

## <sup>198</sup>Au - Comments on evaluation of decay data by E. Schönfeld and R. Dersch

### 1 Decay Scheme

In addition to the 411,8 keV level (2+) and the 1087,7 keV level (2+), <sup>198</sup>Hg has an excited level at 1048,5 keV (4+, half-life 1,80(8) ps) which is below the  $Q$  value. Its spin 4 was deduced from  $\gamma\gamma$  angular correlation in <sup>198</sup>Tl EC decay and its positive parity from the E2 character of the  $\gamma$  transition to the 2+ level. A  $\beta$  transition from the <sup>198</sup>Au (2-) ground state to this level ( $\Delta J = 2$  and parity change,  $E_b^{\max} = 323,7$  keV) would be unique 1<sup>st</sup> forbidden and was not observed. From  $\lg ft$  systematics ( $\lg ft \geq 8,5$ ) an upper limit of 0,004 for the transition probability to this level was derived.

Iwata and Yoshizawa (1980) estimated the probability of a possible EC transition leading to the ground state of <sup>198</sup>Pt (unique first forbidden) to be less than 0,0017 % from  $\lg ft$  systematics, i. e. negligible for most purposes.

### 2 Nuclear Data

The following values of the half-life have been considered ( $T_{1/2}$  in d):

1	2,7	Mc Millan et al. (1937)
2	2,73(2)	Diemer and Groendijk (1946)
3	2,69(1)	Silver (1949)
4	2,69	Saxon and Heller (1949)
5	2,73(2)	Sinclair and Holloway (1951)
6	2,66(1)	Cavanagh et al. (1951)
7	2,697(3)	Lockett and Thomas (1953)
8	2,699(3)	Bell and Yaffe (1954)
9	2,686(5)	Tobailem (1955)
10	2,697(3)	Johansson (1956)
11	2,694(6)	Sastre and Price (1956)
12	2,704(4)	Keene et al. (1958)
13	2,699(4)	Robert (1960)
14	2,687(5)	Starodubtsev (1964)
15	2,694(4)	Anspach et al. (1965)
16	2,693(5)	Reynolds et al. (1966)
17	2,697(5)	Lagoutine et al. (1968)
18	2,695(7)	Goodier (1968)
19	2,695(2)	Vuorinen and Kaloinen (1969)
20	2,696(4)	Costa Paiva and Martinho (1970)
21	2,6946(10)	Cabell and Wilkins (1970)
22	2,693(3)	Debertin (1971)
23	2,6937(2)	Merritt and Gibson (1977)
24	2,6935(4)	Rutledge et al. (1980)
25	2,695(2)	Hoppes et al. (1982)
26	2,6966(7)	Abzouzi et al. (1990)
27	2,69517(21)	Unterweger et al. (1992)
28	2,6837(50)	Mignonsin (1994)
29	2,6944(8)	LWM, adopted value

Values 1 - 6 are only of historical interest. Value 25 is not used because it is replaced by value 27. Value 28 was rejected because identified as outlier by LWM. The adopted value 29 is a weighted average of 20 values with expanded uncertainty so range includes the most precise value 23 which contributes 43 % to the mean. The reduced

$\chi^2$  is 2,9. The adopted value 29 is very close to the value recommended in the IAEA-TECDOC 619 (2,6943(8)) - based on 16, 17, 18, 19 - 22, 24, 25.

Nyikos et al. (1973) studied the influence of the chemical surrounding on the half-life of <sup>198</sup>Au and found  $\lambda(\text{Au}) - \lambda(\text{Au}_2\text{O}_3)/\lambda(\text{Au}) = (1,0 \pm 0,3) \cdot 10^{-4}$ . If this result is correct, it would need to be taken into account if any additional very precise values are reported. This chemical shift is comparable to the uncertainties for values 23 and 27.

The  $Q$  value was calculated by adding the level difference  $\gamma_{1,0}$  (411,8 keV) to the evaluated maximum beta energy of the beta transition  $\beta_{0,1}$  (960,4 keV). This value is 1372,2(10) compared to the Audi and Wapstra (1995) value of 1372,4(5) keV.

