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NUCLEAR DATA PROCESSING FOR CROSS-SECTIONS GENERATION FOR FUSION-FISSION, ADS, AND IV GENERATION REACTORS UTILIZATION

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ABSTRACT

One of the mains topics about nuclear reactors is the microscopic cross section for incident neutrons. Therefore, in this work, it is evaluated the microscopic and macroscopic cross section for a nuclide and a material. One of the nuclides microscopic cross-section studied is the ^{56}Fe which is the highest compound from the material macroscopic cross section studied SS316. On the other hand, it was studied the microscopic cross section of the ^{242}Pu which is one of the nuclides that composes the nuclear fuel. The nuclear fuel chosen is a spent fuel reprocessed by UREX+ technique and spiked with thorium with 20% of fissile material. Therefore it was studied the macroscopic cross section from this nuclear fuel. Both of them were compared by using three different ways to reprocess the nuclides, one for LWR, another for ADS and the last one for Fusion reactors. The library used was JEFF-3.2 recommend for the reactors studied. The comparison was made at 1200 K for the nuclear fuel and 700K for the SS316.The results present differences due to the energy discretization, the number of groups chosen for each reactor and some nuclear reactions taken into consideration according to the neutron spectrum for each reactor. The nuclides were processed by NJOY99.364 and plotted with MCNP-Vised.

1. INTRODUCTION

The microscopic cross section is an effective area quantifying the likelihood of interaction between an incident particle and a target (nuclide) [1]. One of the most interesting particles to study for a nuclear reactor is the neutron, because the set of neutrons with different energies is called neutron spectrum. The neutron spectrum depends on the nuclear reactor such as thermal reactor (light water reactor), fast reactors, the hybrid reactor (ADS and Fusion Fission reactors) and fusion reactor. The thermal reactor has a wide range of energy until 10 MeV produced by the fission reactions, ADS produce few neutrons over 25 MeV coming from the spallation reactions and Fusion systems produce neutrons at 14.1 MeV produced by the nuclear fusion reactions. The main features to consider when referring to the microscopic cross section for neutrons are the energy and the temperature. The target cross section depends on, the energy of the incident neutron and the interaction temperature due to the Doppler Effect, which affects the cross section when increasing the temperature. The cross section refers different reactions such as radiative capture, inelastic scattering, elastic scattering, particle production, neutron production and fission, etc.

Laboratories from different countries around the world have made an approximation of the nuclides microscopic cross section and they are in the ENDF-6 format [2-7]. The JEFF-3.2 is the joint evaluated fission and fusion file project which collaborates with NEA DATA Bank member country. This library was used due to its recommendation for fission and fusion application, as well as, for ADS systems [3, 8]. Each system mentioned has its own characteristics with neutron production in different energy range. Therefore, the nuclides should be processed in a different way due to the neutron spectrum in each reactor depends on, the collapsed energies desired according to the properties of the system used such as Light Water Reactor (LWR) [9], Accelerator Driven System (ADS)[10] or Fusion Fission System (FFS) [11]. The DEN/UFMG has been using the NJOY.99-364 [112] to process the library information according to the needs for the reactor simulation.

2. METHODOLOGY

The JEFF-3.2 library was processed in three different forms, one for fusion reactors, another one for an ADS and the last one for a LWR. The main differences between the processing were the number of collapsed groups (energies), the energy values and the nuclear reactions between them. The nuclide cross section and the material cross section were plotted on the MCNP-Vised, which allows plotting a single nuclide or a material used on the system. The SS316 was plotted for 8 different temperature 293.6, 400, 500, 600, 700, 800, 900 and 1200 K, but chosen at 700 K as the main temperature, which is the temperature studied for the SS316. On the other hand, the nuclides used for the nuclear fuel were processed just for one temperature at 1200 K.

Two materials were processed for each case; the first one is a typical stainless steel SS316. The stainless steel SS316 was chosen because is one of the most used materials in the nuclear field for structure design and shielding. Table 1 presents the composition of the SS316 and the nuclide chosen from them is the most abundant on the material that is the ^{56}Fe. Table 2 is the nuclear fuel that is reprocessed by UREX+ technique spiked with uranium with 20% of fissile material. To identify the different process between the LWR, ADS, and Fusion, the nuclide ^{242}Pu was chosen randomly for the comparison.

