Magicity in Super Heavy Elements

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Introduction:

Even though the macroscopic liquid drop model (LDM) suggests that the potential barrier approaches zero when the atomic number Z >100, putting an upper limit to the stability of nuclei, microscopic nuclear theories predict a significant enhancement in nuclear stability when approaching the closed spherical shells with new magic numbers such as Z = 114, 120, 122 and N = 184[1]. Super heavy elements (SHE) with atomic numbers Z = 104 − 118 have been synthesized with cold fusion reactions or with hot fusion induced by ^{48}Ca projectiles. Alpha emission from super heavy elements have much relevance since the majority of proton-rich super heavy nuclides are identified through the α decay chains [2]. Determination of stability island is one of the thrust area in current nuclear physics, at first proposed by Seaborg.

Theory:

α decay is one of the prominent decay channel of SHE.. The decay constant, which can give primary information about the stability of a nucleus, can be computed either using the Preformed Cluster Model (PCM) or Unified Fission Model(UFM). In the PCM [3] decay constant $\lambda = P_0 P$, where P_0 is the preformaton probability, P is the penetrability after separation of the alpha particle and υ is the assault frequency, the frequency with which it assault the barrier. In UFM decay constant is simply the product of assault frequency and barrier penetrability [4]. i.e., $\lambda = \upsilon P$, which ignores preformation probability. P is the total penetrability which includes the post scission and pre scission penetrabilities.

The α preformation factor is very important from the viewpoint of the nuclear structure. It is a measure that α particle exists as a recognizable entity inside the nucleus before its emission. It can be calculated either empirically or theoretically, based upon different approaches. An empirical cluster preformation probability is defined simply as a measure of the disagreement between a calculation and the experimental data on decay constant (or half life). The theoretical cluster preformation probability is a calculated quantity based on the nuclear structure information of the decay process, which is defined differently in different models. Poenaru et al. [5] developed another simple method. Accordingly within the fission model the preformation probability can be calculated as the penetrability of the internal part (overlap region) of the potential barrier. The present work is an attempt to compute preformation probability within UFM based on Poenaru's formalism in the super heavy elements of even atomic number in the range 106 - 118. The potential that we have used is the phenomenological Blocki's proximity potential [6]. The interacting potential barrier for a parent nucleus and alpha particle during alpha decay is given by $V = V_c + V_N$, where Vc is the Coulomb interaction term and V_N is the proximity potential.

$$V_C = \frac{\left(1.44\, Z_H Z_L e^2\right)}{D}$$

in units of MeV, for tip distance > 0. The nuclear interaction term is given by:

$$V_N(r) = 4\pi\gamma b\, \bar{R}\, \phi(\varepsilon)\, MeV$$

where $\bar{R}$ is the mean curvature radius and for two spheres it has the form :

$$\bar{R} = \frac{C_1 C_2}{C_1 + C_2}$$

'b' is the diffuseness width which is usually approximated to unity. The universal proximity function φ (ε) has of the form:

$$\phi(z/b) = -4.41\, e^{\frac{-\varepsilon}{0.7176}} \quad \text{for } \varepsilon \geq 1.9475$$

$$\phi(z/b) = -1.7817 + 0.9270\,\varepsilon + 0.1696\,\varepsilon^2 - 0.05148\,\varepsilon^3 \quad \text{for } 0 \leq \varepsilon \leq 1.9475 .$$

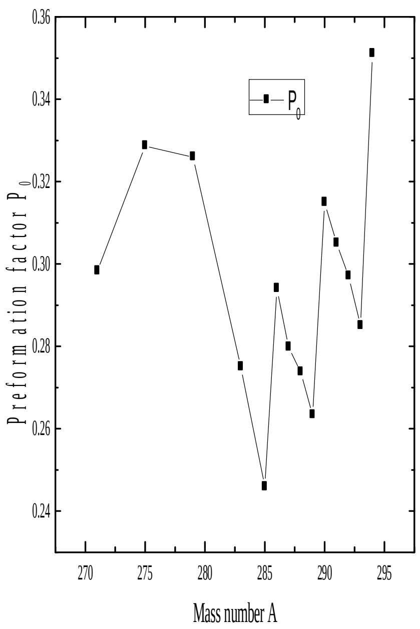
For the computation of pre-scission penetrability, Power law interpolation [7] is used.

Results &Discussion:

The preformation probability in heavy nuclei has been found to follow a simple dependence on the mass of the cluster and the fact that closed shell structures play a key role for the preformation mechanism was confirmed [8]. The study of even - even nuclei from ^{108}Te to ^{294}118 reveals that, the shell closure effects play the key role in the alpha preformation. According to Generalized Liquid Drop Model (GLDM) more the nucleon number is close to the magic numbers, the more the formation of alpha cluster is difficult inside the mother nucleus [9]. According to barrier penetration theory, penetrability will be minimum whenever the stability of the nucleus is high. Since total penetrability is the product of inner penetrability (pre-scission) and external penetrability (post-scission), preformation is certainly to contribute stability.

In this work an attempt has been made to calculate the preformation probability based on Poenaru's[5] formalism and half life under UFM for super heavy element having even atomic number. The preformation factors calculated in our model shows variation as shown in figure 1. Accordingly preformation is minimum when A = 285. The corresponding half life is 43.81 seconds which is much higher compared to the neighbouring nuclei.

Figure 1: Variation of Preformation probability (P_0) with Mass number (A).



These two factors tempt us to conclude that A= 285 is a magic number.

Table 1: Half life (T) and Mass number (A) of super heavy element of even mass number.

A	Z	Q MeV	T(s)	P_0
271	106	8.67	32.84	0.2983
275	108	9.44	5.342	0.3286
279	110	9.84	3.10	0.3259
283	112	9.67	13.61	0.275
285	112	9.29	43.81	0.2459
286	114	10.33	3.37	0.294
287	114	10.16	5.85	0.2798
288	114	10.09	7.09	0.2737
289	114	9.96	10.53	0.2633
290	116	11.00	0.20	0.3149
291	116	10.89	0.38	0.30746
292	116	10.80	0.65	0.2965
293	116	10.67	1.45	0.2852
294	118	11.81	0.00651	0.351

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