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ACTINIDES TRANSMUTATION - A COMPARISON OF RESULTS FOR PWR BENCHMARK

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ABSTRACT

The physical aspects involved in the Partitioning and Transmutation (P&T) of minor actinides (MA) and fission products (FP) generated by reactors PWR are of great interest in the nuclear industry. Besides these the reduction in the storage of radioactive wastes are related with the acceptability of the nuclear electric power. From the several concepts for partitioning and transmutation suggested in literature, one of them involves PWR reactors to burn the fuel containing plutonium and minor actinides reprocessed of UO_2 used in previous stages. In this work are presented the results of the calculations of a benchmark in P&T carried with WIMSD5B program using its new cross sections library generated from the ENDF-B-VII and the comparison with the results published in literature by other calculations. For comparison, was used the benchmark transmutation concept based in a typical PWR cell and the analyzed results were the k_∞ and the atomic density of the isotopes Np-239, Pu-241, Pu-242 and Am-242m, as function of burnup considering discharge of 50 GWd/tHM.

1. INTRODUCTION

The basic idea behind the Partitioning & Transmutation (P&T) of the minor actinides is simple [1,2]. After identifying the nuclides which more contribute negatively with the radioactive wastes of the nuclear reactors, they are partitioned from the others using a conventional chemical processes. These radionuclides are then placed in a high flux of neutrons and by absorption process they are transmuted in stable isotopes or isotopes with much shorter half-life. This ensures that its radionuclide would decay to safe level in a much shorter time than would without P&T. Although the basic idea is simple, its execution is not so easy to attainment. The identification of which radionuclide are important to be transmuted does not only consider their decline time but also which of then can be transported out of repository by ground water flow. Beyond the question of the waste storage, the technologies of P&T contribute for the recover and reuse of the potentially available energy contained in the radioactive wastes of a once thought fuel cycle. One another favorable aspect of this technology is with regard to the anti-proliferation of nuclear materials. The simple nuclear fuel storage is presented as the creation of a “plutonium mine” that could facilitate the access to this material with warlike purpose. The reprocessing of the nuclear fuel inside of the technology of partitioning and transmutation assures that the plutonium is not produced in isolated form but with other minor actinides to difficult its use with weapon purposes. For the implementation of this technology, some studies had been carried to considerer the several fuel cycles to be employed. An effective program of partitioning and transmutation are attained if PWR reactors, Fast Reactors and Accelerating machines are applied in the reuse of

the reprocessed fuels. To evaluate the capacity of calculation in this area, a benchmark [3] was defined based on a conventional PWR cell.

In this work, it is carried a comparative study of the results attained in k_∞ calculation and isotopes concentration of minor actinides, for the benchmark. The WIMSD5B [4] computational program with its libraries was used. One of its libraries was generated using the basic data library ENDF/B-7 and the other library was the recommended by IAEA and generated in the WLUP project (WIMS Library Update Project) [5].

2. FUEL CELL MODEL

The calculations models involving partitioning and transmutation was based on the conventional calculations of fuel burning in conventional PWR reactors. Although satisfactory, the nuclear data library for minor actinides are not very exact and the decay chain frequently uses approach [6] in the calculations it was necessary evaluate a benchmark to define the range of confidence in the results. The benchmark defined not has experimental values, so the results attained can be compared with similar calculations carried by other institutions.

The benchmark [2] consists in calculate the isotope concentration of materials that compose a pin fuel of PWR reactor, after burning, reprocessing and reuse as mixing oxide form (MOX),or reuse in fast reactors (FR) or reuse in accelerators drive systems (ADS). Three stages was defined. In the first stage it is considered the fuel UO_2 of a PWR reactor. A representative pin cell is used to perform the burn-up calculation to 50 GWd/tHM. After this stage, the fuel is reprocessed after seven years of cooling and the plutonium and minor actinides are recovered. These materials are then used to specify the fuel composition for the second stage, now mixing Pu and U in oxide form (MOX). The time considered for the manufacture of the fuel is three years, allowing buildup Am-241 in the fuel. This new fuel can be used in PWR pin cell or fast reactors FR. The spent fuel of this stage will suffer a new reprocessing and will be used to defining a new fuel composition for the third stage. This stage is called the partitioning and transmutation stage. Now the fuel can be reused as MOX fuel in PWR, or MOX fuel in reactors fast (FR) or to supply systems drive accelerators (ADS).