Table 1. SS316 fuel composition in mass percent

Nuclide	%w	Nuclide	%w	Material	%w
^{10}B	3.9800E-06	^{54}Cr	4.0205E-03	^{64}Ni	1.2038E-02
^{11}B	1.6020E-05	^{55}Mn	1.8000E-02	^{92}Mo	2.9680E-03
^{12}C	4.9445E-04	^{54}Fe	3.8313E-02	^{94}Mo	1.8500E-03
^{13}C	5.5500E-06	^{56}Fe	6.0143E-01	^{95}Mo	3.1840E-03
^{28}Si	1.8600E-04	^{57}Fe	1.3890E-02	^{96}Mo	3.3360E-03
^{29}Si	2.8020E-04	^{58}Fe	1.8485E-03	^{97}Mo	1.9100E-03
^{30}Si	5.5338E-03	^{58}Ni	8.8500E-02	^{98}Mo	4.8260E-03
^{50}Cr	7.3865E-03	^{60}Ni	3.4090E-02	^{100}Mo	1.9260E-03
^{52}Cr	1.4244E-01	^{61}Ni	1.4820E-03		
^{53}Cr	1.6152E-02	^{62}Ni	4.7242.E-03		

Table 2. Nuclear fuel reprocessed by UREX+ spiked with thorium with 20% fissile material

Nuclide	%w	Nuclide	%w	Nuclide	%w
^{232}Th	5.9782E-01	^{242}Pu	1.7122E-02	^{244}Cm	8.6174E-04
^{237}Np	9.2824E-03	^{241}Am	9.9499E-03	^{245}Cm	4.5406E-05

^{238}Pu	4.9164E-03	^{242}Am	2.6613E-06	^{246}Cm	5.8440E-06
^{239}Pu	1.4347E-02	^{243}Am	3.7364E-03	^{16}O	1.2006E-01
^{240}Pu	6.0165E-02	^{242}Cm	2.1577E-07		
^{241}Pu	3.2521E-02	^{243}Cm	1.1463E-05		

2.1. Fusion Processing

The fusion processing has the structure for NJOY in the following order: moder-moder-reconr-broadr-heatr-gaspr-purr-acer-acer-groupr-reconr-gaminr-matxsr. All the nuclides for fusion processing follow this sequence. The *broadr* (Doppler broaden) has a tolerance between 0.1 to 0.2% with 0 max. energy for broadening and thinning. The *heart* (heating kerma and damage energy) process seven types different of partial kerma for reaction for gamma file some of them are elastic heating, inelastic, fission, capture heating, total kinematic kerma and total. The *purr* module (the process of unresolved resonance range) has 10 number of sigma zeros, 20 probabilities bins, and 100 resonance ladder. The *groupr* (multigroup data for neutrons) has main features like 10 gamma group structure, 11 weight function and 6 Legendre order and 10 number of sigma zeros distrusted as (1.E+10 1.E+04 1.E+03 1.E+02 3.E+01 1.E+01 3.E+00 1.E+00 1.E-01 1.E-03) and the energies are collapsed to 211 groups. The fusion process includes a module for photo-atomic processing data [13]. The collapse energies are divided in 211 group between 1.0000100E-05 to 5.5000000E+07. The acer module as well as the purr module are useful to put the information in a readily format to MCNP. This procedure is the same for the ADS and LWR processings.

