Investigation of probable decays in Rhenium isotopes

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Introduction

Making use of effective liquid drop model (ELDM)[1], the feasibility of proton and alpha decays and various cluster decays is analysed theoretically. For different neutron-rich and neutron-deficient isotopes of Rhenium in the mass range $150 < A < 200$, the half lives of proton and alpha decays and probable cluster decays are calculated considering the barrier potential as the effective liquid drop one which is the sum of Coulomb, surface and centrifugal potentials. The calculated half lives for proton decay from various Rhenium isotopes are then compared with the universal decay law (UDL) model[2] to assess the efficiency of the present formalism. Geiger-Nuttal plots of the probable decays are analysed and their respective slopes and intercepts are evaluated.

The Model

The barrier potential V is the effective liquid drop one[1] which is the sum of Coulomb and surface potentials plus the centrifugal potential.

$$V = \frac{8\pi a^5 \epsilon(x_1, x_2)\rho_c}{9} + 4\pi(R^2 - R_1^2 - R_2^2)\sigma_{eff} + \frac{\hbar^2}{2\mu\zeta^2} l(l+1) \quad (1)$$

ρ_c is the charge density, a is the neck radius of the decaying system and $\epsilon(x_1, x_2)$ is a function of angular variables. R is the radius of the parent nucleus and σ_{eff} is the effective surface tension. The emitted fragment and the daughter nucleus have radius R_1 and R_2 respectively. The geometrical centres of the fragments are separated by a distance represented by ζ[3]. The barrier penetrability factor is calculated as:

$$P = exp\left\{-\frac{2}{\hbar}\int_{\zeta_1}^{\zeta_2}\sqrt{2\mu(V-Q)}d\zeta\right\} \quad (2)$$

where μ is the inertia coefficient and Q is the Q-value of the decay. Now the decay constant is given by the expression,

$$\lambda = \nu P \quad (3)$$

where ν is the assault frequency. The decay half-life is calculated by the expression,

$$T_{1/2} = \frac{0.693}{\lambda} \quad (4)$$

Results and Discussion

The decay half lives calculated using ELDM model for proton, alpha, ^{8}Be, ^{12}C, and ^{16}O cluster emissions are found to be well within the measurable range ($T_{1/2} < 10^{30}s$) and hence they are predicted to be the probable decay modes in neutron-deficient Rhenium isotopes. The probability of cluster emission is observed to decrease with the rise in neutron number and consequently, no cluster radioactivity is identified in the case of neutron-rich isotopes. The calculated half lives for proton decay from various Re isotopes are found to be

TABLE I: Mass ranges of Re isotopes exhibiting proton, α and various cluster emissions with half lives in the measurable range.

Decays with $T_{1/2} < 10^{30}s$	Mass range (A)
Proton decay	160-163, 165
α decay	160-182
^{8}Be decay	159-167
^{12}C decay	159-170
^{16}O decay	159-169

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TABLE II: Comparison study of half lives using ELDM and UDL models for proton decay of Re isotopes.

Mass	$log_{10}T_{1/2}$ ($T_{1/2}$ in s)		
A	ELDM	UDL	Literature[4]
160	−4.3786	−6.4232	−3.046
161	−3.5829	−5.6197	−3.432
162	3.5629	1.5773	-
163	5.2335	3.2556	-
165	25.8259	23.9070	-

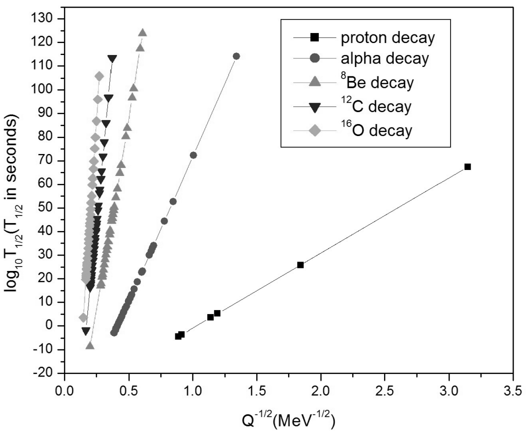

FIG. 1: Geiger-Nuttal plots for proton, alpha, ^{8}Be, ^{12}C, and ^{16}O emissions from various Re isotopes.

in good agreement with the available experimental data. When compared with the UDL model, it is revealed that ELDM model is the better tool for reproducing the experimental data. The Geiger-Nuttal plots for proton, alpha, ^{8}Be, ^{12}C, and ^{16}O decays are shown in fig. 1. Apparently, they all exhibit linear behaviour. It is an established fact that Geiger-Nuttal law is suitable in the case of the system under pure Coulomb potential and the generated profiles indicate that the inclusion of surface potential instills no significant variation to the linear nature of G-N plots. The tabulated values of slopes and intercepts varies remarkably for proton, alpha, and different cluster decays and these in turn, point out the presence of surface potential and shell effects in Rhenium isotopes.

TABLE III: Geiger-Nuttal plots : slopes and intercepts

Cluster emitted	Slope	Intercept
^{1}H	31.7361	−32.5649
^{4}He	122.1261	−50.4371
^{8}Be	327.7004	−75.7123
^{12}C	564.2414	−97.4749
^{16}O	818.4866	−117.5361

Conclusion

Fission model calculations with the effective liquid drop potential predict that the most probable decay modes in neutron-deficient Rhenium isotopes are proton and alpha decays and ^{8}Be, ^{12}C, and ^{16}O cluster emissions. The evaluated half lives for proton decay agree well with the corresponding experimental data and when compared with the UDL model, ELDM data displays better conformity. It is observed that the linear nature of G-N plots stays unaltered even if the surface potential is included in the interaction potential. The variation in slopes and intercepts of G-N plots depicts the presence of surface potential and shell effects in Re isotopes.

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