^{95}Zr - Comments on evaluation of decay data by R. G. Helmer.

1 Decay Scheme

There are 4 levels in ^{95}Nb below the decay energy in the Adopted Levels of the 93Bu08 evaluation that are not reported in this decay scheme; these are 730 6 (5/2$^+$), 799 5 (3/2$^-$), 1011 8 (5/2$^-$), and 1088 keV. These levels have only been reported in reaction studies and their γ-decay modes are not known. The 730 level would be fed by an allowed β^- decay, so this evaluator suggests it is actually the 724 level and the J^π assignment is incorrect. The failure to observe decays to the possible 799 and 1011 levels is surprising since these would be 1st forbidden decays and from β-decay systematics (73Ra10) could have branches of several percent. Therefore, one must rely on the fact that other γ rays have not been reported to support the completeness of this scheme.

2 Nuclear Data

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

The half-life values available are, in days:

63	(5)	40Sa08	
67.8		45Po01,	omitted due to lack of uncertainty
65	(2)	51Br ,	as quoted in 76Ha51
65.2	(10)	53Co23	
65.5	(2)	65Fl02,	omitted due to large deviation from average
65.1	(9)	65Si16	
63.98	(6)	71De11,	replaced by 83Wa26
64.05	(2)	76Ha51,	published σ has been divided by 3
64.030	(6)	80Ho17	
64.09	(10)	83Wa26	
64.032	(6)	Adopted	

If all eight values with uncertainties are used, the set is not consistent and the Limited Relative Statistical Weight method increases the uncertainty for the 80Ho17 value from 0.006 to 0.050 in order to reduce its relative weight from 98.6% to 50%. The resulting weighted average is 64.09 with internal σ of 0.035 and a reduced-χ^2 of 7.8; the LRSW method then reports to the unweighted average of 64.5 with the uncertainty expanded to 0.5. If the discrepant value of 65Fl02 is removed the set is consistent and the LRSW analysis gives the weighted average of 64.032 with the internal σ of 0.006 and a reduced-χ^2 of 0.72. Since this set of seven values is consistent, the LRSW analysis does not change the uncertainty of the 80Ho17 value and its relative weight remains at 98.6% ! If σ(80Ho17) were increased from 0.006 to 0.020 to reduce its relative weight to 50%, the resulting weighted average would be 64.041(14).

If one leaves the value of 65Fl02 in the data set, it is desirable to use either the RAJEVAL or Normalized Residual method to treat this discrepancy. The RAJEVAL method increases the uncertainty for the 65Fl02 value from 0.2 to 0.88 and gives the resulting value of 64.032(6) while the Normalized Residual method increases this uncertainty to 0.58 and give a result of 64.032(6). So, the adopted value is the same for each of these three methods.

2.1 b$^-$ Transitions

The probabilities for the β^- branches to the levels at 0 and 235 keV are from the β-spectrum analysis of 74An22. From the β-decay systematics (73Ra10), the branch to the ground state is a fast 2nd forbidden decay with log ft = 11.22(13) and that to the 235 level is common unique 1st forbidden decay with log f_1t = 10.28(3).

Other measured values are 2% for 235 level (54Mi28) and ≤ 0.075% for ground state (63La06), which are both consistent with 74An22 results.

The other two values are from the relative γ-ray emission probabilities.

2.2 Gamma Transitions

The multipolarities are from the Adopted γ data in the Nuclear Data Sheets (93Bu08).

3 Atomic Data

The data are from Schönfeld and Janßen.

3.1 X Radiations and 3.2 Auger Electrons

The data were computed by EMISSION program by Schönfeld.

4 Radiation Emission

4.1 Electron Emission

Data were computed by EMISSION and LOGFT.

4.2 Photon Emissions

The γ-ray energies are from 76Ho04 for 235 keV and 97HeZZ for 724 keV. For 756 keV the value of 78He21 was scaled down 6 ppm to correspond to the energy scale of 97HeZZ.
The half-life of the 235-keV level is 86.6 h, so some care is needed to assure that a source is in equilibrium when it is measured. And, at that point the decay rate of the level will be somewhat larger than the rate of decay into the level; this ratio is 1.060. At the same time, 2.52(7)% of the decays of the 235-keV level are by β^- decay, rather than by the 235 γ-ray transition. Therefore, the γ-ray transition rate is finally $1.060 \times 0.9748 = 1.033$ times the rate of feeding of this level. The β^- branching ratio comes from $I_\gamma(235)$=25.1 (5), $I_\gamma(204)$ =2.36 (7), other γ's in ^{95}Mo following β- decay = 0.016, α(235) = 2.85, α(204) = 1.052 which give 97.48% of the level decays via the 235-keV γ-ray transition.