2.2. ADS Processing

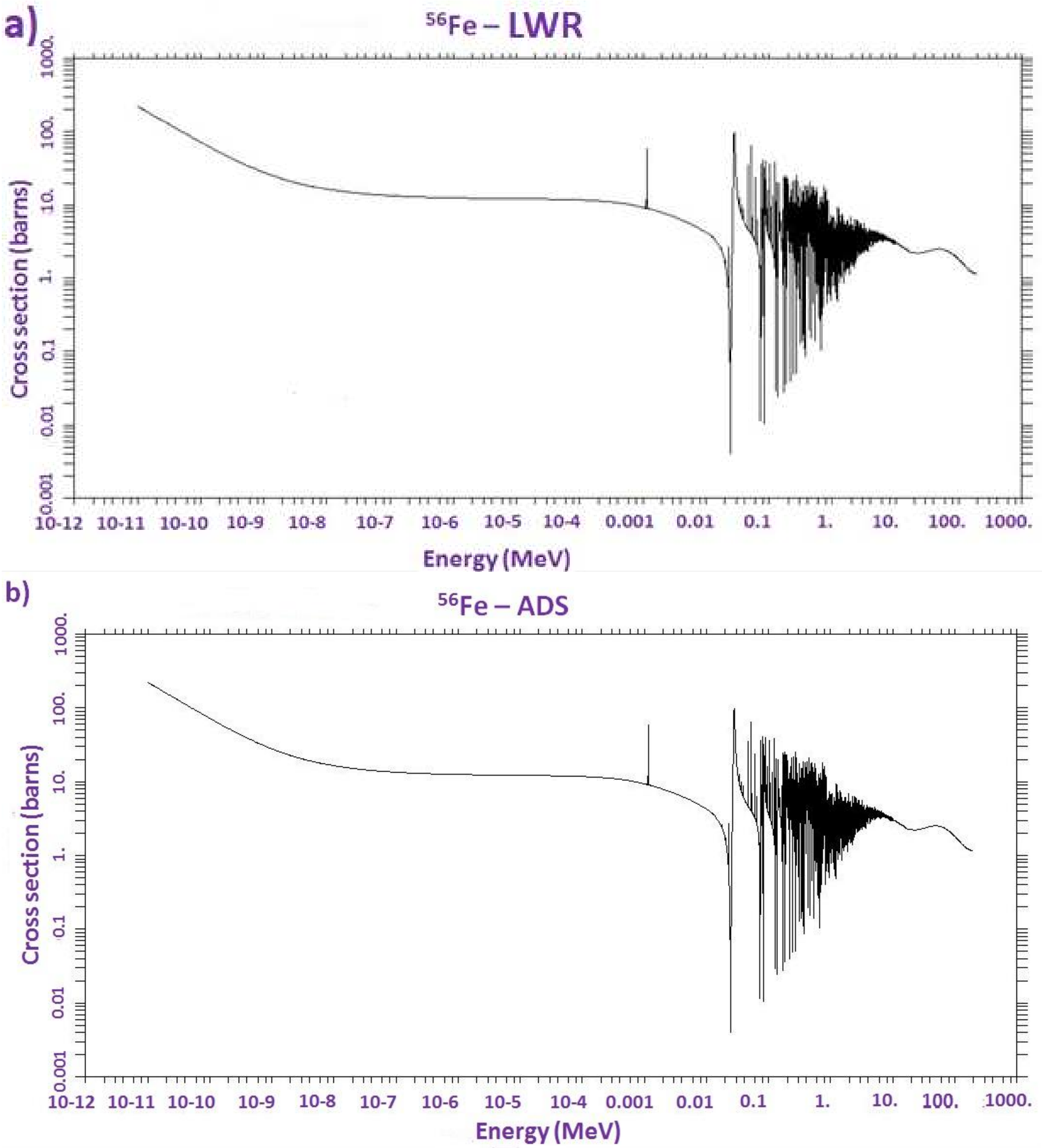
The ADS processing has the structure for NJOY99-3.64 in the following order: moder-reconr-broadr-heatr-gaspr-purr-thermr-moder-acer-acer-moder-groupr-matxsr. All the nuclides for ADS processing follow this sequence. The *broadr* module has a tolerance between 0.1 to 0.3% with a 1.0E6 max. energy for broadening and thinning. The *heart* module have just two treatment for heating kerma and damage energy the total kinematic kerma and total. For processing it is used the *thermr* module with 12 equi-probable angles, computed as a free gas, with an inelastic distribution and with 221 principal atoms. The *purr* module has 10 sigma zeros, 20 probabilities bins and 100 resonance ladders. The *groupr* module has 10 sigma zeros distributed as (1.E+10 2.E+4 3600. 1000. 260. 140. 64. 52. 28. 10.) and 421 energy groups [14]. The collapse energies are divided in 421 group between 1.000000-5 to 2.000000+7.

2.3. LWR Processing

The LWR processing has the structure for NJOY99-3.64 in the following order: moder-reconr- broadr-heatr-gaspr-thermr-purr-acer-acer-groupr-matxsr. All the nuclides for the LWR processing follow this sequence. The *broadr* module has a tolerance between 0.1 to 0.3% with 2.0e+6 max. energy for broadening and thinning. The *heatr* module has seven types different of partial kerma for reaction for gamma file some of them are elastic heating, inelastic, fission, capture heating, total kinematic kerma and total. It also includes a *thermr* module that processes thermal scattering data with 12 equi-probable angles, computed as a free gas, with an inelastic distribution, and with 221 principal atoms. The purr module has 5 sigma zeros, 20 probabilities bins and 64 resonance ladders. The *groupr* module has 5 sigma zeros distributed as (1.E+10 1.E+04 1.E+03 1.E+02 1.E+01) and 238 energy groups [3]. The collapse energies are divided into 238 groups from 1.0000E-05 to 2.0000E+07.

3. RESULTS

The nuclide studied is the ^{56}Fe which has the higher concentration composition on the SS316. Therefore, it is compared this nuclide with the three different processing types (LWR, ADS, Fusion). The figure 1a shows LWR processing, figure 1b shows the ADS processing and figure 1c the Fusion processing. The Fusion has a peak at 0.001 MeV higher than the other ones because the other two are below 100 barns and the one for the fusion is higher than this value.



