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Properties of heaviest nuclei

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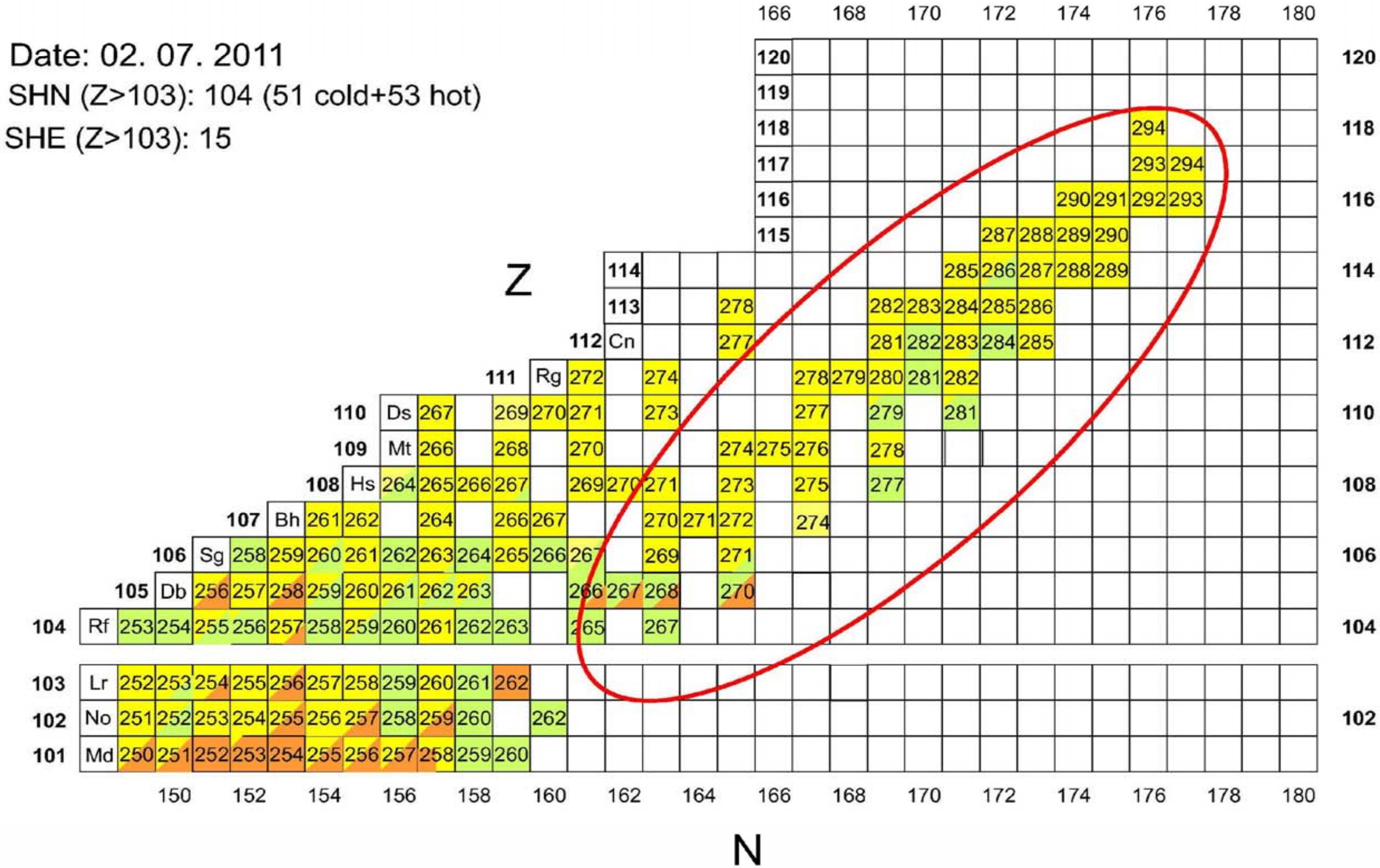

Fig. 1. Present view of the part of the nuclear chart corresponding to superheavy nuclei (SHN: $Z \geq 104$).

