# $^{88}$Y – Comments on evaluation of decay data by E. Schönfeld

This evaluation was completed by E. Schönfeld (PTB) in November 1998.
The half-life evaluation was updated by M.-M Bé (LNHB) in February 2003.

## 1 Decay Scheme

Below the *Q*-value of 3622,6 keV there are two additional levels at 3486,6 and 3523,6 keV (both probably 2+). They are not shown in the decay scheme because they are not populated in the disintegration of $^{88}$Y. Ardisson *et al.* (1974) did not found the 3523,6 keV level but they confirmed the 3584,7 keV level which is populated in the $^{88}$Y decay. Up to now these levels were observed only in other disintegration processes, for example in the decay of $^{88}$Rb (17,78 min).

An EC or $\beta^+$ transition to the ground state of $^{88}$Sr was also not observed. This is due to the high forbiddeness of such a transition ($4^- \rightarrow 0^+$). Thus, the decay scheme shown above is almost complete.

The half-lives of the excited levels and the lg *ft* values were taken from Müller (1988).

## 2 Nuclear Data

The following measured values of the half-life were taken into consideration :

| Reference | Value (in days) | Uncertainty | Comments |
|---|---|---|---|
| DuBridge (1940) | 105 | 5 | Omitted, too large uncertainty |
| Peacock (1948); Lazar (1956) | 104 | | Omitted, no uncertainty |
| Ramaswamy (1960) | 105 | | Omitted, no uncertainty |
| Wyatt (1961) | 108,1 | 0,3 | Omitted, outlier |
| Anspach (1965) | 106,52 | 0,03 | Replaced by Hoppes |
| Anspach (1965) | 106,67 | 0,03 | Replaced by Hoppes |
| Grotheer (1969) | 108,4 | 0,9 | Omitted, outlier |
| Lagoutine (1975) | 106,6 | 0,4 | Superseded by Amiot |
| Bormann (1976) | 107,1 | 1,4 | |
| Konstantinov (1977) | 107,15 | 0,65 | |
| Houtermans (1980) | 106,612 | 0,032 | Original uncertainty = 0,014 |
| Debertin (1982) | 106,64 | 0,08 | Superseded by Walz |
| Hoppes (1982) | 106,64 | 0,05 | Superseded by Unterweger |
| Walz (1983) | 106,66 | 0,06 | |
| Unterweger (1992) | 106,626 | 0,044 | |
| Martin (1997) | 106,65 | 0,13 | |
| Amiot *et al.* (2003) | 106,63 | 0,05 | |
| **Recommended value** | **106,626** | **0,021** | |

An analysis of these values was done using the "Limitation of relative statistical weight" program. The first three values have been omitted from the analysis, the Grother and Wyatt's (Grother *et* *al.*, 1969) value have been omitted as outliers as suggested by Chauvenet's criterion (Chauvenet, 1976) and the uncertainty on the Houtermans's value (Houtermans *et al.*, 1980) has been increased to 0,032 to ensure that its value has the same "weight" as the most recent values. The reduced $\chi^2$ of this set of data is 0,22. Finally, the recommended value is the weighted mean of the seven remaining values.

The *Q*-value is taken from Audi and Wapstra (1995).

## 2.1 Electron Capture Transitions

The fractional capture probabilities $P_K$, $P_L$, $P_M$ were calculated on the basis of the paper of Schönfeld (1998). The corresponding values for the transition $\varepsilon_{0,1}$ have been estimated by the evaluator.

## 2.2 Positron Transitions

A positron transition to the ground state was not observed. However, sufficient energy for a positron transition is available for a transition to the 1836 keV level. The maximum energy of these positrons were determined to be 767,1(10) keV by Barkov *et al.* (1974) while there emission probability were determined to be 0,00203(16) per disintegration by the same authors. The corresponding EC/$\beta^+$ ratio was found to be 26(3) which agrees with the theoretical value of 25,6(8) for an unique first forbidden transition interpolated from the table of Gove and Martin (1971). For the value given for the positron emission probability in Table 2.2, the theoretical value was used. The maximum beta energy of the $\beta^+$spectrum was found by Antonewa *et al.* (1974) to be 764,6(15) keV corresponding to a *Q* value of 3622,6(15) keV.