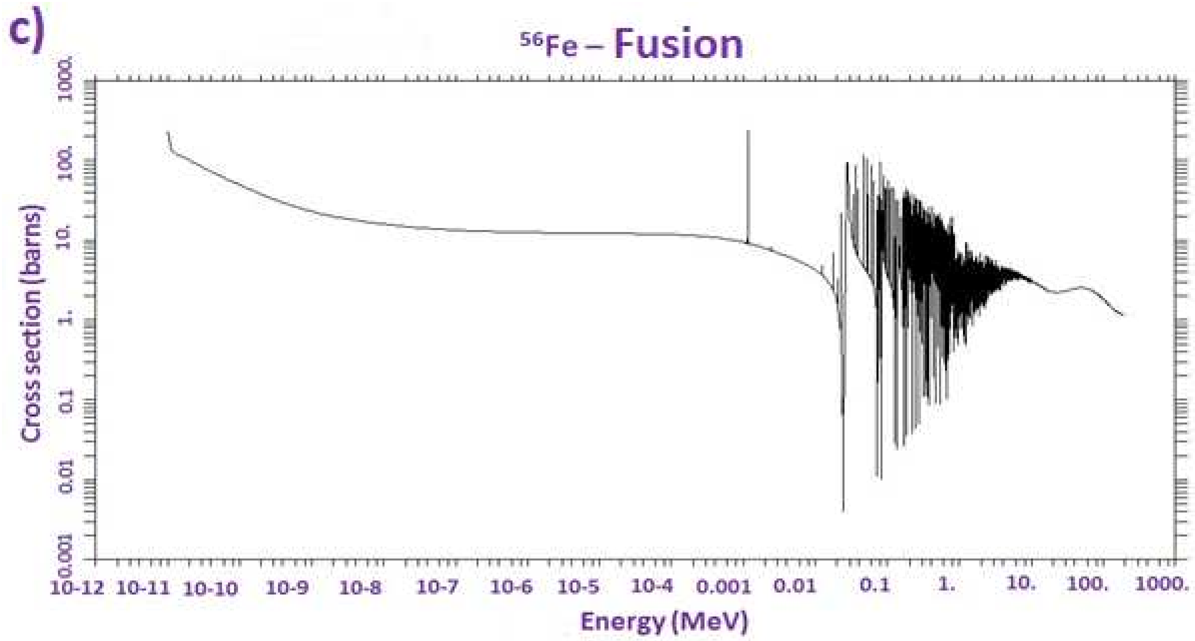
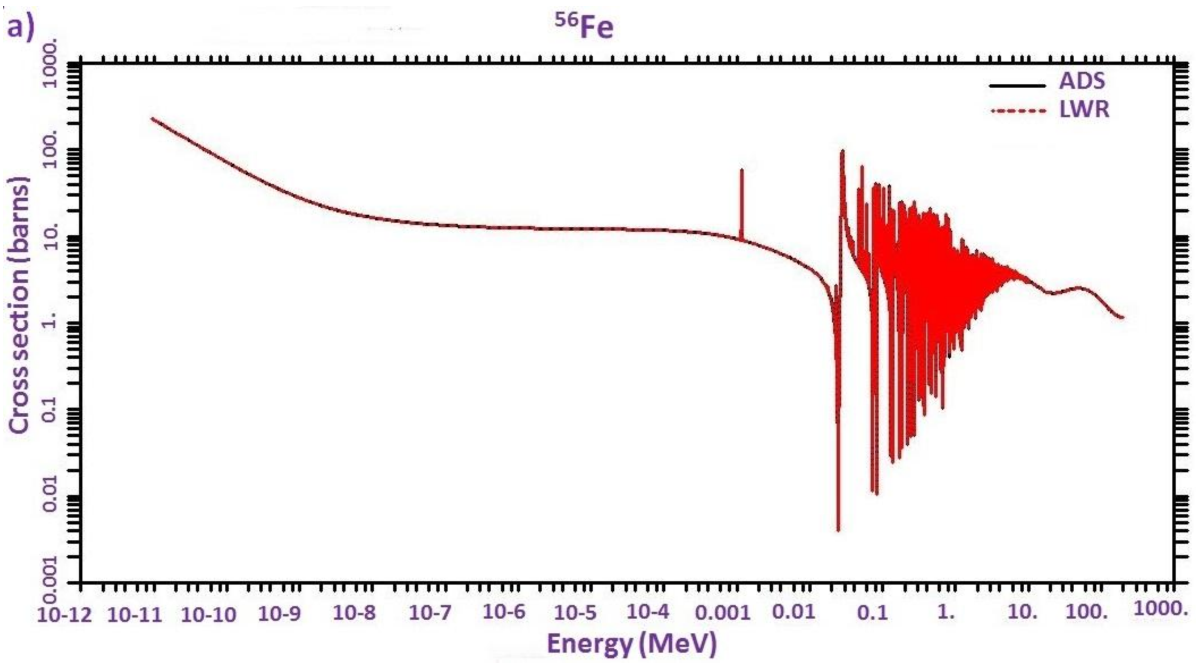
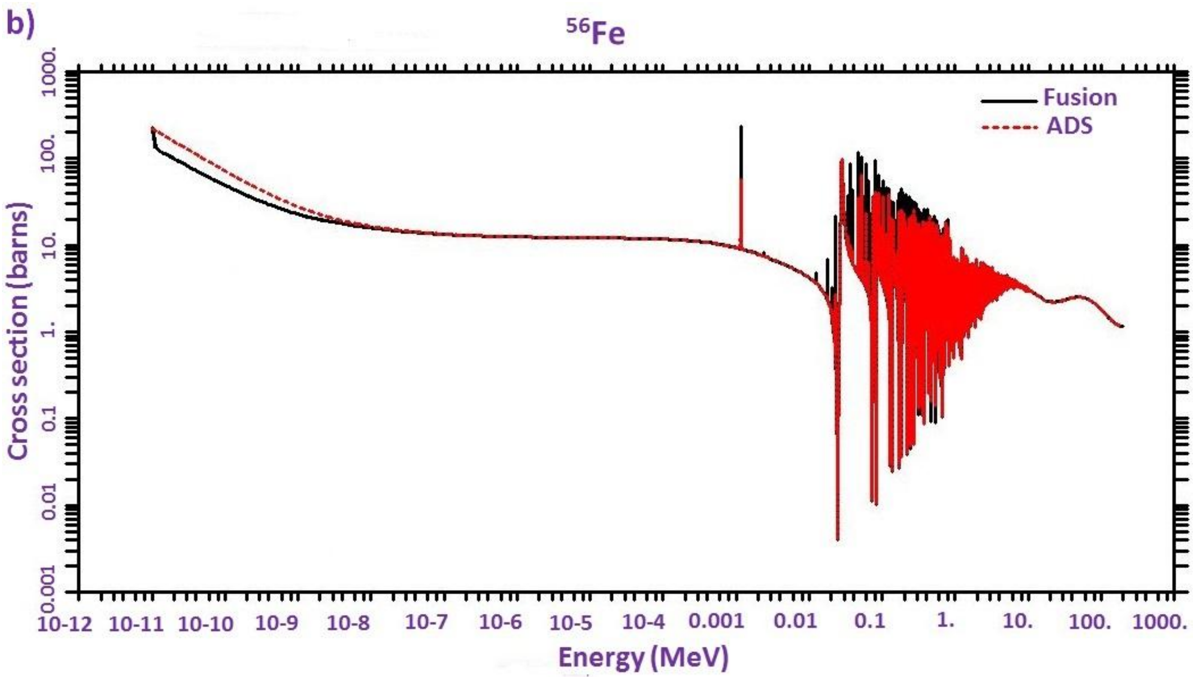


