Fission processes in heavy and superheavy elements within the dinuclear system model

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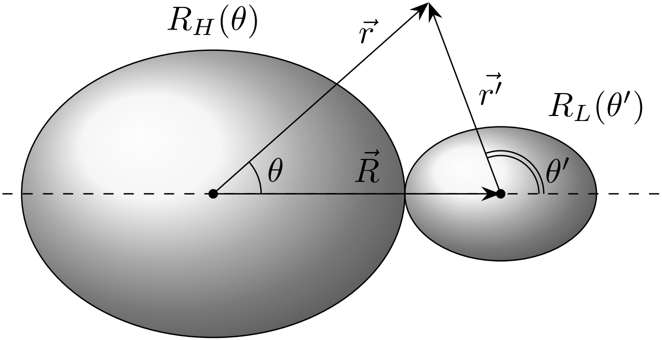
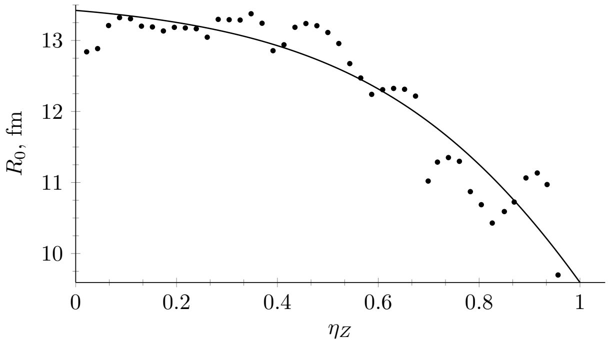
Dinuclear system (DNS)



Charge asymmetry:

$$\eta_Z = \frac{Z_H - Z_L}{Z_H + Z_L},\ \ Z_{H,L} \text{ -- charge number}$$



DNS preformation

- Movement in η_Z coordinate
- Spectroscopic factor (preformation probability) S_L

DNS decay

- Movement in R coordinate
- Penetration probability P_L

DNS state

The system is described by stationary wave function $\Psi(\eta_Z)$:

$$\hat{H}\Psi_n(\eta_Z) = E_n\Psi_n(\eta_Z),$$

где

$$\hat{H} = \hat{T}_{\eta_Z} + U(\eta_Z)$$

Kinetic energy

$$\hat{T}_{\eta_Z} = \frac{\hbar^2}{2}\frac{\partial}{\partial\eta_Z}B^{-1}_{\eta_Z}\frac{\partial}{\partial\eta_Z}$$

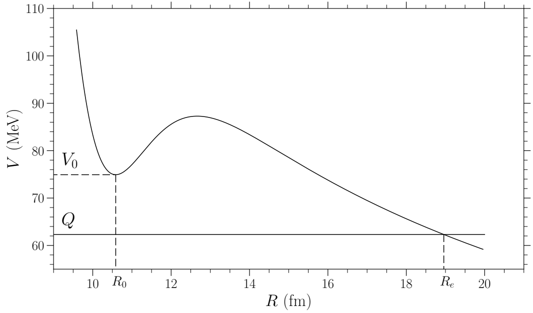
Potential energy

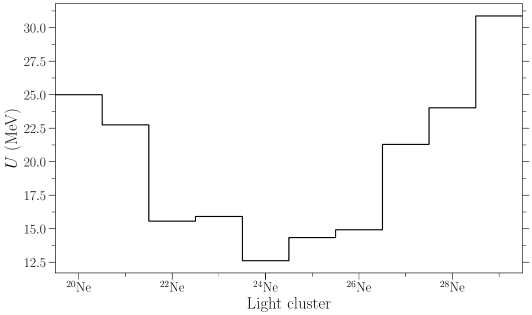
[G. Adamian *et al.* Int. J. Mod. Phys. A, 1996]