In this work, only the burnings related with PWR reactors had been studied. It was used of the definition of a typical cell with the geometry shown in Fig. 1. The volumetric ratio of moderator to fuel was of 1.929 which results in a moderator radius of 0.7410 cm, external cladding radius of 0.4750 cm and external fuel radius of 0.4096 cm. That is equivalent to a 1.3133 cm cell square pitch. The initial fuel composition used in this work was originated of the burn-up of 50 GWd/tHM of a conventional PWR fuel with UO_2 4.65 % in the first stage and the addition a 2.5 wt% of minor actinides was considered.

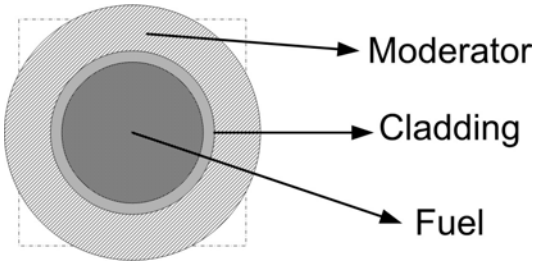

Figure 1 Benchmark cell geometry

The number densities for each region in the pin cell are presented in Table 1.

Table 1. Number densities of the PWR lattice

Isotope	Fuel
235U	1.2639E-04
238U	1.7651E-02
237Np	2.5357E-05
238Pu	1.9044E-04
239Pu	1.9462E-03
240Pu	1.4167E-03
241Pu	4.8771E-04
242Pu	5.2487E-04
241Am	3.3540E-04
243Am	1.5041E-04
244Cm	6.5121E-05
O	4.5839E-02
	Cladding
Zr	4.3365E-02
	Moderator
H	4.7769E-02
O	2.3885E-02

Using these values for the initial concentrations in the fuel, a burn-up of 50 GWd/tHM was carried, using the steps presented in the Table 2.

Tabela 2 – Steps for depletion calculation

Steps	Burn-up (MWd/tHM)	ΔT* (day)
1	0	0,000
2	150	3,916
3	500	9,138
4	1.000	13,055
5	2.000	26,110
6	4.000	52,219
7	6.000	52,219
8	10.000	104,439
9	15.000	130,548
10	20.000	130,548
11	22.000	52,219
12	26.000	104,439
13	30.000	104,439
14	33.000	78,329
15	33.300	7,833
16	35.000	44,386
17	40.000	130,548
17	40.000	130,548
19	50.000	130,548

* Linear Power Rating = 180,02 W/cm

3. RESULTS

Since does not exist an experimental value to this benchmark, the results gotten with program WIMSD5B, using two different libraries was compared to the values gotten by other institutions. The two libraries was used in the program WIMSD5B: a) the library generated from the basic data of library ENDF/B-7 and b) the library IAEA, generated and recommended for project WLUP (WIMS Library Update Project). In Fig. 2 the graph of the k_∞ in function of the burn-up steps is presented. In this, the legend means: “ENDF/B-7 lib”, values calculated with WIMSD5B program using the library of data generated from ENDF/B-VII; “IAEA lib”, values calculated with WIMSD5B program using the library of data recommended in project WLUP; “ITEP”, values calculated by the Institute of Theoretical and Experimental Physics, Moscow; “IPPE”, values calculated by the Institute of Physics and Power Engineering, Obninsk; “JARI”, values calculated by the Japan Atomic Energy Research Institute, “FZK”, values calculated by the Forschungszentrum Karlsruhe, Germany; “Average”, averaged values among the foreign institutions.

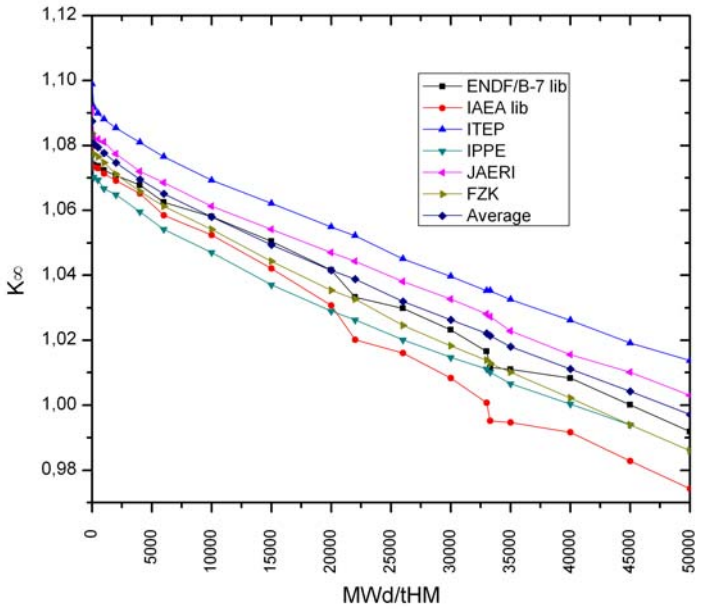

Figure 2 - K_∞ as function of the burn-up (50 GMd/tHM) for PWR fuel .

