Microscopic study of proton emission from heavy nuclei

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Introduction

In recent years many theoretical calculations have been employed to explain the observed lifetimes of proton radioactivity and alpha decay processes in the region of proton rich nuclei. These data are very promising for the analysis of possible irregularities in the structure of these proton-rich nuclei. They are also of great interest in rapid proton capture processes. Some new results for proton radioactivity in this region of proton-rich nuclei have indicated that the proton emission mode is rather competitive with the alpha decay one [1–3]. In the energy domain of radioactivity, proton can be considered as a point charge having highest probability of being present in the parent nucleus. It has the lowest Coulomb potential among all charged particles and mass being smallest it suffers the highest centrifugal barrier, enabling this process suitable to be dealt within WKB barrier penetration model. However in most of the calculations, the density of the daughter nucleus is taken from phenomenological models. Since Relativistic Mean Field (RMF) approach is now a standard tool in low energy nuclear structure we have replaced this density by RMF calaculation and may be expected to reproduce the results more accurately.

Formulation

The nuclear matter densities are calculated by using the linear relativistic mean-field theory (RMFT) formalism in which an effective Lagrangian is taken to describe the nucleons interactions through the meson and electromagnetic (e.m.) fields. Then, the nucleon-nucleus potentials have been obtained by single folding the densities of daughter nuclei with a realistic effective interaction supplemented by a zero-range pseudopotential for exchange term to the Michigan-3-Yukawa (M3Y) [4] [and relativistic mean field-3-Yukawa (R3Y), proposed by us and collaborators in a very recent study [5]] effective interaction. In our calculation we have used the preformed cluster model of Gupta and collaborators [6–8]. Details can be found in Refs. [5, 9].

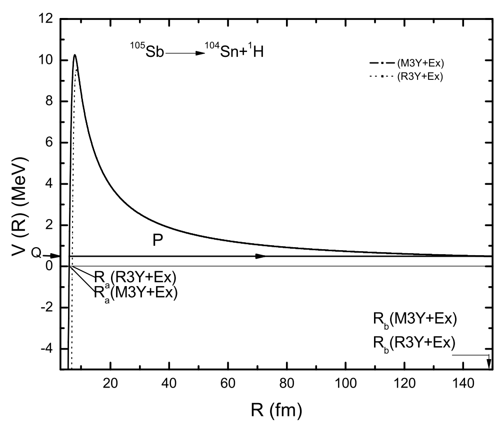

FIG. 1: The total interaction potential V(R) as a function of radial separation R for both the M3Y+EX and R3Y+EX.

Results and Discussions

Fig. 1 illustrates the total interaction potential for proton decay of ^{105}Sb, obtained from both the M3Y+Ex and R3Y+Ex NN interaction using RMFT-HS densities [10]. The penetration path with an energy equal to Q value of the decay is shown. It may be pointed out that, the barrier height is a bit lower for

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TABLE I: The calculated half-lives of proton emitters are presented using M3Y+EX and R3Y+EX NN interactions. The results of the present calculations have been compared with the experimental values and with the results of [11, 12]. The experimental Q values, half-lives, and l values are taken from [11]. The asterisk symbol ($\star$) denotes the isomeric state.

Parent nuclei	Q (MeV)	Ang. momentum l	*Expt.* $log_{10}T(s)$	$(M3Y+EX)$ $log_{10}T(s)$	$(R3Y+EX)$ $log_{10}T(s)$	[11] $log_{10}T(s)$	[12] $log_{10}T(s)$
^{105}Sb	0.491	2	2.049	3.07	2.436	2.085	1.97
^{109}I	0.819	0	-3.987	-5.627	-5.897	–	–
^{112}Cs	0.814	2	-3.301	-2.857	-3.555	–	–
^{113}Cs	0.973	2	-4.777	-5.236	-5.803	–	–
^{117}La	0.803	2	-1.628	-1.943	-2.504	–	–
^{117}La*	0.954	5	-2.0	2.794	1.203	–	–
^{131}Eu	0.940	2	-1.749	-2.097	-2.764	–	–
^{140}Ho	1.094	3	-2.221	-1.374	-2.132	–	–
^{141}Ho	1.177	3	-2.387	-2.487	-3.298	–	–
^{141}Ho*	1.256	0	-5.180	-6.374	-6.846	–	–
^{145}Tm	1.753	5	-5.409	-3.415	-4.698	-5.170	-5.14
^{146}Tm	1.127	5	-1.096	3.384	1.945	–	–
^{146}Tm*	1.307	5	-0.698	0.919	-0.484	–	–

the R3Y case and hence the penetration probability "p" and half-life of proton emitting nuclei as given in Table I. As in our previous work [9], the height and position of Coulomb barrier played the vital role in explaining the exact fusion cross sections, here also might be playing the crucial role. In most of the cases using R3Y interactions it is more closure to the experimental value compared to the M3Y case.

1. Summary and Conclusions

In summary, we have shown that the PCM model proved to be successful to predict the half-life for alpha decay [9] and cluster radioactivity [6]. This model also gives the half-life values of proton emitting nuclei which are in good agreement with the existing data [12, 13] using M3Y and R3Y NN interaction derived from simple linear Walecka Lagrangian. Such calculated results can be treated as useful information to predict the proton decay half-life as well as the structure of nuclei in proton drip line region.

References

[1] R.D. Page et al., Phys. Rev. C. **53**, 660 (1996).

[2] T. Enqvist et al., Z. Phys. A. **354**, 1 (1996).

[3] M. Leino et al., Z. Phys. A. **355**, 157 (1996).

[4] G. R. Satchler and W. G. Love, Phys. Rep. **55**, 183 (1979).

[5] M. Bhuyan, B. B. Singh, S. K. Patra, and R. K. Gupta, *Communicated to J. Phys. G.*

[6] B. B. Singh, S. K. Patra, R. K. Gupta, Phys. Rev. C. **82** (2010).

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

[8] R. K. Gupta and W. Greiner, Int. J. Mod. Phys. E. **3** 335 (Suppl. 1994).

[9] B. B. Singh, B. B. Sahu, S. K. Patra, Phys. Rev. C. **83**, 064601 (2011).

[10] C. J. Horowitz and B. D. Serot, Nucl. Phys. A. **368**, (1981) 503.

[11] M. Balasubramaniam and N. Arunachalam, Phys. Rev. C. **71**, 014603 (2005).

[12] D. N. Basu, P. Roy Chowdhury and C. Samanta, Phys. Rev. C. **72**, 051601(R) (2005).

[13] A. A. Sonzogni, Nucl. Data Sheets. **95**, (2002) 1.