Studies on β decay of isotopes in the heavy region

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Introduction

In nuclear physics, beta decay (β-decay) is a type of radioactive decay in which a beta ray (an energetic electron or positron) and an associated antineutrino or neutrino is emitted from an atomic nucleus. In contrast with alpha decay, progress in understanding beta decay has been achieved at an extremely slow pace. Often experimental results have been created new puzzles and that challenged existing theories. The emission of ordinary negative electrons from the nucleus was among the earliest observed radioactive decay phenomena. Through the process of beta decay an unstable atom obtains a more stable ratio of protons and neutrons. The stability of this ratio forms the nuclear valley of stability [1].

The three processes grouped under beta decay are β^- decay, β^+ decay and orbital electron capture. In negative β decay, a neutron is converted into a proton and electron and antineutrino are emitted. So the atomic number of daughter nucleus is increased by one unit leaving the mass number unchanged. Quantum mechanically, the interaction leading to beta decay can be considered as a weak perturbation and thus Fermi's Golden Rule can be applied to find an expression for the kinetic energy spectrum of emitted beta particle. The maximum kinetic energy corresponds to that expected from the exact rest mass energies of the parent and daughter atoms.

The present works aims to study the possibility of β^- decay from various isotopes in the heavy region with Z ranging from 80-99 using the empirical formula of Fiset and Nix [2].

The empirical formula

The half life for beta decay depends strongly upon the energy released in the process and weakly upon the variations in the intrinsic structure of the original and final nuclei involved [2]. The beta decay half lives are obtained from the decay energies by means of approximations similar to those used by Seeger et al [3]. These approximations completely neglect variations in the nuclear matrix elements and the degree of forbiddenness of transitions. In the present work we use Fiset and Nix formula for half life which is

$$T_\beta = \frac{540\ m_e^5}{\rho\,(W_\beta^6 - m_e^6)} x10^5 \text{ sec} \qquad (1)$$

where m_e is the rest mass electron in MeV, ρ is the density of nuclear states and is given by

$\rho = e^{A/290}$ x number of states within 1MeV ground state and is obtained from the results of Seeger et al [3]. W_β is the total maximum energy of the emitted beta particle,

$$W_\beta = Q_\beta + m_e \qquad (2)$$

The energy released in a beta decay process is its Q value and is given as,

$$Q_\beta(Z,N) = M(Z,N) - M(Z+1,N-1) \qquad (3)$$

Here Z and N are the proton and neutron number of the parent nucleus respectively. The Q value must be positive for any decay process to occur.

Results, discussion and conclusion

In the present works we have computed the β^- decay half lives from various isotopes in the heavy region with Z ranging from 80-99 using the empirical formula of Fiset et al [2]. The Q-values are computed using the experimental binding energies of Audi et al [4].

Figures 1 to 3 represent the computed beta decay half life time versus neutron number of parent nuclei in the heavy region with Z ranging from 80-99. It is clear from these plots that beta decay half lives decreases with increase in neutron number. That is, beta decay occurs in isotopes which are neutron rich. When the number of neutrons in the nucleus increases, the Coulomb force becomes weak due to the hindrance of the repulsive among the protons. In such cases, the width of the two turning points is very large and the barrier height is small. Thus, the probability of alpha decay in this region is almost infinity and these types of nuclei are stable against alpha or cluster radioactivity. In such isotopes beta emission is the possible decay mode. Atoms which undergo beta decay are located below the line of stable elements on the chart of the nuclides, and are typically produced in nuclear reactors.

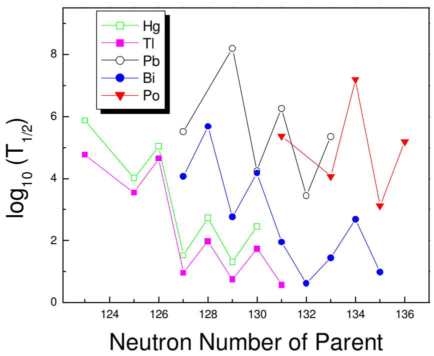

Fig. 1 Computed beta decay half life time versus neutron number of parent for different Hg, Tl, Pb, Bi and Po isotopes.

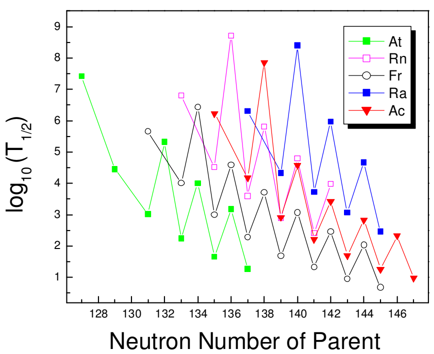

Fig. 2 Computed beta decay half life time versus neutron number of parent for different At, Rn, Fr, Ra and Ac isotopes.

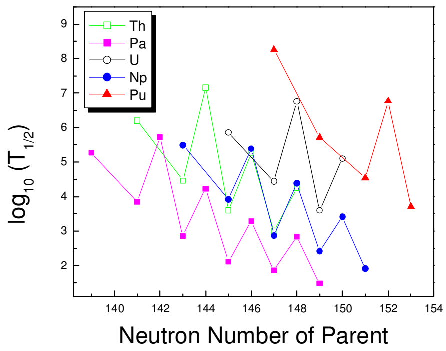

Fig.3 Computed beta decay half life time versus neutron number of parent for different Th, Pa, U, Np and Pu isotopes.

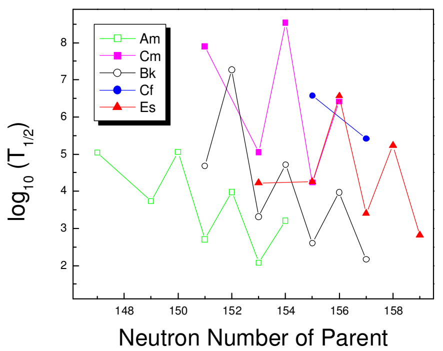

Fig.4 Computed beta decay half life time versus neutron number of parent for different Am, Cm, Bk, Cf and Es isotopes.

References

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