Comments on Evaluation of ^{192}Ir b^{-}- and Electron-Capture Decay Data by E. Browne

Evaluation Procedures

The *Limitation of Relative Statistical Weights* [1] (LWM) method, used for averaging numbers throughout this evaluation, provided a uniform approach for the analysis of discrepant data. The uncertainty assigned to the recommended value was always greater than or equal to the smallest uncertainty of the values used to calculate the average.

Decay Scheme

^{192}Ir decays by β^- (95.13 (13) %) to ^{192}Pt (Q(β^-)=1459.7 (19) keV), and by electron capture (4.87 (13) %) to ^{192}Os (Q(EC)=1046.2 (23) keV). These modes of decay populate *only* excited states in the daughter nuclides (transitions to the ground states are highly hindered by spin selection rules.) Therefore, the sum of all the relative gamma-ray emission probabilities to the ground states of ^{192}Pt and ^{192}Os provided a total (photons + electrons) relative transition intensity to normalize the decay scheme of ^{192}Ir, and thus deduce absolute gamma-ray emission probabilities. These quantities, and their corresponding total conversion coefficients, were used to deduce β^- and EC decay branchings to individual levels.

Nuclear Data

The recommended half-life of ^{192}Ir, 73.827 (13) d, is a weighted average (LWM, χ^2/ν=2.6) of (in days) 73.84 (5) and 73.814 (17) (92Wo06), 73.810 (19) (92Un01), 73.831 (8) (80Ho17), 74.02 (6) (72La14), 73.6 (4) (63Ha17), and 74.2 (2) (61Wy01). The LWM method changed the uncertainty of 0.008, given by 80Ho17, to 0.012, in order to reduce its statistical weight from 0.70 to 0.50. Values of 74.37 (7) (51Ka39) and 74.17 (7) (60Al15) were not used here for averaging. These values had been measured with *electrometers* (analog instruments), the authors did not report uncertainties and determined the half-life of ^{192}Ir by using unweighted least-squares-fits. Their reported uncertainties in the half-life values are just the standard deviations in the unweighted fits.

Gamma Rays

Energies. The precise gamma-ray energies are from Helmer [2]. These values are based on a revised energy scale that uses the new adjusted fundamental constants and wave lengths deduced from an updated value of the lattice spacing of Si crystals (Cohen and Taylor [3].) Helmer et al [2] fitted the adjusted gamma-ray energies to a level scheme, so their recommended values are from level-energy differences. The less precise values are weighted averages (LWM) from 88Li06, 87Me14, 85Ei01, 84Iw03, 75Bo07, 73Ge05, 69LeZU, and 66Sc20 (See Table 1.)

Emission Probabilities. The absolute emission probabilities given in Section 2.1 were produced as follows:

1. By averaging (LWM) the experimental relative emission probabilities reported by 94Mi22, 92Si25, 88Li06, 87Me14, 86Me07, 85Ei01, 85DaZX, 84Iw03, 83Sc12, and 73Ge05. Values from 75Pr03 are statistically inconsistent (outliers), therefore they were not used in the averaging (See Table 2).

2. By using the sum of the relative gamma-ray transition probabilities (photons + electrons) to the ground states of ^{192}Os and ^{192}Pt to normalize the decay scheme of ^{192}Ir. Since there are no direct β^- or (EC+β^+) populations to the ground states of the daughter nuclei, the above mentioned sum should equal 1.0.

Conversion Coefficients

Total conversion coefficients in Section 2.1 are theoretical values from 78Rö22, interpolated for the recommended transition energies, multipolarities, and mixing ratios. Multipolarities and mixing ratios are recommended values from 91Sh12. Multipolarities between brackets given in Section 2.1 were not experimentally determined, but are those expected from the spins and parities of the levels.

