Prediction for superheavy element Z = 120

G. Saxena[1]* and M. Kaushik[2]

[1]*Department of Physics, Govt. Women Engg. College, Ajmer - 305002, INDIA and*
[2]*Deptartment of Physics, Shankra Institute of Technology, Kukas, Jaipur - 302006, INDIA*

The synthesis of superheavy nuclei has received remarkable attention in recent years with the advancement of modern accelerators and suitable detectors. Recently, in 2010, synthesis of new element 117 with the isotopes $^{293}117$ and $^{294}117$ along with their α-decay chains have been reported by Oganessian et al. [1]. The heaviest element 118 was synthesized with the cross section of about 1 pb in fusion of ^{48}Ca with heaviest available target of ^{249}Cf [2]. Future progress for synthesis of superheavy element Z > 118 is going on, specially for the element Z = 120. Some predictions have already made by Zagrebaev et al. from different nuclear reactions (fusion of stable and radioactive nuclei, multi-nucleon transfers and neutron capture) [3]. Predictions are made by A. Sobiczewski [4] for the decay chains of the nuclei $^{298}120$ and $^{299}120$ which were planned to be synthesized in the nuclear reaction ^{54}Cr + ^{248}Cm, in an experiment to be performed in Darmstadt (Germany). More recently, occurrence of the spherical shell closures with Z = 120, 138 and N = 172, 184, 228 and 258 for superheavy nuclei in the framework of the relativistic Hartree-Fock-Bogoliubov (RHFB) theory has been discussed by J. J. Li et al. and predicted the nuclide $^{304}120$ as the next spherical doubly magic one beyond ^{208}Pb [5].

The existence of superheavy nuclei is controlled mainly by the alpha decay and spontaneous fission. The superheavy nuclei which have small alpha decay half-life compared to spontaneous fission half-life will survive fission and can be detected in the laboratory through alpha decay. Encouraged by the study in the direction to discover element Z = 120, we have studied alpha decay half-life and spontaneous half-life of some superheavy elements with Z = 120 to make an attempt of prediction for nuclide with Z = 120. This kind of theoretical study may provide a very helpful insight to conduct experiments to realize the presence of these nuclei.

For our study α-decay half-lives are calculated with the use of a recently proposed simple phenomenological formula [6]:

$$log_{10}T_\alpha(Z;N) = aZ[Q_\alpha(Z;N)-E_i]^{-1/2}+bZ+c \quad (1)$$

where the parameters a,b,c are a = 1.5372; b = -0.1607; c = -36.573 (and the parameter E_i (average excitation energy of the daughter nucleus) is $E_i = 0$ for e-e; $E_i = E_p = 0.113$ MeV for o-e; $E_i = E_n = 0.171$ MeV for e-o; and $E_i = E_p + E_n$ for o-o nuclei. In this formula values of Q_α has been calculated using results of Relativistic Mean Field theory with TMA parameters, which has been proved already as a successful tool for the study of exotic nuclei throughout the periodic chart [7, 8].

The spontaneous fission half-life T_{SF} is calculated using the phenomenological formula proposed by Ren and Xu taken from Ref. [9].

$$log_{10}T_\alpha(Z;N) = 21.08 + C_1\frac{(Z-90-\upsilon)}{A} + C_2\frac{(Z-90-\upsilon)^2}{A} + C_3\frac{(Z-90-\upsilon)^3}{A} + C_4\frac{(Z-90-\upsilon)(N-Z-52)^2}{A} \quad (2)$$

where C_1 = -548.825021, C_2 = -5.359139, C_3 = 0.767379 and C_4 = -4.282220, the seniority term υ was introduced taking the blocking effect of unpaired nucleon on the transfer of many nucleon-pairs during the fission process and υ = 0 for spontaneous fission of even-even nuclei, υ = 2 for odd A and odd-odd nuclei.

*Electronic address: gauravphy@gmail.com

TABLE I: Calculated values of Q_α,α-decay half life T_α and spontaneous fission half life T_{SF} for decay chain of $^{292}120$.

Nucleus	Q_α (MeV)	T_α	T_{SF}	T_{SF}/T_α
$^{292}120$	11.843	5.5 ms	1.3×10^{19}s	2.4×10^{21}
$^{288}118$	11.887	1.2 ms	4.2×10^{11}s	3.5×10^{14}
$^{284}116$	13.075	1.2 μs	3.7×10^{5} s	2.9×10^{11}
$^{280}114$	11.89	84 μs	7.94s	9.3×10^{4}
$^{276}112$	11.224	0.6 ms	3.4 ms	5.2
$^{272}110$	11.009	0.5 ms	25×10^{-6}s	0.05
$^{268}108$	9.3	3.24 s	2.7×10^{-6}s	8.4×10^{-7}

TABLE II: Same as Table 1 but for $^{298}120$.

