

⁴⁶Sc - Comments on evaluation of decay data by R. G. Helmer

1 Decay Scheme

The only levels in ⁴⁶Ti below the decay energy are those populated in this ⁴⁶Sc β⁻ decay, so that portion of the decay scheme is complete. However, ⁴⁶Sc can also electron-capture decay, ε, to levels in ⁴⁶Ca with a decay energy of 1368 keV. The available levels are 0⁺ at 0 keV and 2⁺ at 1346 keV with ε branches that are 4th forbidden and 2nd forbidden, respectively. From systematics (1998Si17), the corresponding log *ft* limits are ≥ 22.5 and ≥ 10.6, and the deduced P_{ε+β+} limits are ≤ 1.0 × 10⁻¹² % and ≤ 2.5 × 10⁻⁶ %, respectively. Therefore, these ε branches are negligible.

The J^π values and half-lives for the excited levels are from Adopted Levels in Nuclear Data Sheets (2000Wu08).

2 Nuclear Data

Q value is from Audi and Wapstra 1995 (1995Au04).

The half-life values available are, in days:

85 (1)	(1940Wa01)	omitted from analysis
84.1 (3)	(1956Sc87)	omitted from analysis
83.89 (12)	(1957Ge07)	omitted from analysis
84.4 (2)	(1957Wr37)	omitted from analysis
83.80 (3)	(1965An07)	superseded by 1982HoZJ
84.34 (13)	(1974Cr05)	omitted as outlier
83.75 (3)	(1977MeZP)	superseded by 1980RuZY
83.819 (6)	(1980Ho17)	
83.79 (6)	(1980Ol03)	
83.752 (15)	(1980RuZY)	
83.79 (6)	(1982HoZJ)	superseded by 1992Un01
83.752 (15)	(1982RuZV)	same as 1980RuZY
83.73 (12)	(1983Wa26)	
83.83 (7)	(1992Un01)	
83.788 (22)	Adopted value	

This set of values is inconsistent which causes the adopted value to depend on the choice of the values used and the "averaging" method used. The values have decreased over time; the unweighted average of the four not superseded values before 1978 (1940Wa01, 1956Sc87, 1957Ge07, and 1957Wr37) is 84.18, whereas the same average for the five values after 1978 (1980Ho17, 1980Ol03, 1980RuZY, 1983Wa26, and 1992Un01) is 83.78. The values reported before 1960 were omitted from the analysis since it would have been difficult to determine the presence of a small amount of a longer-lived impurity with the spectroscopy methods then available.

The discrepancy among the values is illustrated by the values of 84.34(13) (1974Cr05),

83.819(6) (1980Ho17), and 83.752(15) (1980RuZY). The first two values differ by 0.52(13) and the last two by 0.067(16), or about 4σ in each case. The latter two values have the greatest weight in any weighted average, so the results will depend on how the analysis modifies their relative weight, and the first value will give the largest contribution to the χ^2 value. Of the remaining six values not superseded, that of 84.34(13) (1974Cr05) is considered an outlier and is omitted.

For the remaining five values not superseded, the following averages are obtained:

unweighted	83.784 (19)
weighted	83.810, $\sigma_{\text{int}}=0.006$, reduced- $\chi^2=4.46$, $\sigma_{\text{ext}}=0.013$
RAJEVAL	83.776 (20)
Normalized residuals	83.793 (16)
LRSW - weighted average	83.788, $\sigma_{\text{int}}=0.010$, reduced- $\chi^2=1.67$, $\sigma_{\text{ext}}=0.022$ and $\sigma_{\text{LRSW}}=0.031$

The RAJEVAL method (1992Ra08) increases both of the two smallest uncertainties, namely, 0.006 to 0.043 and 0.015 to 0.026, which causes the value of 1980RuZY to have the largest weight. The Normalized Residuals method (1992Ja06) also increases both of the two smallest uncertainties but by different amounts, namely, 0.006 to 0.022 and 0.015 to 0.028, which leaves the value of 1980Ho17 with the largest weight, but only by a small amount. In contrast, the Limitation of Relative Statistical Weight, LRSW, method (1985ZiZY, 1992Ra08) only increases the most precise uncertainty, namely that of 1980Ho17, from 0.006 to 0.014 in order to reduce its relative weight to 50% from its initial 84%. The LRSW method expands the final uncertainty to 0.031 in order to include the most precise value. [The LRSW method finally suggests the unweighted average of 83.96(14), but that choice is not accepted here.]

The results from the RAJEVAL, Normalized residuals, and LRSW methods all are in good agreement and the adopted value, 83.788(22) is taken as the latter value with its external uncertainty.

2.1 β^- Transitions

The β^- branch to the ground state of ^{46}Ti is 4th forbidden with an expected $\log ft \geq 22.5$ (1998Si17) and a corresponding $P_{\beta^-}(0) \leq 1 \times 10^{-11} \%$, the measured limit is $\leq 1 \times 10^{-4} \%$ (1954Ke04).

Similarly, for the 2nd forbidden decay to the 889 level, the expected $\log ft \geq 10.6$ which corresponds to $P_{\beta^-}(889) \leq 0.8 \%$. The measured I_{β^-} to this level are 0.096(1) (1954Ke04), 0.0036(7) (1956Wo09), ≤ 0.06 (1950Mo62), and ≤ 0.05 (1950So57). Some previous evaluators (e.g., 1986Al19) have assigned $I_{\beta^-}(889) = 0.0036(7)$ because it is consistent with the limits of 1950Mo62 and 1950So57. However, this evaluator has some reservations about the resulting precision for I_{β^-} (2009) and, therefore, has expanded the uncertainty and gives $I_{\beta^-}(889) = 0.004 \%$ (+36-4), which is consistent with the two limits and the value of 1956Wo09, and thus $I_{\beta^-}(2009) = 99.996(+4-36)$.

If symmetric uncertainties are required, as in ENSDF, for these quantities, $I_{\beta^-}(889) = 0.02(2)$ and $I_{\beta^-}(2009) = 99.98(2)$, adopted values.

The β^- average energies and $\log ft$ values are from LOGFT code.

2.2 Gamma Transitions

The J^π assignments are from the Adopted Levels in the Nuclear Data Sheets (2000Wu08) and these imply the two γ -rays have E2 multiplicities.

The internal-conversion coefficients were interpolated from the Band tables (1976Ba63).

The internal-pair-formation coefficient was interpolated from the theoretical values (1979Sc31) and is $IPFC(1120) = 0.0000022$ (4). This value is only about 2 % of the corresponding internal-conversion coefficient and, therefore, is negligible.

3 Atomic Data

The data are from 1996Sc06.

3.1 and 3.2

None

4 Radiation Emissions

4.1 Electron Emission

The emission intensities are calculated from the atomic data and the decay data.

4.2 Photon Emission

The γ -ray energies are from 2000He14 for the 889 and 1120 lines and the 2009 energy is the sum of these values corrected for nuclear recoil.

The relative γ -ray emission probability of the 2009-keV γ -ray is from 1980Fu07.

The emission probability of the 889-keV γ -ray is $[100.0 - P_\gamma(2009)] / [1.0 + \alpha(889)] = 99.999987(10)/1.000167(5) = 99.9833(5)$ where the uncertainty is 5 ppm from the $(1.0 + \alpha)$ term.

That of the 1120-keV γ -ray is $[I_\beta(2009) - P_\gamma(2009)] / [1.0 + \alpha(1120)] = 99.996(+4-36)/1.000095(3) = 99.986(+4-36)$, with symmetric uncertainties 99.98 (2). Here, $\alpha(2009)$ has been neglected.

6 References

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