Shell closures in super heavy region next to Z=82, N=126

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Introduction

One of the fundamental factors in the study of super heavy elements is the prediction and/or production of doubly magic nucleus, next to Z=82, N=126 (^{208}Pb). The existence of super heavy nuclei with Z $\geq$ 104 is due to quantum shell effects, pronounced shell gaps can stabilize nuclei. In the super heavy mass region, the proton numbers Z = 114,120,126 and neutron numbers N = 172,184 have been predicted to be magic numbers. In the present work an attempt is made to examine the possibility of next neutron and proton shell closure in super heavy region.

Mass Parabolas

Mass parabola (Plot connecting $-\Delta M$, the difference in masses of parent and daughter nuclei versus neutron number of daughter nuclei) for various clusters emitted from various Z=116 parents is studied. Figure 1 represent isotopic mass parabola for ^{16}C, ^{20}O, ^{10}Be, ^{14}C cluster emission from various Z=116 parents. Minima (slope discontinuity) of mass parabola occur at magic neutron number N=162,184. We would like to mention that minima of mass parabola represent the lowest half life $T_{1/2}$ for the corresponding cluster. Half life measurement for cluster emission may not be possible because few atoms of short lived super heavy nuclei are produced but in future more mass measurements will be available and by noting the minima in mass difference, it will be possible to find neutron magicity in super heavy region.

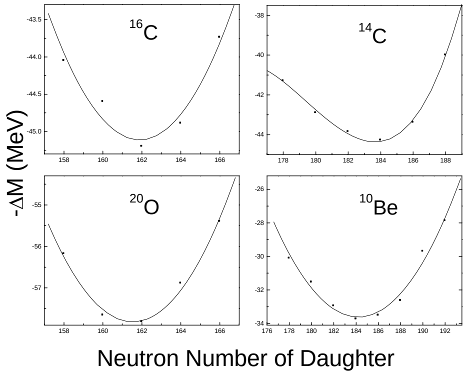

Fig. 1 Mass parabola for ^{16}C, ^{14}C, ^{20}O, ^{10}Be cluster emission from Z=116 parent

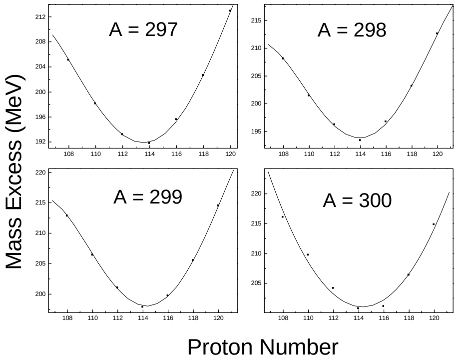

Fig. 2 Isobaric mass parabola connecting mass excess with proton number

Following the prescription of Zeldes [1] we studied isotopic and isobaric mass parabola, the plot connecting mass excess and neutron number. Figure 2 represents isobaric mass parabola for A = 297-300. The minima (slope discontinuity) in the plot indicate proton magicity at Z = 114. We would like to point out that by noting the minima in mass excess it will be possible to find neutron and proton magicity in super heavy region. We would like to point out that once the fragmentation potential (driving potential) is minimized in η_z and the behavior of $T_{1/2}$ studied as a function of N (equivalently η_N) there is no need for plotting mass parabola since the three variables η, η_z and η_N are connected and only two of them are enough. Since only few atoms of short lived super heavy nuclei are produced it will not be possible to find neutron and proton magicity in super heavy region by cluster radioactivity experiments. However in future more mass measurements will be available and by noting the minima in mass parabola, it will be possible to find neutron and proton magicity in super heavy region.

Results and discussion

The half life time calculations are done by taking interacting barrier as the sum of Coulomb and Nuclear Proximity Potential [2] for post scission region. Fig. 3 represents the plot connecting computed half lives and Q-value for ^{16,18}O clusters against neutron number of the daughter. It is found that these figures are mirror reflection of the other. In half lives plot, at the points N = 162,172 and 184 a dip is present and in plot for Q-value a rise is present at N = 162,172 and 184. Both these facts show that these are due to the presence of sub magic shell closure at 162 and spherical neutron shell closure at 172 and 184. Cluster radioactivity is energetically possible only if Q value is positive. If we plot all positive Q values (or half lives) against A_2, mass of light fragment, the plot will not give any information on magic shell closure even though information on shell effects are contained in the Q value. We took those Q values (or half lives) which lie in the cold valley, i.e. the proper choice of Q value (or half lives) will give information about magicity. The dynamical quantity, half life time in principle depends not only on nuclear structure but also on nuclear inertia.

Figure 4 represents the plot connecting mass deviation with neutron number for super heavy nuclei with Z=108-122. The mass deviations are obtained by subtracting mass of an undistorted liquid drop [3] from the theoretical mass estimate of KTUY [4]. The mass deviation represents the shell correction in a method other than Strutinsky [5, 6]. The mass of an undistorted liquid drop is given by

$$M_0 = M_n N + M_H Z - C_1 A + +\delta$$

$$C_2 A^{2/3} + C_3 \frac{Z^2}{A^{1/3}} - C_4 \frac{Z^2}{A} \qquad (1)$$

Here M_n is the neutron mass and M_H, the mass of hydrogen atom, the third term is the volume energy term, fourth term represents the surface energy, fifth term is Coulomb energy term and the last term is the odd-even correction. From these plots we see that a large deviation in mass difference occur at N = 184, the spherical neutron shell closure.

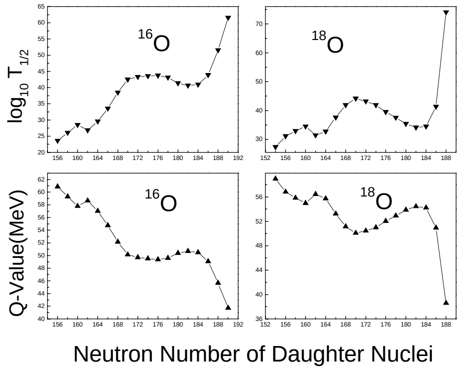

Fig. 3 Computed Q-value and half-life time versus neutron number of daughter nuclei with Z=116 emitting from ^{16,18}O isotopes.

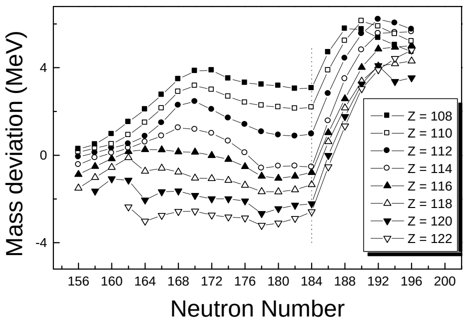

Fig. 4 Plot for mass deviation with neutron number for various parents with Z=108-122.

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