It is observed that average values of the k_∞ are as near to the values calculated with IAEA library as those values calculated using the ENDF/B-7 library. The Fig. 3 shows the atomic number densities of Np-237 as a function of the burn-up.

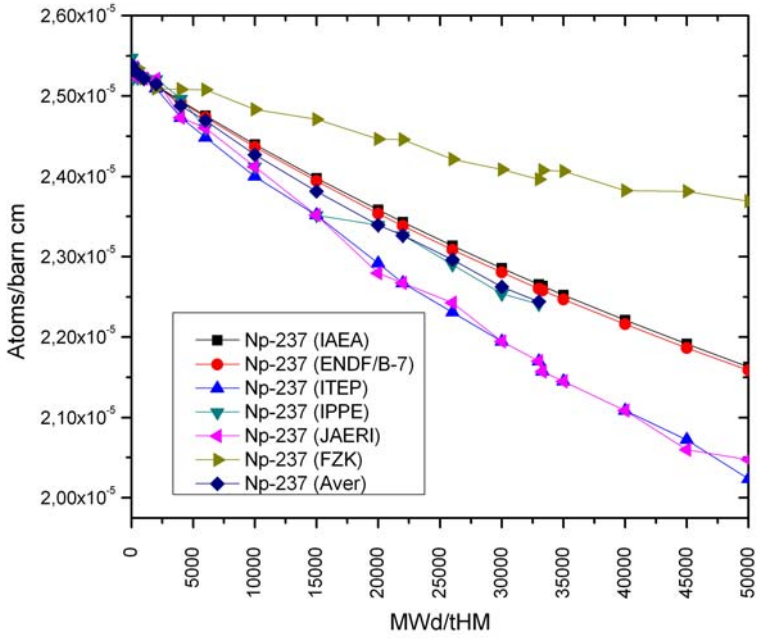

Figure 3 - Atomic number densities of Np-237 as a function of burn-up.

It is observed that the values calculated with both libraries, IAEA and ENDF/B-7 are very similar to the average values presented by other institutions. In Fig. 4 the atomic number densities of Pu-241 as a function of burn-up are presented.

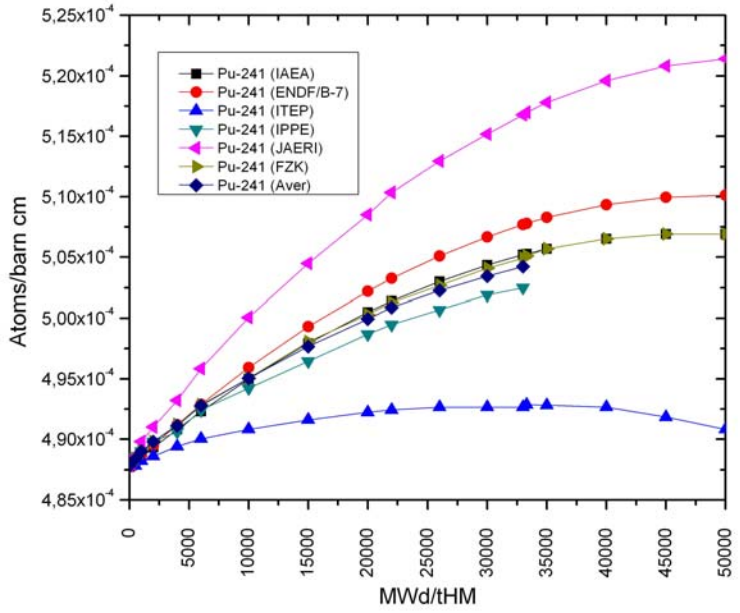

Figure 4 - Atomic number densities of Pu-241 as a function of burn-up.

It is observed that the values calculated with IAEA library are near to the average values than the values calculated using the ENDF/B-7 library. In Fig. 5 the atomic number densities of Pu-242 as a function of burn-up are presented.

