

Even Z  
 $T_z = +29/2$

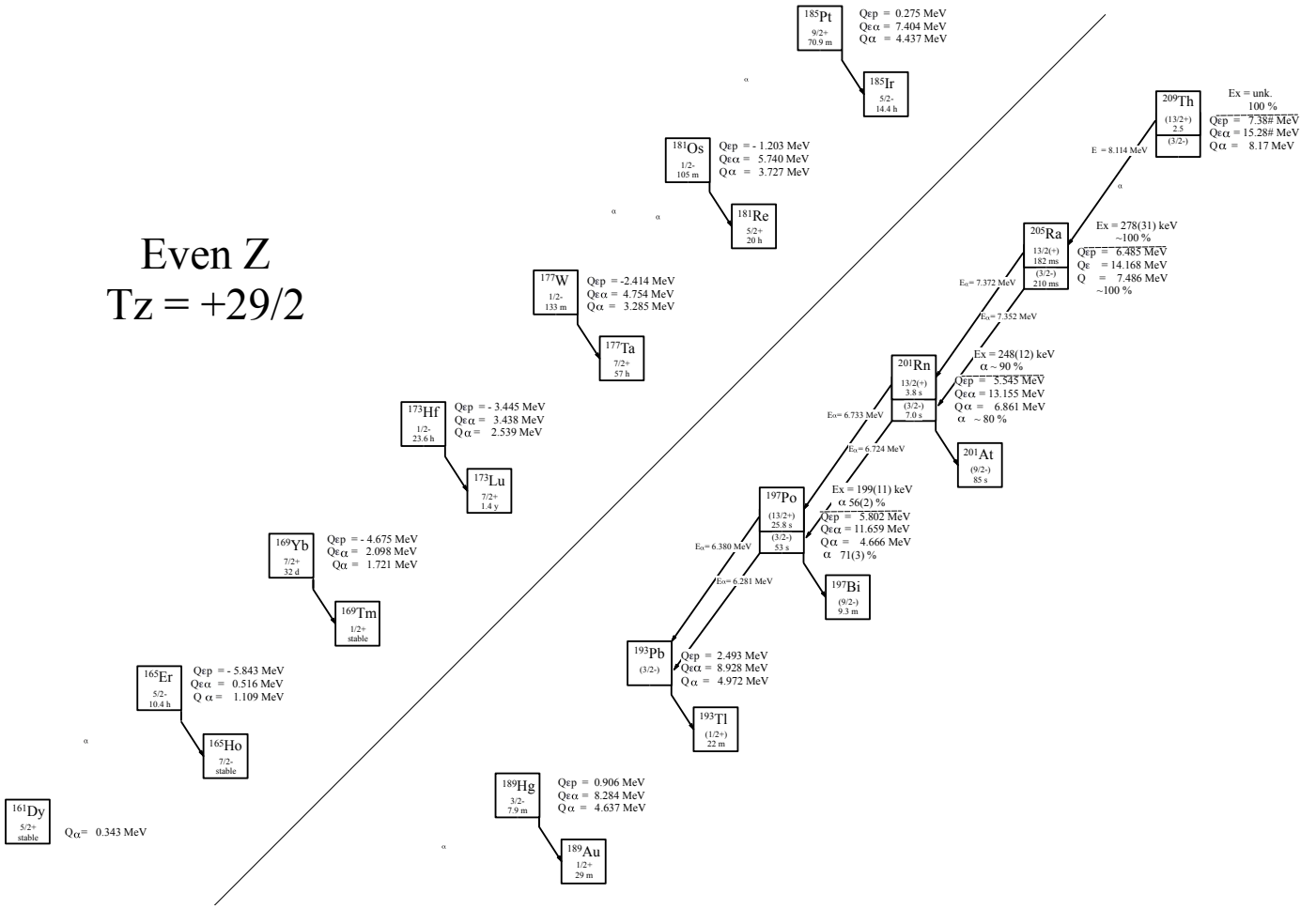


Fig. 1: Known experimental values for heavy particle emission of the even-Z  $T_z = +29/2$  nuclei.

