Available online at www.sciencedirect.com

ScienceDirect

Nuclear Physics A 929 (2014) 20–37

NUCLEAR PHYSICS A

www.elsevier.com/locate/nuclphysa

Heavy particle radioactivity from superheavy nuclei leading to $^{298}114$ daughter nuclei

K.P. Santhosh *, B. Priyanka

School of Pure and Applied Physics, Kannur University, Swami Anandatheertha Campus,
Payyanur 670 327, Kerala, India

Received 19 March 2014; received in revised form 14 May 2014; accepted 26 May 2014

Abstract

The feasibility for the alpha decay and the heavy particle decay from the even–even superheavy (SH) nuclei with $Z = 116$–124 has been studied within the Coulomb and proximity potential model (CPPM). Our predicted half lives agree well with the values evaluated using the Universal formula for cluster decay (UNIV) of Poenaru et al., the Universal Decay Law (UDL) of Qi et al., and the Scaling Law of Horoi et al. The spontaneous fission half lives of the corresponding parents have also been evaluated using the semi-empirical formula of Santhosh et al. Within our fission model, we have studied the cluster formation probability for various clusters and the maximum cluster formation probability is found for the decay accompanying $^{298}114$. In the plots for $\log_{10}(T_{1/2})$ against the neutron number of the daughter in the corresponding decay, the half life is found to be the minimum for the decay leading to $^{298}114$ ($Z = 114$, $N = 184$). Most of the predicted half lives are well within the present upper limit for measurements ($T_{1/2} < 10^{30}$ s) and the computed alpha half lives for ^{290,292}Lv agree well with the experimental data.

Keywords: Heavy particle decay; Alpha decay; Superheavy nuclei; Spontaneous fission

---

* Corresponding author. Tel.: +91 9495409757; fax: +91 4972806402.
E-mail address: drkpsanthosh@gmail.com (K.P. Santhosh).

http://dx.doi.org/10.1016/j.nuclphysa.2014.05.015
0375-9474/

1. Introduction

The radioactive decays, especially the alpha decay and the heavy particle decay, have been a topic of great interest among both the experimentalists and the theoreticians. The exotic decay of particle heavier than the alpha particle, referred to as the cluster decay which comes under the class of cold decays, contradicts the hot fission through its exclusive feature of the formation of the decay products in the ground or the lowest excited states. This well established, rare, cold (neutron-less) mode of decay was first predicted by Sandulescu et al., [1] in 1980 on the basis of quantum mechanical fragmentation theory [2], numerical and analytical superasymmetric fission models, as well as by extending the alpha decay theory to heavier fragments [3]. The first experimental confirmation of such decay was given by Rose and Jones [4] in 1984 through the radioactive decay of ^{223}Ra by the emission of ^{14}C. Later, Barwick et al., [5] observed the decay of ^{24}Ne from ^{232}U, for the first time using the solid state nuclear track detectors (SSNTD) and this method is found to be the most effective for cluster decay studies. Extensive experimental search for cluster emission from various parents in the trans-lead region has led to the detection of about 20 cases of spontaneous emission of clusters ranging from ^{14}C to ^{34}Si, from ^{221}Fr to ^{242}Cm [6]. The emission of heavier fragments from heavier parent nuclei in such a way that daughter nuclei are always doubly magic or nearly doubly magic (i.e. ^{208}Pb or closely neighboring nuclei) can be regarded as the far-fetched feature of these emissions.

The studies on the competition of α decay and cluster decay in the region of the heaviest superheavy (SH) nuclei have turned out to be a hot topic among both theoreticians and experimentalists, as these studies could provide valuable information regarding the stability, mode of decay and structure of these nuclei. The investigations for the existence of SH nuclei beyond the valley of stability and the urge to reach the island of stability around $Z = 120, 124$ or 126 and $N = 184$ [7] have been progressing through a series of cold fusion experiments (performed at GSI, Darmstadt and RIKEN, Japan) [8,9] and hot fusion reactions (performed at JINR-FLNR, Dubna) [10]. The successful synthesis of the heavy elements with $Z = 107$–112 at GSI, Darmstadt [8,11–13], is to be recalled as the first triumph in the production of SH nuclei. Later on, Oganessian et al., in collaboration with the LLNL researchers [14–18], synthesized the SH nuclei with $Z = 113$–116 and 118 along with the isotopes of $Z = 107$–112 at JINR-FLNR, Dubna and very recently they were also successful in the synthesis of two isotopes of $Z = 117$ [19]. Morita et al. have identified an isotope of $Z = 113$ at RIKEN, Japan [9,20] and have also reconfirmed [21] the existence of $Z = 110, 111,$ and 112 reported earlier by GSI group. The majority of proton-rich SH nuclei are identified through the α decay chains and up to now, only α decay, β decay, and spontaneous fission of SH nuclei have been observed. Even though new experiments are presently running at GSI, Darmstadt and attempts to produce $Z = 120$ are reported [22], the heaviest element known so far is $Z = 118$ [17,23], and any further progress in the synthesis of new elements with $Z > 118$ is not quite evident. The low probability of formation, and the separation of the short lived compound nucleus from the very high flux of incident projectile nuclei can be quoted [24] as the main experimental difficulties in identifying the new SH nuclei.

Extensive theoretical studies have been performed on both the cluster decay and alpha decay from heavy and SH nuclei within various theoretical models. A truly universal formula, valid for the radioactivity of all clusters, including α particles was given by Qi et al., [25,26] on the basis of the microscopic mechanism of the charged particle emission. Since 1984, the Analytical Superasymmetric Fission Model (ASAFM) has been successfully used [27,28] to compute half life for alpha and cluster radioactivity in heavy and superheavy nuclides. Recently Poenaru et al., [24] have changed the concept of heavy-particle radioactivity (HPR) to allow emitted particles