Cluster radioactivity of $^{218-236}U$ isotopes

G.Shivakumara swamy[1] and T K Umesh[2*]
[1]J S S College for women (Autonomous), Mysore-570009
[2]Department of studies in Physics, University of Mysore, Mysore-06, India
*email:tku@physics.uni-mysore.ac.in

Introduction

The spontaneous emission of nuclei heavier than alpha particle from radioactive nuclei without accompanied by the emission of neutrons is called cluster radioactivity (CR) or exotic radioactivity. The process of emission of clusters heavier than alpha particle is called cluster decay or exotic decay. In 1980, Sandulescu et al [1] predicted cluster radioactivity(CR) on the basis of quantum mechanical fragmentation theory. In 1984,for the first time, Rose and Jones [2] experimentally observed ^{14}C emission from ^{223}Ra using solid state counter telescope. Subsequently several cluster decay modes from heavier parent nuclei in the trans-lead region have been experimentally confirmed. In the case of $^{230,232-236}U$ isotopes, the emission of ^{22}Ne, ^{24}Ne, ^{25}Ne, ^{26}Ne, ^{28}Mg, ^{29}Mg and ^{30}Mg clusters have been experimentally confirmed [3].

A survey of literature reveals the fact that half-life values for different modes of cluster decay from different isotopes of uranium have been calculated using different theoretical models such as the Analytical super asymmetric fission model(ASAFM), Preformed cluster model (PCM), Coulomb and Proximity potential model (CPPM) etc., [4-12]. Recently, some semi-empirical formulae, i.e, single line of Universal curve (UNIV) for alpha and cluster radioactive decay [13] and Universal Decay law (UDL)[14] have also been proposed to explain cluster decay data. The emission of neon clusters from isotopes of uranium leads to the formation of daughter nuclei in the vicinity of doubly magic nucleus, ^{208}Pb. So, in the present work, we have calculated half-life values for cluster decay of ^{24}Ne cluster from even A uranium ($^{218-236}U$) isotopes. The logarithmic half lives calculated were expected to throw light on the role of ^{208}Pb (which is a doubly magic nucleus) and provide evidences for the possible nuclear shell effects in cluster radioactivity.

Calculations

In the present work, we have calculated the logarithmic half lives for ^{24}Ne cluster emission from $^{218-236}U$ isotopes by using three different approaches which were based on, UNIV, UDL and the CPPM model respectively.

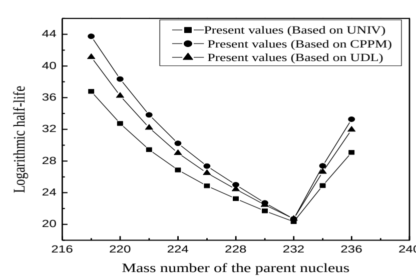
The UNIV calculations were made by using equation (4) of Poenaru et al [13].

Our CPPM based calculations were similar to those described in our recent papers [15-16].

The UDL calculations were made by using equation (12) of Qi et al [14].

Results and discussion

The UNIV, CPPM and UDL based values of the logarithmic half-lives ($\log_{10}(T_{½})$) for ^{24}Ne cluster decay from $^{218-236}U$ isotopes so obtained were designated as 'a', 'b'and 'c' respectively and listed in Table 1. In all the three calculations, the Q-values used were taken from the Q-value calculator which is based on the atomic mass tables of Audi et al 2003 [17-18]. The logarithmic half-lives listed in table 1 were plotted as a function of mass number of the corresponding parent nucleus. This was done for all the uranium isotopes of present interest($^{218-236}U$).



The resulting plots are as shown in Fig.1.

All the three plots indicate that the logarithmic half lives for ^{24}Ne cluster emission systematically decrease with increasing mass number of the parent from ^{218}U upto ^{232}U registering a minimum value for the decay of

^{232}U isotope with ^{24}Ne emission which leads to the formation of doubly magic nucleus, ^{208}Pb. Thereafter, the plots show a systematic increase in the logarithmic half lives as the mass number of U increases beyond 232.