Phenomenological model for T_α (see Ref. [1])

$$\log_{10} T_\alpha^{\rm ph}(Z,N) = aZ[Q_\alpha(Z,N) - \bar{E}_i]^{-1/2} + bZ + c, \tag{1}$$

where the parameters a,b,c are

$$a = 1.5372, \quad b = -0.1607, \quad c = -36.573 \tag{2}$$

and the parameter $\bar{E}_i$ (average excitation energy of the daughter nucleus) is

$$\begin{aligned} &\bar{E}_i = 0 \text{ for e-e}, \quad \bar{E}_i = \bar{E}_{\rm p} = 0.113 \text{ MeV for o-e}, \\ &\bar{E}_i = \bar{E}_{\rm n} = 0.171 \text{ MeV for e-o}, \quad \text{and } \bar{E}_i = \bar{E}_{\rm p} + \bar{E}_{\rm n} \text{ for o-o nuclei.} \end{aligned} \tag{3}$$

Here, e.g. o-e, means (odd-Z, even-N) nuclei, where Z is the proton and N is the neutron number.

Table 1: Values of the quantities characteristic for the decay chain of $^{293}117$, calculated with our (HN) Q_α [2,3] (see [4])

Nucleus	$^{293}117$	$^{289}115$	$^{285}113$	^{281}Rg	^{277}Mt	^{273}Bh	^{269}Db	^{265}Lr
$Q_\alpha^{\rm t}$	11.42	10.63	10.10	10.37	9.73	8.78	8.06	6.51
T_α	7.0 ms	0.15 s	0.84 s	38 ms	0.42 s	55 s	42 m	27 y
$T_{\rm sf}^{\rm av}$	20 h	24 m	2.8 s	42 ms	51 ms	3.0 s	28 s	23 s
$T_{\rm sf}^{\rm av}/T_\alpha$	$1.0 \cdot 10^7$	$9.7 \cdot 10^3$	3.3	1.1	0.12	$5.4 \cdot 10^{-2}$	$1.1 \cdot 10^{-2}$	$2.7 \cdot 10^{-8}$

Table 2: Same as in Table 1, but for the decay chain of $^{294}117$.

Nucleus	$^{294}117$	$^{290}115$	$^{286}113$	^{282}Rg	^{278}Mt	^{274}Bh	^{270}Db	^{266}Lr
$Q_\alpha^{\rm t}$	11.15	10.37	9.70	9.57	9.27	8.55	7.83	6.65
T_α	31 ms	0.70 s	11 s	5.6 s	8.8 s	5.1 m	4.8 h	5.9 y
$T_{\rm sf}^{\rm av}$	0.62 y	1.5 d	17 m	1.4 s	29 ms	1.5 s	14 s	12 s
$T_{\rm sf}^{\rm av}/T_\alpha$	$6.3 \cdot 10^{8}$	$1.9 \cdot 10^{5}$	$0.92 \cdot 10^{2}$	0.25	$3.3 \cdot 10^{-3}$	$4.9 \cdot 10^{-3}$	$0.81 \cdot 10^{-3}$	$6.4 \cdot 10^{-8}$