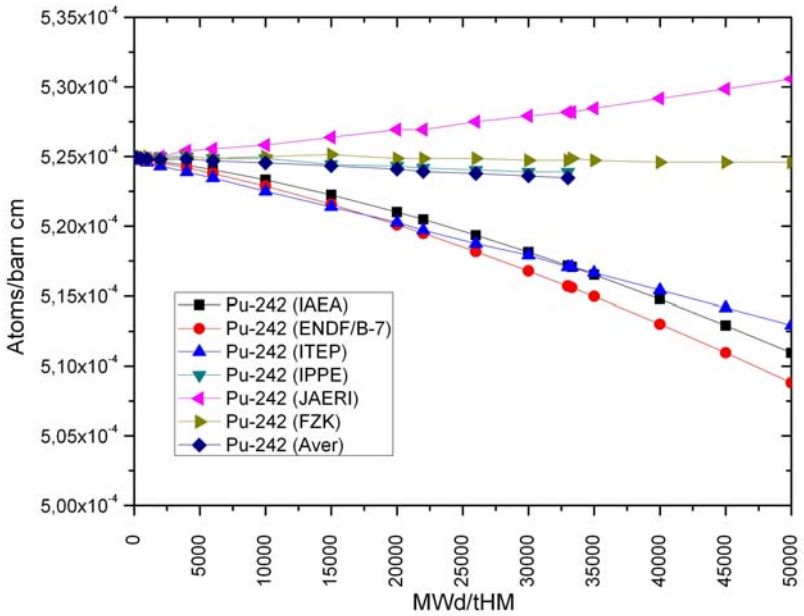

Figure 5 - Atomic number densities of Pu-242 as a function of burn-up.

It is observed discrepancies in the values calculated for the atomic density of the Pu-242 as compared with the values showed by in other institutions, except the ITEP values are similar to calculated here. In Fig. 6 the atomic number densities of Am-242 (metastable) as a function of burn-up are presented.

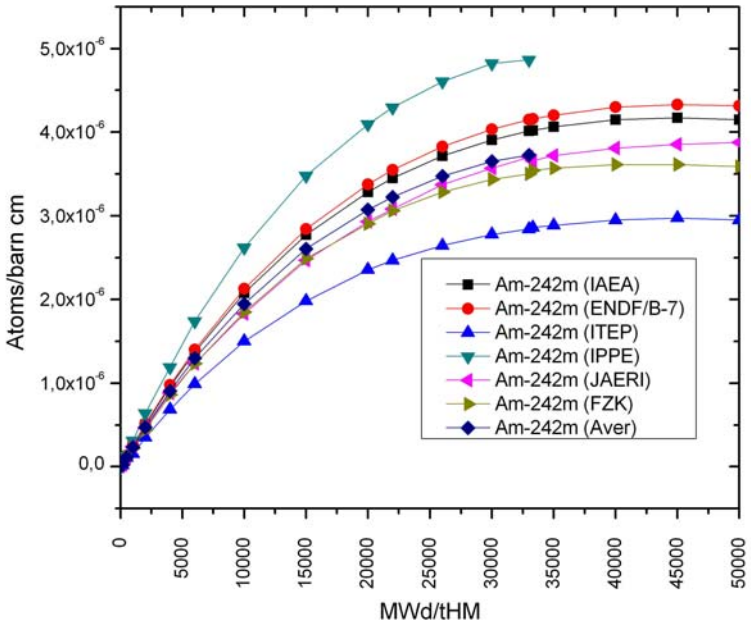

Figure 6 - Atomic number densities of Am-242m as a function of burn-up.

It is observed that the values calculated using the IAEA library or the ENDF/B-7 library is very similar and they are practically the same presented by other institutions, except the ITEP values.

4. CONCLUSIONS

In general, the calculations of k_∞ using the program WIMSD5B, with the ENDF/B-7 or IAEA libraries, present good agreement with the values calculated by other institutions. The maximum difference occurs when compared to the value calculated by ITEP, for the burn-up step of 50000MWd/tHM, and using the IAEA library. Beside this, such discrepancies can be considered normal because between the external institutions, the same discrepancies in calculations can be found. For the atomic number densities of the actinides, the calculation produces the same results if using one or another library. The concentration of the Np-237, calculated by FZK becomes higher than all the other results, as the burn-up steps increases but this is a general behavior. However, the results presented in this work are not sufficient to guarantee the validation of the used libraries, in the calculations of partition and transmutation and they suggest and recommend a confrontation with other experimental results.

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