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

Relative γ-ray emission probability

γ energy (keV) =	235	724	756
Reference			
65Br37		78.1 (24)	100.0
66Ts01	4	81 (4)	100 (4)
67Br21	< 0.4	77.6 (13)	100
68BoZX	4.5 (19)	82.5 (11)	100.0 (11)
68HiZZ		80.1	100
68Hi		79.4	100
69Br29	0.34 (3)	81.0 (10)	100
69Fo01	0.6 (2)	82.5 (16)	100
69GuZV		78.8 (16)	100.0 (20)
72Er08	0.4 (1)	77.0 (20)	100.0
73Ha	0.67 (7)	82.9 (5)	100.0
75De17	0.54 (3)	81.0 (3)	100.0
		81.3 (4)	

76Ho04	0.43 (2)	78.9 (14)	100.0 (20)
Adopted	0.49 (6)	81.4 (4)	

For the 235 γ ray, the LRSW analysis, of the six values below 1.0 that have uncertainties, increases the uncertainty of the 76Ho04 value from 0.02 to 0.026 to reduce its relative weight from 63% to 50%. The adopted value is the resulting weighted average of 0.49; the associated internal σ = 0.019, the reduced-χ^2 = 3.2, and the external σ = 0.03. The LRSW analysis expands the uncertainty of 0.03 to 0.06 so as to include the most precise value of 0.43(2). Note than even with this enlarged uncertainty, only two of the four values with uncertainties of < 0.1 fall within the 0.49(6) range.

Since these data are clearly inconsistent, one can also treat them with the RAJEVAL and Normalized Residual methods which increase the uncertainties of the more discrepant values. For the RAJEVAL method, the uncertainty for 68BoZX becomes 2.5, for 69Br29 0.08, 73Ha 0.15, and 75De17 0.07 and the resulting value is 0.438 (18). For the Normalized Residual method the increased uncertainties are 69Br29 0.05, 73Ha 0.09, and 75De17 0.04 and the result is 0.447(31). Although these resulting values might be justified mathematically, their smaller uncertainties are not very satisfying because only one of the four values with uncertainties of < 0.1 fall within the 0.44(3) range. Therefore, the LRSW result is adopted.

For the 724 γ ray, eleven values (the two values of 75De17 were combined) were used in the LRSW analysis. This analysis increased the uncertainty of the 75De17 value from 0.30 to 0.37 in order to decrease its relative weight from 60% to 50%. This set is inconsistent and the LRSW analysis reports the unweighted average of 80.1(10). However, the evaluator has adopted the weighted average of 81.4 with the external uncertainty of 0.4; the associated internal σ = 0.3 and the reduced-χ^2 = 2.88. The adopted uncertainty may be overly optimistic, but it is consistent with the most precise values [81.0(3) and 81.3(4)]. This set of data has an unusual distribution with three values near 82.6, three near 81.0, and five below 79.

Since these data are clearly inconsistent, one can also treat them with the RAJEVAL and Normalized Residual methods which increase the uncertainties of the more discrepant values. For the RAJEVAL method, the uncertainty for 67Br21 becomes 2.0, for 72Er08 2.3, and 73Ha 1.0 and the resulting value is 81.07(21). For the Normalized Residual method the increased uncertainties are 67Br21 1.4 and 73Ha 0.7 and the result is 81.09 (32). These values are lower than that from the LRSW method because more weight is given to the low precise value of 81.0(3). Although the LRSW value is adopted, it is acknowledged that a value of 81.08 is also reasonable.

These relative emission probabilities were normalized by requiring that

$$P_\gamma(724)[1.0 + \alpha(724)] + P_\gamma(756)[1.0 + \alpha(756)] = 100.0 - I_\beta(0) - I_\beta(235) = 98.8.$$

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