## 2.1 b<sup>-</sup> Transitions

For the evaluation of the maximum energy of the beta transition  $\beta_{0,1}$  the following values were considered:

1	958,8(16)	weighted mean of eight results 1948 - 1954 cited by Dzhelepov et al. 1955
2	959,0(25)	Elliott et al. 1954
3	960(2)	Porter 1956
4	962(1)	Depommier and Chabre 1961, as recalculated by Beekhuis and de Waard
5	964(3)	Graham 1961, as recalculated by Beekhuis and de Waard
6	960(3)	Hamilton et al. 1962
7	957(5)	Sharma et al. 1962
8	959(2)	Lewin et al. 1963
9	965(2)	Lehmann 1964
10	960,5(8)	Keeler and Connor 1965
11	961,0(12)	Paul 1965
12	962(1)	Lewin 1965
13	959,4(5)	Beekhuis and de Waard 1965, value which is cited in their text
14	960,4(5)	LWM with external uncertainty; reduced $\chi^2 = 1.54$
15	960,4(10)	adopted value with an uncertainty enlarged to cover the most precise value 13

The values of Wapstra et al. (1958) and de Vries (1960) were not used; they are replaced by value 8. The values 4 and 5 are recalculated by Beekhuis and de Waard (1965). The most precise values are 4 and 10 to 13. The maximum beta energies of the other beta transitions were calculated from the maximum beta energy of the transition  $\beta_{0,1}$  and level differences taken from  $\gamma$  ray measurements.

## 2.2 Gamma Transitions

The energies of the level differences are calculated from the  $\gamma$  ray energies (section 4.2) and the recoil energies.

The probabilities  $P_{\gamma+ce}$  were calculated from the  $\gamma$  ray emission probabilities (see section 4.2) and the conversion coefficients.

For the conversion coefficients of the 411,8 keV  $\gamma$  transition the following values were considered:

	$a_K$	$a_L$	$a_M$	$a_t$	
1	0,0301(5)				Lewin et al. 1963
2	0,0302(4)				Bergkvist and Hultberg 1964
3	0,0299(4)	-	-	0,0444(5)	Keeler and Connor 1964
4	0,0308(9)				Petterson et al. 1965
5	0,0299(2)				Paul 1965
6	0,0302(4)	-	-	0,0447(6)	Bosch and Szichman 1967
7	0,0301(3)				Nagarajan et al. 1972
8	0,03035(45)				El-Nesr and Mousa 1973
9	0,0300(3)	-	-	0,043(4)	Reddy 1976

10	0,03005(12)			0,0445(4)	LWM of the exp. values
11	0,03016	0,01073	0,00268	0,04439	interpol. from Rösel et al. 1978 (theory)
12	0,0301(2)	-	-	0,044(2)	Hansen 1985 evaluated
13	0,0301(2)	0,01091(25)	0,0027(2)	0,0447(5)	adopted in the present eval.

For  $a_K$  there is good agreement between measured values and the theory (value 10 and value 11). The arithmetic mean between 10 and 11 is taken as finally adopted value. It coincides with the value 12 evaluated by Hansen (1985). The uncertainty is estimated from the difference between theory and experiment and the spread of the experimental values. The values given for  $a_L$  and  $a_M$  are calculated from the adopted value for  $a_K$  and the adopted ratios (see below). A value for  $a_t$  is calculated as the sum of  $a_K$ ,  $a_L$  and  $a_{MNO}$ , where  $a_{MNO}$  is calculated from the ratio  $MNO/L = 0,347(6)$  according to Kel'man and Metskhvarisvili. The result is 0,0448(4). With respect to the experimental value 10 the finally adopted value for  $a_t$  was taken to be 0,447(5).