$$U(R,\eta_Z) = V(R,\eta_Z) - (Q_M - Q_L - Q_H)$$

$$V(R,\eta_Z) = V_{\mathrm{C}}(R,\eta_Z) + V_N(R,\eta_Z) + V_r(R,\eta_Z)$$

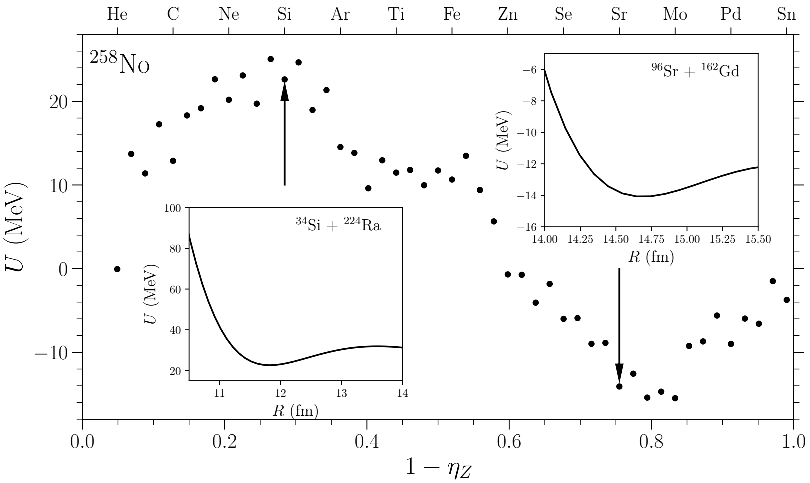
Driving potential



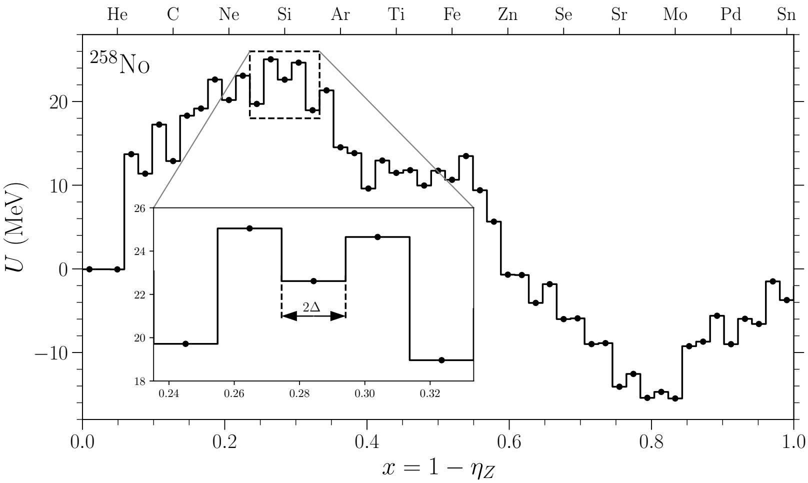


$$a_0 = 0.47 - 0.56 \text{ fm}; \quad r_0 = 1.00 - 1.16 \text{ fm}$$

Formation of the driving potential

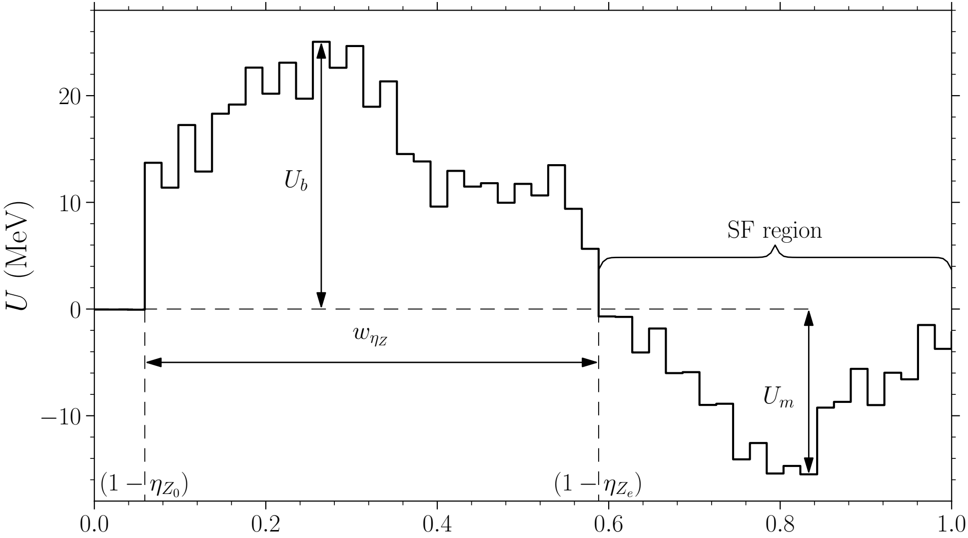


Formation of the driving potential

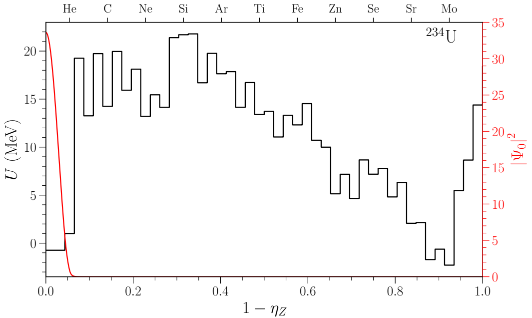


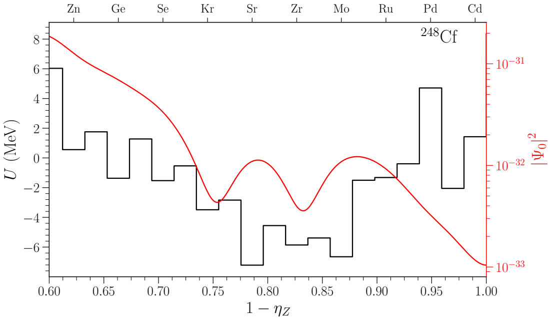
$$\eta_Z \to x = 1 - \eta_Z; \quad \Delta = 1/Z;$$

Driving potential characteristics



Wave function