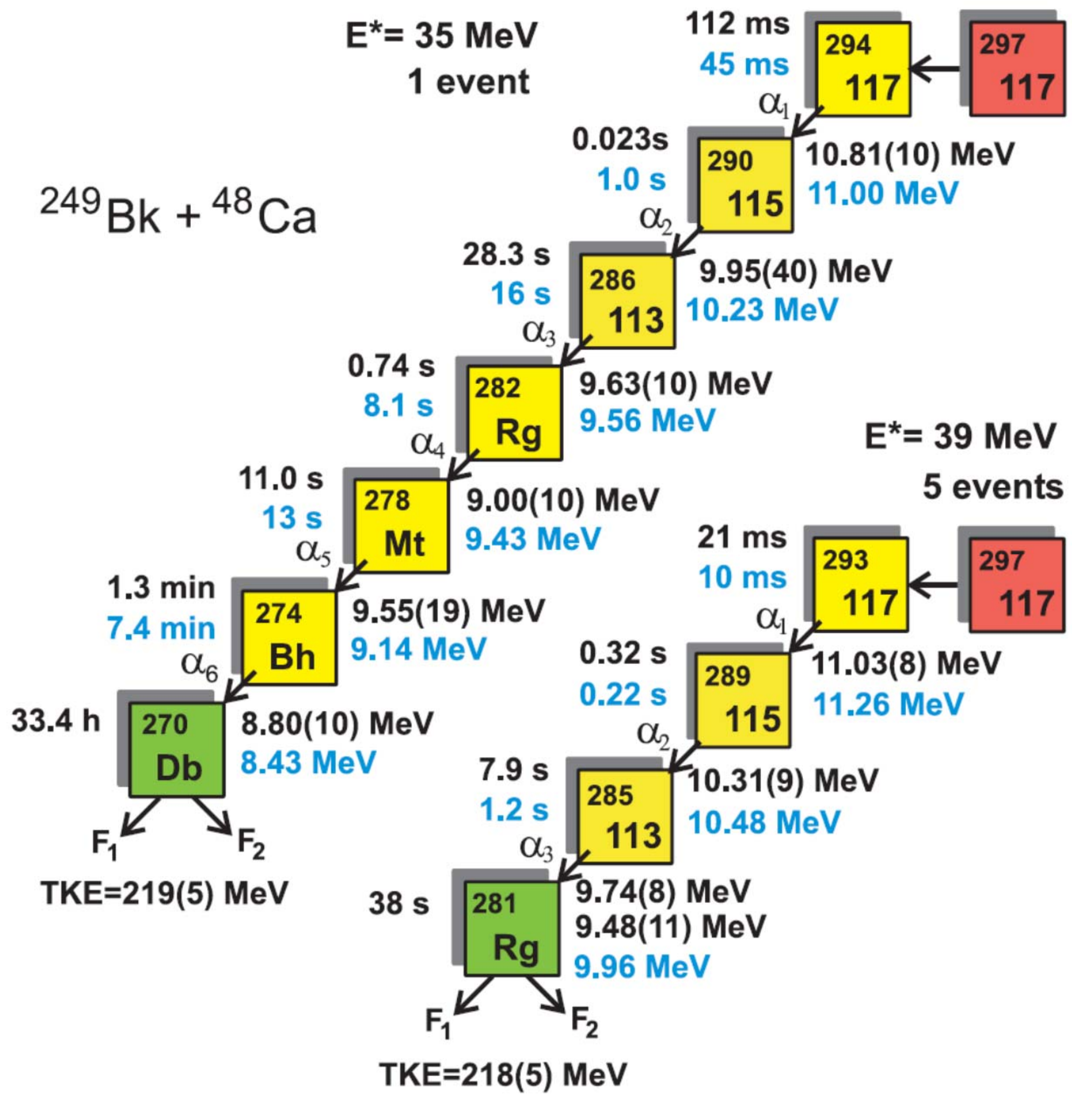

Fig. 2. Comparison of predicted (color blue) α-particle energies and lifetimes with experimental ones (color black) done in Ref. [5]. The predicted values were calculated in [4].