For the ratios of the conversion coefficients the following values were found:

	K/L	K/LM	K/LMN	
1	2,69(2)	2,15(4)	2,00(4)	Kel'man and Metskhvarishvili 1959
2	-	-	2,08(6)	Bosch and Szichman 1967
3	-	2,06	-	Keeler and Connor 1964
4	2,79(4)	-	-	Herrlander and Graham 1964
5	-	2,17(8)	-	Kurey and Roy 1963
6	2,54(6)	-	1,98(5)	Parsignault 1966
7	2,75(10)	-	-	Bogdanovich et al. 1968
8	-	-	2,36(60)	Reddy 1976
9	2,70(5)	2,16(4)	2,01(3)	LWM of exp. values
10	2,81	2,25	2,12	Theory (Rösel et al., 1978)
11	2,76(6)	2,21(6)	2,06(6)	In this evaluation adopted values

Herrlander and Graham (1964) cited for K/L taken from theory 2,72 (Sliv and Band, 1958) and 2,75 (Rose, 1958). These values are slightly lower than the value which was interpolated from the tables of Rösel (value 10). The adopted values are in all cases the unweighted mean between experiment (values 9) and theory (value 10). The uncertainties of the adopted values were taken with a look to the differences experiment - theory and the spread of the experimental values. The one value without uncertainty in the above table was not included in the averaging procedure. L and M subshell ratios were determined by Kel'man and Metskhvarishvili 1959, Herrlander and Graham 1964 and Dragoun et al. 1972.

Values for the K conversion coefficients of the two other  $\gamma$  transitions are:

	1	2	3	4
676 keV	0,0224(19)	0,019(5)	0,03(1)	0,0211(15)
1088 keV	0,00450(31)	0,0046(6)	0,0046(6)	0,00419(12)

- 1 Elliot et al. 1954 based on  $a_K(412) = 0,0317$ ;  $K/L = 5,7(5)$  and  $6,3(5)$
- 2 Volpe and Hinman 1956
- 3 Bosch and Szichman 1967
- 4 Theory, Rösel et al. 1978; the value for the 676 keV transition is based on a mixing ratio of 44(5) % M1 + 56(5) % E2.

There is agreement between experiment and theory within the quoted uncertainties.

From the conversion electron ratio measured by Elliot et al. (1954) a value for the emission probability of the 676 keV gamma quanta can be derived:

$$P_g(676) = \frac{ce_K(676)}{ce_K(412)} \cdot \frac{a_K(412)}{a_K(676)} \cdot P_g(412)$$

The three factors on the right hand side are 0,0059(2) (from Elliot et al.), 1,43(5) (from theory) and 0,9554(7) (from the present evaluation). This gives  $P_\gamma(676) = 0,00806(39)$  in excellent agreement with the present evaluation but with a greater uncertainty.

The M1 admixture to the 676 keV E2 + M1 transition was determined to be:

	% M1	$\delta$	
1	52(5)	- 0,96(10)	Schrader et al. 1953
2	40(10)	- 1,22(22)	Schiff and Metzger 1953
3	32(6)		Elliot et al. 1954
4	36(23)		Volpe and Hinmann 1956
5	33(4)	- 1,43(14)	Sakai et al. 1964
6	45(5)	- 1,1	Béraud et al. 1965
7	39(4)	- 1,26(8)	Uhl and Wahaneck 1966
8	36(4)	- 1,34(9)	Koch et al. 1967
9	43(6)	- 1,14(16)	Pakkanen 1971
10	54(2)		Venkata Ramana 1972
11	39,4(25)		Kawamura and Tomiyama 1974
12	44,3(25)		weighted mean of 1 - 11
13	44(5)		adopted value with an uncertainty enlarged to cover the most precise value, value 11

Values 1, 2 and 4 - 11 were derived from  $\gamma\gamma$  angular correlation measurements of the 676-412 keV cascade. For the 1088 keV transition we assumed pure E2 character and assigned an uncertainty of 3 % to the conversion coefficients interpolated from the tables of Rösler et al. (1978).

### 3 Atomic Data

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

#### 3.1 X Radiation

The energy values are calculated from the wave lengths in Å\* as given by Bearden (1967).

The relative emission probabilities of K X rays are taken from Schönfeld and Janßen (1996).

The relative emission probability of L X rays is calculated from the value in table 4.2 putting  $P(K_{a_1}) = 1$ .

#### 3.2 Auger Electrons

The energy values are taken from Larkins (1977) (KLL) and the Table de Radionucléides (LMRI 1982) (KLX, KXY). The relative emission probabilities of K Auger electrons are taken from Schönfeld and Janßen (1996).

The relative emission probabilities of the L Auger electrons is calculated from the value in table 4.1 putting  $P(KLL) = 1$ .

