Half Lives of the α - Decay Chains of Recently Reported New Isotopes

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Introduction

Heavy-ion reactions have been playing a crucial role in producing and studying nuclei far away from the stability line. Recently, five new neutron deficient unstable isotopes produced in the collisions of ^{48}Ca + ^{248}Cm, carried out at GSI have been reported [1]. The decay energies (E_α) and half-lives of the respective α - decay chains of these new isotopes, $^{216}_{92}$U, $^{223}_{95}$Am, $^{219}_{93}$Np, $^{229}_{95}$Am and $^{233}_{97}$Bk have been measured. Here, we present and discuss the α - Decay lifetimes, calculated in the WKB approximation which requires Q - values and α - daughter potential ($V_{\alpha-D}$). The potential $V_{\alpha-D}$ is calculated in the double folding model. For details see ref. [2].

1. Details of the calculation, Results and Discussion

The calculated, employing Lagrangian parameter set $NL3^*$ [3], in the Relativistic Mean Field (RMF) framework [4], the Q - values of α - decay of the new isotopes and their daughter nuclei along with those obtained by Moller and Nix ([5]), labelled as $NL3^*$ and MN respectively, are listed in table I. The experimental Q - value of the new isotope ^{223}Am is not available. The corresponding values of the rest of the nuclei taken from the live chart [6] marked by superscript (*) are also shown in the same table.for completeness. The inspetion of table reveals that both $NL3^*$ and MN Q - values of α - decay are similar and reasonably agree with the experiment, though the agreement of the MN values with the experiment is relatively superior. Quantitatively, the deviations rise even up to 3 MeV in some cases.

As stated before, the α - decay half-lives are calculated in the WKB approximation. The required α - daughter nucleus potential ($V_{\alpha D}$) is calculated by folding the effective nucleon nucleon potential (M3Y interaction + pseudo potential to incorporate the exchange effects) with the calculated RMF density distributions of the daughter nucleus. The density of α - particle is assumed to be of standard Gaussian shape. It is known (e.g. see [4]) that the calculated RMF nucleon density distributions give good account of the experiment. Therefore, the calculated $V_{\alpha D}$ potentials are reliable and can be used with confidence in the calculation of α - decay half lives.

The calculated WKB α - decay half-lives are very. sensitive to its respective Q - values. Even a few hundred keV difference in Q - value can change calculated half-lives by a few orders of magnitude (see Ref. [2]). The results are displayed in table I. The symbols $NL3^*$, MN and Expt. correspond to the calculated WKB α- decay half-lives using their respective Q - values. The values of the half-lives for the known isotopes which have not been measured in [1] taken from the live chart [6] are shown with the superscript *. It is clear from the table that the calculated half-lives ($NL3^*$, MN and Expt., using their respective Q - values, differ widely among themselves indicating high sensitivity on the Q - values

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TABLE I: The Q - values (MeV) and the estimates of the $\alpha-$ decay half-lives (in seconds) along with the corresponding experimental values. For details see text.

	Q - value (MeV)			WKB-with Q-values			Measured
	$NL3^*$	MN	Expt.	$NL3^*$	MN	Expt.	ref. [1]
${}^{233}_{97}Bk_{136}$	8.56	8.26	7.90	1.15×10^{-1}	1.08	19.0	21^{+48}_{-17}
${}^{229}_{95}Am_{134}$	9.27	8.03	8.14	1.93×10^{-4}	1.14	0.49	$3.7^{+10.4}_{-2.2}$
${}^{225}_{93}Np_{132}$	9.82	7.32	8.79*	1.58×10^{-6}	68.10	8.63×10^{-4}	$3.6^{+10.2}_{-2.2}\times10^{-3}$
${}^{221}_{91}Pa_{130}$	9.31	10.70	9.25*	6.53×10^{-6}	4.15×10^{-9}	9.68×10^{-6}	$5.9^{+1.7}_{-1.7}\times10^{-6}$ *
${}^{217}_{89}Ac_{128}$	9.73	9.93	9.83*	5.86×10^{-7}	4.83×10^{-8}	8.09×10^{-8}	$6.9^{+0.4}_{-0.4}\times10^{-8}$ *
${}^{213}_{87}Fr_{126}$	4.31	6.85	6.88	2.81×10^{15}	14.70	11.20	63^{+177}_{-38}
${}^{223}_{95}Am_{128}$	11.58	11.37		1.58×10^{-9}	4.08×10^{-9}	3.39×10^{-8}	$5.2^{+12.0}_{-4.4}\times10^{-3}$
${}^{219}_{93}Np_{126}$	8.35	8.71	8.98*	2.82×10^{-2}	2.32×10^{-3}	1.16×10^{-4}	
${}^{215}_{91}Pa_{124}$	6.34	7.90	8.23	1.98×10^{5}	0.14	1.21×10^{-2}	$6.0^{+13.8}_{-5.0}\times10^{-3}$
${}^{211}_{89}Ac_{122}$	5.47	7.61	7.62*	6.90×10^{8}	0.22	0.20	$7.80^{+179.0}_{-64.0}\times10^{-2}$
${}^{207}_{87}Fr_{120}$	5.21	6.49	6.89*	2.04×10^{9}	6.43×10^{2}	14.20	$1.7^{+3.9}_{-1.4}$
${}^{216}_{92}U_{124}$	6.31	8.20	8.49	9.44×10^{5}	3.85×10^{-2}	4.85×10^{-3}	$3.8^{+8.8}_{-3.2}\times10^{-3}$
${}^{212}_{90}Th_{122}$	6.21	7.96	7.98	3.10×10^{5}	0.04	0.03	$0.17^{+0.40}_{-0.14}$
${}^{208}_{87}Fr_{121}$	4.78	6.67	6.74	1.17×10^{12}	1.06×10^{2}	55.00	51^{+117}_{-42}

used, as expected. The calculated $NL3^*$ half lives differ considerably, from the corresponding experimental values in most of the cases, either grossely underesatimating or overestimating the experimental values. Similar observations are noticed, though to a lesser extent, for the case of MN half lives. Therefore the calculated values of the half lives for both $NL3^*$ and MN are not reliable, mainly due to the fact that their respective Q - values differ from the experiment. The caculated half lives, listed under EXPT which uses the experimental Q - values reasonably agree with the corresponding measured [1] values. This indicates that the said deficiency (departure from the experimental Q - values) can be rectified by using accurate (experimental or very close to the experimental) Q - values.

The measured ([1]) values of half lives listed in the table range from seconds to $\sim \times10^{-6}$ seconds, besides having large errors, in view of this observation the agreement with in a factor of 10 with the experiment is acceptable in such studies. Therefore the agreement obtained between the calculed (EXPT) and the experimental half lives is remarkable indeed.

2. Summary and Conclusion

It is strongly advocated that the use of accurate Q - values (close to experimental ground state Q - values) is essential in the WKB type calculations of the half-lives to obtain a reliable description of the experiment.

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