^{22}Na - Comments on evaluation of decay data

M. Galán

No substantial differences with previous Helmer and Schönfeld ^{22}Na evaluation (1999BeZQ) are found. Only Q-value is changed and a new ε/β^+ experimental ratio (2009NA08) is available since 1997.

1) Decay Scheme

^{22}Na disintegrates by electron capture and β^+ emission to excited level of 1274-KeV in ^{22}Ne.
^{22}Na ground state has $J_\pi = 3^+$ from Helmer and Schönfeld evaluation (1997).

The level scheme is complete. A good agreement has been found between the total decay energy of 2843,0 (24) keV computed for this decay scheme by RADLST code and the Q value of 2843,02 (21) keV.

2) Nuclear Data

The Q value is from new values of 2009AuZZ: Q β^+ = 2843,02 (21) keV. Other: 2842,3 (4) (2003AU03).

The measured ^{22}Na half-life values, in years, are:

Reference	Value (a)	Comments
2002UN02, 1992UN01	2,6037 (3)	
1982RUZV	2,6018 (7)	
1980HO17	2,6019 (4)	
1965AN07	2,613 (11)	Rejected by Chauvenet's criterion
1965AN07	2,603 (1)	
1965AN07	2,602 (11)	
1961WY01	2,62 (2)	Rejected by Chauvenet's criterion
1957ME47	2,58 (3)	Rejected by Chauvenet's criterion

	Mean	Reduced χ^2
LWM	2,6029 (8)	3,32
NRM	2,6023 (3)	2,37
RT	2,6021 (3)	

1965AN07 reported a fourth value of 2,5917 (30) which has been omitted from the analysis as it is inconsistent with all of other values. The previous values of 2,6019 (3) in 1980RUZX (replaced by 1982RUZV) and that of 2,5775 (3) in 1982HOJZ (replaced by 1992UN01) have not been included.
The Lweight for Excel and AveTool computer codes have been used with these eight input values. The weighted mean of the Limitation of Relative Statistical Weight Method (LWM) was the same result in both codes. AveTool also estimates the weighted mean by two more methods: Normalised Residual Method (NRM) (1992JA06) and Rajeval Technique (RT) (1992RA08). Following the most conservative method of LWM the eight values have been considered.

As it was discussed by Helmer and Schönfeld in their previous ^{22}Na evaluation (see Comments on ^{22}Na evaluation, 1999BeZS), the value of 2002UN02 is inconsistent with the other recent values from 182RUZV and 1980HO17 and one could exclude the values before the 70's.
The values in 1957ME47, 1961WY01 and 1965AN07 were rejected based on the Chauvenet's criterion. For the remaining values, the largest contribution to the weighted average comes from the value of Unterweger (2002UN02). The LWM method increased the uncertainty of this value 1,093 times in order to reduce its relative weight to 50 %. The final uncertainty is also expanded from 0,0004 to 0,0008 to include de most precise value of 2,6037.

The recommended value is the more conservative LWM mean, 2,6029 (8) a or 950,6 (3) d [1 a = 365,24219878 d (1999BeZQ)] with an internal uncertainty of 0,0002 and an external of 0,0004.

Level energy has been obtained from a least-squares fit to γ-ray energies (GTOL computer code).

2.1) Electron Capture and Positron Transitions

Many different ε/β^+ ratios for the 1274-keV level have been measured. They are reported in Table 1 and compared with theoretical estimations:

Reference	ε/β^+ (experimental)	ε/β^+ (theoretical)	Comments
1954KR01†	0,124 (12)		
1954SH01†	0,110 (6)	0,1135 (20)	
1954ZW01†		0,111	
1955AL01†	0,122 (10)		
1958KO75	0,109 (8)		
1959RA09	0,112 (4)		
1964WI04	0,1041 (7)		
1967LE07	0,1048 (7)	0,1138 (25)* 0,100 (6)**	* omitting e^- exchange correction ** with e^- exchange correction
1968VA13	0,1042 (10)	0,1118 (25)	
1969MC06	0,1136 (97)*		* From K/β^+=0,1050(90). The factor 1/1.0816 from 1977BO10 was used
1976MA38	0,1077 (6)		
1977BA48		0,1117 (4)	
1977BO10	0,1128 (57)		
1978FI11		0,1152 (3)	
1983BA41	0,1079 (3)		
1990KU11	0,1050 (29)	0,1116 (3)	
2009NA08	0,1084 (27)		

As can be seen in Table 1, experimental results present important discrepancies and they do differ substantially from theoretical predictions. Firestone et al. (1978FI11) discussed further about the anomalous ε/β^+ in ^{22}Na.