Electron-Capture Transitions

EC transition energies are from Q(EC)=1046.2 (23) keV (95Au04) and the individual level energies. Transition probabilities (P_{EC}), from total gamma-ray transition probability balances at each level, are given as branchings in percent (%) on the decay scheme. Fractional atomic shell electron-capture probabilities were calculated using data from 95ScZY.

b^- Transitions

Endpoint energies have been deduced from $Q(\beta^-)$=1459.7 (19) keV (95Au04) and the individual level energies. Transition probabilities (P_{β}-) are from total (photons + electrons) gamma-ray emission probability balances at each level. These values are given in percent (%) on the decay scheme.

Total b^- and EC Branchings

These quantities have been deduced from the sum of total (photons + electrons) absolute gamma-ray emission probabilities to the ground states of ^{192}Pt and ^{192}Os.

Atomic Data

The X-ray and Auger electron probabilities given in Section 3 are values calculated by the computer program RADLST [4] using gamma-ray data from Section 2.1, and atomic data from 96Sc06. The experimental K x-ray emission probabilities agree well with the calculated values, as shown below:

Measured*	Calculated&	
Os $K_{\alpha1}$	0.0202 (3)	0.0209 (5)
Os $K_{\alpha2}$	0.0116 (1)	0.01211 (25)
Os $K_{\beta1}$’	0.0067 (1)	0.00710 (21)
Os $K_{\beta2}$’	0.0017 (1)	0.00180 (6)
Pt $K_{\alpha1}$	0.0446 (4)	0.0455 (8)
Pt $K_{\alpha2}$	0.0256 (3)	0.0266 (5)
Pt $K_{\beta1}$’	0.0149 (2)	0.0158 (3)
Pt $K_{\beta2}$’	0.00411 (7)	0.00411 (10)

* Weighted average (LWM) of data from 86Me07, 83Sc12, and 92Si25
& From Section 3
See Table 3 for data from the individual measurements.

Total Average Radiation Energy

The following table shows the total average radiation energies released (by β^-, neutrinos, nuclear recoil, gamma rays, and atomic electrons) in the β^- and EC decay of ^{192}Ir, as well as the total decay energies from mass differences (95Au04).

	Total Average Radiation Energy* (keV)	Total Decay Energy& Q x Branching (keV)
^{192}Ir β^- Decay	1386.9 (25)	1388.6 (26)
^{192}Ir EC Decay	49.7 (7)	50.9 (14)

* From RADLST [4], using the recommended radiation data given in this evaluation
& Q-values (Q_{β^-} and Q_{EC}) are from 95Au04

The good agreement between *measured* and *deduced* x-ray and total average radiation energies confirm the quality and completeness of the decay scheme.

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192Ir Gamma-ray Energies

Helmer (Priv. Comm)	88Li06*	87Me14	85Ei01	84Iw03	75Bo07	73Ge05	69LeZU	66Sc20	Wght. Avg.**	Adopted E_γ
			110.67 (30)				110.092 (19)		110.4 (3)	110.4 (3)
136.34257 (26)										136.3426 (3)
	177.01 (15)						176.98 (4)		176.98 (4)	176.98 (4)
	201.39 (15)		201.43 (30)		201.3112 (7)[&]	201.281 (20)			201.3112 (7)	201.3112 (7)
205.79430 (9)										205.79430 (9)
								214.7 (5)[#]		214.7 (5)[#]
	280.51 (15)						280.03 (5)		280.27 (24)	280.27 (24)
	283.34 (15)		283.20 (30)		283.2668 (8)[&]	283.255 (20)			283.2668 (8)	283.2668 (8)
295.95650 (15)										295.95650 (15)
308.45507 (17)										308.45507 (17)
								314.8 (3)[#]		314.8 (3)[#]
316.50618 (17)										316.50618 (17)
	329.27 (15)		328.88 (30)			329.13 (20)			329.17 (15)	329.17 (15)
	374.52 (15)		374.43 (30)		374.4852 (8)[&]	374.472 (25)			374.4852 (8)	374.4852 (8)
								415.4 (5)[#]		415.4 (5)[#]
416.46876 (73)										416.4688 (7)
	420.63 (15)		420.57 (30)			420.50 (6)			420.52 (6)	420.52 (6)
468.06885 (26)										468.0688 (3)
484.57514 (43)										484.5751 (4)
	489.05 (15)		489.06 (30)			489.064 (30)[&]			489.06 (3)	489.06 (3)
588.58100 (70)										588.5810 (7)
	593.49 (15)		594.03 (30)			593.38 (5)			593.49 (13)	593.49 (13)
	599.41 (15)									599.41 (15)
604.41105 (25)										604.41105 (25)
612.46215 (26)										612.4621 (3)
		624,9								624,9
	703.97 (15)		703.59 (30)			703.7 (4)			703.87 (15)	703.87 (15)
								739[#]		739[#]
	765.8 (3)									765.8 (3)
		784,52								784,52
884.53652 (74)										884.5365 (7)
		904,52		904,7						904,6
				912,1						912,1
		920,85								920,85
	1061.46 (15)		1061.61 (50)			1061.48 (4)			1061.48 (4)	1061.48 (4)
	1089.55 (15)	1089,58	1090.31 (50)			1089.9 (8)			1089.9 (3)	1089.9 (3)
	1378.20 (15)		1378.8 (10)			1378.0 (5)			1378.20 (15)	1378.20 (15)