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**Table 1**

Observed and predicted  $\beta$ -delayed particle emission from the even- $Z$ ,  $T_z = +29/2$  nuclei.  $J^\pi$  values for  $^{161}\text{Dy}$ ,  $^{14}\text{Er}$ ,  $^{169}\text{Yb}$ ,  $^{173}\text{Hf}$ ,  $^{177}\text{W}$ ,  $^{181}\text{Os}$ , and  $^{185}\text{Pt}$  are taken from ENSDF. Unless otherwise stated, all Q-values are taken from [2021Wa16] or deduced from values therein.

| Nuclide            | Ex        | $J^\pi$    | $T_{1/2}$              | $Q_\epsilon$ | $Q_{\epsilon p}$ | $Q_{\epsilon\alpha}$ | Experimental                   |
|--------------------|-----------|------------|------------------------|--------------|------------------|----------------------|--------------------------------|
| $^{161}\text{Dy}$  |           | $5/2^+$    | stable                 | —            | —                | —                    |                                |
| $^{165}\text{Er}$  |           | $5/2^-$    | 10.36(4) h*            | 0.377(1)     | -5.843(1)        | 0.516(2)             | [1963Zy01, 1963Ry01, 1963Ra15] |
| $^{169}\text{Yb}$  |           | $7/2^+$    | 32.1047(93) d          | 0.899(0.8)   | -4.675(0)        | 2.098(1)             | [2002Un02]                     |
| $^{173}\text{Hf}$  |           | $1/2^-$    | 23.6(1) h              | 1.469(28)    | -3.445(28)       | 3.438(28)            | [1951Wi08]                     |
| $^{177}\text{W}$   |           | $1/2^-$    | 133(3) m**             | 2.013(28)    | -2.414(28)       | 4.754(28)            | [1963Sa14, 1950Wi67]           |
| $^{181}\text{Os}$  |           | $1/2^-$    | 105(3) m               | 2.967(28)    | -1.203(25)       | 5.740(26)            | [1966Ho16]                     |
| $^{185}\text{Pt}$  |           | $9/2^+$    | 70.9(24) m             | 3.650(40)    | 0.275(26)        | 7.404(29)            | [1970FiZZ]                     |
| $^{189}\text{Hg}$  |           | $3/2^-$    | 7.9(2) m***            | 3.960(40)    | 0.906(32)        | 8.284(42)            | [1975Be17, 1970ErZX, 1950Wi67] |
| $^{193}\text{Pb}$  |           | $(3/2^-)$  |                        | 5.248(12)    | 2.493(19)        | 8.928(23)            |                                |
| $^{197}\text{Po}$  |           | $(3/2^-)$  | 53(1) s                | 6.294(13)    | 4.666(13)        | 11.659(12)           | [1993Wa04]                     |
| $^{197m}\text{Po}$ | 0.199(11) | $(13/2^+)$ | 25.8(1) s              | 6.493(17)    | 4.865(17)        | 11.858(16)           | [2017Al34, 1993Wa04]           |
| $^{201}\text{Rn}$  |           | $(3/2^-)$  | 7.0(4) s               | 6.682(13)    | 5.545(13)        | 13.155(13)           | [1971Ho01]                     |
| $^{201m}\text{Rn}$ | 0.248(12) | $13/2^+$   | 3.8(4) s               | 6.930(18)    | 5.793(18)        | 13.403(18)           | [2017Al34, 1971Ho01]           |
| $^{205}\text{Ra}$  |           | $(3/2^-)$  | $210^{+41}_{-26}$ ms@  | 7.114(24)    | 6.485(24)        | 14.168(24)           | [1996Le09, 1995Le15]           |
| $^{205m}\text{Ra}$ | 0.278(31) | $13/2^+$   | $182^{+38}_{-24}$ ms@@ | 7.392(39)    | 6.763(39)        | 14.446(39)           | [2017Al34, 1996Le09, 1995Le15] |
| $^{209}\text{Th}$  | x         | $(3/2^-)$  |                        | 7.55(12)#    | 7.38(10)#        | 15.28(10)#           |                                |
| $^{209m}\text{Th}$ | x         | $(13/2^+)$ | $2.5^{+1.7}_{-0.7}$ ms | 7.55(12)#+x  | 7.38(10)#+x      | 15.28(10)#+x         | [2010He25]                     |

\* Weighted average of 10.39(7) h [1963Zy01], 10.34(5) h [1963Ry01] and 10.4(1) h [1963Ra15].

\*\* Weighted average of 135(3) m [1963Sa14] and 130(3) m [1950Wi67].

\*\*\* Weighted average of 7.5(2) m [1975Be17], 7.7(2) m [1970ErZX] and 130(3) m [1950Wi67].

