

**PRODUCTION OF ^4He , ^3He , AND TRITIUM FROM BE IRRADIATED IN FFTF-MOTA-2B -
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OBJECTIVE

The purpose of this work was to provide quantitative predictions of ^4He , ^3He and tritium production from Be irradiated in the FFTF-MOTA-2B experiment.

SUMMARY

The production of ^4He , ^3He , and tritium has been calculated for beryllium irradiated in the Materials Open Test Assembly (MOTA)-2B experiment in the Fast Flux Test Facility (FFTF). Reaction rates were based on adjusted neutron spectra determined from reactor dosimetry measurements at seven different elevations in the irradiation assembly. Equations are given so that gas production, dpa, and neutron fluences can be calculated for any specific elevation in the MOTA-2B assembly.

PROGRESS AND STATUS

Introduction

The irradiation conditions for the MOTA-2B experiment are described in a report by M. L. Hamilton, et al [1]. The MOTA-2B subassembly was irradiated from May 27, 1991, to March 19, 1992, for a total of 203.3 effective full power days at 291 Mwt. Beryllium specimens were irradiated in four different subcapsules including BCA-1 (-62.19 to -55.84 cm); 4B1 (+23.73 to +30.08 cm); 2B2 (-21.48 to -15.38 cm); and 2B4 (-27.81 to -21.71 cm). Each of these subcapsules contained two cylinders of beryllium measuring 0.635 and 2.03 cm in length. One subcapsule only contained one beryllium cylinder measuring 3.05 cm in length.

Neutron dosimetry capsules were located at seven different locations in the MOTA-2B assembly. A full report of the neutron dosimetry results has been published previously [2]. The dosimetry measurements were used to adjust neutron flux spectra at eight different heights in the assembly. Beryllium reaction rates were then calculated at each of these locations using the dosimetry-adjusted neutron flux spectra. Table 1 lists the neutron fluences and reaction rates for these locations. Figure 1 shows the dependence of the Be dpa and fast neutron fluences on reactor elevation. Trendline equations shown on the figure were used to calculate values at the specific locations of each beryllium cylinder, as shown later in Table 4.

Gas Production Calculations

The production of tritium, ^3He , and ^4He from beryllium is dependent on the nuclear reactions: $^9\text{Be}(n,\alpha)^6\text{Li}$, $^9\text{Be}(n,2n)2\alpha$, $^9\text{Be}(n,d)2\alpha$, $^6\text{Li}(n,\alpha)t$, and $^9\text{Be}(n,t)^7\text{Li}$. At short irradiation times, only the direct Be reactions are important. However, as ^6Li grows in, this reaction can become an increasingly important source of both helium and tritium due to the very high

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Table 1. Neutron fluences and dpa for MOTA-2B

Neutron Energy, MeV	Neutron Fluence, $\times 10^{22}$ n/cm ²						
	Height,cm:	-64.7	-41.2	-27.3	-5.8	0.5	16.8
Total	3.15	5.63	7.91	8.11	8.73	9.91	4.78
> 0.1 MeV	1.53	3.28	4.91	5.22	5.52	6.36	2.96
> 1 MeV	0.14	0.55	0.81	0.94	1.00	0.94	0.49
dpa,Fe	5.63	13.5	20.1	21.8	23.3	25.0	12.2
dpa,Be	10.3	21.1	30.8	32.0	34.2	39.7	18.5