## 4 Radiation Emission

### 4.1 Electron Emission

The energies of the Auger electrons are the same as in 3.2. The energies of the conversion electrons are calculated from the transition energy (2.2) and the binding energies.

The emission probabilities of the conversion electrons are calculated using the conversion coefficients given in 2.2. The values of the emission probabilities of the Auger electrons are calculated using the transition probabilities given in 2.1 and 2.2, the atomic data given in 3 and the conversion coefficients given in 2.2. and the program EMISSION.

### 4.2 Photon Emission

The energy of the X rays are the same as in 3.1. The energies of the gamma rays were taken from Helmer (2000). They are mainly based on measurements of Deslattes et al. (1980).

The emission probabilities of the K X rays were determined with the program EMISSION using the evaluated atomic data, transition probabilities and conversion coefficients. The total emission probabilities of L X rays was also calculated with the help of the program EMISSION.

For the relative  $\gamma$ -ray emission probabilities the following values were taken into account:

	411,8 keV	675,9 keV	1087,7 keV
1	100	1,5	0,4
2	100	1,4(1)	0,25(5)
3	100	1	0,2
4	100	1,3	0,25
5	100	0,842(56)	0,170(12)
6	100	1,11(5)	0,26(2)
7	100	1,0	0,28
8	100	0,75	0,15
9	100	0,841(5)	0,1664(22)
10	100	0,846(11)	0,165(4)
11	100	0,844(7)	0,166(3)

1	Cavanagh et al. 1951
2	Hubert 1951
3	Brosi et al. 1951
4	Maeder et al. 1954
5	Elliott et al. 1954
6	Dzhelepov et al. 1955
7	Keeler and Connor 1965
8	Bosch and Szichman 1967
9	Iwata and Yoshizawa 1980, recalculated from 100,0(4) to 100 for the 411,8 keV line
10	Chand et al. 1989, recalculated from 100,0(8) to 100 for the 411,8 keV line
11	Adopted values (LRSW of 5, 9 and 10)

The normalization factor  $f_N$  was calculated from

$$\left[ P_g(412) \left( 1 + a_t(412) \right) + P_g(1088) \left( 1 + a_t(1088) \right) \right] \cdot f_N = 1 - P_b(1372)$$

With the evaluated values of the total conversion coefficients and  $P_b(1372) = 0,00025(5)$  as measured by Elliot et al. 1954, we obtained  $f_N = P_\gamma(412) = 0,9554(7)$ .

Concerning KX/γ ratios there is excellent agreement between the values recommended by Campbell and Mc Nelles (1975) and the values evaluated in the present paper:

	Campbell	calculated
$P(K_{\alpha})/P_{\gamma}(412)$	0,0229(5)	0,0228(2)
$P(K_{\beta})/P_{\gamma}(412)$	0,00635(15)	0,00630(10)

For the emission probabilities of X rays the following values were considered:

	Energy in keV	1	2	3
$L_{\ell}$	8,7213(6)	0,00027(3)	0,00020(16)	-
$L_{\alpha}$	9,90-9,99	0,00592(17)	0,00440(30)	-
$L_{\beta}$	10,6514(9)	0,000105(15)	0,00008(1)	-
$L_{\eta}$	11,36-12,56	0,00643(19)	0,00483(35)	-
$L_{\gamma}$	13,41-14,47	0,00124(5)	0,00130(10)	-
$L_{total}$	8,72-14,47	0,01397	0,01081	0,0121(2)
$K_{a_2}$	68,8952(12)	0,00816(24)	-	0,00809(8)
$K_{a_1}$	70,8196(12)	0,0141(4)	-	0,01372(12)
$K'_{b_1}$	79,82-80,75	0,00485(12)	-	0,00466(8)
$K'_{b_2}$	82,44-83,04	0,00137(7)	-	0,00136(4)
$K_{total}$	68,89-83,04	0,0285(5)	-	0,02784(22)

- 1 Chand et al. 1989
- 2 Beghzanov et al. 1987
- 3 calculated values = adopted values in this evaluation

In the case of the K X rays there is agreement between measured and calculated values within the quoted uncertainties.

## 5 Main Production Modes

Taken from Zhou Chunmei (1995).

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