Stability of Nobelium isotopes against decay

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Introduction:

In the region of trans-fermium elements the nuclear shell structure acquires special importance for the nuclear stability as the fission barriers decreases to zero. The investigation of the radioactive decay properties is one of the main directions of modern nuclear physics and has recently made great progress due to the use of efficient detector arrays. We have calculated the binding energy (B.E.) hence Q-value of even-even isotopes of Nobelium (Z =102, A = 234-312) within relativistic mean field model (RMF) [1-3] with NL3* force parameter [4].

Theoretical Formulation:

Modified Royer Formula (MROYER)

To calculate $\mathrm{Log_{10}T_{1/2}}(\alpha)$ we use modified Royer formula by Akrawy *et al.*[5]

$$\mathbf{Log_{10}T_{1/2}\alpha\ (s) = a + b\ A^{1/6}\sqrt{Z} + \frac{cZ}{\sqrt{Q_\alpha}} + dI + eI^2}$$

Where $I = \frac{N-Z}{A}$ and a , b , c , d ,are constant parameters taken from royer formula pdf .Here Q^{α} is the energy released during alpha decay .

Modified Universal Decay Law (MUDL)

By adding the asymmetry term to Universal decay law it gets modified and known as modified universal decay law [6], Which is

$$Log_{10}^{T_{1/2}^{\alpha}} = a\ z_\alpha z_d\sqrt{\frac{A}{Q_\alpha}} + b\sqrt{AZ_\alpha Z_d(A_d^{\frac{1}{3}} + A_\alpha^{\frac{1}{3}})} + c + dI + eI^2$$

Here $A = \frac{A_d A_\alpha}{A_\alpha + A_d}$ where A_d and A_α are mass number of daughter and alpha particle respectively , $I = \frac{N-Z}{A}$ is the asymmetry term, a,b,c,d,e are constant parameters taken from [6]

Spontaneous Fission

The formula for $T_{1/2}$ of spontaneous fission [7] is

$$T_{sf}^{1/2} = \exp\{2\ \pi[c_0 + c_1 A + c_2 z^2 + c_3 z^4 + c_4(N-z)^2 - \frac{z^2}{A^{\frac{1}{3}}}(0.13323 - 11.64)]\}$$

This is valid for even-even nuclei ,here Z,N and A are atomic number ,neutron number and mass number respectively .c_0 , c_1, c_2, c_3, c_4 are constant parameters from [7]

Universal Decay Law (UDL)

To calculate the half life of Cluster decay ($T_{1/2}$) from Z=102 for ^{12}C & ^{14}C (instead of α)respectively using Universal decay law

$$Log_{10}^{T_{1/2}^{\alpha}} = a\ z_\alpha z_d\sqrt{\frac{A}{Q_\alpha}} + b\sqrt{AZ_\alpha Z_d(A_d^{\frac{1}{3}} + A_\alpha^{\frac{1}{3}})} + c$$

Here all the symbols have usual meaning ,&a,b,c are constant parameters taken from [6]

Conclusion:

From the Table-1, it is clear that favourable decay mode for most of the nuclei is spontaneous fission except Z=102,N=152,154. Our study indicates a constant deformation in the isotope chain of nobelium around the neutron shell closure N = 152 and /or 154.

References:

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Table:1

A	N	$LogT_{1/2}(\alpha)$ (s) (MROYER)	$LogT_{1/2}(\alpha)$ (s) (MUDL)	$LogT_{1/2}$(s) SF	$LogT_{1/2}$ (s) ($^{12}_{6}C$) (UDL)	$LogT_{1/2}$ (s) ($^{14}_{6}C$) (UDL)	Favourable Decay Mode
234	**132**	**-5.264**	**-6.04141**	**-99.7196**	**0.2328**		**SF**
236	**134**	**-4.363**	**-5.0731**	**-81.6644**	**3.286**	**8.477**	**SF**
238	**136**	**-2.133**	**-2.72638**	**-65.262**	**8.573**	**12.647**	**SF**
240	**138**	**-1.239**	**-1.77889**	**-50.5117**	**13.105**	**18.583**	**SF**
242	**140**	**-1.411**	**-1.94892**	**-37.4128**	**17.298**	**22.52**	**SF**
244	**142**	**-0.692**	**-1.1944**	**-25.9648**	**18.186**	**26.569**	**SF**
246	**144**	**0.43**	**-2.34677**	**-16.1659**	**19.216**	**26.343**	**SF**
248	**146**	**9.351**	**9.27794**	**-8.0159**	**25.538**	**31.41**	**SF**
250	**148**	**4.092**	**3.78129**	**-1.5138**	**23.822**	**27.699**	**SF**
252	**150**	**3.748**	**3.4079**	**3.3410**	**25.934**	**27.481**	**SF**
254	**152**	**5.106**	**4.8060**	**6.5489**	**27.468**	**27.715**	**α**
256	**154**	**6.558**	**6.29958**	**8.1112**	**28.137**	**27.281**	**α**
258	**156**	**8.336**	**8.1293**	**8.0282**	**30.928**	**26.618**	**SF**
260	**158**	**10.642**	**10.50589**	**6.3007**	**35.649**	**28.242**	**SF**
262	**160**	**12.378**	**12.28477**	**2.9294**	**40.452**	**31.105**	**SF**
264	**162**	**13.806**	**13.7395**	**-2.0852**	**44.21**	**33.794**	**SF**
266	**164**	**10.395**	**10.13927**	**-8.7425**	**44.194**	**33.032**	**SF**
268	**166**	**10.366**	**10.06749**	**-17.0417**	**44.259**	**31.592**	**SF**
270	**168**	**11.565**	**11.27387**	**-26.9828**	**45.434**	**31.567**	**SF**
272	**170**	**15.465**	**15.2973**	**-38.5644**	**48.458**	**32.83**	**SF**
274	**172**	**20.738**	**20.7522**	**-51.7862**	**57.292**	**38.692**	**SF**
276	**174**	**16.871**	**16.6623**	**-66.6478**	**63.531**	**43.346**	**SF**
278	**176**	**20.651**	**20.5544**	**-83.1485**	**63.022**	**47.643**	**SF**
280	**178**	**22.615**	**22.5485**	**-101.2881**	**64.07**	**46.582**	**SF**
282	**180**	**15.258**	**14.8073**	**-121.0658**	**61.784**	**41.93**	**SF**
284	**182**	**18.348**	**17.9731**	**-142.4810**	**60.116**	**40.631**	**SF**
286	**184**	**17.138**	**16.6465**	**-165.5337**	**57.411**	**37.705**	**SF**
288	**186**	**7.174**	**6.1748**	**-190.2229**	**49.414**	**29.698**	**SF**
290	**188**	**17.899**	**17.3098**	**-216.5485**	**48.423**	**28.126**	**SF**
292	**190**	**22.602**	**22.15337**	**-244.5099**	**44.008**	**26.487**	**SF**
294	**192**	**22.895**	**22.39033**	**-274.1065**	**58.526**	**22.735**	**SF**
296	**194**	**27.426**	**27.05203**	**-305.3388**	**69.645**	**31.354**	**SF**
298	**196**	**38.466**	**38.51353**	**-338.2048**	**81.453**	**38.563**	**SF**
300	**198**	**51.067**	**51.60446**	**-372.7050**	**101.482**	**45.553**	**SF**
302	**200**	**55.602**	**56.26916**	**-408.8390**	**124.954**	**54.202**	**SF**
304	**202**	**72.307**	**73.64801**	**-446.6063**	**155.018**	**64.148**	**SF**
306	**204**	**84.864**	**86.69298**	**-486.006**	**170.174**	**73.47**	**SF**
308	**206**	**93.791**	**95.94593**	**-527.039**	**179.555**	**75.146**	**SF**
310	**208**	**127.05**	**130.62323**	**-569.7039**	**195.714**	**76.585**	**SF**
312	**210**	**132.164**	**135.89143**	**-614.0005**	**205.551**	**76.507**	**SF**