Half-lives

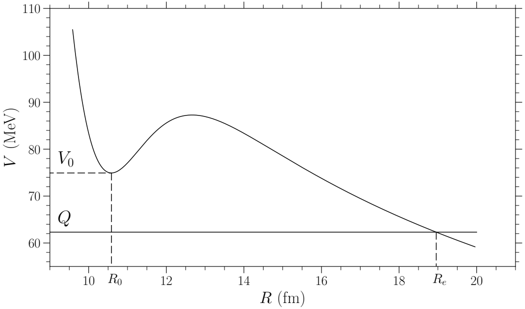
$$S_L = \int_{\eta_Z(Z_l)-\Delta}^{\eta_Z(Z_L)+\Delta} |\Psi(\eta_Z)|^2 d\eta_Z$$

$$\Delta = 1/Z$$

$$\Gamma_L = \frac{\hbar\omega_0}{\pi} S_L P_L, \; T_{1/2} = \frac{\hbar \ln 2}{\Gamma_L}$$

$$T_{1/2} = \frac{\pi \ln 2}{\omega_0 S_L P_L}$$

$$P_L = \left(1 + \exp\left[\frac{2}{\hbar}\int_{R_0}^{R_{Jl}} \sqrt{2\mu(V(R,\eta_Z) - Q)} dR\right]\right)^{-1}$$



Spectroscopic factor for SF

The SF decay width is

$$\Gamma_{SF} = \sum_L \Gamma_L = \frac{\hbar\omega_0}{\pi} \sum_L S_L P_L$$

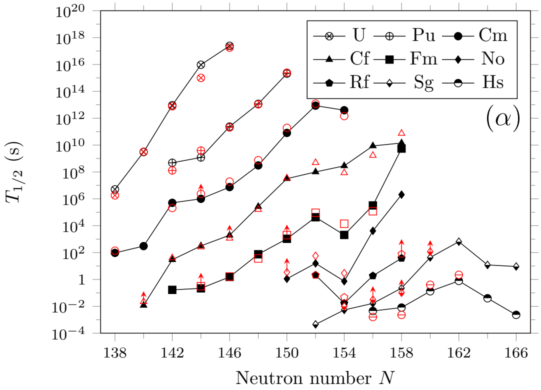
For SF region $P_L = 1$, so:

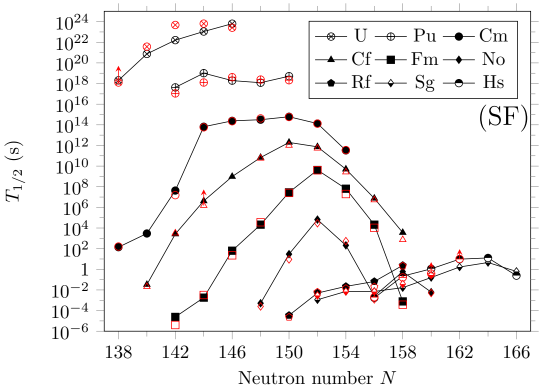
$$\Gamma_{SF} = \frac{\hbar\omega_0}{\pi} \sum_L S_L = \frac{\hbar\omega_0}{\pi} S_{SF},$$

and the spectroscopic factor S_{SF} for SF:

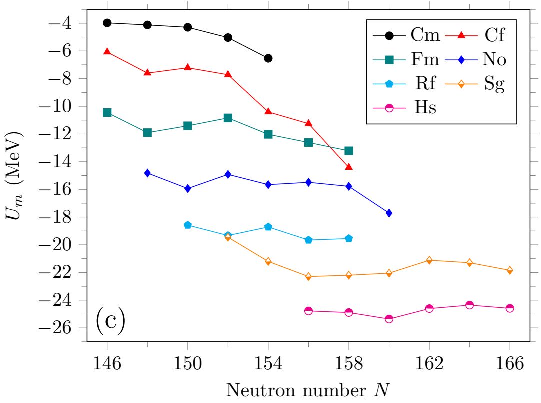
$$S_{SF} = \sum_L S_L,$$

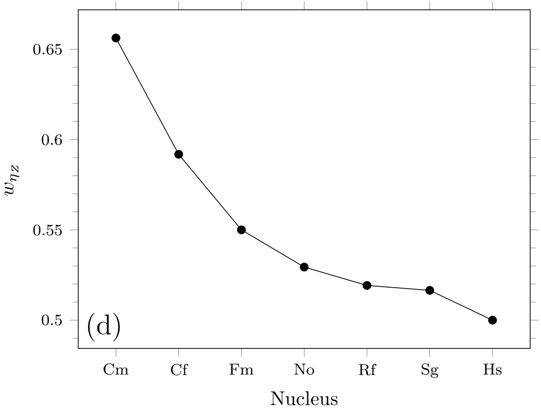
Even-even nuclei half-lives



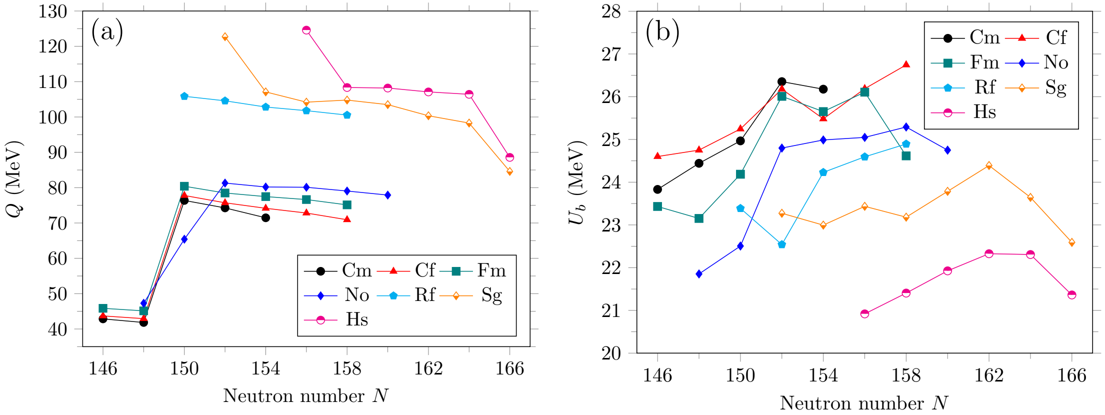


Driving potential characteristics



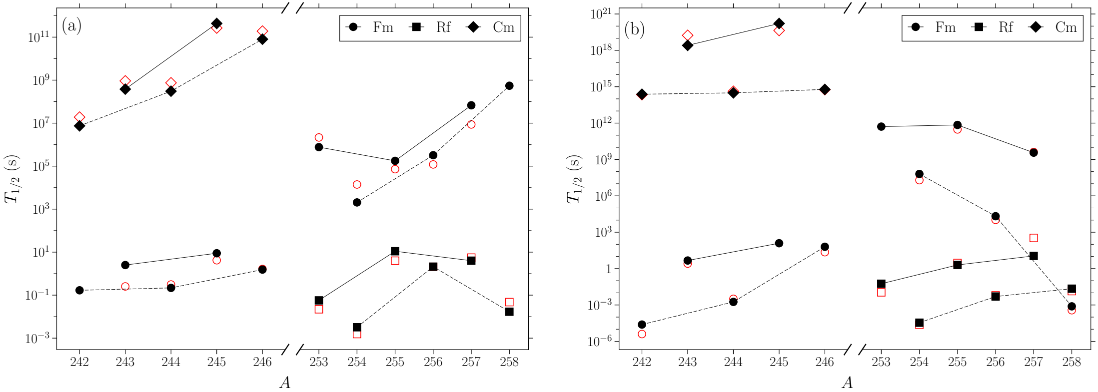


Driving potential characteristics

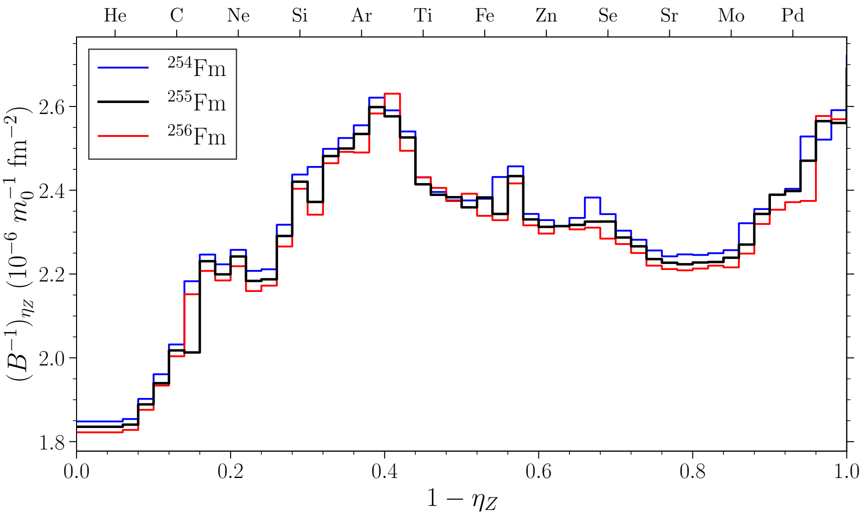


$$Q = (Q_M - Q_L - Q_H), \text{ for } \eta_Z \text{ at } U_b$$

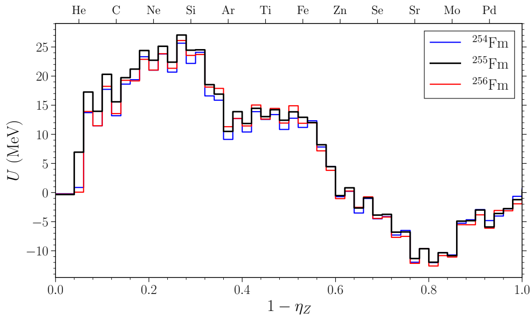
Even-odd nuclei half-lives

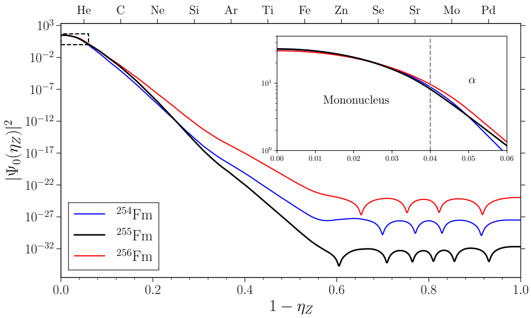


HF origins. Inertia parameter influence



