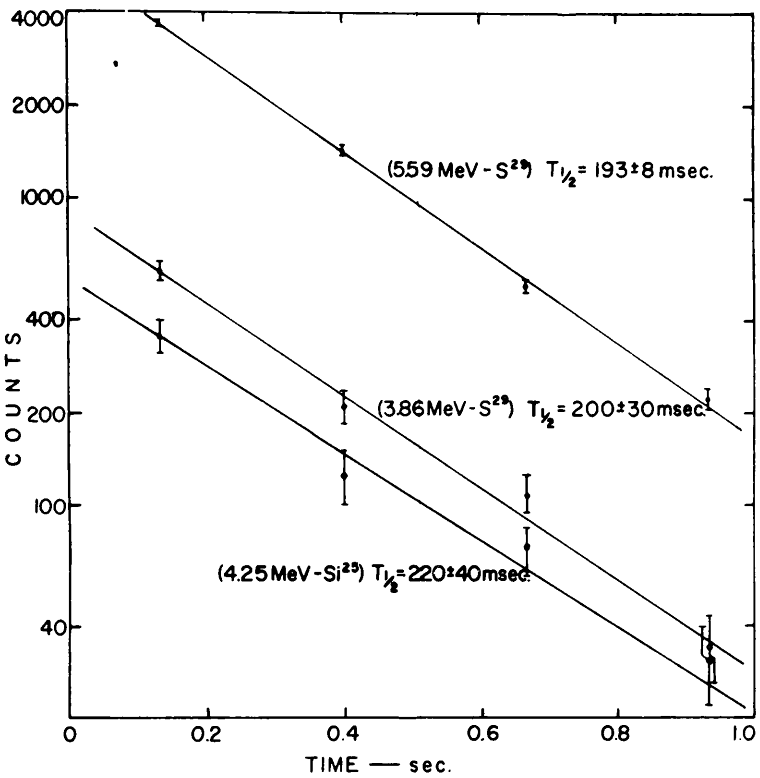

Fig. 2. Typical four-point decay curves for peaks in the spectrum of protons following bombardment of sulfur. The energy of the peak considered, its source, and its measured half life are indicated for each curve.

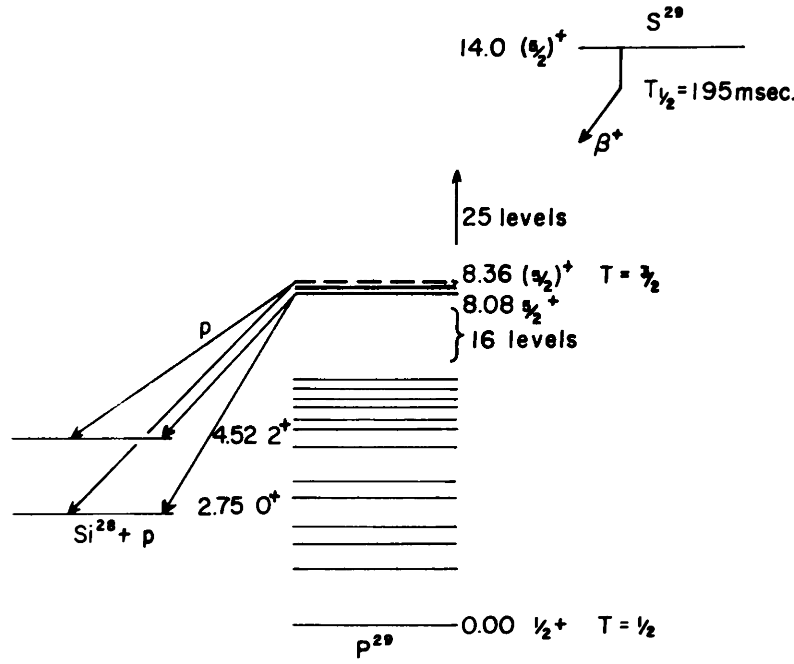

Fig. 3. Proposed decay scheme of S^{29}. The proposed $T = \frac{3}{2}$ level is shown dashed at 8.36 MeV; all other levels and assignments are from the compilation of Endt and van der Leun [5].

itron decay to the 8.08 MeV level should be allowed. If a log ft between 4.0 and 5.0 is assumed for this transition, then from the relative intensities of the proton peaks, the decay to the 8.36 MeV level has a log ft between 2.5 and 3.9, indicative of a super-allowed transition. Combining this with the fact that the expected energy of the first $T = \frac{3}{2}$ state in P^{29} is 8.2 ± 0.5 MeV, it is reasonable to assign this isotopic spin to the level at 8.36 ± 0.03 MeV. Like the similar levels in Al^{25} and Na^{21} [4], this level can proton-decay only through an admixture of $T = \frac{1}{2}$. If this admixture is small, then it is to be expected that the level should not appear in resonance data for proton reactions on Si^{28}. This appears to be the case.

There are several other levels in P^{29} with a spin of $\frac{5}{2}^+$ or $\frac{3}{2}^+$ which are apparently not populated sufficiently to be observed in this experiment. This, however, is not inconsistent with these levels being fed by allowed transitions, since, on the basis of the range of log ft's previously assumed, transitions with high allowed log ft's could result in peaks with unobservably low intensities.

Using the value 8.36 MeV for the lowest $T = \frac{3}{2}$ state in P^{29} and the calculated Coulomb energy difference, a revised estimate of the Q_{β^+} for S^{29} is 14.0 ± 0.2 MeV; this value is shown in fig. 3.

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