Data Evaluation of ^{188}Re b^{-} Decay

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Evaluation Procedures

We applied the *Limitation of Relative Statistical Weight* [1] (LWM) method for averaging numbers throughout this evaluation. The uncertainty assigned to the average value was always greater than or equal to the smallest uncertainty of the values used to calculate the average.

Decay Scheme

The decay scheme of ^{188}Re is based mostly on the measurements of 75Sv01 and 84Zh08. ^{188}Re decays 100% by β^- to ^{188}Os. A significant fraction (71.1(22) %) directly populates the ground state. Measured values are: 79% (56Jo05) and 74(6)% (65Ma44).

The agreement between Q(β^-)=2120.4(4) keV, from the *1993 Atomic Mass Evaluation* (95Au04), and the sum of all average radiation energies (including that for the neutrinos), 2120(45) keV, suggests the decay scheme is complete.

Nuclear Data

The recommended half-life of ^{188}Re, 17.005(4) h, is the weighted average (LWM, χ^2/ν=0.54) of: 17.021(25) h (94Co02), 17.006(4) h (89Ab18), 16.93(17) h (84Zh08), 16.98(2) h (71Mi16), 16.7(5) h (54Dz19), and 16.9(3) h (51Li07). The *unpublished* value of 16.74(6) h (58Gu09) significantly deviates from more recent and precise values, so it was not included in the average.

Gamma Rays

Most γ-ray energies and relative emission probabilities are weighted averages (LWM) from Ge(Li) data of 75Sv01 and 84Zh08 (see Tables 1 and 2). Several relative emission probabilities (mostly from 84Zh08) have fractional uncertainties smaller than 1%. The evaluator considered these values to be unrealistically accurate and set a minimum value of 1%. The relative emission probabilities of the following gamma rays were affected by this decision: 453 (7.708(13)), 632 (124.94(20)), 672 (10.948(21)), 829 (40.354(20)), 931 (54.30(15)), 1457 (1.814(11)), 1610 (9.58(6)), 1669 (1.010(3)), 1802 (3.553(26)), 1864 (0.490(4)) from 84Zh08; 931 (54.0(1)), from 75Sv01. Absolute emission probabilities have been deduced from relative values (given in Table 2) normalized to 0.152(6) for the 155-keV γ-ray. This value comes from I_{eK}(155)/β^-=0.049(1) (number of K-conversion electrons per β^-) (69Bu10), and a theoretical K-conversion coefficient of 0.323(10) (78Ro22).

Table 1

^{188}Re Gamma-Ray Energies (keV)					^{188}Re Gamma-Ray Energies (keV)				
75Sv01	84Zh08	Average[&]	χ2	Rec. Value[#]	75Sv01	84Zh08	Average[&]	χ2	Rec. Value[#]
155.04 (2)	155.035 (6)		0.06	155.041 (4)*	1191.96 (9)	1191.72 (7)	1191.84 (12)***	4.4	1191.84 (12)
312.17 (14)	311.998 (20)	312.001 (24)	1.5	312.001 (24)	1209.88 (8)	1209.78 (2)	1209.790 (24)	1.5	1209.790 (24)
322.96 (5)	322.91 (4)	322.93 (3)	0.61	322.93 (4)	1302.4 (4)	1302.4 (3)	1302.40 (24)	0.0	1302.4 (3)
453.33 (3)	453.345 (21)	453.34 0(17)	0.17	453.340 (20)	1304.7 (4)	1304.9 (2)	1304.86 (18)	0.2	1304.86 (20)
477.96 (3)	478.008 (8)			477.992 (25)**	1308.02 (6)	1308.15 (18)	1308.03 (6)	0.5	1308.03 (6)
486.08 (3)	486.088 (11)	486.087 (10)	0.061	486.087 (11)	1323.10 (6)	1322.71 (6)	1322.91 (20)***	21	1322.91 (20)
514.82 (7)	514.94 (5)	514.88 (6)***	1.9	514.88 (6)		1331.95 (7)			1331.95 (7)
557.7 (1)	557.8 (4)	557.71 (10)	0.061	557.71 (10)	1457.67 (9)	1457.41 (8)	1457.54 (13)***	4.7	1457.54 (13)
624.1 (4)	623.65 (26)	623.78 (22)	0.89	623.8 (3)		1463.0 (6)			1463.0 (6)
633.04 (10)^	632.981 (21)	632.983 (21)	0.33	632.983 (21)		1530.5 (3)			1530.5 (3)
	634.98 (7)			634.98 (7)	1549.4 (6)	1549.26 (10)	1549.26 (10)	0.05	1549.26 (10)
672.51 (3)	672.542 (16)	672.535 (14)	0.89	672.535 (16)		1574.57 (25)			1574.57 (25)
810.5 (2)	810.49 (4)	810.49 (4)	0.0021	810.49 (4)	1610.43 (5)	1610.34 (7)	1610.40 (4)	1.0	1610.40 (5)
825.87 (61)	824.44 (10)	825.2 (7)***	5.3	825.2 (7)	1652.63 (15)	1652.35 (4)	1652.49 (14)***	3.3	1652.49 (14)
829.51 (3)	829.440 (19)	829.475 (35)***	3.9	829.47 (4)	1669.93 (15)	1669.90 (7)	1669.91 (6)	0.03	1669.91 (7)
845.10 (4)	845.03 (2)	845.065 (35)***	2.5	845.07 (4)	1786.06 (8)	1785.83 (9)	1785.95 (12)***	3.6	1785.95 (12)
931.32 (3)	931.348 (10)	931.345 (9)	0.78	931.345 (10)	1802.10 (20)	1802.04 (4)	1802.04 (4)	0.08	1802.04 (4)
	979.25 (17)			979.25 (17)	1807.9 (3)	1807.29 (10)	1807.6 (3)***	3.7	1807.6 (3)
	984.1 (5)			984.1 (5)		1809.54 (30)			1809.54 (30)
1017.57 (7)	1017.76 (3)	1017.67 (10)***	6.2	1017.67 (10)	1865.16 (20)	1864.66 (5)	1864.91 (25)***	5.9	1864.91 (25)
1071.2 (4)	1071.54 (30)	1071.42 (24)	0.46	1071.4 (3)		1867.20 (22)			1867.20 (22)
	1096.8 (4)			1096.8 (4)		1936.9 (3)			1936.9 (3)
1132.35 (4)	1132.304 (20)	1132.310 (18)	1.0	1132.310 (20)	1941.03 (23)	1940.73 (28)	1940.91 (18)	0.68	1940.91 (23)
	1149.7 (4)			1149.7 (4)	1957.12 (20)	1956.79 (10)	1956.96 (17)***	2.2	1956.96 (17)
	1150.5 (4)			1150.5 (4)	2022.8 (3)	2022.45 (16)	2022.53 (14)	1.0	2022.53 (16)
1174.57 (5)	1174.57(3)	1174.570 (26)	0.0	1174.57 (3)					