Driving potential influence





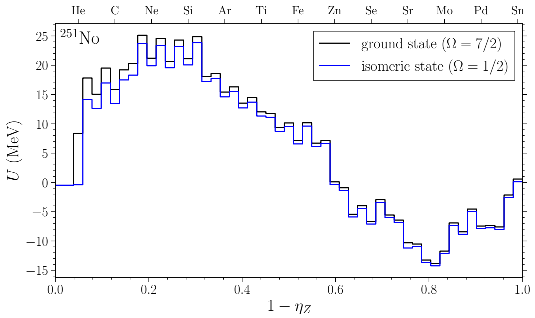
Rotational part influence

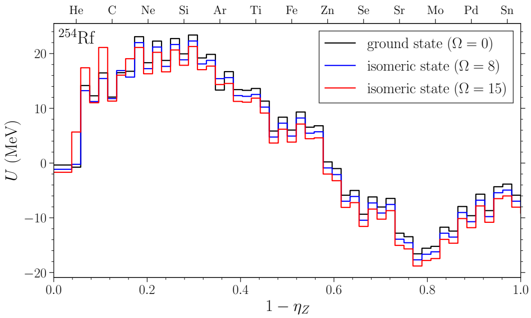
	Ω	S_α	$S_\alpha^{\Omega=0}$	$T_{1/2}$, s	$T_{1/2}^{\Omega=0}$, s	$T_{1/2}^{\text{est}}$, s
^{243}Cm	$5/2$	0.0526	0.0707	2.57×10^{18}	1.02×10^{14}	2.75×10^{14}
^{245}Cm	$7/2$	0.0428	0.0947	1.65×10^{20}	7.34×10^{14}	4.35×10^{14}
^{243}Fm	$7/2$	0.0712	0.0904	3.51	3.14×10^{-4}	2.08×10^{-4}
^{255}Fm	$7/2$	0.0527	0.0816	3.01×10^{11}	1.62×10^{6}	1.16×10^{6}
^{257}Fm	$9/2$	0.0481	0.0888	4.13×10^{9}	1.19	4.02
^{255}Rf	$9/2$	0.0691	0.0930	2.00	2.95×10^{-3}	4.14×10^{-4}
^{257}Rf	$1/2$	0.0893	0.0918	1.11×10^{1}	3.99×10^{-2}	1.05×10^{-2}

