

³⁶Cl - Comments on evaluation of decay data by V.P. Chechev

1. Decay Scheme and Decay Energies

³⁶Cl decay scheme is based on the measurements /1,2/.

The Q-values taken from Audi and Wapstra (1995) /5/. They are based on many measurements. References for early measurement results (before 1980) can be found in Kholnov et al.(1980) /19/.

2. Half-Life

The following values of the ³⁶Cl half-life in relation to β^- -decay into ³⁶Ar($T_{1/2\beta^-}$) presented in Table 1 have been considered .

Table 1. The results of ³⁶Cl \rightarrow ³⁶Ar decay half-life measurements

Reference No.	NSRkeynumber	$T_{1/2\beta^-}$ in 10^5 y	Method
14	47Hu**	20	
15	47Ov**	10	
16	49Re**	2	
10	49Wu15	4,4(5)	Spec.Activity, β GM
11	55Ba93	3,08(3)	Spec.Activity, $4\pi\beta$ pc
12	57Wr37a	2,6(4)	Cl(n, γ)Yield, β GM
12	57Wr37b	2,5(4)	Spec.Activity, β GM
13	66Go07a	3,10(4)	Spec.Activity, $4\pi\beta$ pc
13	66Go07b	3,06(2)	Spec.Activity,liq.scint.

** NSR keynumber is not found

For the statistical data processing, the six measurement results /10-13/ with quoted uncertainties have been selected (set "1"= set "2", see the evaluation technique description in /17/). In the set "2" among the six results the relative weight of the 66Go07b has exceeded 0,50 (i.e., it is 58,8 %) and the set "3" (with reduced $\chi^2=2,26$) have been formed by increasing its uncertainty from 0,02 to 0,024 as per the LWM procedure /18/. The final results of the data processing are shown below.

Table 2. Results of ³⁶Cl β⁻ half-life data processing obtained with different statistical procedures and the recommended value. See /18/ for definitions of the procedure symbols.

Procedure	Half-Life (β ⁻), year	Uncertainty, years
UWM	0,31233E+01	0,27681E+00
WM	0,30732E+01	0,16890E-01
CHV	0,28680E+01	0,13094E+00
UINF	0,30732E+01	0,25392E-01
PINF	0,30732E+01	0,25392E-01
BAYS	0,30732E+01	0,32781E-01
MBAYS	0,30732E+01	0,28389E-01
LWM	0,30732E+01	0,25392E-01
IEXW	0,30847E+01	0,24160E+00
NORM	0,30729E+01	0,16892E-01
RAJ	0,30722E+01	0,16897E-01
WM,tS	0,30732E+01	0,27931E-01
Recommended value	3,07(3)·10 ⁵ years	

The weighted average with the external uncertainty has been chosen as the recommended value:

$$T_{1/2}\beta^- (^{36}\text{Cl}) = (3,07 \pm 0,03) \cdot 10^5 \text{ y}$$

Hence the total half-life of ³⁶Cl is obtained as $T_{1/2}\beta^- \times 0,981(1) = 3,01(3) \cdot 10^5 \text{ y}$.

3. Electron Capture

The recommended values P_K, P_L, P_M have been calculated using the ratio P_L/P_K=0,099(8) obtained as the weighted average of the theoretical (P_L/P_K)_T =0,094(5) and the experimental value (P_L/P_K)_{exp} =0,112(8) measured in /8/.

The theoretical value (P_L/P_K)_T has been obtained from the tables of Schönfeld /6/ and using the LOGFT program in assumption of an allowed transition. At this the adopted Qε -value was used and the conservative uncertainty 5% of using P_K, P_L for the non-unique second order forbidden transition ³⁶Cl→³⁶S was taken into account. According to /20/ this uncertainty does not exceed 3% if Qε is considerably more than the K-electron binding energy. The calculation of P_L/P_K with the LOGFT program gives 0,0944 /24/ and the tables /6/ show the value of 0,094(5). The uncertainty of the recommended (weighted average) value of P_L/P_K=0,099(8) has been obtained in according with the evaluation procedure /17/ as an external error S=0,008.

The P_{M+} has been calculated from the ratio P_{M+}/P_K =0,0115(12) for allowed transitions /24/ with the adopted uncertainty of 10%.

The probability of the electron capture P_{EC}=0,019(1) has been calculated using the measured ratio P_{ε_K}/P_{β⁻} =0,017(1) and P_{ε_K} = 0,9037(25) P_{EC} /1/.

4. b+ Transition

The probability P_{β⁺}=1,5(3)·10⁻⁵ has been obtained by averaging the experimental data shown in Table 3.

Table 3.

The measurement results for the probability of ³⁶Cl β⁺-decay (P_{β⁺}).

Reference No.	NSR keynumber	P _{β⁺} (×10 ⁵) Set «1» = «2»	P _{β⁺} (×10 ⁵) Set «3»
8	62Do07	1,2(5)	1,2(5)
21	62Be29, 63Be38	2,3(9)	2,3(9)
22	65To**	1(1) ^{*)}	1(1)
2	67Pi03	1,66(11)	1,66(40)
Recommended value		1,5(3)	

^{*)} Uncertainty attributed by the evaluator

The recommended value P_{β⁺} has been obtained using the LWM- procedure (see /17, /18/) in which the relative weight of the measurement of 67Pi03 is decreased to 50% by increasing the uncertainty from 0,11 to 0,40.

5. b⁻ Transition

The probability P_{β⁻} = 0,981(1) has been calculated from the balance relation

$$P_{\beta^-} = 1 - P_{EC} - P_{\beta^+}$$

6. Atomic Data

The atomic constants ω_K, n_{KL} have been taken from /7/. The energy values for K X-ray components have been calculated from the wavelengths in Å as given by Bearden /9/.

The energy values for Auger electrons have been taken from Larkins (1977) /4/.

The relative emission probabilities of K X-ray components and K-Augur electrons have been taken from the tables of Schönfeld and Janßen (1996) /7/.

7. Radiation Emission

The energy values are the same as above.

The emission probabilities of K X-ray components and K-Augur electrons of sulphur have been calculated from the probability of the electron capture P_{EC} and the adopted values P_K and ω_K.

The emission probabilities of K X-ray components and Auger electrons of argon due to K-shell auto-ionization have been calculated using P_{XK}(Ar)/P_{XK}(S)=0,149(22) from /3/, and atomic constants /7/.

The number of photons per 100 disintegrations for the annihilation radiation has been calculated as 2I_{β⁺} where I_{β⁺} is the number of positrons of β⁺ decay per 100 disintegrations.

The end-point of the ³⁶Cl β⁻ spectrum has been obtained from E_{β⁻} = Q_{β⁻} - E_r where E_r = 18eV is the maximum recoil energy of the ³⁶Ar atom. The end-point energy of the ³⁶Cl β⁺ spectrum has been calculated as E_{β⁺} = Qε - E_r - 1022,0 keV, where E_r = 2eV is the maximum recoil energy of ³⁶S atom.

The average energies of the β⁺ and β⁻ spectra have been calculated using data from /20/ and by the LOGFT program for the allowed spectrum form. These are approximate energies of β⁺, β⁻ - particles because ³⁶Cl β⁺ and β⁻ - transitions are non-unique forbidden transitions with the change of spin ΔJ=2. Nuclear shape factors for these transitions are unknown. Mantel /23/ calculated the average energy of ³⁶Cl β⁻ spectrum as 320 keV assuming that the spectrum form is similar to unique first order forbidden one. This value is considerably higher than that given in section 4.3 for the allowed form.

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