## 2.3 Gamma Transitions

The level differences have been calculated from the gamma ray energies (Table 4.2) and the recoil energies. The probabilities $P_{\gamma+ce}$ were calculated from the gamma ray emission probabilities and the total conversion coefficients. The multipolarities were taken from Müller (1988).

Conversion coefficients were measured as follows:

| | $a_K$ | $a_t$ | K/L+M+... |
|---|---|---|---|
| 898 keV | 0,000301(21) [1] | 0,000345(24) [1] | 7,0(5) [1] |
| E1 | 0,00025(3) [2] | 0,00028(3) [2] | 8,0(2) [2] |
| | | 0,00034(7) [3] | |
| | | 0,00027 [4] | |
| | 0,00028(2) [5] | 0,00032(3) [5] | |
| | 0,000274 [6] | 0,000310 [6] | 7,6 [4] |
| | 0,000277(20) [7] | 0,000315(23) [7] | 7,3 [5] |
| 1836 keV | 0,000124(16) [2] | 0,000140(16) [2] | 7,8(3) [2] |
| E2 | | 0,00017(4) [3] | |
| | | 0,00013 [4] | |
| | 0,000146 [6] | | |
| | 0,000135(14) [7] | 0,000152(15) [7] | 7,9(3) [7] |

[1] Hamilton *et al.* 1966
[2] Allan 1971
[3] Metzger and Amacher (1952)

[4] Peacock and Jones cited in [2]
[5] weighted mean of [1] and [2]
[6] theory, interpolated from the tables of Rösel *et al.* (1978)
[7] adopted value

All the other conversion coefficients were interpolated from the tables of Rösel *et al.* (1978).

The mixing ratio parameter for the 898 keV transition has been evaluated in the basis of four publications by Müller (1988) to be $\delta = -0,002(9)$, i. e. this transition is an almost pure E1 transition. For the 1382 keV transition, $\delta$ was found to be 0,057(18) corresponding to 99,7 % M1 and 0,3 % E2. As the conversion coefficients for these multipolarities are very close together ($\alpha_t$ = 0,000287 for E2 and 0,000292 for M1) the uncertainty of this mixing ratio has a very small influence on the finally adopted value for the conversion coefficient of this transition.

The internal pair creation coefficients were determined experimentally by Allan (1971) as follows:

1836 keV $\alpha_\pi$ = 0,00023(3) in good agreement with the theoretical value of 0,00023 for E2 multipolarity

2734 keV $\alpha_\pi$ = 0,00033(5) in fair agreement with the theoretical value of 0,00044 for E3 multipolarity

## 3 Atomic data

The atomic data are taken from Schönfeld and Janßen (1996).

### 3.1 X Radiations

The energies are based on the wavelengths of Bearden (1967). The relative probabilities have been taken from Schönfeld and Janßen (1996). The relative probability of the L X rays is calculated from the absolute value setting $P(K_{\alpha_1}) = 1$.

### 3.2 Auger Electrons

The energies are taken from the compilation of Larkins (KLL, KLX) or estimated by the evaluator (KXY). The relative probabilities of K Auger electrons are taken from Schönfeld and Janßen (1996). The relative probability of the L Auger electrons is calculated from the absolute value setting *P*(KLL) = 1.

## 4 Radiation Emissions

### 4.1 Electron Emissions

The energies of the Auger electrons are the same as above. The energies of the conversion electrons are calculated from the transition energies and the binding energies. The number of Auger electrons per disintegration are calculated using the above-mentioned atomic shell data and the program EMISSION (PTB 1997). The numbers of conversion electrons per disintegration are calculated from the transition probabilities and the conversion coefficients.

### 4.2 Photon Emissions

The energies of the X rays are the same as above. The number of X rays per disintegration are calculated using the above given atomic shell data and the program EMISSION.