$$T_{1/2} = F \cdot T_{1/2}(\Omega = 0), F = \exp\left[\frac{c \cdot \Omega(\Omega+1)}{\sqrt{(B^{-1})_{\eta Z_\alpha}}}\right], \ c = 0.086 \ \mathrm{MeV}^{-1/2}\mathrm{s}^{-1}$$

Nucleus	Ω	$T_{1/2}(\Omega = 0)$ (s)	F	$T_{1/2}^{\mathrm{fit}}$ (s)	$T_{1/2}^{exp}$ (s)
^{243}Cm	5/2	1.02×10^{14}	3.47×10^{3}	3.54×10^{17}	2.57×10^{18}
^{243}Fm	7/2	3.14×10^{-4}	1.20×10^{4}	3.77	4.64
^{245}Cm	7/2	7.34×10^{14}	2.63×10^{6}	1.93×10^{21}	1.65×10^{20}
^{255}Fm	7/2	1.62×10^{6}	7.72×10^{5}	1.25×10^{12}	7.04×10^{11}
^{255}Rf	9/2	2.95×10^{-3}	3.17×10^{4}	9.38×10^{1}	2.00
^{257}Fm	9/2	1.19	3.33×10^{8}	3.96×10^{8}	3.64×10^{9}
^{257}Rf	1/2	2.02×10^{-2}	1.59	3.21×10^{-2}	1.15×10^{1}

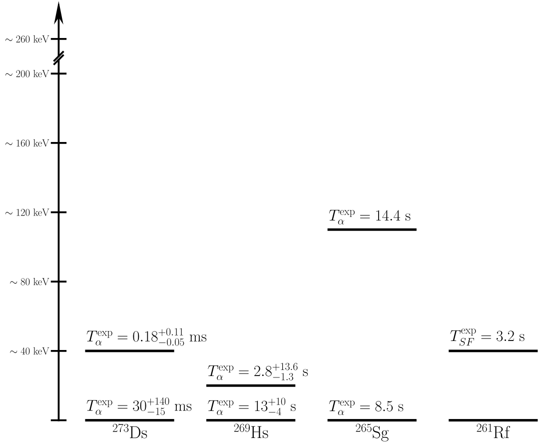
Isomers decay





Decay chains ^{273,275}Ds

[Yu. Ts. Oganessian, V. K. Utyonkov *et al.* Phys. Rev C 109, 054307 (2024)]



