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R. McPHERSON, J.C. HARDY and R.E. BELL

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DELAYED PROTON EMISSION FOLLOWING THE DECAY OF Ne^{17}

R. McPHERSON, J. C. HARDY and R. E. BELL
Radiation Laboratory, McGill University, Montreal

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This report describes the decay of Ne^{17}, the heaviest neon isotope that can be a precursor of β-delayed protons. The existence (i. e. particle stability) and β-decay energy of Ne^{17} have been predicted by several authors [1-3], using isobaric invarience principles and known masses of neighbouring or mirror nuclei to predict the masses of possible light nuclei. Experimentally, Ne^{17} was first identified by Barton et al. [4] when proton peaks at approximately 3.8 and 5.0 MeV (centre-of-mass) were detected following its decay. These protons were probably the source of the otherwise unidentified delayed proton events first observed by Karnaukhov et al. [5] following bombardment of Ni with 130 MeV Ne^{20} ions. A later work by the same group [6] shows a broad proton group at roughly 5 MeV with an observed half life of 85 ± 15 ms, attributed by the authors to a nuclide not differing greatly in mass from Ne^{20} (for example Ne^{17} or Mg^{20}). The more detailed results to follow definitely assign an activity to Ne^{17} that would explain the Russian results.

The apparatus consisted of a surface barrier silicon detector of 200 mm^2 area and 300μ depletion depth (6 MeV for protons), mounted 6 cm from a thin target foil. This whole assembly was mounted on a probe that could be inserted into the circulating proton beam of the McGill synchrocyclotron. Depending on the cyclotron radius chosen for bombardment, the proton beam traversed the target foil from 10 to 50 times, and hence the counting rates were such as would be obtained with a beam of some tens of microamperes. Counting was performed between repetitive 40 ms bursts of cyclotron operation. A digitally controlled counting period of desired length was initiated 100 ms after each burst. This delay was chosen long enough to allow dissipation of cyclotron beam storage effects and obtain quiet spectra. The counting period could be divided into four equal periods, enabling the spectrum to be sequentially stored in the four quadrants of a 256 channel analyzer. Four point decay curves were thus obtained from the spectra.

Fig. 1 shows the delayed proton spectra from two types of thin target containing fluorine (monoisotopic F^{19}). The upper curve shows the spectrum obtained following bombardment of 2.5 mg/cm^2 of LiF deposited as a slurry on a 2.6 mg/cm^2 mylar film backing. The three proton peaks are attributed to the decay of Ne^{17}. The lower curve is the spectrum from 2.0 mg/cm^2 of LiF vacuum evaporated onto Al foil of 2.4 mg/cm^2, in which case there appear also the delayed proton peaks from Si^{25} produced in the aluminium [4]. The energies shown have been corrected to centre-of-mass and have uncertainties of about +0.05 MeV. Targets of teflon $(CF_2)_n$ gave a spectrum similar to that from LiF on mylar, where the background continuum is believed due to some activity induced in carbon. The apparent yield of Ne^{17} is lower in teflon than in LiF, an effect attributed to the high gas permeability of teflon, allowing diffusion of neon into the cyclotron vacuum.

