

Transmutation Long Lived Fission Fragments ^{135}Cs , ^{79}Se , ^{126}Sn , ^{93}Zr by Accelerator Driven System (ADS)

Nguyen Thi Ai Thu¹

Ph.D, Faculty of Natural Science, Saigon University, Hochiminh City, South Vietnam¹

ABSTRACT: One of the greatest challenges facing nuclear energy is the highly radioactive long – lived material generated during power production. The option merges accelerator and fission reactor technologies into a single system that has the potential to efficiently generate electricity from nuclear fission and transmute the long – lived waste material.

In the work, we use semi-empirical formulas established from the TARC experiment to calculate the transmutation rate of the long lived radioactive isotopes ^{135}Cs , ^{79}Se , ^{126}Sn and ^{93}Zr into short lived or stable elements. The obtained results proved that Adiabatic Resonance Crossing is very efficient for destroying fission fragments and can be used to induce any other type of nuclear transmutation.

KEYWORDS: TARC, nuclear waste, transmutation, adiabatic resonance crossing.

I. INTRODUCTION

In the Accelerator Driven System (ADS) as proposed by Carlo Rubbia [1], radiotoxicity of waste is dominated by long – lived fission fragments (LLFFs) which can only be destroyed by nuclear decay following neutron capture. This system can transform LLFFs into short – lived or stable elements [2,3]

By using the semi-empirical formulas from TARC experiment [4] and cross –section $\sigma(E)$ from JENDL 3.2, we have calculated the transmutation ratio [5,6] for ^{135}Cs , ^{79}Se , ^{126}Sn and ^{93}Zr with a proton momentum of 3.5 GeV/c, nuclear reaction of (n,γ) and an efficiency of detector $\varepsilon = 1$ for very thin samples. Our calculating programs are written in Math 4.0 language and we expand the scope of the formulas for energy range from 0.1 eV to 1 MeV. To simplify our work, we assumed a constant k coefficient and extrapolated the results for standard deviation curves.

Our calculations in the range of $10^{-3}\text{eV} \leq E \leq 0.1\text{eV}$ energy region resulted in the lack of accuracy because of the lack of data in the low energy of JENDL 3.2 library. The obtained results indicate that the long – lived radioactive isotopes can capture neutron and turn into stable or short – lived radioactive isotopes.

II. RELATED WORK

1. Apparent cross section

The samples that need to be transmuted contain a 1 mg target element. We placed each sample at different positions in the lead volume one of 12 holes. We chose the location at hole10, because it is at $z = 7.5\text{ cm}$ and it is not too close and not too far from the center of the lead block. Results are showed in figs. from 1 to 4.

2. Transmutation rate

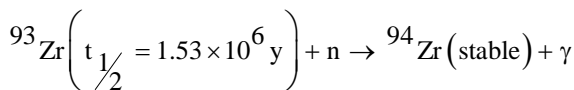
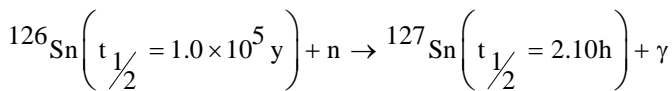
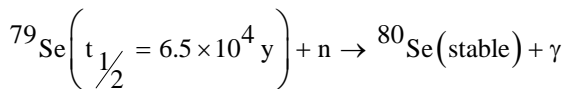
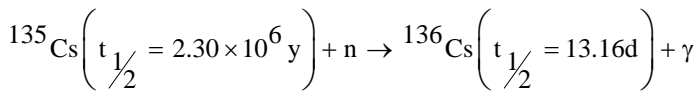
Neutron capture on ^{135}Cs , ^{79}Se , ^{126}Sn and ^{93}Zr and subsequent decay scheme:

International Journal of Innovative Research in Science, Engineering and Technology

(A High Impact Factor, Monthly, Peer Reviewed Journal)

Visit: www.ijirset.com

Vol. 6, Issue 11, November 2017



III. RESULTS

The results of calculation of apparent neutron capture cross section on ^{135}Cs , ^{79}Se , ^{126}Sn and ^{93}Zr were showed in fig.1 below:

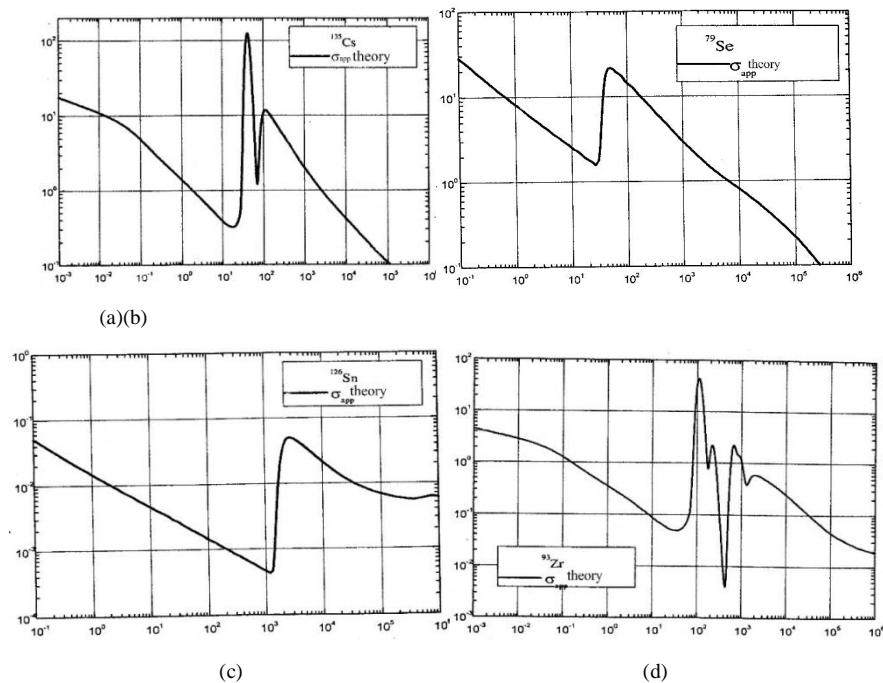


Fig.1 Calculation of apparent neutron capture cross section on the long lived radioactive isotopes by Math 4.0 and data of JENDL 3.2
(a) ^{135}Cs (b) ^{79}Se (c) ^{126}Sn (d) ^{93}Zr

Theoretical transmutation rates (tr_{thE}) for these isotopes calculated on very thin samples were showed in fig.2 from (a) to (d) below:

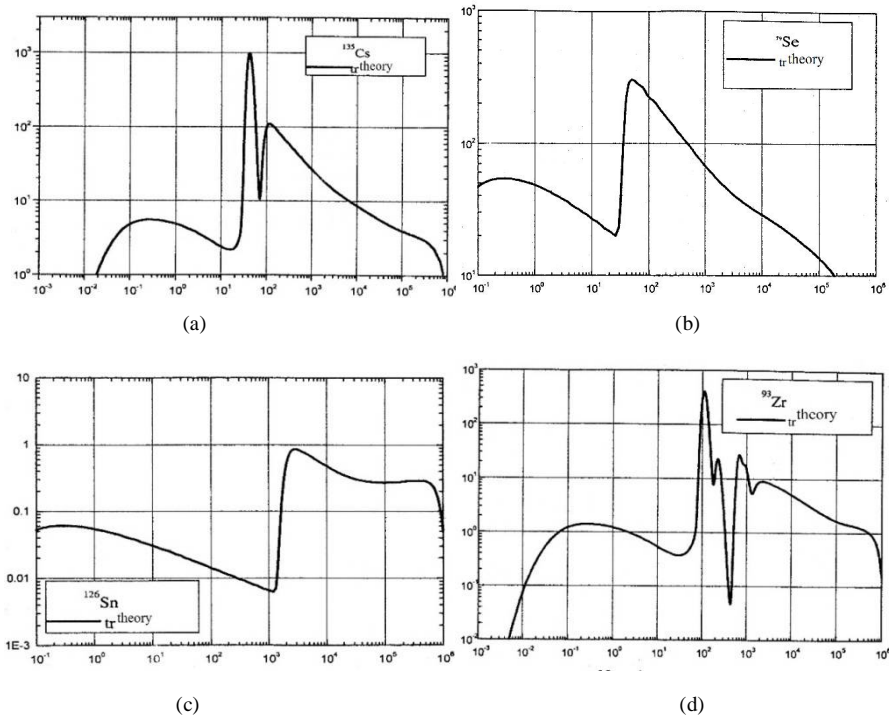


Fig. 2 Transmutation rate ($tr_{in}E$) for the long lived radioactive isotopes calculated on very thin sample of 1 gram (a) ^{135}Cs (b) ^{79}Se (c) ^{126}Sn (d) ^{93}Zr

Results from the calculation have proved that possibility of transmutation is enhanced in resonance region and is localized at some main resonance peaks where the highest neutron capture cross section occurs.

The results gave us:

- The transmutation rate is about 8% in the range of 10^{-3}eV to 20eV and 91% in the range of 20eV to 10^4eV with the isotope of ^{135}Cs .
- The transmutation rate is about 79% in the range of 1eV to 10^4eV with the isotope of ^{79}Se .
- The transmutation rate is about 66% in the range of 10^3eV to 10^6eV with ^{126}Sn . However, in the low energy region, ^{126}Sn has also a range of possibilities to capture neutrons and it is about 34% (can see this by fig.1(c))
- With ^{93}Zr , the transmutation rate is about 6% in the range 10^{-3}eV to 50eV and about 92% in the range of 10^{-3}eV to 10^6eV .
- We can see the percent rate of capturing neutrons in the table 1 and transmutation rate of ^{135}Cs , ^{79}Se , ^{126}Sn and ^{93}Zr with mass 1 gram of samples in fig.2