* ΔE=0.15 keV assigned by evaluator. ΔE=0.03 - 0.3 keV suggested by authors.

[&] Corrected by 83Sh48 to calibration of 80De40.

[#] Measured conversion electrons only

** Limitation of Relative Statistical Weights method

192Ir Relative Gamma-Ray Emission Probabilities													
Adopted E_γ	94Mi22	92Si25	88Li06	87Me14	86Me07	85Ei01	85DaZX	84Iw03	83Sc12	75Pr03	73Ge05	Wght. Avg.#	Adopted I_γ
110.4 (3)			0.014 (2)		0.016 (1)	0.011 (4)				0.0014 (14)*		0.0147 (13)	0.0147 (13)
136.3426 (3)		0.260 (8)	0.214 (8)		0.307 (10)	0.209 (8)		0.35 (6)	0.278 (24)	0.19 (6)*	0.218 (10)	0.24 (3)	0.24 (3)
176.98 (4)			0.0048 (15)			0.006 (2)						0.0052 (12)	0.0052 (15)
201.3112 (7)		0.57 (2)	0.581 (16)		0.578 (10)	0.62 (2)		0.57 (4)	0.566 (11)	0.56 (5)*	0.551 (12)	0.572 (7)	0.572 (10)
205.79430 (9)	4.055 (22)	3.08 (6)*	4.01 (10)		4.22 (3)	3.93 (7)	3.982 (16)	4.01 (6)	4.02 (6)	3.90 (45)*	3.86 (8)	4.03 (5)	4.03 (5)
214.7 (5)#													
280.27 (24)			0.0099 (6)		0.030 (2)*	0.0025 (25)					0.0020 (20)	0.011 (6)	0.011 (6)
283.2668 (8)		0.303 (9)	0.315 (14)		0.321 (5)	0.317 (9)		0.304 (22)	0.326 (4)	0.39 (8)*	0.320 (8)	0.321 (3)	0.321 (4)
295.95650 (15)	34.62 (16)	34.52 (60)	34.7 (7)		34.94 (18)	34.81 (66)	34.65 (14)	34.69 (17)	34.54 (36)	35.6 (13)*	34.64 (35)	34.70 (7)	34.70 (14)
308.45507 (17)	35.84 (16)	35.77 (62)	35.8 (7)		35.81 (20)	36.34 (73)	35.89 (15)	35.87 (19)	36.00 (36)	37.1 (8)*	35.77 (36)	35.86 (8)	35.86 (15)
314.8 (3)#													
316.50618 (17)	100.0 (4)	100.0 (10)	100.0 (10)	100.0 (5)	100.0 (5)	100.0 (10)	100.0 (4)	100.0 (5)	100.0 (8)	100.0 (10)*	100.0 (10)	100.0 (2)	100.0 (5)
329.17 (15)		0.033 (5)*	0.019 (6)	0.019 (1)		0.023 (1)					0.019 (3)	0.021 (2)	0.021 (2)
374.4852 (8)		0.888 (17)	0.875 (24)		0.889 (7)	0.87 (2)		0.860 (9)	0.877 (15)	0.79 (3)*	0.875 (15)	0.878 (5)	0.878 (7)
415.4 (5)#													
416.4688 (7)		0.776 (15)	0.807 (24)		0.834 (8)	0.77 (2)		0.797 (11)	0.806 (18)	0.89 (64)*	0.802 (15)	0.809 (25)	0.809 (25)
420.52 (6)		0.072 (5)	0.072 (8)		0.092 (3)	0.078 (4)		0.078 (9)	0.092 (6)		0.070 (6)	0.083 (9)	0.083 (9)