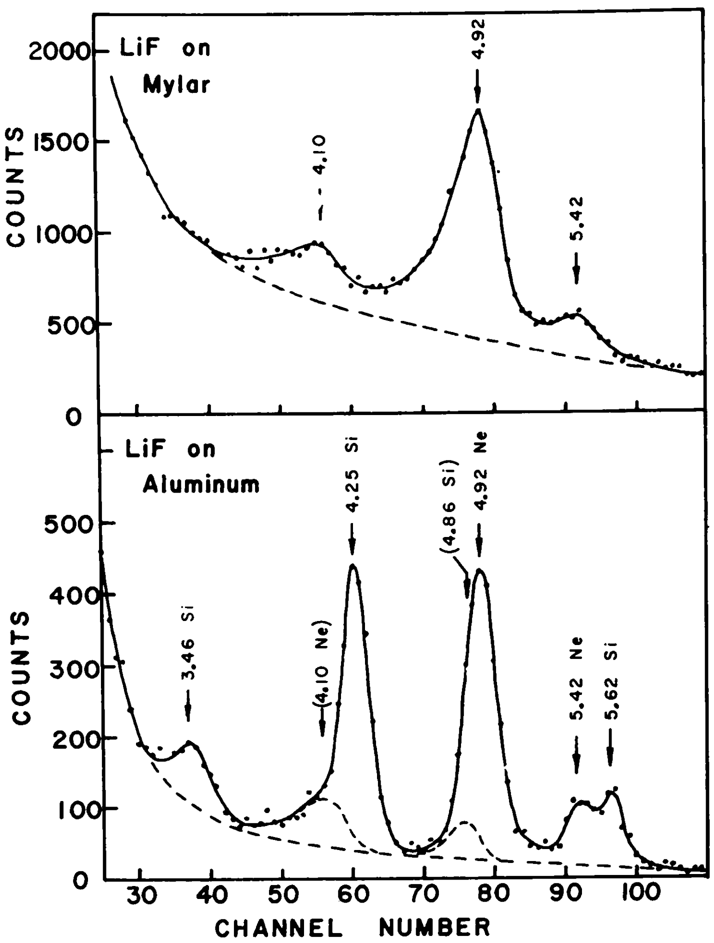

Fig. 1. Delayed proton spectra from two types of target, where the energies in MeV have been corrected to centre-of-mass. The upper curve shows three proton groups from Ne^{17}. The lower curve shows these groups plus groups from Si^{25} produced in the aluminium target backing. The superior resolution in the lower curve is due to a thinner and more uniform target as well as an improved detector.

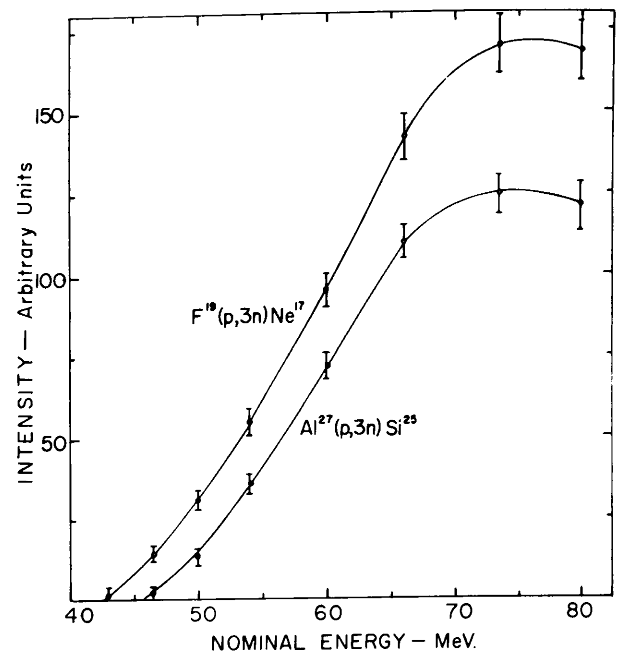

Fig. 2. Yields of Ne^{17} and Si^{25} activities as functions of nominal cyclotron proton energy. (The real proton energies will be 2 to 5 MeV lower). No significance should be attached to the height of one curve relative to the other.