Table1: The percent rate of capturing neutrons in the i^{th} resonance region (tr_i) and in the full resonance region (tr_{tot})

Element	Full integrated region [$10^{-3}, 10^6$] (eV)					
	^{135}Cs		^{79}Se	^{126}Sn	^{93}Zr	
Integrated region (eV)	[$10^{-3}, 20$]	[$20, 10^4$]	[$1, 10^4$]	[$10^3, 10^6$]	[$10^{-3}, 50$]	[$50, 10^4$]
tr_i / tr_{tot}	8%	91%	79%	66%	6%	92%

International Journal of Innovative Research in Science, Engineering and Technology

(A High Impact Factor, Monthly, Peer Reviewed Journal)

Visit: www.ijirset.com

Vol. 6, Issue 11, November 2017

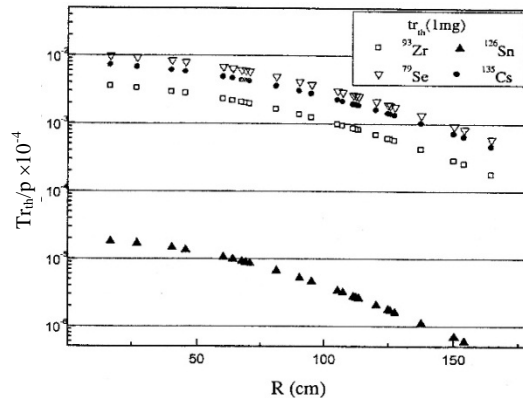


Fig.3: Transmutation rate per proton $\left(\frac{tr_{th}}{p}\right) \times 10^{-4}$ obtained from theoretical calculation

V. CONCLUSION

From the obtained results, we can draw the conclusions:

- In the resonance region a neutron has the highest probability of capturing and the highest transmutation rate. It is clearly seen that Adiabatic Resonance Crossing is very efficient for destroying fission fragments.
- In the resonance region the transmutation rate tr_{th} of ^{79}Se is highest in comparison to ^{135}Cs and ^{93}Zr while the transmutation rate of ^{126}Sn is lowest. This proved that in the thermal neutron energy region, ^{126}Sn has the high probability of capturing thermal neutrons. Therefore, we can use the Energy Amplifier system (EA) [7,8] to burn it.

REFERENCES

- [1]. Rubbia C. et al., Conceptual design of a fast neutron operated high energy amplifier, CERN internal report, CERN/AT/95-44 (ET), September 1995; see also C. Rubbia. A high gain energy amplifier operated with fast neutrons. AIP Conference Proceedings. Vol.346, International Conference on Accelerator-Driven Transmutation Technologies and Applications, Las Vegas, 1994.
- [2]. Jungmans A, Beyer R, Kogler T, Schwengner R, Transmutation of high level radioactive waste-Perspectives. Cern.ch, proceedings.2014cds; 175-181.
- [3]. Abanades A, Alvarez Velarde F, Gonzalez Romero EM, Ismailov K, Lafuente A, Nishihara K, Saito M, Stanculescu A, Sugawara T. Monte Carlo analysis of the long-lived fission product neutron capture rates at the transmutation by Adiabatic Resonance Crossing (TARC) experiment, Nuclear Engineering and Design. 2013; 254:148-153.
- [4]. Available:
<http://www.academia.edu/7765877/ResultstheTARCexperimentspallationonneutronphenomenologyinleadandneutrondrivenucleartransmutationbyadibaticresonancecrossing>
- [5]. Rubbia C. Buono S, Kadi Y, Rubio JA. Fast neutron incineration in the energy amplifier as alternative to geological storage: the case of Spain, CERN/LHC/97-01 (EET), February 1997; C. Rubbia et al., A realistic plutonium elimination scheme with energy amplifiers and thorium-plutonium fuel, CERN Internal report, CERN/AT/95-53 (ET); 1995.
- [6]. Nguyen Mong Giao, Nguyen Thi Ai Thu, TuThanhDanh, Huynh Thi Kim Chi, Ability of Accelerator Driven System to transmute Long-Lived Fragments, IAEA-ICTP-IC/2010/067, Trieste, Italy, 2010; 1-9.
- [7]. Degweler SB, Pitambar Singh P, Satyamurthy, Amar Sinha, Accelerator Driven Systems for thorium utilization in India, International Thorium Energy Conference. CERN in Geneva, Switzerland; 2013.
Available:<http://cds.cern.ch/record/1551982/files/CERN-Proceedings-2014-002.pdf>
- [8]. Gu Long, Head of Nuclear Reactor Physics laboratory Lanzhou, China, Status of the Chinese Accelerator driven System (ADS) project, A&T seminar; 2014.
Available:
<http://indico.cern.ch/event/312986/material/0/0.pdf>