468.0688 (3)	57.76 (24)	56.97 (99)	57.2 (12)		58.01 (41)	58.24 (97)	57.8 (3)	57.76 (23)	57.61 (48)	59.7 (20)*	58.0 (9)	57.77 (13)	57.77 (23)
484.5751 (4)	3.899 (27)	3.818 (67)	3.77 (8)		3.92 (3)	3.62 (7)	3.867 (22)	3.828 (18)	3.86 (4)	4.10 (21)*	3.81 (5)	3.854 (26)	3.854 (26)
489.06 (3)		0.516 (11)	0.504 (13)		0.547 (5)	0.49 (5)		0.527 (9)	0.537 (10)	0.36 (12)*	0.48 (1)	0.529 (17)	0.529 (17)
588.5810 (7)	5.468 (21)	5.395 (95)	5.36 (14)		5.56 (5)	5.47 (9)	5.48 (3)	5.423 (21)	5.45 (5)	5.46 (20)*	5.52 (10)	5.458 (13)	5.458 (21)
593.49 (13)		0.059 (4)	0.046 (3)		0.052 (2)	0.0043 (7)*		0.052 (3)	0.058 (5)	0.010 (3)*	0.045 (3)	0.0509 (20)	0.0509 (20)
599.41 (15)			0.0047 (20)										0.0047 (20)
604.41105 (25)	9.949 (39)	9.87 (17)	9.77 (23)		10.10 (9)	10.39 (18)	10.00 (6)	9.79 (4)	9.89 (7)	10.9 (6)*	10.04 (26)	9.91 (4)	9.91 (4)
612.4621 (3)	6.488 (28)	6.25 (11)	6.34 (16)		6.61 (6)	6.77 (12)	6.54 (4)	6.365 (25)	6.41 (5)	6.7 (4)*	6.55 (13)	6.45 (9)	6.45 (9)
624,9				0.0026 (3)									0.0026 (3)
703.87 (15)		0.006 (2)	0.0062 (13)	0.007 (2)		0.006 (2)					0.007 (2)	0.0064 (8)	0.0064 (13)
739#													
765.8 (3)			0.0016 (7)										0.0016 (7)
784,52				0.031 (3)									0.031 (3)
884.5365 (7)		0.346 (8)	0.347 (8)		0.360 (3)	0.366 (6)		0.3435 (24)	0.356 (9)	0.45 (3)*	0.364 (7)	0.352 (8)	0.352 (8)
904,6				0.0038 (5)				0.0047 (6)				0.0042 (4)	0.0042 (5)
912,1								0.0024 (6)					0.0024 (6)
920,85				0.0031 (6)									0.0031 (6)
1061.48 (4)		0.062 (3)	0.063 (2)		0.067 (2)	0.063 (2)		0.0633 (11)	0.064 (4)	0.070 (4)*	0.067 (3)	0.0639 (7)	0.0639 (11)
1089.9 (3)		0.0020 (6)	0.0012 (5)	0.0012 (3)		0.0018 (5)		0.0010 (5)		0.0030 (2)*	0.0020 (7)	0.00139 (19)	0.00139 (20)
1378.20 (15)			0.0015 (4)			0.0010 (5)		0.0016 (5)		0.0020 (4)*	0.0015 (7)	0.0014 (4)	0.0014 (4)

Limitation of Relative Statistical Weights method

* Value not included in the average. Most values from 75Pr03 are statistical outliers.
Data from 75Pr03 usually do not agree with values from other authors.