[&] Weighted average, unless otherwise specified.

[#] Uncertainty greater than or equal to the smallest uncertainty in input values.

* Weighted average of 155.032(12) (63Ma08), 155.04(20) (63Sc05), 155.045(4) (72Sh13) (Bent-crystal measurements), 155.04(2) (75Sv01), 155.035(6) (84Zh08) (Ge(Li) measurements).

** Weighted average of 478.033(35) (72Sh13) (Bent-crystal measurement), 477.96(3) (75Sv01) and 478.008(8) (84Zh08) (Ge(Li) measurements).

*** Unweighted average

^ From 72Sh13 (Bent-crystal measurement).

Table 2

^{188}Re Relative Gamma-Ray Emission Probabilities							^{188}Re Relative Gamma-Ray Emission Probabilities					
Energy (keV)	75Sv01	84Zh08	Average[&]	$\chi 2$	Rec. Value[#]		Energy (keV)	75Sv01	84Zh08	Average[&]	$\chi 2$	Rec. Value#
155.041 (4)	1433 (35)	1535 (19)	1484 (51)*	6.6	1484 (51)		1191.84 (12)	1.33 (9)	1.298 (25)	1.300 (25)	0.11	1.300 (25)
312.001 (24)	0.31 (8)	0.521 (18)	0.42 (11)*	6.6	0.42 (11)		1209.790 (20)	0.28 (3)	0.294 (6)	0.293 (6)	0.2	0.293 (6)
322.93 (4)	1.5 (1)	1.661 (21)	1.58 (8)*	2.5	1.58 (8)		1302.4 (3)	0.62 (9)	0.49 (3)	0.56 (7)*	1.9	0.56 (7)
453.340 (20)	6.77 (18)	7.708 (77)[a]	7.2 (5)*	27	7.2 (5)		1304.86 (20)	0.52 (8)	0.27 (3)	0.40 (13)*	8.6	0.27 (3)[@]
477.984 (24)	100.0 (25)	100	100.0 (25)		100 (3)		1308.03 (6)	6.5 (3)	6.35 (12)	6.37 (11)	0.2	6.37 (12)
486.087 (11)	7.5 (3)	7.76 (13)	7.72 (12)	0.63	7.72 (13)		1322.91 (20)	0.83 (6)	1.333 (28)	1.1 (3)*	55	1.1 (3)
514.88 (6)	0.49 (5)	0.532 (21)	0.526 (19)	0.60	0.526 (21)		1331.95 (7)		0.17 (2)			0.17 (2)[@]
557.71 (10)	0.088 (15)	0.097	0.093 (5)*		0.093 (5)		1457.54 (13)	1.9 (1)	1.814 (19)[a]	1.817 (19)	0.7	1.817 (19)
623.8 (3)	0.28 (5)	0.19 (4)	0.24 (5)*	2.0	0.24 (5)		1463.0 (6)		0.076 (29)			0.08 (3)[@]
632.981 (21)	120 (11)	124.9 (12)[a]	124.8 (12)	0.20	124.8 (12)		1530.5 (3)		0.054 (16)			0.054 (16)[@]
634.98 (7)	14.2 (46)	14.46 (20)	14.46 (20)	0.030	14.46 (20)		1549.26 (10)	0.25 (5)	0.066 (5)	0.16 (9)*	13	0.16 (9)
672.535 (16)	10.6 (3)	10.95 (11)[a]	10.91 (11)	1.3	10.91 (11)		1574.57 (25)		0.062 (10)			0.062 (10)[@]
810.49 (4)	0.071 (22)	0.109 (7)	0.090 (20)*	2.7	0.090 (20)		1610.40 (5)	9.41 (40)	9.58 (10)[a]	9.56 (10)	0.2	9.56 (10)
825.2 (7)	4.90 (49)	1.72 (5)			1.72 (5)[@]		1652.49 (14)	0.32 (5)	0.349 (27)	0.342 (24)	0.26	0.342 (24)
829.47 (4)	39.3 (11)	40.35 (40)[a]	40.2 (4)	0.8	40.2 (4)		1669.91 (7)	1.02 (8)	1.010 (10)[a]	1.010 (10)	0.02	1.010 (10)