@ Weighted average of  $210^{+60}_{-40}$  ms [1996Le09] and  $210^{+55}_{-35}$  ms [1995Le15].

@@ Weighted average of  $170^{+60}_{-40}$  ms [1996Le09] and  $190^{+50}_{-30}$  ms [1995Le15].

**Table 2**

Particle separation, Q-values, and measured values for direct particle emission of the even- $Z$ ,  $T_z = +29/2$  nuclei. Unless otherwise stated, all S and Q-values are taken from [2021Wa16] or deduced from values therein.

| Nuclide            | $S_p$      | $S_{2p}$   | $Q_\alpha$ | $\text{BR}_\alpha$     | Experimental                                                                                                             |
|--------------------|------------|------------|------------|------------------------|--------------------------------------------------------------------------------------------------------------------------|
| $^{161}\text{Dy}$  | 7.508(1)   | 14.072(1)  | 0.343(1)   |                        |                                                                                                                          |
| $^{165}\text{Er}$  | 6.830(1)   | 12.718(1)  | 1.109(1)   |                        |                                                                                                                          |
| $^{169}\text{Yb}$  | 6.352(2)   | 11.664(1)  | 1.721(1)   |                        |                                                                                                                          |
| $^{173}\text{Hf}$  | 5.965(28)  | 10.683(28) | 2.539(28)  |                        |                                                                                                                          |
| $^{177}\text{W}$   | 5.625(42)  | 9.798(28)  | 3.285(40)  |                        |                                                                                                                          |
| $^{181}\text{Os}$  | 5.002(33)  | 8.833(29)  | 3.727(38)  |                        |                                                                                                                          |
| $^{185}\text{Pt}$  | 4.366(38)  | 7.602(56)  | 4.437(10)  |                        |                                                                                                                          |
| $^{189}\text{Hg}$  | 4.544(32)  | 7.519(40)  | 4.637(41)  | $< 3 \times 10^{-7}\%$ | [1963Ka17]                                                                                                               |
| $^{193}\text{Pb}$  | 3.646(33)  | 6.215(25)  | 4.972(33)  |                        |                                                                                                                          |
| $^{197}\text{Po}$  | 2.673(26)  | 4.233(11)  | 6.411(3)   | 71(3)%*                | [1996Ta18, 1993Wa04, 1981Sc01, 1987Wo04, 1971Ho01, 1970HoZT, 1967Le21, 1967Si09, 1965Br17, 1965Si22]                     |
| $^{197m}\text{Po}$ | 2.474(28)  | 4.034(16)  | 6.610(11)  | 56(2)%**               | [2002Va13, 1996Ta18, 1993Wa04, 1981Sc01, 1987Wo04, 1973BoXL, 1971Ho01, 1970HoZT, 1967Le21, 1967Si09, 1965Br17, 1965Si22] |
| $^{201}\text{Rn}$  | 2.408(26)  | 3.447(11)  | 6.861(2)   | $\approx 80\%$         | [1996Ta18, 1993Wa04, 1971Ho01, 1987He10, 1967Va17, 1965Nu04]                                                             |
| $^{201m}\text{Rn}$ | 2.160(29)  | 3.199(16)  | 7.109(12)  | $\approx 90\%$         | [1996Ta18, 1993Wa04, 1971Ho01, 1987He10, 1967Va17, 1965Nu04]                                                             |
| $^{205}\text{Ra}$  | 2.092(34)  | 2.590(24)  | 7.486(20)  | $\approx 100\%$ ***    | [1996Le09, 1995Le04, 1995Le15, 1987He10]                                                                                 |
| $^{205m}\text{Ra}$ | 1.814(46)  | 2.312(39)  | 7.764(37)  | $\approx 100\%$ ***    | [1996Le09, 1995Le15]                                                                                                     |
| $^{209}\text{Th}$  | 1.66(12)   | 1.70(12)   | 8.17(11)   |                        |                                                                                                                          |
| $^{209m}\text{Th}$ | 1.66(12)-x | 1.70(12)-x | 8.17(11)+x | 100%                   | [2010He25, 1996Ik01, 1996IkZY]                                                                                           |

\* Weighted average of 76(3)% [1993Wa04] and 44(7)% [1981Sc01].

\*\* Weighted average of 55(2)% [1993Wa04] and 84(9)% [1981Sc01].

\*\*\* Based on short half-life.

