α-decay chains relevant with superheavy isotopes $^{270\text{-}318}118$

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Introduction

Understanding the decay modes and knowing the involved half-lives are of prime importance to identify the decay chains of superheavy elements, which are the experimental signature of the formation of the elements in fusion reactions. In the present study α-decay half-lives are found out using coulomb and proximity potential model[1] and spontaneous fission half-life are found out using the formula of Ren et al., [2]. The range of isotopes in which α-decay shall occur are found out by making use of the difference in α-decay half-life and the fission decay half- life as criterion. It is done in the case of 275 even-even isotopes of the isotopic chains from $^{270\text{-}318}118$ to $^{230\text{-}278}98$. From that it has been found that there exist an upper transition point in which α-decay half-life becomes smaller to fission half-life and a lower transition point in which fission decay half-life becomes smaller to α-decay half-life, for all the elements from Z=118 to 98. From the result, probable α-decay chains are elucidated. In the case of few chains which do not cease at Z=98, above type of calculation is carried forward until the point where α-decay is forbidden with negative Q-value (described later) or α-chain ceases with spontaneous fission (SF). Thus we considered decay up to Z=76 .

The model

The interacting potential barrier for a parent nucleus exhibiting exotic decay is given by

$$V = Z_1 Z_2 e^2 / r + V_p(z) + \frac{\hbar^2 l(l+1)}{2\mu r^2}$$

$$P = \exp\{-\frac{2}{\hbar}\int_a^b \sqrt{2\mu(V-Q)}dz\}$$

The possibility to have an α–decay process is:Q=M(A,Z) - M(A_1,Z_1) - M(A_2,Z_2) > 0 where M's are the atomic masses of the parent ,daughter and α–particle, in order.

The α–decay half-life $T_{1/2}$= ln2/νP , where ν is the number of assaults on the barrier per second. SF half-lives are calculated by the formula proposed by Ren at al [2]

$$\mathrm{Log}_{10}[T_{1/2}(\mathrm{yr})] = C_1\frac{(Z-90-\nu)}{A} + C_2\frac{(Z-90-\nu)^2}{A} + C_3\frac{(Z-90-\nu)^3}{A} + C_4\frac{(Z-90-\nu)(N-Z-52)^2}{A} + d$$

where C_1= -548.825021; C_2=-5.359139; C_3=0.767379; C_4=-4.282220; d=21.08;ν=0 for even-even nuclei and ν=2 for odd A and odd-odd nuclei

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Results and discussion

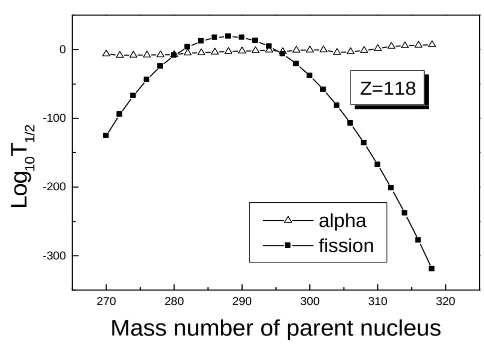

Fig.1. α-decay half life and SF half life for Z=118 isotopes.

If α-decay half-life (denoted as a.h.l) is smaller than SF half-life (denoted as f.h.l), α-decay would occur and if SF half-life is smaller to α- decay half life, SF would take place. Therefore, (a.h.l-f.h.l) is taken as a criterion to know as to which decay shall occur. Provided a.h.l. is smaller, the larger the magnitude of the above quantity, the larger the chance for α-decay to occur.

Of the range of isotopes of each Z value, a window exists where α-decay would occur. In $^{294}118$ to $^{282}118$, $^{290}116$ to $^{278}116$, $^{284}114$ to $^{274}114$, $^{280}112$ to $^{272}112$, $^{276}110$ to $^{268}110$, $^{270}108$ to $^{266}108$, $^{264}106$ to $^{262}106$, $^{260}104$ to $^{258}104$, $^{258}102$ to $^{254}102$, $^{254}100$ to $^{248}100$, $^{250}98$ to $^{242}98$ isotopes, α-decay shall take place.

The transition points have got no definite relationship to magic neutron numbers.

Various isotopes having the same Z value have got different chances of α-disintegration as evinced by the various values of (a.h.l.-f.h.l).

We found that the isotopes associated with 1st (highest) value of each Z are related as α-decay parent and successive daughters. Thus a chain of nuclei exists with parent and many successive daughters. In a similar manner, generally, nuclei associated with the 2nd values, the 3rd values, the 4th values etc. form their own chains.