Table.1 Calculated logarithmic half-life values for ^{24}Ne cluster emission from $^{218-236}$U isotopes.

Parent nucleus	Daughter Nucleus	Q-value (MeV)	$\log T_{1/2}$ values
^{218}U	^{194}Pb	52.082	36.78^{a} 43.74^{b} 41.12^{c}
^{220}U	^{196}Pb	54.341	32.73a 38.34b 36.23c
^{222}U	^{198}Pb	56.301	29.43a 33.82b 32.20c
^{224}U	^{200}Pb	57.908	26.87a 30.23b 29.01c
^{226}U	^{202}Pb	59.214	24.86a 27.35b 26.49c
^{228}U	^{204}Pb	60.286	23.25a 25.00b 24.44c
^{230}U	^{206}Pb	61.351	21.70a 22.70b 22.46c
^{232}U	^{208}Pb	62.31	20.34a 20.69b 20.71c
^{234}U	^{210}Pb	58.826	24.89a 27.38b 26.64c
^{236}U	^{212}Pb	55.945	29.08a 33.27b 31.95c

Conclusions

Thus, we may conclude that the ^{24}Ne cluster emission from ^{232}U isotope leads to the formation of doubly magic daughter nucleus ^{208}Pb. Hence, it has the lowest half-life value. Also, this decay mode has been experimentally confirmed.

These observations stress the role of doubly magic ^{208}Pb nucleus in trans-lead cluster radioactivity and confirm the existence of nuclear shell effect.

References

[1] A Sandulescu, D N Poenaru and Greiner W, Sov. J. Part. Nucl. **11,** 528 (1980)

[2] H J Rose and G A Jones Nature. **307,** 245 (1984)

[3] R Bonetti and Guglielmetti, Romanian reports in Physics, **59,** 301(2007)

[4] D N Poenaru, M Ivscu, A Sandulescu and W Greiner, J.Phys.G.Nucl.Phys.**10,**183 (1984)

[5] Yi-Jin and W J Swiatecki, Nucl.Phys.A,**438,** 450 (1985)

[6] S. S. Malik and R. K. Gupta, Phys. Rev. C **39**, 1992 (1989).

[7] B Buck, A C Merchant , S M Perez and P Tripe, J.Phys.G:Nucl.part.Phys.**20,**351 (1994)

[8] K P Santhosh, R K Biju and Antony Joseph,J..Phys.G:Nucl.Part.Phys.**35,** 85102 (2008)

[9] Sushil kumar, Ramna Rani and Rajesh Kumar, .Phys.G:Nucl.Part.Phys.**36**,015110 (2009)

[10] K.P Santhosh,R K Biju and Sabina Sahadevan, Nucl.Phys.A, **838**,38 (2010)

[11] BirBikram Singh and S K Patra, Phys.Rev.C,**82,** 014607 (2010)

[12] Zongqiang Sheng, Dongdong Ni and ZhongzhouRen, J.Phys.G:Nucl.Part.Phys. **38,** 055103(2011)

[13] D N Poenaru, R A Gherghescu and W Greiner Phys. Rev. C **83** 014601 (2011)

[14] C Qi, F R Xu, R J Liotta, R Wyss, M Y Zhang, C Asawatangtrakuldee and D Hu Phys .Rev. C. **80,** 044326 (2009)

[15] G Shivakumara swamy and T K Umesh Phys. At. Nucl. **74,** 675 (2011)

[16] G Shivakumara swamy and T K Umesh, International Journal of Modern Physics E**20,**(2011) (accepted and to be published) DOI No:10.1142/S021830131102023X

[17] Audi G, Wapstra A H and Thibault C, Nucl.Phys. A. **729,** 337 (2003)

[18] Wapstra A H, Audi G and Thibault C Nucl. Phys. A **729,** 129 (2003)