Possible fission fragments of ^{262}Lr

N. Manjunatha[1,2], ,H.C. Manjunatha[1*], N. Sowmya[1*],T.Ganesh[2]
[1]Department of Physics, Government College for Women, Kolar, Karnataka, India.
[2]Department of Physics, Rajah Serfoji Government College, Thanjavur-613005, Affiliated to Bharathidasan University, Tiruchirappalli-TamilNadu.
Corresponding Author:manjunathhc@rediffmail.com, sowmyaprakash8@gmail.com

Introduction

Initially, the fission fragments of Uranium by slow neutrons were experimentally identified in 1940's [1]. During fission process of unstable nuclei, comparable fission fragments were formed in case of Uranium [2]. Among the formed fission fragments any one of them or both may contain magic number of protons or neutrons [3]. The experimental failure reactions to synthesis superheavy elements leads to know the possible fission fragments formed [4]. Theoretically the possible fission fragment combination of superheavy element Z=126 [5] have been studied.

The superheavy element ^{259}Lr and ^{258}Lr was first reported in 1971 [6] by bombarding projectile ^{14}N on ^{248}Cm targets. Theoretical investigation [7] shows possible decay modes in the superhevay elements. Hence, the present work aims at identification of possible binary fission fragments of heavy element ^{262}Lr using modified liquid drop model (MGLDM). In the present work, probable binary fission fragments are investigated by calculating the driving potential, penetration probability and relative yield for all possible fragments of ^{262}Lr using MGLDM.

Theoretical Frame work

The total energy (E) of the system is a sum of volume, surface, Coulomb, proximity and centrifugal energies are evaluated as explained in literature [8]. The volume, surface and Coulomb energies are given as;

$$E_V = -15.494[(1-1.8I_1^2)A_1 + (1-1.8I_2^2)A_2] \text{ MeV} \quad (1)$$

$$E_S = 17.9439[(1-2.6I_1^2)A_1^{2/3} + (1-2.6I_2^2)A_2^{2/3}] \text{ MeV} \quad (2)$$

$$E_C = 0.6e^2Z_1^2/R_1 + 0.6e^2Z_2^2/R_2 + e^2Z_1Z_2/r \text{ MeV} \quad (3)$$

here Z_i and A_i, are the atomic and mass number respectively. R_i and I_i are the radii of the two nuclei and relative neutron excess of the two nuclei. The centrifugal energy is expressed as;

$$E_l(r) = \frac{\hbar^2}{2\mu}\frac{l(l+1)}{r^2} \quad (4)$$

Where μ, l, and r are the reduced mass, angular momentum and the distance between the mass centers of the two nuclei respectively. The proximity energy term is as defined in literature [8]. The barrier penetrability is evaluated as follows;

$$P = \exp[-\frac{2}{\hbar}\int_{R_{in}}^{R_{out}} \sqrt{2B(r)(E(r)-E(sphere)]} \quad (5)$$

where $R_{out} = e^2 Z_d Z_\alpha / Q_\alpha$, $R_{in} = R_d + R_\alpha$ and $B(r)=\mu$ is the reduced mass. The decay half-life is defined as;

$$T_{1/2} = \frac{\ln 2}{\lambda} = \frac{\ln 2}{\nu_0 P} \quad (6)$$

The term ν_0 is the assault frequency is taken as $\nu_0 = 10^{20}$ S^{-1}.

Results and Discussions:

The possible fission fragments of heavy nuclei ^{262}Lr have been studied using MGLDM. The amount of energy released during binary fission is evaluated by considering recent mass excess values available in the literature [9]. The driving potential is the difference between total potential and amount of energy released during binary fission. The figure 1 shows variation of total potential with the separation distance for different fission fragment combinations such as ^{36}S+^{226}Fr, ^{48}Ca+^{214}Bi, ^{50}Ti+^{212}Tl, ^{64}Ni+^{198}Re, ^{82}Se+^{180}Tm, ^{86}Kr+^{176}Ho and ^{96}Zr+^{166}Eu. The potential well for the ^{36}S+^{226}Fr is having lower value when compared to other fission fragment combinations. The penetration probability is evaluated using Wentzel–Kramers–Brillouin integral. The half-lives are evaluated using equation (6).

The variation of logarithmic half-lives with mass number of the fission fragment A_1 is plotted and it is as shown in figure 2. The logarithmic half-lives are found to be shorter for the fission fragment combinations $^{48}Ca+^{214}Bi$, $^{54}Cr+^{208}Au$, $^{70}Zn+^{192}Ta$, $^{76}Ge+^{186}Lu$, $^{86}Kr+^{176}Ho$, $^{70}Nb+^{192}Sm$, $^{110}Pd+^{152}La$, $^{116}Cd+^{146}Cs$, $^{76}Sn+^{186}I$, $^{130}Te+^{132}Sb$ and $^{139}La+^{123}Pd$.