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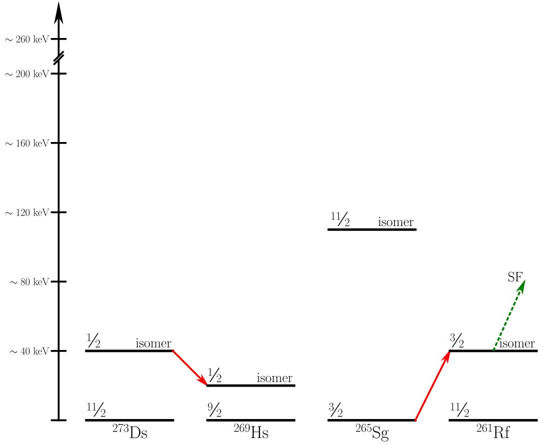

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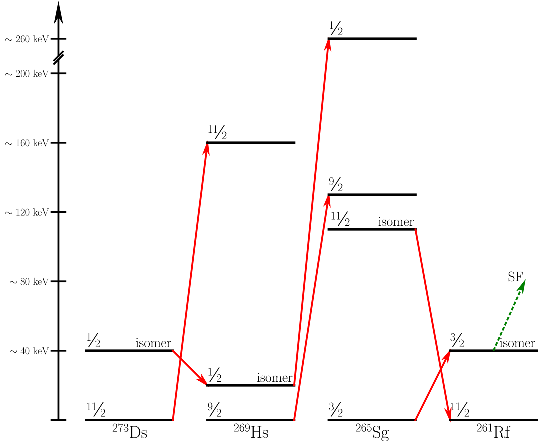

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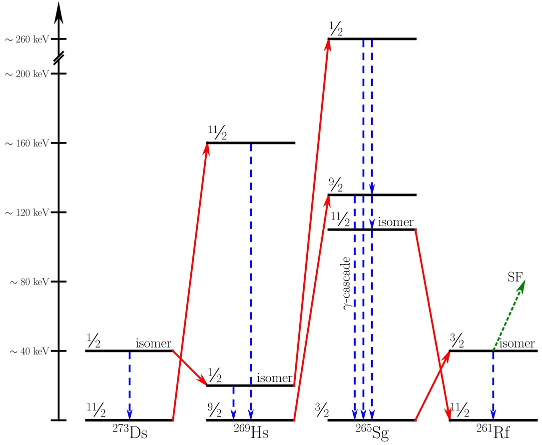

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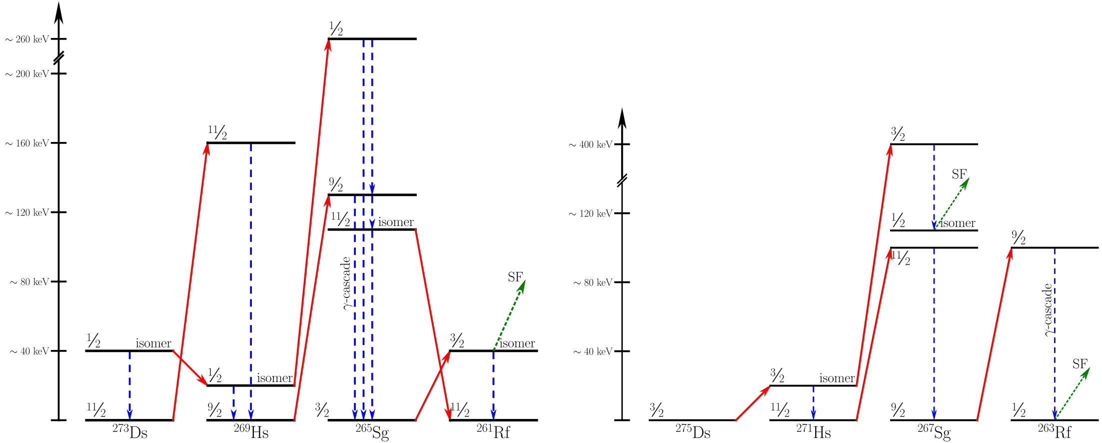

Thank you for your attention