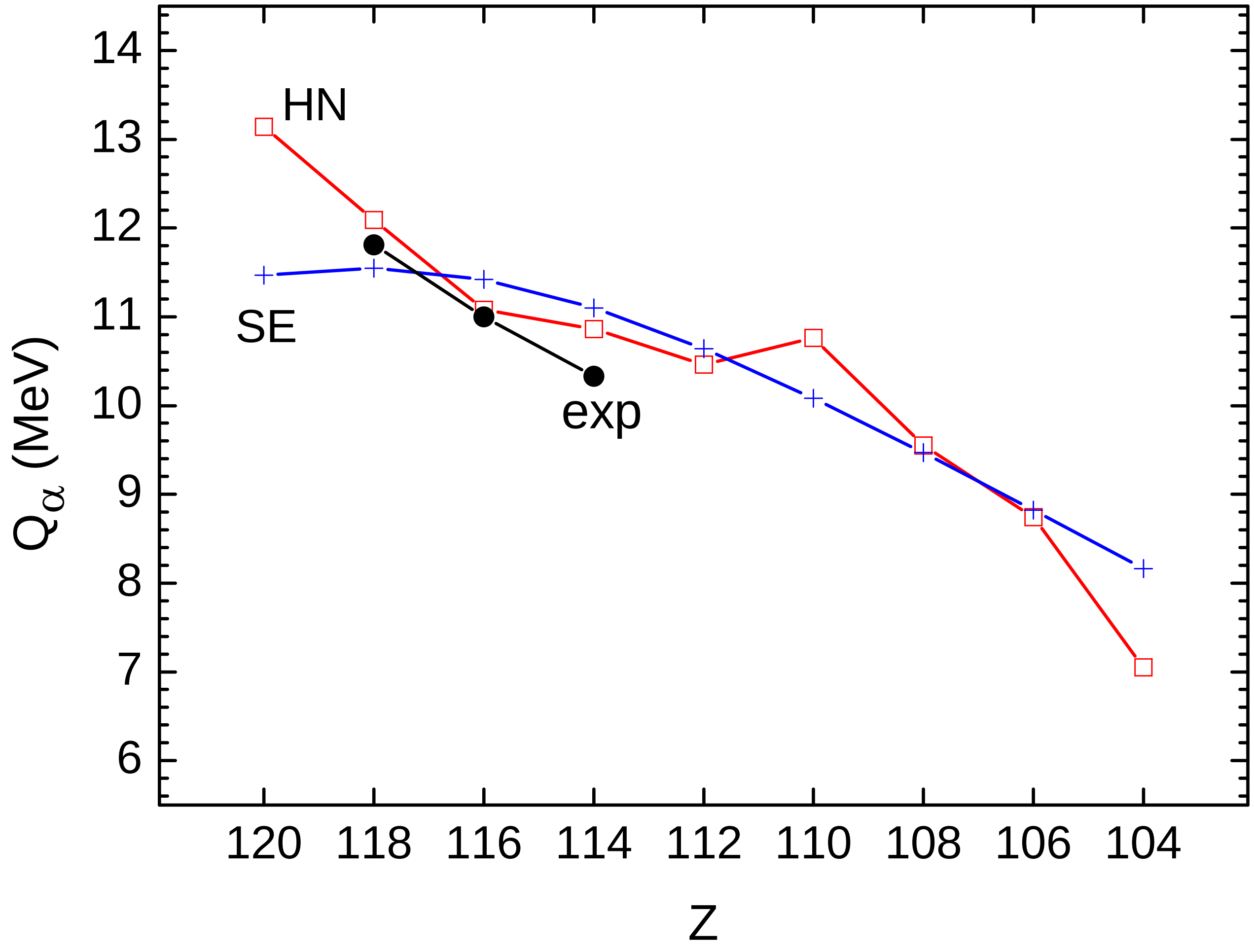

Fig. 3. Comparison of our Q_α (HN) with semi-empirical ones [6] for a decay chain of the not-yet-observed nucleus $^{298}120$ [7]. Experimental values measured for the decay chain of $^{294}118$ [8] are also shown (see [7]).