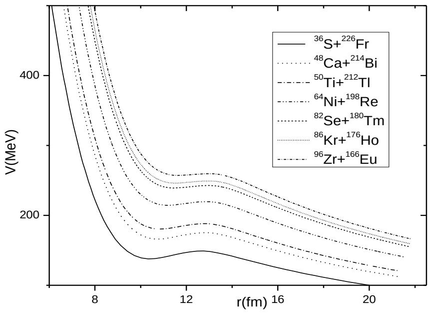

Fig 1: Variation of total potential with the separation distance for different fission fragment combination.

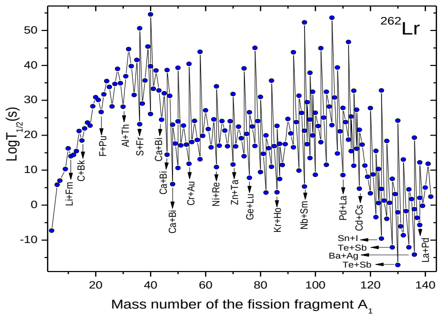

Fig 2: Variation of logarithmic half-lives of ^{262}Lr with mass number of fission fragment combinations.

Among all these, the fission fragment combination $^{130}Te+^{132}Sb$ is having shortest half-lives when compared to all other fission fragment combinations due its shell effects. The fission fragment ^{130}Te with Z=52 and N=78, ^{132}Sb with Z=51 and N=81 in which both fission fragment combinations the atomic and neutron number are near to magic/semi magic number.

The table-1 shows the tabulated values of possible fission fragment combinations and the predicted half-lives are in auto seconds from the heavy nuclei $^{254-256,\ 259-266}Lr$. From the analysis it is observed that the most probable fission fragment combination consists of proton and neutron number with near magic/semi-magic nuclei.

Table 1: Fusion-fission half-lives obtained using MGLDM for possible fission fragment combinations from the parent nuclei $^{254-256,\ 259-266}Lr$.

Parent nuclei	Fission Fragments	MGLDM $LogT_{1/2}(s)$
^{254}Lr	$^{130}Te+^{124}Sb$	-10.40
^{255}Lr	$^{130}Te+^{125}Sb$	-12.40
^{256}Lr	$^{130}Te+^{126}Sb$	-10.93
^{259}Lr	$^{130}Te+^{129}Sb$	-15.30
^{260}Lr	$^{130}Te+^{130}Sb$	-13.34
^{261}Lr	$^{130}Te+^{131}Sb$	-16.58
^{262}Lr	$^{130}Te+^{132}Sb$	-17.40
^{264}Lr	$^{130}Te+^{134}Sb$	-16.16
^{266}Lr	$^{130}Te+^{136}Sb$	-11.71

Conclusions

The binary fission of heavy element ^{262}Lr is studied using modified liquid drop model. The mass excess values have been taken from recent data available in the literature. The life-times of all possible fission fragments from the heavy nuclei $^{254-256,\ 259-266}Lr$ have been predicted. The detail analysis shows possible fission fragment combinations in which both fission fragment combinations, the atomic and neutron number are near to magic/semi magic number.

References:

[1] G.N. Glasoe, J. Steigman. Phys. Rev. 58(1), 1-6(1940).

[2] N Sowmya, H.C. Manjunatha. Bulg. J. Phys. 46, 16-27(2019).

[3] D. N. Poenaru, et al., Phys. Rev. C. 59(6), 3457-3460(1999).

[4] H. C. Manjunatha, K. N. Sridhar. Phys. Part. Nucl. 16(6), 647–655(2019).

[5]H.C.Manjunatha, N.Sowmya, Nucl. Phys. A. 969, 68–82(2018).

[6] K. Eskola, P. Eskola, M. Nurmia, A. Ghiorso, Phys. Rev. C. 4(2), 632-642(1971).

[7] N.Sowmya, H.C.Manjunatha, N.Dhananjaya. J. Radioanal. Nucl. Chem. 323, 1347–1351(2020).

[8] H.C. Manjunatha, N.Sowmya et al., Int. J. Mod. Phys. E, 29(05), 2050028(2020).

[9] Meng Wang et al., Chinese Phys. C 45, 030003(2021).

[10] H.C. Manjunatha, L. Seenappa, P.S.Damodara Gupta, N.Manjunatha, K.N. Sridhar, N. Sowmya, T. Nandi. Phys. Rev. C. 103, 024311(2021).