Nucleus	Q_α (MeV)	T_α	T_{SF}	T_{SF}/T_α
$^{298}120$	11.216	0.17 s	4487.58 s	26864.48
$^{294}118$	11.154	0.06 s	1.3 ms	0.02
$^{290}116$	10.452	0.87 s	1.17×10^{-08} s	1.34×10^{-08}
$^{286}114$	10.595	0.09 s	2.43×10^{-12} s	2.76×10^{-11}
$^{282}112$	10.648	0.01 s	1.03×10^{-14} s	6.68×10^{-13}
$^{278}110$	10.158	0.06 s	7.54×10^{-16} s	1.18×10^{-14}
$^{274}108$	8.945	38.06 s	7.84×10^{-16} s	2.06×10^{-17}

For our study we have chosen four isotopes of Z = 120 to discuss i.e. $^{292}120$, $^{298}120$, $^{299}120$ and $^{304}120$. These isotopes has been examined by various theoretical methods and likely to be observed experimentally [3–5]. We have shown in the Table I, II, III and IV calculated values of α-decay half life T_α and spontaneous fission half life T_{SF} for these isotopes $^{292}120$, $^{298}120$, $^{299}120$ and $^{304}120$ respectively. After comparison from the tables it is seen that T_{SF} are much larger than T_α for the first five nuclei in the decay chain of $^{292}120$, and for $^{298}120$. Whereas for other isotopes $^{299}120$ and $^{304}120$, T_{SF} is rather very small. So it is predicted that $^{292}120$ and $^{298}120$ may be observed in future experiments. Authors would like to thank Prof. H. L. Yadav and Prof. A. Ansari for their unconditional support and guidance.

TABLE III: Same as Table 1 but for $^{299}120$.

Nucleus	Q_α (MeV)	T_α	T_{SF}	T_{SF}/T_α
$^{299}120$	10.939	2.27 s	2.10×10^{-08} s	9.24×10^{-09}
$^{295}118$	11.132	0.17 s	4.52×10^{-13} s	2.52×10^{-12}
$^{291}116$	10.375	4.05 s	2.27×10^{-16} s	5.62×10^{-17}
$^{287}114$	9.829	31.32 s	2.28×10^{-18} s	7.28×10^{-20}
$^{283}112$	10.424	0.15 s	3.82×10^{-19} s	2.43×10^{-18}
$^{279}110$	10.164	0.17 s	8.94×10^{-19} s	5.14×10^{-18}
$^{275}108$	9.154	29.03 s	2.40×10^{-17} s	8.28×10^{-19}

TABLE IV: Same as Table 1 but for $^{304}120$.

Nucleus	Q_α (MeV)	T_α	T_{SF}	T_{SF}/T_α
$^{304}120$	10.089	165.11 s	2.27×10^{-42} s	1.37×10^{-44}
$^{300}118$	10.003	65.49 s	2.81×10^{-46} s	4.30×10^{-48}
$^{296}116$	9.989	16.03 s	1.08×10^{-48} s	6.75×10^{-50}
$^{292}114$	9.538	70.70 s	1.11×10^{-49} s	1.57×10^{-51}
$^{288}112$	8.72	5388.89 s	2.61×10^{-49} s	4.84×10^{-53}
$^{284}110$	8.677	1423.91 s	1.18×10^{-47} s	8.31×10^{-51}
$^{280}108$	8.546	726.95 s	8.69×10^{-45} s	1.19×10^{-47}

References

[1] Yu. Ts. Oganessian et al., Physical Review Letter, **104**, 142502 (2010).

[2] Yu. Ts. Oganessian et al., Phys. Rev. **C 74**, 044602 (2006).

[3] Valeriy Zagrebaev et al., Journal of Physics: Conference Series **420**, 012001 (2013).

[4] A. Sobiczewski, Acta Physica Polonica **42**, 1871 (2011).

[5] Jia Jie Li et al., arXiv:1303.2765v3 (2014)

[6] A. Parkhomenko, A. Sobiczewski, Acta Phys. Pol. **B 36**, 3095 (2005).

[7] D. Singh et al., International Journal of Modern Physics E **21**, 1250076 (2012).

[8] G. Saxena et al., Canadian Journal of Physics **92**, 253 (2014).

[9] Z. Ren, C. Xu, Nucl. Phys. **A 759**, 64 (2005).