Using the composite target of LiF on Al, yield curves were measured for production of the main peak in both Si^{25} and what we have called Ne^{17}; if this assignment is correct, the production reactions are $Al^{27}(p,3n)Si^{25}$ and $F^{19}(p,3n)Ne^{17}$ respectively. The estimated laboratory energy thresholds for these reactions are 39.2 ± 0.5 MeV and 36.6 ± 0.3 MeV respectively. The uncertainties are due almost entirely to the estimations [3] of $Q_{\beta}+$ for Si^{25} and Ne^{17}, the only unmeasured mass links. Fig. 2 shows the relative activation as a function of nominal energy corresponding to the target radius in the cyclotron. It must be understood that this will tend to overestimate the actual energy by 2 to 5 MeV due to radial oscillations of the cyclotron beam for which no correction has been made in the figure. It has also been established that the spectrum does not appear following bombardment of O^{16} at 100 MeV. The only proton-rich nuclides that can be produced by bombarding F^{19} but not O^{16}, and that are not already well known, are the isotopes of Ne of mass 17 or less. The observed threshold is then consistent only with the reaction $F^{19}(p,3n)Ne^{17}$. Its relative separation from the threshold for the identical reaction in Al, as shown in fig. 2, is in excellent agreement with expectation.

Fig. 3 shows the four point time decay of the area under the largest peak of the Ne^{17} spectrum made with the same target used for the threshold measurement. The indicated half life is 102 ± 7 ms. Similar curves over varying numbers of half lives from the LiF slurry target all gave values near 103 ms. Various teflon targets, on the other hand, gave half lives in the range 68 to 76 ms. Again we attribute this to the high rate of diffusion of neon from teflon targets during the counting interval. Consequently we adopt the value 103 ± 7 ms for the half life of Ne^{17}, with the reservation that some upward adjustment for diffusion from LiF may be necessary. The assigned possible error does not include this unlikely contingency.

Fig. 4 shows the proposed decay scheme of Ne^{17} on the right; on the left, for comparison, is shown a decay scheme of its mirror nuclide N^{17}. The data for the delayed neutron emitter N^{17} are taken from the recent paper of Silbert and Hopkins [7] and the level information for F^{17} is based on the work of Salisbury and Richards [8]. The three proton groups at 5.40 ± 0.05, 4.92 ± 0.05 and 4.10 ± 0.05 MeV following production of Ne^{17} fit the levels at 6.04, 5.52 and 4.69 within experimental error. The spins and parities of these levels indicate that they should be excited by allowed β transitions from the presumably $\frac{1}{2}^-$ ground state of Ne^{17}. Using 14.4 MeV [3] for the estimated Q_{β^+} of Ne^{17}, and assuming that no other β decays occur, the experimental $\log ft$ values for the β decays to the three levels are 4.3, 3.7 and 4.5 respectively. A further β branch to the $\frac{1}{2}^-$ level of F^{17} at 3.10 MeV is expected at first sight. The 2.5 MeV proton group that would follow this β branch was sought but not found. Owing to background problems, our limit is not very good, but we can say that the $\log ft$ for β transitions to this level must be greater than 5.5. If appreciable β decays are found to this or lower levels of F^{17}, the $\log ft$ values given above will have to be adjusted upward. Fig. 4 shows the expected excellent parallelism between the decays of the mirror nuclei N^{17} and Ne^{17}.

The results of D'Auria and Preiss [9], attributed by them to Ne^{17}, do not agree with those given here.