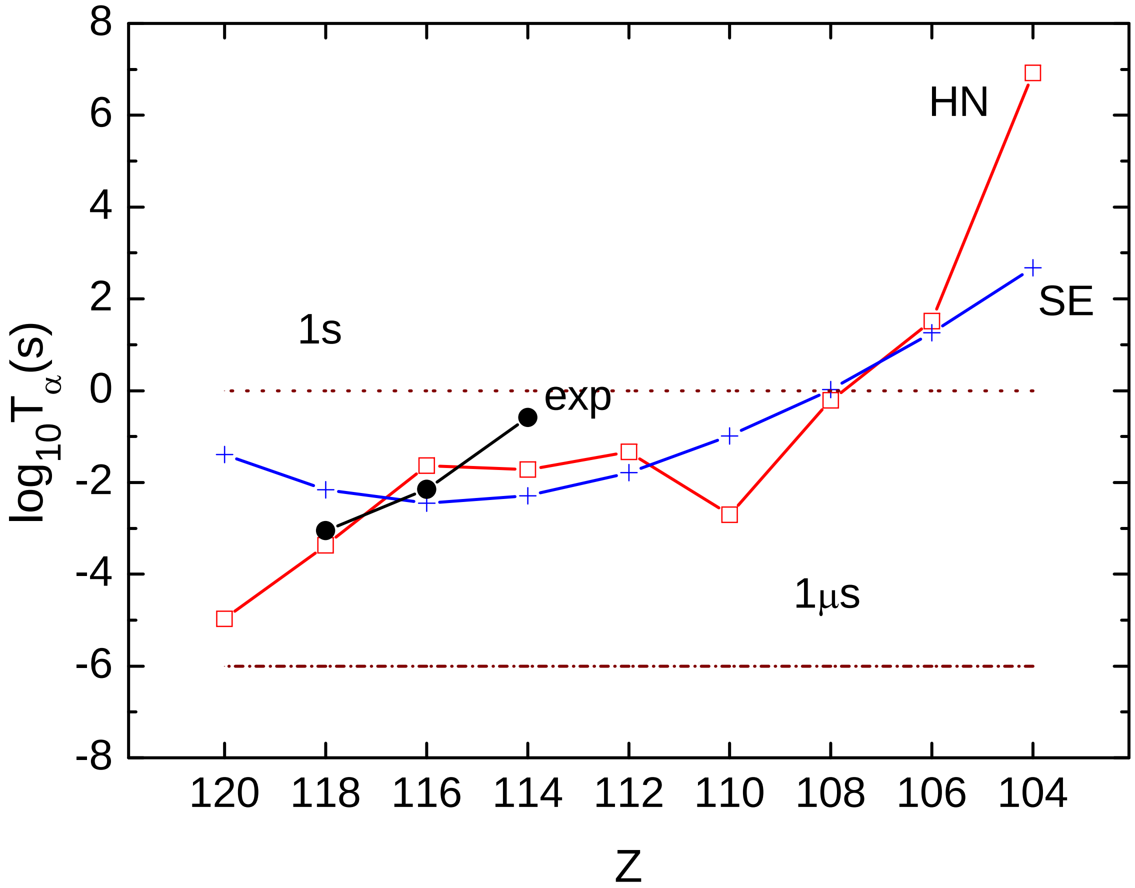

Fig. 4. Same as in Fig. 3, but for the $\log_{10}T_\alpha(s)$.

Table 3. Same as in Table 1, but for the nucleus $^{298}120$ [7].

Nucleus	$^{298}120$	$^{294}118$	$^{290}116$	$^{286}114$	^{282}Cn	^{278}Ds	^{274}Hs	^{270}Sg	^{266}Rf
Q_α^{t}	13.14	12.09	11.08	10.86	10.46	10.76	9.55	8.74	7.05
T_α	11 μs	0.43 ms	23 ms	19 ms	46 ms	2.0 ms	0.62 s	32 s	0.27 y
T_{sf}	28 ms	22 m	12 m	1.5 s	71 ms	56 ms	5.8 s	55 s	23 s
T_{sf}/T_α	2.6×10^3	3.2×10^6	3.3×10^4	78	1.6	28	9.3	1.7	2.7×10^{-6}

Table 4. Same as in Table 1, but for the nucleus $^{299}120$ [7].

Nucleus	$^{299}120$	$^{295}118$	$^{291}116$	$^{287}114$	^{283}Cn	^{279}Ds	^{275}Hs	^{271}Sg	^{267}Rf
Q_α^{t}	13.06	12.05	10.74	10.39	9.99	10.07	9.24	8.54	7.24
T_α	15 μs	0.52 ms	0.16 s	0.30 s	0.80 s	0.11 s	4.9 s	2.4 m	16 d
T_{sf}	42 ms	2.0 h	20 h	18 m	2.0 s	34 ms	2.9 s	28 s	12 s
T_{sf}/T_α	2.7×10^3	1.4×10^7	4.6×10^5	3.5×10^3	2.6	0.31	0.59	0.20	0.88×10^{-5}