**Table 3**  
direct  $\alpha$  emission from  $^{197}\text{Po}$ ,  $J_i^\pi = (3^-)$ ,  $T_{1/2} = 53(1) \text{ s}^*$ ,  $BR_\alpha = 71(3)\%^{**}$ .

| $E_\alpha$ (c.m.) | $E_\alpha$ (lab)        | $I_\alpha$ (abs)     | $J_f^\pi$         | $E_{daughter} (^{193}\text{Pb})$ | coincident $\gamma$ -rays | $R_0$ (fm) <sup>@</sup> | HF      |
|-------------------|-------------------------|----------------------|-------------------|----------------------------------|---------------------------|-------------------------|---------|
| 6.411(2)          | 6.281(2) <sup>***</sup> | 71(3)% <sup>**</sup> | (3 <sup>-</sup> ) | 0.0                              | —                         | 1.5044(24)              | 1.19(8) |

\* [1993Wa04].

\*\* Weighted average of 76(3)% [1993Wa04] and 44(7)% [1981Sc01].

\*\*\* [1996Ta18].

**Table 4**  
direct  $\alpha$  emission from  $^{197m}\text{Po}$ , Ex. = 199(11) keV\*,  $J_i^\pi = (13/2^+)$ ,  $T_{1/2} = 25.8(1) \text{ s}^{**}$ ,  $BR_\alpha = 56(2)\%^{***}$ .

| $E_\alpha$ (c.m.) | $E_\alpha$ (lab)        | $I_\alpha$ (rel) | $I_\alpha$ (abs) | $J_f^\pi$            | $E_{daughter} (^{193}\text{Pb})$ | coincident $\gamma$ -rays | $R_0$ (fm) <sup>@</sup> | HF                                  |
|-------------------|-------------------------|------------------|------------------|----------------------|----------------------------------|---------------------------|-------------------------|-------------------------------------|
| 5.739(25)         | 5.622(25) <sup>@@</sup> | $\geq 0.05(3)\%$ | $\geq 0.03(2)\%$ | (13/2 <sup>+</sup> ) | 0.757(1)                         | 0.757(1)                  | 1.5044(24)              | 1.9 <sup>+2.9</sup> <sub>-0.7</sub> |
| 6.512(1)          | 6.380(1) <sup>@</sup>   | 100%             | 56(2)%           | (13/2 <sup>+</sup> ) | 0.0                              | —                         | 1.5044(24)              | 1.86(12)                            |

\* [2017Al34].

\*\* [1993Wa04].

\*\*\* Weighted average of 55(2)% [1993Wa04] and 84(9)% [1981Sc01].

@ [1996Ta18].

@@ [2002Va13].

**Table 5**  
direct  $\alpha$  emission from  $^{201}\text{Rn}$ ,  $J_i^\pi = (3^-)$ ,  $T_{1/2} = 7.0(4) \text{ s}^*$ ,  $BR_\alpha = \approx 80 \text{ \%}^*$ .

| $E_\alpha$ (c.m.) | $E_\alpha$ (lab)       | $I_\alpha$ (abs)          | $J_f^\pi$         | $E_{daughter} (^{197}\text{Po})$ | coincident $\gamma$ -rays | $R_0$ (fm) <sup>@</sup> | HF            |
|-------------------|------------------------|---------------------------|-------------------|----------------------------------|---------------------------|-------------------------|---------------|
| 6.861(2)          | 6.724(2) <sup>**</sup> | $\approx 80 \text{ \%}^*$ | (3 <sup>-</sup> ) | 0.0                              | —                         | 1.5156(71)              | $\approx 1.6$ |

\* [1971Ho01].

\*\* Weighted average of 6.725(2) MeV [1996Ta18] and 6.7237(25) MeV [1993Wa04].

**Table 6**  
direct  $\alpha$  emission from  $^{201m}\text{Rn}$ , Ex. = 248(12) keV\*,  $J_i^\pi = 13/2^{(+)}$ ,  $T_{1/2} = 3.8(4) \text{ s}^{**}$ ,  $BR_\alpha = \approx 90 \text{ \%}^{**}$ .

| $E_\alpha$ (c.m.) | $E_\alpha$ (lab)        | $I_\alpha$ (abs)             | $J_f^\pi$           | $E_{daughter} (^{197}\text{Po})$ | coincident $\gamma$ -rays | $R_0$ (fm) <sup>@</sup> | HF             |
|-------------------|-------------------------|------------------------------|---------------------|----------------------------------|---------------------------|-------------------------|----------------|
| 6.910(2)          | 6.733(2) <sup>***</sup> | $\approx 90 \text{ \%}^{**}$ | 13/2 <sup>(+)</sup> | 0.199(11)                        | —                         | 1.5156(71)              | $\approx 1.16$ |

\* [2017Al34].

