^{14}C - Comments on evaluation of decay data by M.M. Bé and V.P. Chechev

This evaluation was completed in 1998, it was updated in January 2012 to include the most recent Q(β⁻) update. The literature available by this date was included.

Nuclear Data

Half-life

In literature there are many measurements of the ^{14}C half-life dating from 1946 to 1954 (Table 1). Mann *et al.* (1961) discussed the problem of spread of these measurement results from 4 700 to 7 200 years. They connect the divergence with very low enrichment of ^{14}C (a few percentages) and a large systematic uncertainty arose from retention of a small quantity of carbon dioxide with a high specific activity during a gas dilution phase. Therefore, following Holden (1990Ho28) who evaluated the ^{14}C half-life in 1990, we have omitted the measurement results before 1961 and considered only later measurements (Table 2). In all the latter works the number of ^{14}C atoms has been determined by the mass-spectrometric method and the counting rate was measured by different methods as shown in Table 1.

Table 1: Results of ^{14}C half-life measurements

NSR keynumber	Half-life of ^{14}C, years	Method
1946Re10	4 700 (400)	SA: GM; MS
1948No02	5 100 (200)	- " -
1948Ya02	7 200 (500)	- " -
1949Ha52	6 360 (200)	- " -
1949Jo07	5 589 (75)	- " -
1950En59	5 580 (90)	- " -
1950Mi10	6 360 (190)	- " -
1950Mi10	5 513 (165)	SA: PC ; MS
1951Ma30	5 370 (200)	SA: IC ; MS
1952Je11	6 030	SA: GM ; gas density
1954Ca41	5 900 (250)	SA: Cal ; gas density
1961Ma32	5 760 (50)	SA: PC ; MS
1961Wa16	5 780 (65)	SA: PC ; MS
1962Ol14	5 680 (40)	SA: PC ; MS
1964Hu09	5 745 (50)	SA: PC ; MS. 1961Ma32 value revised
1968Be47	5 660 (30)	SA: PC(GM) ; MS
1968Re13 + 1972Em01	5 736 (56)	SA: LS ; MS

Usual designations:
SA - method of radionuclide specific activity determination, by mean of Geiger-Müller counter (GM), proportional counter (PC), calorimeter (Cal), ionization chamber (IC) or liquid scintillation counter (LS);
MS - determination of the number of atoms by the mass-spectrometric method.

Table 2: Selected measurement results and recommended value of ^{14}C half-life

Year	Half-life of ^{14}C, *a*	Reference NSR keynumber
1961	5 780 (65)	1961Wa16
1962	5 680 (40)	1962Ol14
1964	5 745 (50)	1964Hu09
1968	5 660 (30)	1968Be47
1968	5 736 (56)	1968Re13/1972Em01
χ^2 /n-1 = 1,2 ; critical χ^2 = 3,3		
Weighted average	5 697 (21) *a*	
Unweighted average	5 720 (22) *a*	
Recommended value	5 700 (30) *a*	

The adopted value of the ^{14}C half-life is the weighted average of the five results listed in Table 2. Since they were all obtained by the same method of the specific activity measurement, the final uncertainty is taken as the lowest experimental uncertainty of the data set.

It should be noticed that Holden gave a similar evaluation of ^{14}C, $T_{1/2}$ (5 715 ± 30 years), but he adopted the unweighted average of the same measurement results with addition to them of the average of three values obtained in 1949-1950.

From an analysis of fossil corals whose ages were determined *via* ^{234}Th/^{234}U/^{238}U dating, a ^{14}C half-life of "6 030" *a* should be expected (2007Ch**). A re-determination of the ^{14}C half-life is required to improve radiocarbon-based researches.

Decay Energy and Characteristics of Electron Emission (β^-)

The ^{14}C beta decay to the ground state level of ^{14}Ni is expected to be allowed ($0^+ \rightarrow 1^+$). However it has been shown deviations in the shape of the ^{14}C beta spectrum (2000Ku25, 1995Wi20). A summary of measured and predicted spectra is given in 2000Ku25.

The maximum energy of the β spectrum was deduced from the results of measurements, as listed below.

Table 3: Measured β end-point energy, E_0.

Reference	**E_0 (keV)**	**u_c**	**Remarks**
Cook (1948Co10)	156,3	10	
Forster (1954Fo*)	155	1	
Smith (1975Sm02)	156,476	0,005	rf mass spectrometer
Sur (1991Su09)	155,74	0,08	^{14}C-doped Ge detector, taking into account anomalies in the β spectrum
Wietfeldt (1995Wi20)	155,95	0,22	^{14}C-doped Ge detector, taking into account anomalies in the β spectrum
Kuzminov (2000Ku25)	156,27	0,14	Wall-less proportional counter, taking into account anomalies in the β spectrum

It is noteworthy that the value reported by Smith (1975Sm02) is much more precise but also discrepant with the other results obtained by different methods.

The set of the four most precise values is discrepant with a χ^2 /n-1 = 17. Then the uncertainty of the Smith's value has been increased to 0,066 in order to reduce its weight to 50 %. The resulting weighted average with an expanded uncertainty to cover the most precise result is: 156,18 (30) keV.

This value is considerably less precise than the recommended value of 156,476 (4) keV given in Audi *et al.* (2003Au03).
On one hand, the weighted mean is only limited to values following ^{14}C β^- decay and one value that comes from a direct mass-difference measurements using the rf technique; when the value recommended by Audi *et al.* (2003Au03/2011AuZZ) is deduced from the mass differences between ^{14}C and ^{14}N, determined using a robust least-squares procedure.
On the other hand, in that case the whole "robust least-squares procedure" in 2003Au03/2011AuZZ is dominated by the single ultra-precise mass-spectrometric value. And this exact ^{14}C - ^{14}N mass difference affects other masses, and not *vice versa*.

In this evaluation we will accept the Audi *et al.* recommendation, while following the Wietfeld's conclusion (1995Wi20): "We feel there is a significant problem in the ^{14}C Q value and we hope that this will be resolved by future experiments".

The average energy per disintegration has been calculated, expecting an allowed form of β^--spectrum, by using the program BetaShape (2012Mo**) which includes the calculations of "exchange effects".

E_{max} (keV)	E_{mean} (keV)
156,18 (30)	49,1 (3)
156,476 (4)	49,16 (1)

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