Figure 1: Cross section for ^{56}Fe processed by a) LWR, b) ADS and c) Fusion

Figure 2 shows a comparison between the different processing forms (LWR, ADS and Fusion). The most highlighted results are between the fusion process and other two as shown figure 2b, 2c. On the other hand, figure 2a does not show differences between the processed forms between LWR and ADS for just one nuclide.





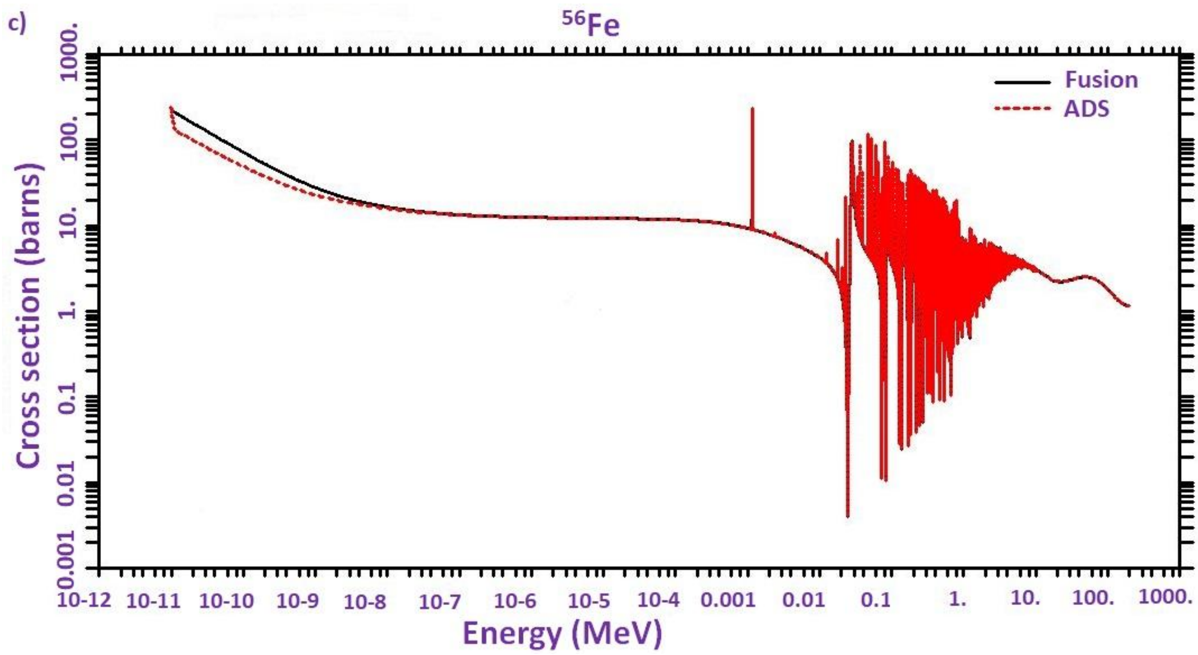


Figure 2. Comparison between the cross section of the ^{56}Fe after the different process at 700 K a) ADS & LWR, b) Fusion &ADS and c) Fusion & LWR