& Measured conversion electrons only

Measured Os X-rays from the decay of 192Ir. Relative and absolute emission probabilities.								
Energy (keV)	Identification	86Me07	83Sc12	92Si25	Wght. Avg.	Adopted	Absolute	Theory
7,8	Os-Lℓ	0.040 (3)					0.00033 (3)	0.00028 (3)*
8.9 - 9.3	Os-Lη,α12 + Pt-Lα12	3.26 (14)	2.61 (16)		2.9 (3)	2.9 (3)	0.0240 (25)	0.0227 (8)*
10.3 - 11.0	Os-Lβ + Pt-Lηβ	3.39 (14)	2.34 (24)		2.9 (5)	2.9 (5)	0.024 (4)	0.0234 (8)*
12.0	Os-Lγ1	0.087 (6)	0.072 (12)		0.080 (8)	0.080 (8)	0.0007 (1)	0.00079 (5)*
12,5	Os-Lγ23	0.021 (3)					0.00017 (2)	0.00026 (2)*
12.9 - 13.2	Os-Lγ23 + Pt-Lγ123		0.33 (4)				0.0027 (3)	0.0032 (2)*
61,5	Os-Kα2	1.40 (2)	1.39 (5)	1.40 (4)	1.400 (17)	1.40 (2)	0.0116 (1)	0.01211 (25)#
63.0	Os-Kα1	2.46 (3)	2.40 (7)	2.39 (8)	2.44 (3)	2.44 (3)	0.0202 (3)	0.0209 (5)#
71,3	Os-Kβ1'	0.80 (2)	0.82 (4)	0.82 (3)	0.808 (15)	0.81 (2)	0.0067 (1)	0.00710 (21)*
73,4	Os-Kβ2'	0.203 (5)	0.222 (7)	0.210 (5)	0.210 (7)	0.210 (7)	0.0017 (1)	0.00180 (6)*
Measured Pt X-rays from the decay of 192Ir. Relative and absolute emission probabilities.								
Energy (keV)	Identification	86Me07	83Sc12	92Si25	Wght. Avg.	Adopted	Absolute	Theory
8,3	Pt-Lℓ	0.110 (10)	0.085 (12)		0.098 (13)	0.098 (13)	0.00081 (11)	0.00076 (7)*
8.9 - 9.3	Pt-Lα12							0.0164 (14)*
10.3 - 11.0	Pt-Lηβ							0.0180 (15)*
12.9 - 13.2	Pt-Lγ123	0.415 (15)	0.320 (36)		0.37 (5)	0.37 (5)	0.0031 (4)	0.0031 (3)*
65,1	Pt-Kα2	3.10 (3)	3.09 (12)	3.08 (10)	3.10 (3)	3.10 (3)	0.0256 (3)	0.0266 (5)#
66,8	Pt-Kα1	5.39 (5)	5.25 (17)	5.58 (19)	5.39 (5)	5.39 (5)	0.0446 (4)	0.0455 (8)#
75,4	Pt-Kβ1'	1.80 (2)	1.78 (6)	1.89 (65)	1.798 (19)	1.80 (2)	0.0149 (2)	0.0159 (13)*
77,9	Pt-Kβ2'	0.497 (10)	0.530 (36)	0.490 (18)	0.497 (8)	0.497 (10)	0.00411 (8)	0.0041 (4)*

* Table of Radioactive Isotopes, E. Browne and R.B. Firestone, John Wiley & Sons, Inc., 1986.

Calculated using program RADLST.