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Comparison of Activation Analysis Codes between ORIGEN-S and FLUKA

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1. Introduction

A Slowing Down Time Spectrometer (SDTS) system [1,2] is a highly efficient technique in isotopic nuclear material content analysis. SDTS is the most feasible technology among the non-destructive techniques to analyze isotopic fissile material content directly. A source neutron is necessary to induce isotopic fissile fission. A high intensity neutron source is required to ensure a high for a good fissile fission. Therefore, the target is required to have a high intensity neutron source through a proper target design. A status of activation on the target is analyzed through the activation code.

New nuclides were generated by neutron irradiation on the target. The energy of the nuclides has an effect on other materials. Therefore information on the nuclides is required. The radioactivity intensity and the kind of nuclides are measured through an activation analysis.

An activation analysis was conducted on the target materials. Generally, Origen-s code [3] is used in the activation analysis. An activation analysis of the Tantalum target was performed using MCNPX [4] and Origen-s combination code. The results were compared with those of the FLUKA code [5,6]. The Origen-s and FLUKA code simulation results are provided for a comparison with the activation analysis code.

2. Experimental Procedure

2.1 ORIGEN-S

Origen-s is an updated version of the Origen code with flexible dimensioning and free-form input processing. One of the primary objectives in developing Origen-s was that the calculations are able to utilize multi-energy-group neutron flux and cross sections in any group structure. Utilization of the Multi-group data is automated through the couple code. Origen-s performs point depletion and decay analyses to obtain the isotopic concentrations, decay heat source terms, and radioactivity source spectra and strengths for use in subsequent system analyses [3].

2.2 FLUKA Code

FLUKA is a general purpose tool for calculations of particle transport and interactions with matter, covering an extended range of applications spanning from proton and electron accelerator shielding to the target design, activation, calorimetry, dosimetry, detector design, Accelerator Driven Systems, cosmic rays, neutrino physics, and radiotherapy [5].

2.3 Simulation Activation Analysis

The activation of neutrons irradiated at the target in the code was predicted. The material composition, average neutron flux of the total area, irradiation time, and source energy are required. The neutron flux in the target structure is calculated using the MCNPX code. The results are applied to the Origen-s code. Fig. 1 shows the calculation procedure of MCNP/ORIGEN-S.

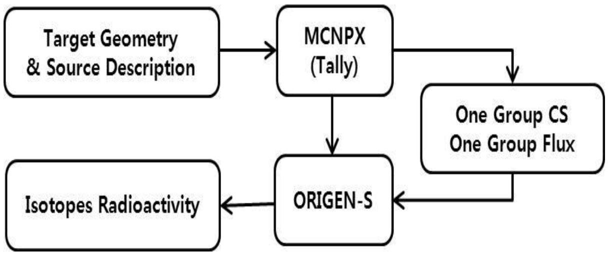

Fig. 1. Calculation procedure of MCNPX /ORIGEN-S

The FLUKA code enters the input file using a flair system. Fig. 2 shows the calculation procedure of FLUKA. The input cards include RADDECAY, IRRPROFI, DCYTIMES, DCYSCORE, RESNUCLE, and AUXSCORE. By applying the condition values in the input card, the input file was run.

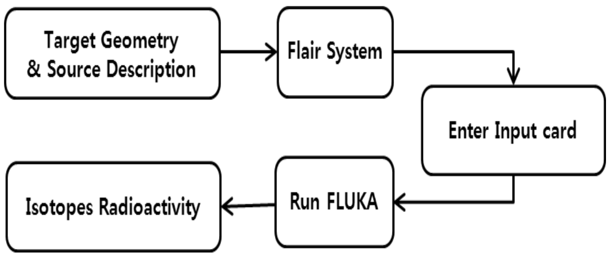

Fig. 2. Calculation procedure of FLUKA

Fig. 3 shows the target structure. It is a cylinder type. The target diameter is 5 cm and the height is 10 cm. The target is composed of tantalum, copper, and lead. The irradiation time of the target is 30 hours. The cooling time is 1 hour, 1 day, 15 days and 30 days. The incident neutron energy is 10 MeV.