The material cross section is a weighted average of the mass fraction contributed to the material from each nuclide. In other words, each nuclide has a contribution to the material cross section according to their mass percent on the material. Figure 3 shows the comparison between the SS316 cross section processed by each different form of processing. Again, there is a huge difference between Fusion process and the ADS and LWR process. Nevertheless, the difference between the ADS and LWR is minimum and can be appreciated by the red line highlighted around 0.001 MeV.

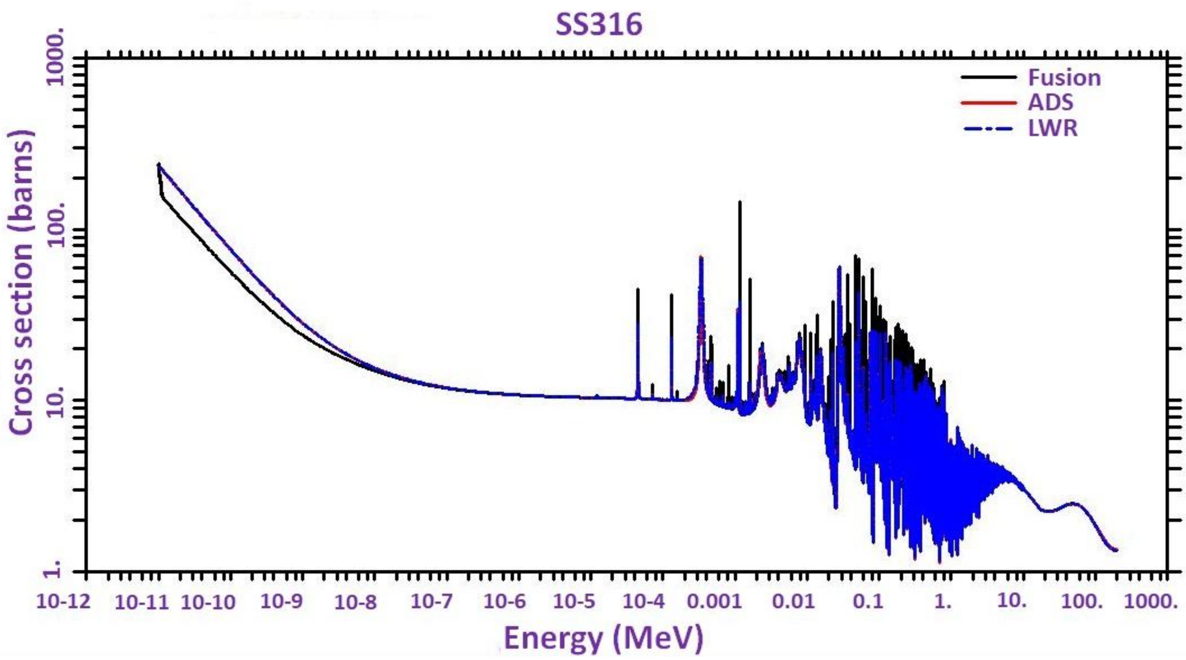
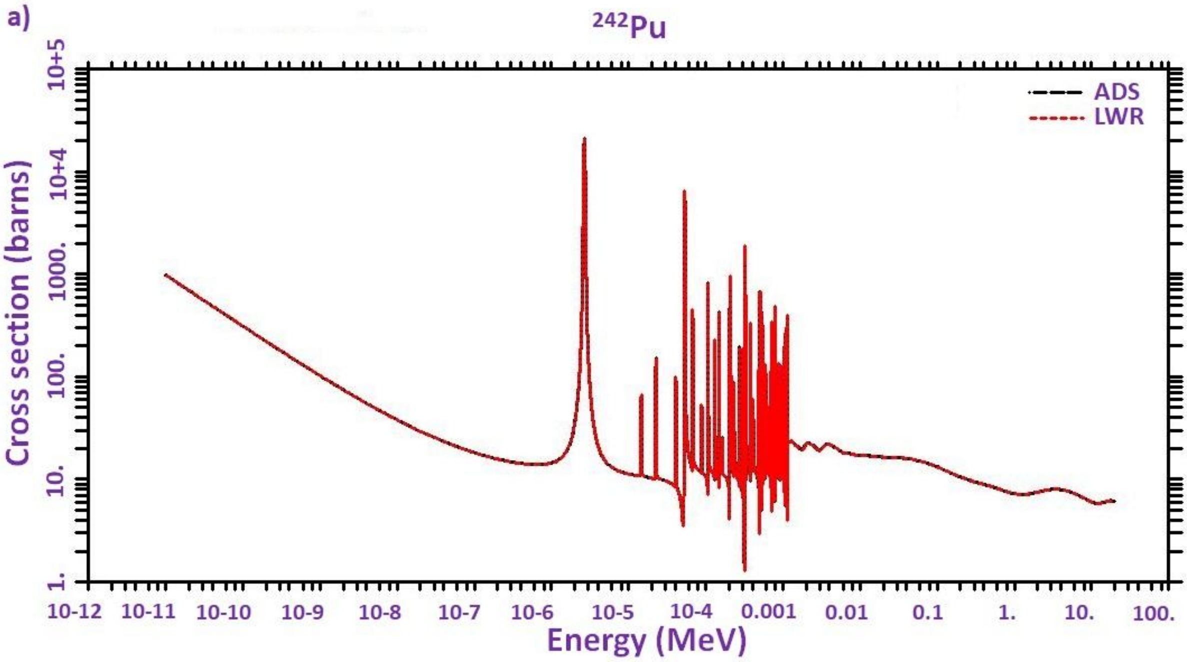


