Resolution of the Sodium-20 Beta Decay Anomaly*

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ABSTRACT

An apparent hindrance of the superallowed Fermi decay $^{20}\text{Na}(\beta^+)^{20}\text{Ne}(10.277 \text{ MeV}, T=1)$ is explained. This anomaly is removed by estimates showing that the process $^{24}\text{Mg}(p,2n)^{23}\text{Al}(\beta^+)^{23}\text{Mg}(0.0)$ (of indistinguishable half-life and endpoint energy) interfered with previous measurements of $^{24}\text{Mg}(p,\alpha n)^{20}\text{Na}(\beta^+)^{20}\text{Ne}(1.633 \text{ MeV})$.

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The decay of ^{20}Na is of special interest for the comparison^[1] of mirror $\beta^\pm$ decays. Recent computations^[1-3] of the $ft^\pm$ asymmetry of mirror $\beta^\pm$ decays to $^{20}\text{Ne}(1.633 \text{ MeV})$ have assumed that the comparator transition $^{20}\text{Na}(\beta^+)^{20}\text{Ne}(10.277 \text{ MeV}, T=1)$ has the full superallowed strength expected for such transitions between isobaric analog states. Measurements, however, indicated an anomalous 50 % inhibition of that transition. This letter discusses and resolves that anomaly.

Wilkinson, et al.^[3] have noted that β -spectrometer measurements of the $^{20}\text{Ne}(1.633)$ and $^{20}\text{Ne}(7.42)$ branches, when combined with β -delayed α -particle data (which include the $^{20}\text{Ne}(7.42)$ and $^{20}\text{Ne}(10.277, T=1)$ branches), and with the ^{20}Na radioactive half-life are not consistent with a full superallowed strength for the Fermi component^[4] of the $^{20}\text{Ne}(10.277, T=1)$ branch. An expected small Gamow-Teller component only increases this anomaly. It was shown^[3] that isospin mixing is unlikely to weaken the $^{20}\text{Ne}(10.277)$ branch sufficiently to account for its computed hindrance factor, although the computed $A=20$ $ft^\pm$ asymmetry might possibly be substantially reduced thereby. It was also shown^[3] that the ^{20}Na anomaly is removed if the branching ratio for $^{20}\text{Na}(\beta^+)^{20}\text{Ne}(1.633)$ is 77 ± 2 % rather than the 90 % value obtained from the β -spectrometer measurements. This change reduces the calculated ft for the superallowed transition from approximately 6000 sec to 2780 ± 80

sec, the value obtained^[3] when an estimate of the Gamow-Teller component is combined with the normal full-strength Fermi component.

Table 1 illustrates the main point of this letter, which is that part of the activity attributed^[5] to $^{20}\text{Na}(\beta^+)^{20}\text{Ne}(1.633)$ originated instead from $^{23}\text{Al}(\beta^+)^{23}\text{Mg}(0.0)$, which is produced by the same beam and target, and which has comparable half-life and endpoint energy.

The ^{23}Al half-life was recently reported by the Berkeley group^[7] who observed the delayed proton activity in the process

In that experiment considerable attention was given to eliminating the possibility of interference from the simultaneous process

Because the original ^{20}Na β -spectrometer measurements^[5] (before the discovery of ^{23}Al) also used the $^{24}\text{Mg}(p, \alpha n)$ production reaction, we consider the reverse contamination problem, that $^{23}\text{Al}(\beta^+)$ interfered with the $^{20}\text{Na}(\beta^+)$ measurements.

We may calculate an approximate value for the ratio R of the interfering branches and see if $^{23}\text{Al}(\beta^+)^{23}\text{Mg}(0.0)$ contamination can reasonably have resulted in an erroneous 90 % measurement for a 77 % $^{20}\text{Na}(\beta^+)^{20}\text{Ne}(1.633)$ branch. That would correspond to a value

$$R = \frac{^{23}\text{Mg}(0.0)}{^{20}\text{Ne}(1.633)} = \frac{90-77}{77} \approx 0.17.$$

(Here nuclear level symbols indicate intensities of β^+ branches to levels in the original 45 MeV $^{24}\text{Mg} + p$ experiments [5] on ^{20}Na .)