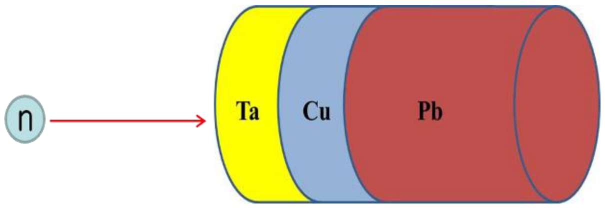

Fig. 3. Structure and material of the target

3. Result

The results of radioactivity and created nuclides were compared in two different activation codes. Tables I and II show the activation results of Ta. The activation results using the Origen-s code and FLUKA code were somewhat different. In addition, the radioactivity intensity in the case of the same nuclide was different. The radioactivity intensity is decreased proportionally to the half-life of the nuclide. The nuclide, Lu-176, has a long half-life. The radioactivity intensity for 30 days was not changed in the Origen-S activation results. However, the result of the FLUKA code was zero. Tables III and VI show the activation results of Cu. According to two different activation codes, the radioactivity intensity of the Co-58 and Co-60 was different. The activation results for the lead showed a similar trend as tantalum and copper. The results of the Origen-s are consistent with the half-life; however, the FLUKA code was not satisfied.

Table I: Activation result of Ta by ORIGEN-S

Unit : Bq

Nuclide	Cooling Time				Half-Life
	60min	1day	15day	30day	
Lu-177	8.51E+03	7.93E+03	1.84E+03	3.86E+02	6.7days
Lu-176	3.91E-11	3.91E-11	3.91E-11	3.91E-11	$3.37x10^{10}$year
Ta-183	1.15E-07	1.01E-07	1.51E-08	1.96E-09	5.1days
Ta-182	2.80E+00	2.78E+00	2.56E+00	2.34E+00	114.4days
Ta-180	1.48E+19	2.09E+18	8.25E+05	4.23E-08	8.15hours

Table II: Activation result of Ta by FLUKA

Unit : Bq

Nuclide	Cooling Time				Half-Life
	60min	1day	15day	30day	
Lu-174	8.51E+05	8.48E+05	7.92E+05	7.35E+05	3.3years
Lu-176	5.76E+07	7.18E+05	1.07E-22	0.00E+00	$3.37x10^{10}$year
Lu-177	5.39E+05	5.36E+05	5.04E+05	4.73E+05	6.7days
Hf-178m	8.53E+04	8.53E+04	8.51E+04	8.51E+04	31years
Hf-179m	3.35E+07	3.25E+07	2.21E+07	1.46E+07	25.1days
Ta-182	7.51E+08	4.46E-18	0.00E+00	0.00E+00	114.4days

Table III: Activation result of Cu by FLUKA

Unit : Bq

Nuclide	Cooling Time				Half-Life
	60min	1day	15day	30day	
Co-58	1.50E+09	2.62E+08	2.31E-03	3.31E-15	71.3days
Co-60	1.35E+07	9.49E-02	9.49E-02	9.49E-02	5.26years

Table IV: Activation result of Cu by ORIGEN-S

Unit : Bq

Nuclide	Cooling Time				Half-Life
	60min	1day	15day	30day	
Co-58	1.30E-09	1.82E-09	1.68E-09	1.45E-09	71.3days
Co-60	3.86E+04	3.85E+04	3.83E+04	3.81E+04	5.26years

4. Conclusion

A Slowing Down Time Spectrometer (SDTS) system is a highly efficient technique in a nuclear material analysis. An activation analysis on the shielding and target material was required for the SDTS system.

The simulation results differed in terms of the radioactivity intensity of the nuclides. In addition, the nuclides generated were different. The Origen-s code showed a consistent trend with the half-life However, the FLUKA code was not satisfied. A study on the FLUKA code and Origen-s code is necessary to complement this problem. Simulation results are provided to select the activation analysis code.

5. ACKNOWLEDGMENTS

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