Figure 3. SS316 cross section processed at 700 K for Fusion (black), ADS (red) and LWR (blue)

Figure 4 shows the cross section for the ^{242}Pu, which is one of the nuclides that compose the nuclear fuel. The differences between ADS and LWR is almost not perceptible, but the differences between the Fusion - ADS and Fusion LWR show great differences, although it was processed at the same temperature 1200 K with different parameters for each reactor case.

On the other hand, figure 5 shows the material cross section for the nuclear fuel reprocessed by UREX+ and spiked with thorium at 20 of fissile material. There greater differences as mentioned before is between the Fusion process and the others two. Nevertheless, there is a small difference perceptible between the ADS and LWR processing between 10E-4 to 10E-5

MeV.


a)
242Pu
ADS
LWR
Cross section (barns)
10+5
10+4
1000.
100.
10.
1.
10-12
10-11
10-10
10-9
10-8
10-7
10-6
10-5
10-4
0.001
0.01
0.1
1.
10.
100.
Energy (MeV)

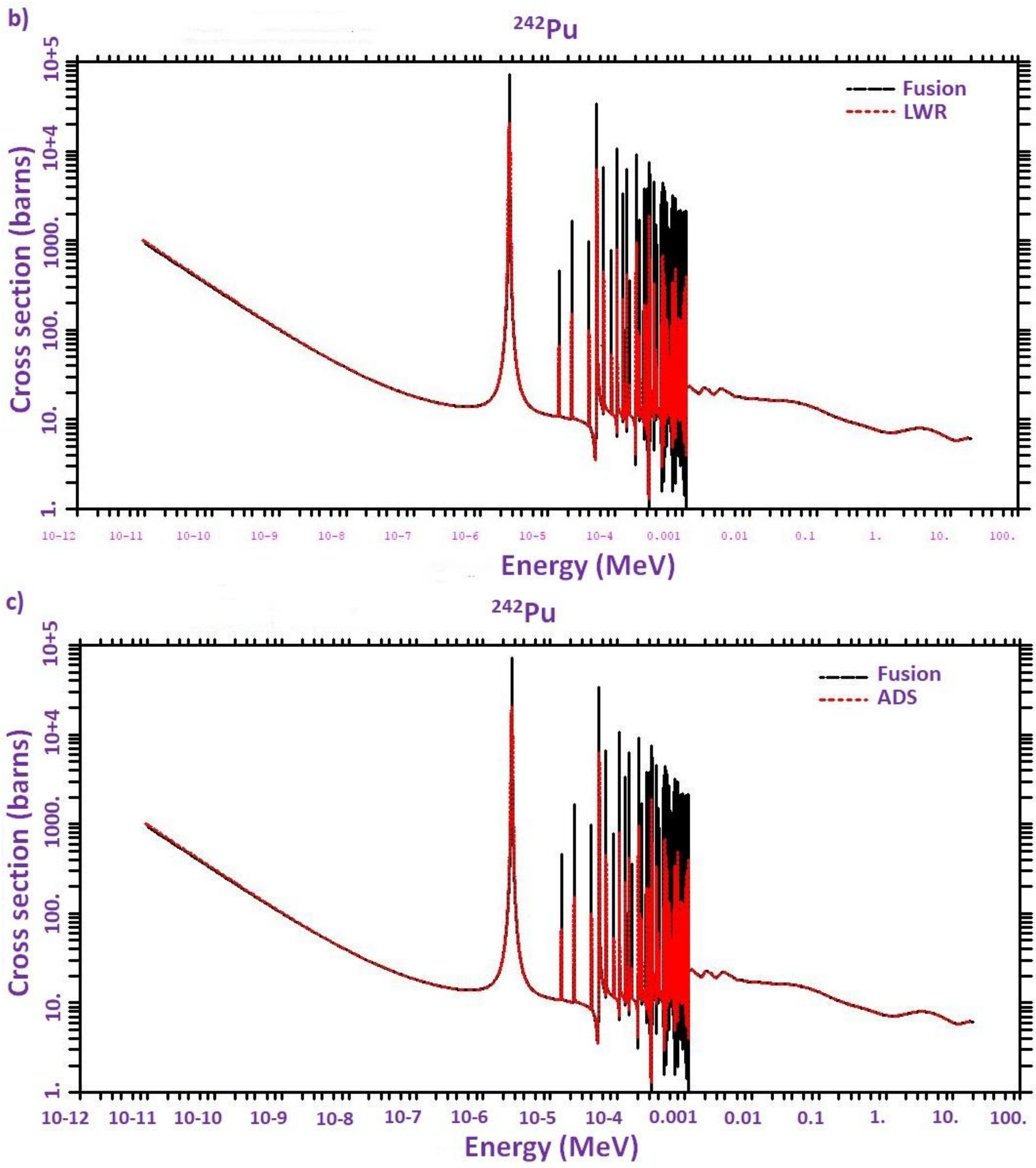


Figure 4. ^{242}Pu cross section comparison between the different processing at 1200 K a) ADS & LWR b) Fusion & LWR c) Fusion & ADS