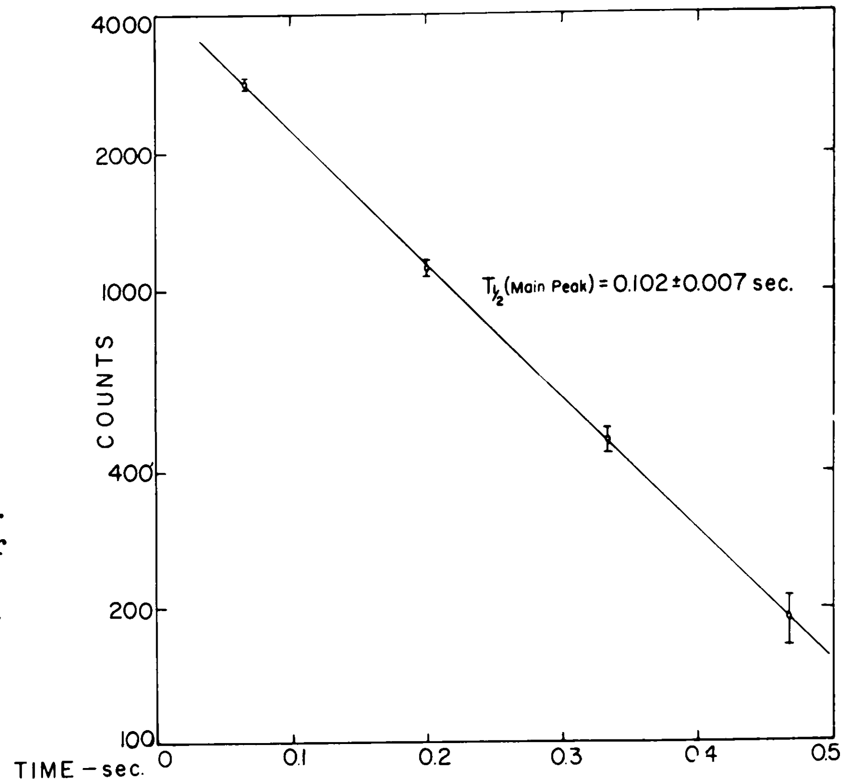

Fig. 3. The time decay of the area under the main proton peak following decay of Ne^{17}.

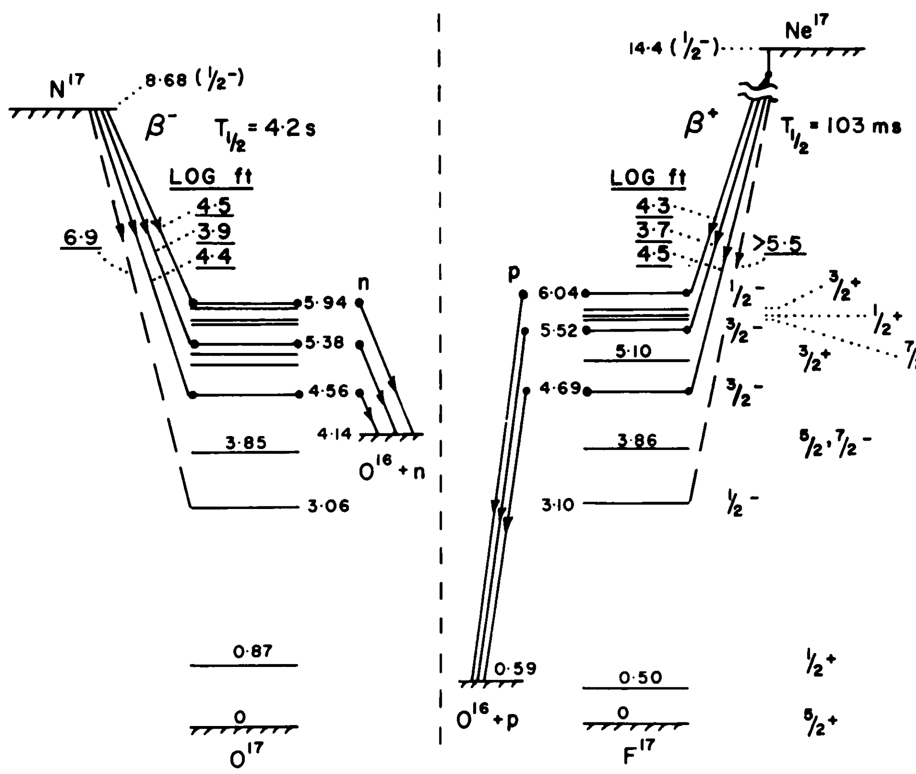

Fig. 4. The proposed decay scheme of Ne^{17} (right) compared with that of its mirror, N^{17} (left). The spin-parities of the F^{17} levels are those assigned in ref. 8. The corresponding levels in O^{17} are easily discerned for all levels of interest here, and have the same spin-parities. The decay scheme of N^{17} is taken from ref. 7, with the omission of two weak β decays to the ground and first excited states of O^{17}.

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