^{113}Sn - Comments on evaluation of decay data by R. G. Helmer

1 Decay scheme

This evaluation was completed in August 1996 with minor editing done May 1997 and July 1998.

In addition to the three excited levels populated in this decay scheme, there is one level in ^{113}In below the decay energy, namely at 1024 keV (J^{π} = 5/2+). The electron capture to this level is negligible, so this scheme is complete.

The main γ-ray, 391 keV, depopulates a level with a $T_{1/2}$ of 99 minutes, so the ratio of its emission rate to the ^{113}Sn decay rate will vary with time. If it has been a sufficient time, about five half-lives of the level, since the sample was prepared, the ratio of the ^{113}In^{m} (99 min) and ^{113}Sn (115 d) decay rates is $T_{1/2}(^{113}Sn)/[T_{1/2}(^{113}Sn)-T_{1/2}(^{113}In^{m})]$ = 1.0006.

From the presence of Cd K x-rays from a ^{113}In^{m} (99 min) source, 70Ra05 (and 69RaZP) reported that this 391-keV level decayed by electron capture with a probability of 0.07(1)%. Such a transition to ^{113}Cd would be 1st forbidden, 1/2^{-} to 1/2^{+}, and would have a log *ft* of 5.1. This intensity of 0.07% is unlikely since the log *ft* systematics (73Ra10) indicate that such transitions have log *ft*'s of > 5.9. Also, 70De22 (see also 69De25) repeated this experiment and placed a limit of < 0.0036% on the electron-capture transition and log *ft* > 6.5. Such an electron capture branch from the 391-keV level is therefore believed to be negligible and has not been included in the scheme.

2 Nuclear Data

Q value is from Audi and Wapstra 1995 (95Au04).

The ^{113}Sn half-life values available are, in days:

107	59Bu08	
115.2 (8)	72Em01	
115.07 (10)	72La	
115.09 (4)	80Ho17	
115.06 (7)	82HoZJ,	replaced by 92Un01
115.12 (13)	82RuZV	
115.08 (8)	92Un01	
115.09 (3)	Weighted average & adopted	

The analysis of 92Un01 replaces that of 82HoZJ. Omitting this value and the one without an uncertainty leaves five values to consider. The weighted average of these five values is 115.09 with an internal uncertainty of 0.03 and a reduced-χ^2 of 0.03. In the LRSW method the uncertainty for the 80Ho17 value is not increased because the set is consistent even though its relative weight is 66%. If this σ (80Ho17) is increased from 0.04 to 0.056 in order to decrease its relative weight to 50%, the weighted average is still 115.09 with an internal uncertainty of 0.04 and the reduced-χ^2 remains unchanged. The very small reduced-χ^2 value suggests that the reported uncertainties are over estimated. It also means that the RAJEVAL and Normalized residual averaging methods give the same result.

The $^{113}In^m$ half-life values available are, in minutes:

105	(10)	39Ba03,	omitted
104	(2)	40La07,	omitted
102	(2)	58Gi07,	omitted
114	(12)	65Ca,	quoted as 1.9 (2) h, omitted from analysis
99.3	(2)	67Ok02	
99.2	(6)	69Va04	
99.48	(3)	70Go48,	quoted as 1.6580 (14) h at 3σ level
99.48	(8)	70Le07,	quoted as 1.658 (4) h at 3σ level
99.8	(2)	70Ro29	
99.47	(7)	71Ha18	
99.2	(6)	71Oo01	
99.78	(18)	72Em01	
102	(2)	75Bu24	
102.4		75Ku10,	omitted
99.21	(13)	82HoZJ	
99.49	(6)	82RuZV	
99.45	(7)	84Iw06,	quoted as 1.6575 (12) h
99.6	(3)	87Ne01,	quoted as 1.660 (5) h
99.476	(23)		Weighted average; LRSW result; and adopted

The first three values were omitted because they are very old, 65Ca value was omitted because its uncertainty is very large, and 75Ku10 values was omitted because its uncertainty is not quoted. The weighted average of the remaining thirteen values is 99.476 with an internal uncertainty of 0.022, a reduced-χ^2 of 1.07, and an external uncertainty of 0.023. In the LRSW method the uncertainty for the 70Go48 value is increased from 0.03 to 0.0316 to reduce its relative weight from 53% to 50%. The results are then the same as those already given to the precision quoted. Since this data set is consistent, the RAJEVAL and Normalized Residual methods give the same result. [A value of 99.8(7) minutes was published in 97We13 after this evaluation was completed. With its large uncertainty, this value would not significantly influence the result.]