R is calculated from three pieces of information:

$$R = \frac{^{23}\text{Mg}(0.0)}{^{20}\text{Ne}(1.633)} = \frac{^{20}\text{Ne}(10.277)}{^{20}\text{Ne}(1.633)} \cdot \frac{^{23}\text{Mg}(8.45)}{^{20}\text{Ne}(10.277)} \cdot \frac{^{23}\text{Mg}(0.0)}{^{23}\text{Mg}(8.45)}.$$

The first factor on the right is $(3.0\% / 77\%) = .039$ if the $^{20}\text{Ne}(10.277)$ branch has the expected full strength, $ft = 2780$ sec.

The second factor is given by the relative yield of .87 MeV protons from $^{23}\text{Mg}(8.45)$ and 4.44 MeV α -particles from $^{20}\text{Ne}(10.277)$. We take .009 for this ratio, an extrapolation to 45 MeV from 35 and 40 MeV measurements [7, 8] of the Berkeley group. The third factor is the ratio of two β^+ branches of the same decay. For equal ft values the endpoint energy difference would give the ratio 660.

With these assumptions we calculate

$$R = \frac{^{23}\text{Mg}(0.0)}{^{20}\text{Ne}(1.633)} \cong (.039)(.009)(660) \cong 0.23,$$

which is sufficiently close to the required $R \cong 0.17$ that $^{23}\text{Al}(\beta^+)$ contamination cannot be ignored. This estimate amounts to assuming $\log ft \cong 5.3$ for both ^{23}Mg branches. This ft value derives [9] from the mirror decay $^{23}\text{Ne}(\beta^-) \rightarrow ^{23}\text{Na}(0.0)$, and is certainly within the range expected for allowed decays [10] in this mass region. Taking instead $\log ft = 5.0$ for the crucial $^{23}\text{Al}(\beta^+) \rightarrow ^{23}\text{Mg}(8.45)$ transition would reduce the calculated value of R by 50 %, leaving our conclusions unchanged.

The above reliance on reasonable extrapolations and ft estimates could be removed by experiments on the decay of ^{23}Al . Specifically, we note that, in the present interpretation, the only unidentified branch reported in the β -spectrometer work (endpoint energy $7.15 \pm .10$ MeV) [5] would correspond to $^{23}\text{Al}(\beta^+)^{23}\text{Mg}(3.97)$. This would be an allowed $5/2^+ \rightarrow 5/2^+$ decay if tentative spin-parity assignments for $^{23}\text{Al}(0.0)$ and $^{23}\text{Mg}(3.97)$ are taken from the levels $^{23}\text{Ne}(0.0)$ [9] and $^{23}\text{Na}(3.91)$ [11] in the mirror nuclei. The intensity of this contaminant branch in the β -spectra will allow the separation of $^{20}\text{Na}(\beta^+)$ and $^{23}\text{Al}(\beta^+)$ if such a $^{23}\text{Al}(\beta^+)$ transition is indeed found.

In view of the assumptions [12] and extrapolations involved, this discussion cannot be considered to establish ft values for $^{20}\text{Ne}(10.277)$ or $^{23}\text{Mg}(8.45)$. Rather, the $^{20}\text{Ne}(1.633)$ branching ratio and the resulting anomalous $^{20}\text{Ne}(10.277)$ ft value must again be considered unmeasured quantities. Therefore, the anomaly is resolved.

I am grateful to G. T. Garvey for pointing out the ^{20}Na difficulty.

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Table 1. Comparison of two interfering beta decay branches.

<u>Decay</u>	<u>Endpoint energy (MeV)</u>	<u>Half-life (sec)</u>
$^{20}\text{Na}(\beta^+)^{20}\text{Ne}(1.633 \text{ MeV})$	$11.25 \pm .04$ [5]	$.408 \pm .006$ [5]
current values	$11.237 \pm .007$ [3]	$.4457 \pm .0031$ [3, 6]
$^{23}\text{Al}(\beta^+)^{23}\text{Mg}(0.000 \text{ MeV})$	$11.220 \pm .080$ [7]	$.470 \pm .030$ [7]