Statistical analyses of the experimental values have been done. In the experimental dataset the LWM method rejected 1954KR01 and 1955AL01 values based on Chauvenet's criterion. The uncertainty of 1983BA41 was changed to reduce its relative weight to 50 %. For the 12 input values the weighted mean is 0,1068 with an internal uncertainty of 0,0002 and a external of 0,0005 and a reduced χ^2 of 2,25. The adopted value is 0,1068 (11) with an uncertainty increased to include the most precise value of 0,1079. If data before 1960 are rejected the LWM is 0,1067 (12) with expanded uncertainty and reduced χ^2 of 2,8.

Experimental data and theoretical estimations are found to differ up to 10 %.

The P_{β^+} and P_ε were derived as follows: with $\frac{P_\varepsilon(1274)}{P_{\beta^+}(1274)} = 0{,}1068(11)$ from experimental results and with $\frac{P_{\beta^+}(1274)}{P_{\beta^+}(0)} = 1600(400)$ from 1953WR13, these ratios were introduced in the relationship $100 = P_{\beta^+}(1274) + P_\varepsilon(1274) + P_{\beta^+}(0)$ neglecting the electron capture branching to the ground state. Then one obtain, $P_{\beta+}(0)$ = 0,056 (14) %.

Then, the LOGFT program (theory) was run considering $P_{\varepsilon+\beta+}(1274)$ = 99,944 (14) % and $P_{\varepsilon+\beta+}(0)$ = 0,056 (14) %. The ε/β^+ for the ground state estimated by the code is 0,01782 (18). Thus one has:

$$100 = P_{\beta^+}(1274) + 0{,}1068(11) \times P_{\beta^+}(1274) + \frac{1}{1600(400)} \times P_{\beta^+}(1274) + 0{,}01782(18) \times \frac{1}{1600(400)} \times P_{\beta^+}(1274)$$

That gives:

$P_{\beta+}(1274)$ = 90,30 (9)
P_ε (1274) = 9,64 (9)
$P_{\beta+}(0)$ = 0,055 (14) %
$P_\varepsilon(0)$ = 0,00098 (25) %

Using EC-Capture program we have: P_K= 0,9233 (35) and P_L=0,0767 (35)

2.2) γ-ray Transitions

Transition Probabilities

The γ-transition probability is $P_{\varepsilon+}(1274)+P_{\beta+}(1274)$ = 90,30 (9) + 9,64 (9) = 99,94 (13) %

Internal conversion coefficients

The internal conversion coefficients (ICC) have been calculated using the BrIcc computer code, which interpolated ICC values from tables of Band et al. (2002BA85). Associated uncertainties are 1,4 %. The theoretical value of 6,71 (9) × 10^{-6} agrees with the value of 6,8 (4) × 10^{-6} from the analysis of experimental data (1985HAZA).

The theoretical α_π (1979SC31) interpolated for this E2 transition is found to be 2,34 (3) x 10^{-5}.

3) Atomic Data

3.1) Atomic values (ω_k, ϖ_L and η_{KL}) are from 1996SC06.

3.1.1) X-Radiations, 3.1.2) Auger electrons

The X-ray and Auger electron emission probabilities have been deduced from γ-ray and conversion electron data by using the computer code EMISSION. Results were verified with the RADLST computer code.

4) Electron Emissions

The β^+ and the electron capture emission probabilities are discussed above.

5) Photon Emissions

Energies

γ-ray energy 1274,537 (7) is from 2000HE14. The level energy has been computed to account for the recoil energy in the daughter nucleus.

γ-ray emissions

The absolute P_γ is evaluated from $P_{\gamma + ce}$ and the total internal conversion coefficient $\alpha = (\alpha_\pi + \alpha_T)$:

$$P_\gamma = \frac{P_{\gamma+ce}}{1+\alpha} = \frac{99{,}94(13)}{1+3{,}01(4)\times10^{-5}} = 99{,}94(13)\%$$

The annihilation radiation emission probability is taken to be 2 times $P_{\beta+}$, that is 180,7 (2) % without the correction factor for the annihilation-in-flight.

Additional reference:

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