\*\* [1971Ho01].

\*\*\* Weighted average of 6.773(2) MeV [1996Ta18] and 6.7721(25) MeV [1993Wa04].

**Table 7**  
direct  $\alpha$  emission from  $^{205}\text{Ra}$ ,  $J_i^\pi = (3^-)$ ,  $T_{1/2} = 210_{-26}^{+41} \text{ ms}^*$ ,  $BR_\alpha = \approx 100 \text{ \%}$ .

| $E_\alpha$ (c.m.) | $E_\alpha$ (lab)       | $I_\alpha$ (abs)         | $J_f^\pi$         | $E_{daughter} (^{201}\text{Rn})$ | coincident $\gamma$ -rays | $R_0$ (fm) <sup>@</sup> | HF                                  |
|-------------------|------------------------|--------------------------|-------------------|----------------------------------|---------------------------|-------------------------|-------------------------------------|
| 7.498(8)          | 7.352(8) <sup>**</sup> | $\approx 100 \text{ \%}$ | (3 <sup>-</sup> ) | 0.0                              | —                         | 1.5269(91)              | 1.5 <sup>+0.5</sup> <sub>-0.3</sub> |

\* Weighted average of 210<sup>+60</sup><sub>-40</sub> ms [1996Le09] and 210<sup>+55</sup><sub>-35</sub> ms [1995Le15].

\*\* Weighted average of 7.340(20) MeV [1996Le09], 7.350(25) MeV [1995Le15], and 7.340(20) MeV [1995Le04]. In addition [1987He10] report one peak from  $^{205}\text{Ra}$  at 7.360(20) MeV which may be an unresolved combination of the two isomers.

**Table 8**

direct  $\alpha$  emission from  $^{205m}\text{Ra}$ , Ex. = 278(31) keV,  $J_i^\pi = 13/2^{(+)}$ ,  $T_{1/2} = 182_{-24}^{+38}$  ms\*,  $BR_\alpha = \approx 100\%$ .

| $E_\alpha$ (c.m.) | $E_\alpha$ (lab) | $I_\alpha$ (abs) | $J_f^\pi$           | $E_{daughter}$ ( $^{201}\text{Rn}$ ) | coincident $\gamma$ -rays | $R_0$ (fm) <sup>®</sup> | HF                   |
|-------------------|------------------|------------------|---------------------|--------------------------------------|---------------------------|-------------------------|----------------------|
| 7.519(16)         | 7.372(16)**      | $\approx 100\%$  | 13/2 <sup>(+)</sup> | 0.248(12)                            | —                         | 1.5269(91)              | 1.5 $_{-0.4}^{+0.5}$ |

\* Weighted average of 210 $_{-40}^{+60}$  ms [1996Le09] and 210 $_{-35}^{+55}$  ms [1995Le15].

\*\* Weighted average of 7.370(20) MeV [1996Le09], and 7.375(25) MeV [1995Le15].

**Table 9**

direct  $\alpha$  emission from  $^{209m}\text{Th}^*$ , Ex. = unk,  $J_i^\pi = (13/2^+)$ ,  $T_{1/2} = 2.5_{-0.7}^{+1.7}$  ms\*\*,  $BR_\alpha = 100\%$ .

| $E_\alpha$ (c.m.) | $E_\alpha$ (lab) | $I_\alpha$ (abs) | $J_f^\pi$            | $E_{daughter}$ ( $^{205}\text{Ra}$ ) | coincident $\gamma$ -rays | $R_0$ (fm) <sup>®</sup> | HF                   |
|-------------------|------------------|------------------|----------------------|--------------------------------------|---------------------------|-------------------------|----------------------|
| 8.272(25)         | 8.114(25)***     | 100 %            | (13/2 <sup>+</sup> ) | 0.278(31)                            | —                         | 1.531(14)               | 1.0 $_{-0.4}^{+0.8}$ |

\* All values from [2010He25], except where noted.

\*\* From [2010He25], obtained from their 4 events and the 2 events from [1996Ik01].

\*\*\* Weighted average of 8.123(25) MeV [2010He25], and 8.080(50) MeV [1996Ik01].

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