The chains of α-decay in order of probability are shown below:

first : $^{288}118 \rightarrow .. ^{276}112 \rightarrow .. ^{264}106 \rightarrow ^{260}104 \rightarrow .. ^{252}100 \rightarrow .. ^{208}78 \rightarrow$ SF # second : $^{286}118 \rightarrow .. ^{270}110 \rightarrow .. ^{258}104 \rightarrow ^{254}102 \rightarrow ^{250}100 \rightarrow .. ^{202}76 \rightarrow$ α-decay forbidden # third : $^{290}118 \rightarrow .. ^{270}108 \rightarrow ^{266}106 \rightarrow$ SF # fourth : $^{284}118 \rightarrow .. ^{268}110 \rightarrow ^{264}108 \rightarrow$ SF # fifth : $^{292}118 \rightarrow .. ^{276}110 \rightarrow ^{272}108 \rightarrow$ SF # sixth : $^{282}118 \rightarrow .. ^{270}112 \rightarrow$ SF # seventh : $^{294}118 \rightarrow ^{290}116 \rightarrow ^{286}114 \rightarrow$ SF # eighth : $^{258}102 \rightarrow .. ^{254}100 \rightarrow ^{250}98 \rightarrow .. ^{214}80 \rightarrow$ SF # ninth : $^{248}100 \rightarrow .. ^{232}92 \rightarrow .. ^{216}84 \rightarrow .. ^{204}78 \rightarrow$ α-decay forbidden # tenth: $^{242}98 \rightarrow .. ^{226}90 \rightarrow .. ^{210}82 \rightarrow ^{206}80 \rightarrow$ α-decay forbidden.

Production of isotopes which belongs to the most probable α-decay chain, which has got the largest (a.h.l-f.h.l) magnitude in each value of Z, shall be, comparatively most easy to be accomplished with that Z value. Production of isotope which belongs to chains subsequent to the first one shall be having a lesser degree of easiness. In the case of isotopes where a.h.l.> f.h.l., fission shall occur with such rapidity that the production of elements can hardly be identified. These shall serve as guiding aspects for future experiments.

For the production of elements of various Z values, isotopes belonging to the corresponding α-decay window might be attempted. Relative easiness mentioned here in production of isotopes is to be understood in the context of using projectile nuclei of same energy and having the same beam dosage.

Fission half-lives of isotopes revealed that maximum values of half-lives are obtained to those having N-Z=52, in the case of elements with Z=118 to Z≥90. This is in true conformity with the experimental observation that there is long life time for SF of elements having N=Z+52 with Z≥90[3].

However, for elements with 90>Z>76 a diametrically opposite effect is found to exist. This is worthy of considering for experimental verification.

The $^{294}118$ which has been produced at J.I.N.R., Dubna falls within the range predicted here for Z = 118 and belongs to the 7th chain. Decay chains originating from $^{294}118$, consisted of 2 or 3 consecutive α-decays and terminated by a spontaneous fission were observed. The present prediction mentions that 2 consecutive α-decays would take place and then spontaneous fission would occur.

In, officially recognized first-productions $^{291}116$,$^{290}116$(J.I.N.R.,Dubna); $^{287}114$, $^{286}114$ (J.I.N.R.,Dubna); ^{277}Cn(G.S.I., Darmstadt) ; ^{269}Ds,^{271}Ds (G.S.I, Darmstadt); ^{265}Hs (G.S.I., Darmstadt and Dubna); ^{263}Sg; $^{260-259}$Rf(Dubna), ^{257}Rf, ^{259}Rf, ^{258}Rf (Berkeley); ^{254}No(Dubna); ^{255}Fm(University of California), ^{254}Fm (L.B.N.L.), (at present A=250, 252, 253, 256); ^{245}Cf (University of California,) (at present A=246,248,249,250.252,254) are obtained.

Most of the isotopes produced are either member of the presented chains, or comes within the range predicted. Also chains found experimentally have got good closeness to the presented ones. All these indicate that our scheme of decay is in good agreement with available experimental facts. This shall pave way for discovering newer isotopes in the heavy and superheavy regions.

References

[1] K.P.Santhosh and Antony Joseph, Pramana-J.Phys. 58,**611**(2002)

[2] Zhongzhou Ren, Chang Xu *Nucl. Phys.* **A 759** 64(2005)

[3] Chang Zu and Zhong Zhou Ren *Phy Rev* C**71**, 014309 (2005)