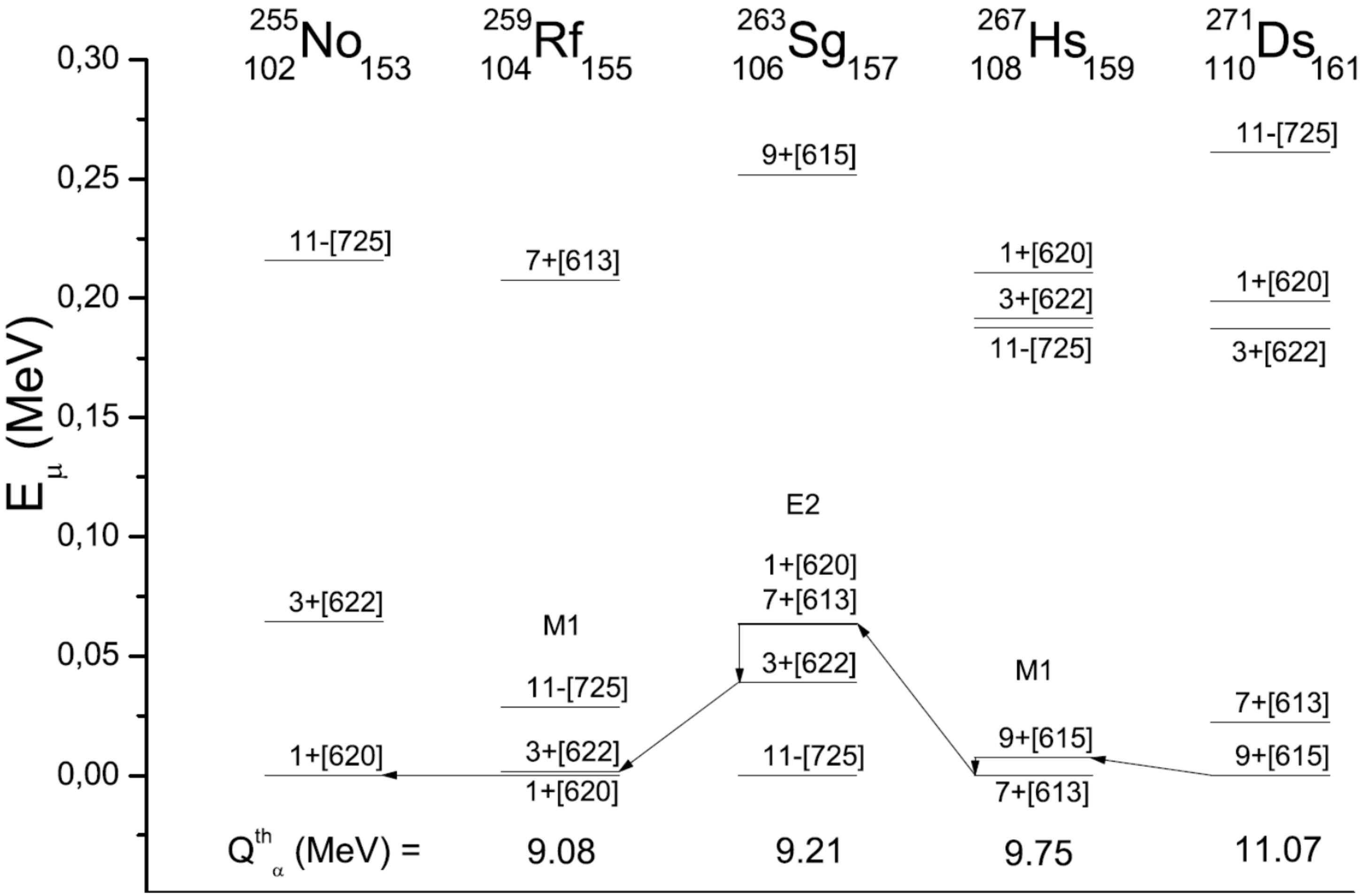

Fig. 5. Illustration of the effect of the single-particle structure on the decay chain of the nucleus ^{271}Ds [9].

References

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Conclusions

1. A 5-parameter phenomenological model for the α-decay half-lives T_α appears to be quite realistic.

2. Here, however, the critical quantity is the α-decay energy Q_α, to which T_α is very sensitive, but for which we do not have sufficiently good model.

3. The model for T_α may be also used to describe, in a direct way, individual properties of nuclei with odd nucleons in decay chains. This needs, however, a good knowledge of the single-particle spectra of the nuclei.

4. The existing models for calculation of such spectra should be first well tested in the region, where such spectra are known, i.e. at least below seaborgium or rutherfordium.