2.1 Electron Capture Transitions

The EC branches to the ground state and the unpopulated level at 1024 keV are 4th forbidden and 2nd forbidden, respectively. From the log *ft* systematics (73Ra10), the expected log *ft* values are > 22 and > 11.0. These limits correspond to $I_{EC}(0) < 1\times 10^{-12}$% and $I_{EC}(1024) < 2\times 10^{-7}$%, so these branches are negligible.
The P_K etc. values are computed from Schönfeld tables. The differences between these values and those from LOGFT program are (S = Schönfeld, L = LOGFT):

Level energy (keV) =	391	646	1029
P_K (S)	0.855	0.849	-
P_K (L)	0.854	0.847	-
P_L (S)	0.116	0.121	0.3 (3)
P_L (L)	0.116	0.121	0.4 (4)
P_M (S)	0.024	0.025	0.54 (20)
P_M (L)	0.030	0.031	0.6 (4)

2.2 Gamma Transitions

The multipolarities are from the Adopted γ data in the Nuclear Data Sheets (90Bl03).

The internal-conversion coefficients are from Rösel (78Ro22), except for the 391-keV γ-ray. For the 391, the total and K-shell values are from the 85HaZA evaluation of the measured data and the L-shell value is 0.970 times the Rösel value, where the 0.970 is the average of the ratios deduce from the measured and calculated total and K-shell values.

3, 3.1, and 3.2

The data were computed by using the RADLST code with the atomic data of Schönfeld.

The K Auger electron intensity from RADLST was divided into three components based on the data of Schönfeld and Janssen.

4.1 Electron Emission

Data were computed with RADLST for the Auger and conversion electrons.

4.2 Photon Emissions

The γ-ray energies are from: for the 391 line - Helmer and van der Leun (95HeZZ) where the values are on a scale on which the strong line from the decay of ^{198}Au is 411.80205(17); for the 255 line - based on 255.126 (10) from 73In06 and scaled up by ratio E_γ(391 used here)/ E_γ(391 in 73In06); for 638 line - from 78He08 or 76De35; for 646 line - from 646 level energy; and for 382 line - from 646 and 1029 level energies. Note that this 255.134(10) energy is quite different from the commonly used value of 255.06(5) from 68Fo07, 76De35, and 78He08.

For the relative γ-ray emission probabilities, the following data were used:

γ-ray energy (keV) =	255	382	391	638	646	
58Gi06	3.0 (3)		100			
59Bu08	2.7 (2)		100			
61Gr11	2.8 (1)		100		< 0.0028	
67Bo18	2.9 (3)		100		< 0.0048	
68Fo07	3.22		100			
73In06	3.33 (13)		100			
76De35	2.85 (7)	< 0.0002	100.0	0.00150 (9)	0.000006 (5),	replaced by 78He08
78He08	2.85 (9)	< 0.0001	100.0 (20)	0.00149 (6)	0.000006 (3)	
93Mu14	3.37 (5)		100			
94De PC	3.27 (8)		100			
90Bl03 eval.		0.000092 (5)		~0.00149 (6)		
Average	3.26 (11)					
Adopted	3.25 (12)	0.000092 (5)	100	0.00149 (6)	0.000006 (3)	
P_γ(%)	2.11 (8)	0.000060 (3)	64.97 (17)	0.00097 (4)	0.000004 (2)	
$(1+\alpha)P_\gamma$	2.21 (8)	same	100.0 (17)	same	same	

The references 76De35 and 78He08 have one author in common and the data are clearly the same (e.g., five E_γ are identical). The uncertainties of 78He08 have been increased to include a 2% detector efficiency uncertainty as discussed in the reference.

This set of data for the 255-keV γ-ray has a bimodal distribution with three values definitely below 2.95 [2.7(2), 2.8(1), and 2.85(9)] and three values definitely above 3.19 [3.27(8), 3.33(13), 3.37(5)]; the two remaining values [2.9(3) and 3.0(3)] spread into both other groups. The 255 γ-ray lies on the Compton edge for the 391-keV γ-ray, so the quality of this measurement should improve as the detector resolution improves. Therefore, the evaluator has excluded all of the results from before 1970, leaving four values to average.

The weighted average of these four values is 3.26 with an internal uncertainty of 0.037, a reduced-χ^2 of 8.63, and an external uncertainty of 0.11. In the LRSW method the uncertainty for the 93Mu14 value is increased from 0.05 to 0.054 in order to reduce its relative weight from 54% to 50%. The weighted average is then 3.25 with an internal uncertainty of 0.038, a reduced-χ^2 of 8.35, and an external uncertainty of 0.11. The LRSW method expands the uncertainty to 0.12, so that the most precise value of 3.37 is within the 1σ range.

The emission probability for the 382 γ, relative to the 638 line, is from the Adopted γ data in the Nuclear Data Sheets (90Bl03) and is based on measurements for ^{113}Cd(p,nγ).

The normalization factor to convert the above relative P_γ to emission probabilities is simply 1.000/[1.00 + α(391)]. The uncertainty in [1.00 + α(391)] is 0.26%. This uncertainty is larger than that for the possible electron capture branch out of the 391-keV level, which is at most 0.003%. The normalization factor in then 0.6494(17). The resulting P_γ values are given in the above table.

6 References

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