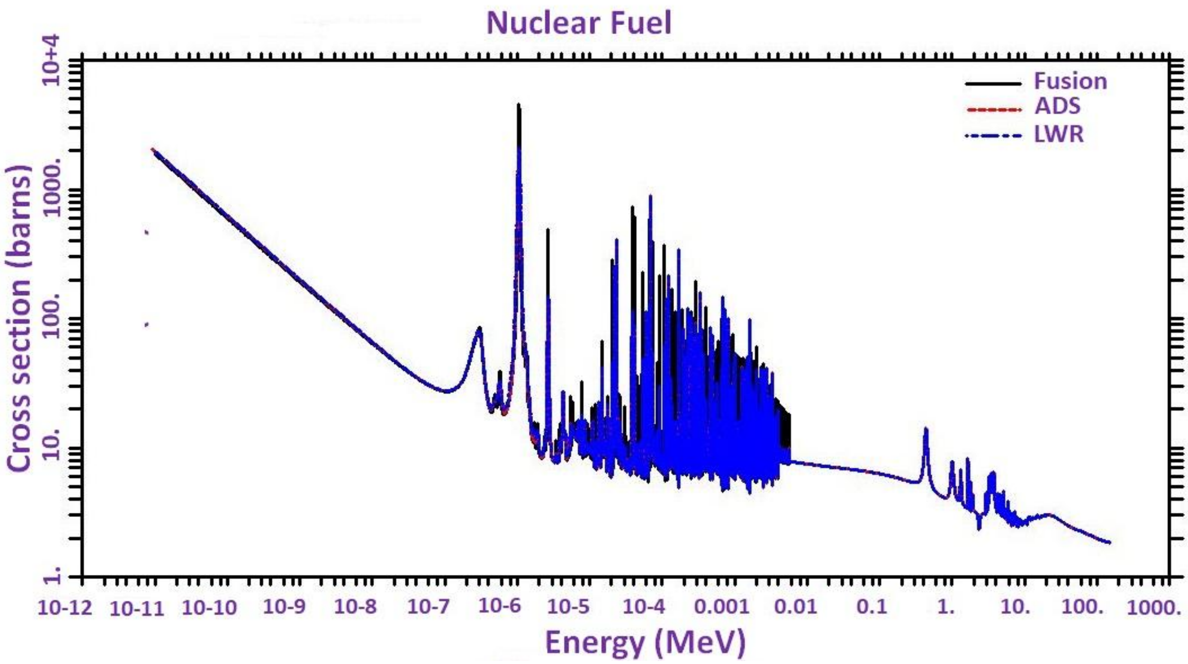


Figure 5. Nuclear fuel with 20% of fissile material reprocessed by UREX+ process spiked with thorium LWR (red), ADS (blue) and Fusion (black)

3. CONCLUSIONS

The ADS and LWR process is very similar if compared one by one nuclide. However, when a fuel composition is compared a small difference appears when a material is plotted. The fusion process diverges from the other two in higher proportion due to the high energy neutrons produced, the collapsed energies and energy the distribution is different for this fusion processing. One of the main differences between the fusion processing is the energy range that is different from the other two, as well as, the discretization between the ranges. The *thermr* module affects also the behavior for neutron moderation. This module is not required for fusion processing because it is not desirable to moderate the neutrons. Future works will show which nuclide or nuclides makes the difference between the ADS and LWR material.

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