Weak beta branches in ^{32}Cl β decay

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In the β^+ decay of ^{32}Cl, precisely-calibrated γ-ray yields have been measured and corresponding β branches determined [1, 2]. The nine lowest $(0, 1, 2)^+$ states previously observed by Détraz *et al.* [3] along with a 1% ground-state branch determined by Armini *et al.* [4] represent most of the γ-ray yield; however, little is known about states populated above 7.2 MeV of excitation energy. Since the Q-value is quite large, Q_{EC} = 12.7 MeV, there remains a further 5 MeV of Q-value window in which no β transitions have been identified. This suggests that there is no strong β feeding of any individual states in this energy region, but it does not rule out the possibility of a large number of weak β transitions. Each of these transitions may be too weak to be detected individually, but they could cumulatively contribute a total β strength of up to a few per cent. This "Pandemonium" effect, originally proposed in Ref. [5], was raised again recently [6] in the context of superallowed β decay in *pf*-shell nuclei. Following the approach advocated in these references, we have used a shell-model calculation to compute the weak β branches and include their predicted strengths in our analysis of the β-delayed γ-ray data. The model space used was the full *sd* shell with three different sets of effective interactions: the USD set of Wildenthal [7] and the two more recent updates USD-A and USD-B of Brown and Richter [8].

We include in our analysis of the branches and yields a total of 51 excited states in ^{32}S. Our shell-model calculation correctly predicts all of the nine lowest $(0, 1, 2)^+$ states with $E_x < 7.2$ MeV reported in Détraz *et al.* [3]. We find that the RMS deviations of the shell-model calculations from the known excitation energies are quite good: 120 keV (USD), 209 keV (USD-A), and 172 keV (USD-B). This is a gratifying indication that the shell model is performing well in this *sd*-shell nucleus. Even though selection rules prohibit β decays to the six lowest $(3,4)^+$ states, those states are included in the analysis when we are accounting for γ-ray de-excitations. The shell-model calculations identify approximately 40 β transitions to states whose excitation energies in ^{32}S lie between 7.2 and 12.2 MeV. Unfortunately, the high density of states in this energy region makes a state-by-state comparison with known states in ^{32}S difficult, especially for the 2^+ states. Nevertheless, based on the good correspondence of excitation energies and de-excitation branches, we are able to identify five of the shell-model 0^+ or 1^+ states in this region with ones in the ENSDF Data Tables [9]. None of the individual shell-model states with high excitation energy is fed by a β-transition with strength greater than 0.3%, but cumulatively the strengths sum to 0.50% in the USD, 0.69% in the USD-A, and 0.55% in the USD-B calculations. We include these weak β strengths and de-excitation rays predicted by the shell model in our overall analysis.

In the analysis, a β branch could be identified as long as there was at least one γ ray lying within the 7.35-MeV energy range of our HPGe detector. The ground-state branch and higher excitation-energy shell-model-state branches that were not observed in this experiment were included in the analysis as missing strength. For the ground state, we take the branch to be $(1.0^{+0.2}_{-0.5})$%, as determined by Armini *et al.* [4], and the combination of all the unseen shell-model states at energies above 7.2 MeV was taken to be the average of the USD, USD-A, and USD-B calculations, with an uncertainty that spans the variation: (0.60 ± 0.10)%. The final results for excitation energies and β branches are published in Table I of Ref. [2].

[1] D. Melconian, S. Triambak, C.Bordeanu, A. Garcia, J.C. Hardy, V.E. Iacob, N. Nica, H.I. Park, G. Tabacaru, L. Trache, I.S. Towner, R.E. Tribble and Y. Zhai, Phys. Rev. Lett. **107**, 182301 (2011).
[2] D. Melconian, S. Triambak, C. Bordeanu, A. Garcia, J.C. Hardy, V.E. Iacob, N. Nica, H.I. Park, G. Tabacaru, L. Trache, I.S. Towner, R.E. Tribble and Y. Zhai, Phys. Rev. C **85**, 025501 (2012).
[3] C. Détraz, C.S. Zaidins, D.J. Frantsvog, R.L. Wilson and A.R. Kunselman, Nucl. Phys. **A203**, 414 (1973).
[4] A.J. Armini, J.W. Sunier and J.R. Richardson, Phys. Rev. **165**, 1194 (1968).
[5] J.C. Hardy, L.C. Carraz, B. Jonson and P.G. Hansen, Phys. Lett. B **71**, 307 (1977).
[6] J.C. Hardy and I.S. Towner, Phys. Rev. Lett. **88**, 252501 (2002).
[7] B.H. Wildenthal, Prog. Part. Nucl. Phys. **11**, 5 (1984).
[8] B.A. Brown and W.A. Richter, Phys. Rev. C **74**, 034315 (2006).
[9] Evaluated Nuclear Structure Data File ENDSF, [www.nndc.bnl.gov].