The energy of the gamma radiation was determined to be (in keV)

| | | | |
|---|---|---|---|
| 1 | 1836,2(3) | 898,2(4) | Robinson et al. 1964 |
| 2 | 1836,08(7) | 898,01(7) | Black and Heath 1967 |
| 3 | 1836,17(12) | - | White and Groves 1967 |
| 4 | 1836,07(10) | 897,90(10) | Ramayya et al. 1967 |
| 5 | 1836,20(8) | 898,09(5) | Legrand et al. 1968 |
| 6 | 1836,127 | 898,020 | Gunnink et al. 1968 |
| 7 | 1836,03(11) | 897,99(4) | Strauss et al. 1969 |
| 8 | 1836,030(30) | 898,010(30) | Kern 1970 |
| 9 | 1836,064(13) | 898,042(4) | Helmer et al. 1979 |
| 10 | 1836,052(13) | 898,036(4) | Helmer and Van der Leun 1998 |

Values 10 are adopted and are based on 411,80205(17) keV for the strong line emitted after the decay of $^{198}$Au.
The energies of the other gamma rays were taken from Müller (1988) after adjusting to the same scale.

The relative emission probabilities were determined as follows:

| E in keV | 850 | 898 | 1382 | 1836 | 2734 | 3219 |
|---|---|---|---|---|---|---|
| 1 | - | 94,0(7) | - | 100 | 0,597(25) | - |
| 2 | - | 91 | 3(?) | 100 | 0,97 | 0,03 |
| 3 | - | - | - | 100 | 0,63(4) | 0,0095(3) |
| 4 | - | 94,9(5) | - | 100 | - | - |
| 5 | 0,066(13) | 92,0(7) | 0,021(6) | 100 | 0,724(70) | 0,0071(20) |
| 6 | - | 92,1 | - | 100 | 0,54(9) | 0,007 |
| 7 | - | 95,2(5) | - | 100 | - | - |
| 8 | 0,030(4) | 93,8(11) | 0,014(3) | 100 | - | - |
| 9 | - | 94,4(3) | - | 100 | - | - |
| 10 | - | 94,9(4) | - | 100 | - | - |
| 11 | - | 94,8(9) | - | 100 | - | - |
| 12 | 0,048(18) | 94,54(22) | 0,016(3) | 100 | 0,618(25) | 0,007(2) |

1 Peelle (1960)
2 Shastry and Bhattacharyya (1964)
3 Sakai et al. (1966)
4 Schötzig et al. (1973), replaced by value 11
5 Ardisson et al. (1974); upper limit for a 3522 keV line: 0,001
6 Heath (1974)
7 Debertin et al. (1977); $P_\gamma$ = 0,946(5) for the 898 keV line from source activity and Ge(Li) measurements, replaced by value 11
8 Antoneva et al. (1979); upper limit for a 484 keV line: $9 \cdot 10^{-4}$
9 Yoshizawa et al. (1980)
10 Hoppes et al. (1982)
11 Schötzig (1989)
12 Adopted value 898 keV: LWM of values 1, 9, 10, 11. Value 5 is classified as outlier, values 2 and 6 are not taken into account because leak of uncertainties ; reduced $\chi^2$ = 0,57; 2734 keV: LWM of values 1, 3, 5, 6, reduced $\chi^2$ = 1,2. LWM has used weighted average and ext. uncertainty.

The normalisation factor is derived from a cut between the ground state and the first excited level of $^{88}$Sr:

| | | $P_\gamma$(rel)$\cdot$(1 + $\alpha_t$)$\cdot$(1 + $\alpha_\pi$) | $P_{\gamma+ce}$ (abs.) |
|---|---|---|---|
| $\gamma_{1,0}$ | 1836 keV | 100,059 | 0,99379 |
| $\gamma_{2,0}$ | 2734 keV | 0,618 | 0,00614 |
| $\gamma_{3,0}$ | 3219 keV | 0,007 | 0,00007 |

From these figures the absolute emission probability of the 1836 keV gamma rays is calculated to be 0,9932(3) photons per disintegration and $P_{\gamma+ce}$ is found to be 0,9938(3).

