The α+nucleus potential for scattering, fusion and decay

Swagatika Bhoi[1] and Basudeb Sahu[2*]
[1]*School of Physics, Sambalpur University, Burla-768019,INDIA and*
[2]*Deptartment of Physics, College of Engineering and Technology, Bhubaneswar-751003, INDIA*

We use complete theory of nucleus-nucleus scattering governed by an interaction potential and evaluate the value of decay time of alpha particle from a radioactive nucleus from the decay of resonant state of the scattering process. Within the same framework, we need to explain the process of formation or fusion of the α particle with a nucleus using the concept of absorption within the interior strong interaction region. In view of this, we wish to construct a potential particularly the attractive nuclear part such that the combined potential of nuclear, electrostatic and centrifugal parts is capable to explain and account for the above three processes of scattering, decay and fusion in an α+nucleus interaction in unison.

The potential developed for the nuclear part is expressed below:

$$V_N = \begin{cases} -4V_0\frac{(1-C)r\rho^3}{(r^2-\rho^2)^2}\frac{(1-e^{\frac{ar^2}{r^2-\rho^2}})e^{\frac{ar^2}{r^2-\rho^2}}}{(1-Ce^{\frac{ar^2}{r^2-\rho^2}})^3} & if r < \rho \\ 0 & if r > \rho \end{cases}$$

Here V_0 and ρ stand for the depth and range of the potential. The parameters C and a account for the slope of the potential. Combining this potential with the usual Coulomb potential with radial parameter r_c = 1.2 fm and the centrifugal potential, we solve the Schrödinger equation and explain different processes in a α+nucleus system. We apply the formulation to the α+ $^{208}_{82}$Pb system for the explanation of the elastic scattering cross sections, fusion cross sections and the decay rate of α particle from the parent $^{212}_{82}$Po nucleus.

The values of the parameters for the nuclear potential are V_0 = 55 MeV, C = 0.94, a = 1.62 and $\rho = \rho_0(A_\alpha^{1/3} + A_D^{1/3})$ with ρ_0 = 1.665 fm. For the α+nucleus system, A_α and Z_α indicate mass and proton number of the α particle and A_D and Z_D stand for the mass and proton number of the daughter nucleus.

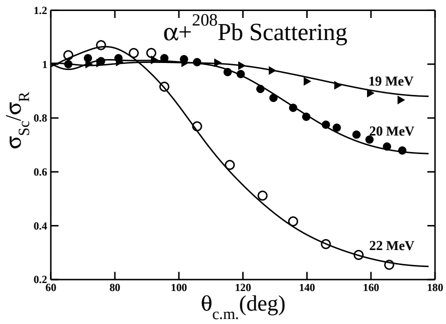

FIG. 1: Angular variation of the elastic scattering cross section at different incident energies.

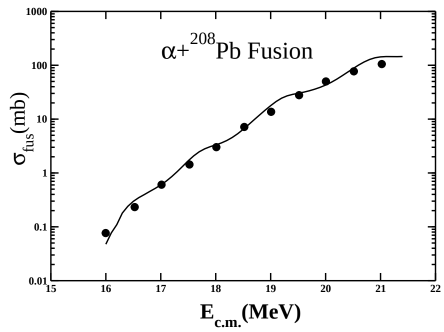

FIG. 2: Fusion cross section as a function of center of mass energy $E_{c.m.}$.

In FIG. 1, we explain the angular variation of the elastic scattering cross section at different incident energies and find that the

*Electronic address: bd_sahu@yahoo.com

TABLE I: Comparison between the experimental α-decay half-lives and calculated half-lives of isotopes of Po.

Parent	$Q^{expt.}$(MeV)	$log_{10}T^{expt.}_{1/2}$(s)	$log_{10}T^{calt.}_{1/2}$(s)
$^{218}_{84}$Po	6.115	2.275	2.78
$^{216}_{84}$Po	6.906	-0.84	-0.428
$^{214}_{84}$Po	7.833	-3.78	-3.53
$^{212}_{84}$Po	8.954	-6.52	-6.62
$^{210}_{84}$Po	5.407	7.08	6.37
$^{208}_{84}$Po	5.215	7.96	7.46
$^{206}_{84}$Po	5.327	7.14	6.85
$^{204}_{84}$Po	5.485	6.28	6.02
$^{202}_{84}$Po	5.701	5.15	4.94
$^{200}_{84}$Po	5.981	3.79	3.62
$^{198}_{84}$Po	6.309	2.27	2.19
$^{196}_{84}$Po	6.657	0.77	0.79
$^{194}_{84}$Po	6.987	-0.41	-0.42
$^{190}_{84}$Po	7.693	-2.61	-2.75

explanation of the experimental results (solid dots) [1] are accounted for quite successfully by our calculated results (solid curves). In FIG. 2, we explain the experimental fusion cross section as a function of center of mass energy $E_{c.m.}$ (solid dots)[2] and calculated results (solid curve) with remarkable success throughout the range of energy. Using the same interaction potential we estimate the Q-value ($\simeq$ 8.954MeV) of the α decay of parent $^{212}_{84}$Po nucleus from the resonance situation with a minor change in the value of Coulomb radius parameter r_c. The width corresponding to this resonance energy gives us the time of decay (half-life) as the logarithm of half-life $log_{10}T_{1/2} = -6.62$ s which is very close to the experimental result of -6.52 s.

We apply the same formulation and the potential to estimate the α-decay half-lives of other isotopes of Po. The calculated results $log_{10}T^{calt.}_{1/2}$ are compared with the corresponding measured values $log_{10}T^{expt.}_{1/2}$ in TABLE I. It is clearly seen that the measured values are accounted for quite well.

In conclusion, we may mention that we have found a new expression for the nuclear potential which is capable of explaining simultaneously three important events: decay, fusion and scattering in a α+nucleus collision.

References

[1] A Bhagwat, Y K Gambhir, *J. Phys. G: Nucl. Part. Phys.* **35**, 065109 (2008).

[2] A R Barnett, J S Lilley, *Phys. Rev.* **C 9**, 2010 (1974).