845.07 (4)	0.69 (5)	0.666 (8)	0.667 (8)	0.22	0.667 (8)		1785.95 (12)	1.99 (11)	1.892 (22)	1.900 (22)	0.76	1.900 (22)
931.345 (10)	54.0 (6)[a]	54.30 (54)[a]	54.2 (4)	0.13	54.2 (5)		1802.04 (4)	3.60 (17)	3.553 (36)[a]	3.56 (4)	0.07	3.56 (4)
979.25 (17)		0.101 (18)			0.101 (18)[@]		1807.6 (3)	0.105 (17)	0.087 (5)	0.088 (5)	1.0	0.088 (5)
984.1 (5)		0.033 (20)			0.033 (20)[@]		1809.54 (30)		0.039 (10)			0.039 (10)[@]
1017.70 (10)	1.40 (12)	1.427 (15)	1.427 (15)	0.04	1.427 (15)		1864.91 (25)	0.54 (5)	0.490 (5)[a]	0.490 (5)	1.0	0.490 (5)
1071.4 (3)	0.077 (15)	0.054 (7)	0.066 (12)*	1.9	0.066 (12)		1867.20 (22)		0.045 (8)			0.045 (8)[@]
1096.8 (4)		0.063 (16)			0.063 (16)[@]		1936.9 (3)		0.021 (2)			0.021 (2)[@]
1132.310 (20)	8.46 (37)	8.13 (11)	8.16 (11)	0.73	8.16 (11)		1940.91 (23)	0.20 (2)	0.181 (3)	0.181 (3)	0.88	0.181 (3)
1149.7 (4)	1.65 (39)	1.55 (3)	1.55 (3)	0.07	1.55(3)		1956.96 (17)	1.5 (1)	1.465 (18)	1.466 (18)	0.12	1.466 (18)
1150.5 (4)	1.65 (39)	1.51 (3)	1.51 (3)	0.13	1.51(3)		2022.53 (16)	0.17 (2)	0.149 (3)	0.149 (3)	1.0	0.149 (3)
1174.57 (3)	1.94 (15)	1.80 (8)	1.83 (7)	0.68	1.83 (8)							
& Weighted average, unless otherwise specified.												
# Uncertainty greater than or equal to the smallest uncertainty in input values.												
* Unweighted average.												
[@] From 84Zh08.												
[a] Evaluator increased to 1% authors' reported fractional uncertainty.												

Conversion Coefficients

Total conversion coefficients in Section 2.2 are theoretical values from 78Ro22 interpolated for the recommended transition energies, multipolarities, and mixing ratios. Multipolarities and mixing ratios are recommended values reported in *Nuclear Data Sheets* (90Si04), except those for the 478-keV (M1+E2, δ=-15(2)), 635-keV (M1+E2, δ=-7(+3-2)), and 1210-keV (M1+E2, δ=-0.036(11)) γ-rays, which are from 75Kr16.

Total pair production conversion coefficients are theoretical values from 79Sc31.

b$^-$ **Transitions**

β^- transition endpoint energies have been deduced from Q(β^-)=2120.4(4) keV (95Au04) and individual level energies. Transition probabilities (P_{β^-}), from total (γ + e) gamma-ray emission probability balance at each level, are given on the level scheme.

Atomic Data

X-ray and Auger electron emission probabilities are values calculated with the computer program RADLST [2], using gamma-ray data from Section 2.1 and atomic data from 95ScZZ.

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