## 5 Main production Modes

Taken from the “Table de Radionucléides”, LMRI, 1985

## 6 References


L. A. DuBridge and J. Marshall. *Phys. Rev.* 58 (1940) 7 [$T_{1/2}$]

W. C. Peacock, J. W. Jones. Report *AECD*, 1812 (1948) [$P_{\beta+}$, $T_{1/2}$]

M. K. Ramaswamy and P. S. Jastram. *Nucl. Phys.* 19 (1960) 243 [Max. beta plus energy, $T_{1/2}$]

R. W. Peelle. report *ORNL*, 3016 (1960), 110 [$P_\gamma$]

J. I. Rhode, O. E. Johnson, W. G. Smith. *Phys. Rev.* 129 (1963) 815 [Max. beta plus energy, $T_{1/2}$]

S. Shastry and R. Bhattacharyya. *Nucl. Phys.* 55 (1964) 397 [*P* gamma]

R. L. Robinson, P. H. Stelson, F. K. McGowan, J. L. C. Ford, Jr. And W. T. Milner. *Nucl. Phys.* 74 (1964) 281 [$E_\gamma$]

J. H. Hamilton et al. *Phys. Letters* 19 (1966) 682 [$a_K$, $a_t$]

M. Sakai, T. Yamazaki, J. M. Hollander. *Nucl. Phys.* 84 (1966) 302 [$P_\varepsilon$, $P_\gamma$]

W. W. Black and R. L. Heath. *Nucl. Phys.*A90 (1967) 650 [$E_\gamma$]

D. H. White and D. J. Groves. *Nucl. Phys.* A91 (1967) 453 [$E_\gamma$]

A. V. Ramayya, J. H. Hamilton, S. M. Brahmavar and J. J. Pinajian. *Physics Letters* 24B (1967) 49 [$E_\gamma$]

J. Legrand, J. P. Boulanger and J. P. Brethon. *Nucl. Phys.* A107 (1968) 177 [$E_\gamma$]

R. Gunnink, R. A. Meyer, J. B. Niday and R. P. Anderson. *Nucl. Instr. Meth.* 65 (1968) 26 [$E_\gamma$]

A. Luukko and P. Holmberg. *Comm. Phys.-math.* 33 (1968) 1 [angular corr.; spin and parity of levels]

S. C. Anspach, L. M. Cavallo, S. B. Garfinkel, J. M. R. Hutchinson, C. N. Smith. private Mitteilung (1968) [$T_{1/2}$]

H. Lycklama, N. P. Archer, T. J. Kenneth. *Can. J. Phys.* 47 (1969) 393 [$J^\pi$, $E_\gamma$]

M. G. Strauss, F. R. Lenkszus and J. J. Eichholz. *Nucl. Instr. Meth.* 76 (1969) 285 [$E_\gamma$]

H. H. Grotheer, J. W. Hammer, K. W. Hoffmann. *Z. Phys.* 225 (1969) 293 [$P_{\beta+}$]

J. Kern. *Nucl. Instr. Meth.* 79 (1970) 233 [$E_\gamma$]

N. B. Gove and M. J. Martin. *Nuclear Data Tables* 10 (1971) 205 [log *f*]

C. J. Allan. *Nucl. Instr. and Meth.* 91 (1971) 117 [$\alpha_K$, $\alpha_t$, $\alpha_\pi$]

L. J. Jardine. *Nucl. Instr. and Meth.* 96 (1971) 259 [$P_\gamma$]

W. Bambynek, D. Reher. *Z. Phys.* 264 (1973) 253 [$P_K w_K$]

A. Heß and H. Schneider. *Z. Phys.* 262 (1973) 231 [mixing ratio, angular correlations]

G. Ardisson, S. Laribi, C. Marsol. *Nucl. Phys* A223 (1974) 616 [$P_\gamma$]

A. V. Barkow, W. M. Winogradow, A. W. Solotawin, W. M. Makarow, T. M. Usypko. *Programm and abstracts of 24. Conference on nuclear spectroscopy and nuclear structure*, Kharkov, 29 Jan. -1 Febr. 1974, AN SSSR, Moscow, 1974, 58 [$\beta^+$, $a_p$]

R. L. Heath. Gamma-ray Spectrum Catalogue. *USAEL*, Rep. ANCR 1000-2 (1974) [$E_\gamma$, $P_\gamma$]

F. Lagoutine, J. Legrand, C. Bac. *Int. J. Appl. Radiat. Isot.* 26 (1975) 131 [$T_{1/2}$]
M. Bormann, H.-K. Feddersen, H.-H. Hölscher, W. Scobel and H. Wagner. *Z. Physik* A277 (1976) 203 [$T_{1/2}$]
N. J. Aminaraschwili, V. A. Dzhashi, W. L. Tschichladse, S. D. Shawgulidse, *Conference: 27. annual conference on nuclear spectroscopy and nuclear structure*, Tashkent, USSR, 22-25 Mar 1977 [$a_K$]
W. Bambynek *et al.*, *Rev. Mod. Phys.* 49 (1977) 77 [$w_K$]
A. A. Konstantinov, T. E. Sazonowa and S. W. Sepman. *Conference: 27. Annual conference on nuclear spectroscopy and nuclear structure*, Tashkent, USSR, 22-25 Mar 1977, p. 6 [$T_{1/2}$]
R. C. Greenwood, R. G. Helmer, R. J. Gehrke. *Nucl. Instr. and Meth.* 159 (1979) 465 [$E_\gamma$]
R. G. Helmer, J. W. Starner, M. E. Bunker. *Nucl. Instr. and Meth.* 158 (1979) 489 [$E_\gamma$]
N. M. Antoneva, V. M. Vindgradov, E. P. Grigorev, P. P. Dmitriev, A. V. Zolotavin, G. S. Katykhin, N. Krasnov, V. N. Makarov. *Bull. Ac. Sci.USSR, Phys. Ser.* 43 (1979) 155 [$P_{\beta+}$, $\alpha$, $E_\gamma$, $P_\gamma$]
H. Houtermans, O. Milosevic, F. Reichel. *Int. J. Appl. Radiat. Isot.* 31 (1980) 153 [$T_{1/2}$]
Y. Yoshizawa, Y. Iwata, T. Kaku, T. Katoh, J. Ruan, T. Kojima, Y. Kawada. *Nucl. Instr. and Meth.*174 (1980) 109 [$P_\gamma$]
K. Debertin, U. Schötzig, K. F. Walz. *NBS-SP* 626 (1982) 101 [$T_{1/2}$, $P_\gamma$]
D. D. Hoppes, J. M. R. Hutchinson, F. J. Schima, M. P. Unterweger. *NBS-SP 626 (1982) 85* [$T_{1/2}$, $P_\gamma$]
K. F. Walz, K. Debertin and H. Schrader. *Int. J. Appl. Radiat. Isot.* 34 (1983) 1191 [$T_{1/2}$]
H.-W. Müller. *Nuclear Data Sheets* 54 (1988) 1 [lg *ft*]
U. Schötzig. *Nucl. Instr. Meth.* A286 (1990) 523 [$P_\gamma$]
A. A. Konstantinov, T. E. Sazonova, S. V. Sepman, A. V. Zanevsky, N. I. Karmalitsyn. *Nucl. Instr. Meth.* A339 (1994) 200
E. Schönfeld and H. Janßen. *Nucl. Instr. Meth.* A369 (1996) 527 [Atomic Data]
R. H. Martin, K. I. W. Burns, J. G. V. Taylor. *Nucl. Instr. Meth.* A390 (1997) 267 [$T_{1/2}$]
M.N. Amiot, J. Bouchard, M.-M. Bé, J.B. Adamo. To be published in Appl. Rad. Isotop. (2004) [$T_{1/2}$]