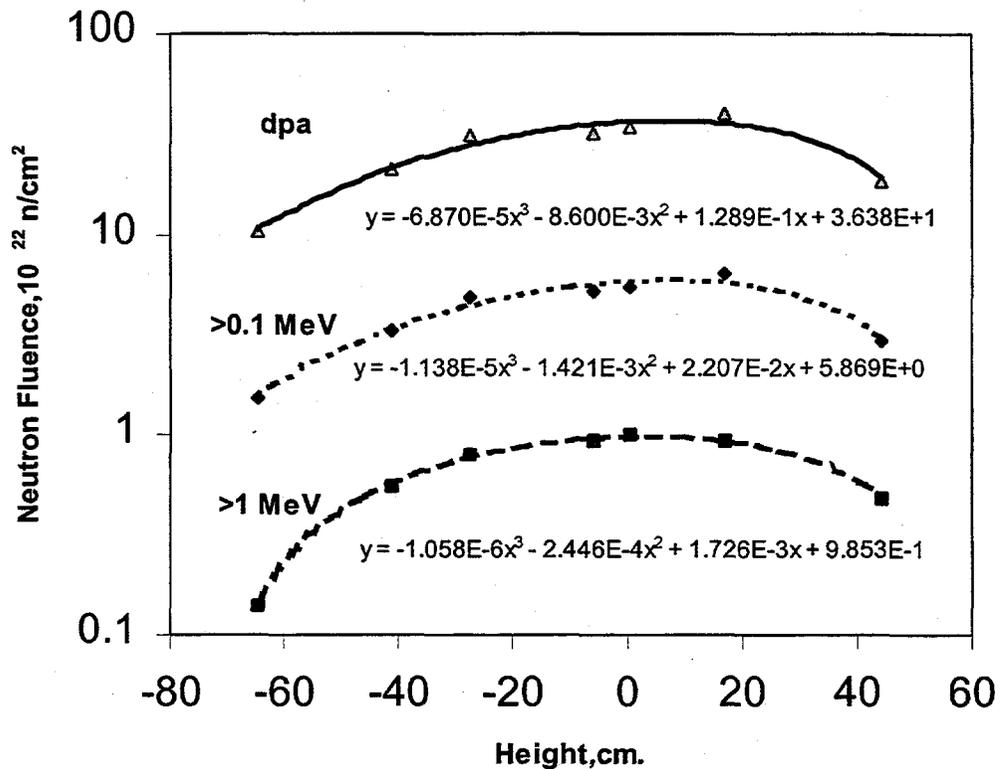


Figure 1. Fast neutron fluence and Be dpa as a function of reactor elevation

thermal neutron cross section. Two other nuclear processes must also be considered, mainly the decay of tritium to ³He and the ³He(n,p)t reaction which has a very high thermal neutron cross section for converting ³He back into tritium.

Neutron cross sections for these reactions were taken from the ENDF/B-V Gas Production File 533 [3]. This file was specially constructed to sum all sources of a particular gaseous species such as helium. The file lists neutron cross section data for the ${}^9\text{Be}(n,\text{helium})$ reaction. This reaction was used to determine the direct production of helium from beryllium. Reaction rates, as calculated from the dosimetry-adjusted neutron spectra, are listed in Table 2 at the elevations spanning the beryllium materials.

Table 2. Reaction rates in beryllium for MOTA-2B (291 MWt)

Reaction	Reaction Rate (at/at-day)						
	Height,cm:	-64.7	-41.2	-27.3	-5.8	0.5	16.8
${}^9\text{Be}(n,\text{he}) \times 10^{-6}$	0.458	3.58	5.48	6.40	6.90	6.25	3.05
${}^9\text{Be}(n,\alpha){}^6\text{Li} \times 10^{-6}$	0.124	0.683	1.01	1.20	1.27	1.16	0.580
${}^9\text{Be}(n,t){}^7\text{Li} \times 10^{-11}$	0.604	4.47	7.43	8.43	8.85	8.26	4.02
${}^6\text{Li}(n,\alpha)t \times 10^{-4}$	3.74	2.33	2.79	2.85	3.07	3.57	1.83
${}^3\text{He}(n,p)t \times 10^{-3}$	2.12	1.32	1.58	1.62	1.74	2.02	1.04

The reaction rates listed in Table 2 are given at the full reactor power of 291 Mwt. Since tritium decays during irradiation and the resultant ${}^3\text{He}$ can burn back to tritium, it is important to consider the reactor power history for the MOTA-2B irradiation. For these calculations, the reaction rates were time-averaged over the entire 297-day irradiation history.

Results and Discussion

Gas production calculations were performed using a Fortran computer program to numerically integrate the production and burnup of each nuclear species on a daily basis over the 297 day irradiation period. The results are listed in Table 3 for the seven neutron dosimetry positions. The He and tritium values are shown as a function of elevation in the reactor in Figure 2. It is important to note that the net production of both He and tritium vary strongly with the elevation in the reactor. The trendlines for the calculated values for each reaction, as well as neutron fluence and Be dpa, are described by polynomials, as shown on the figures. These equations were used to determine the gas production at the specific heights of the beryllium cylinders as shown later in Table 4. However, the equations should not be used at higher or lower elevations than shown on the figures since the polynomials are not defined in these regions.

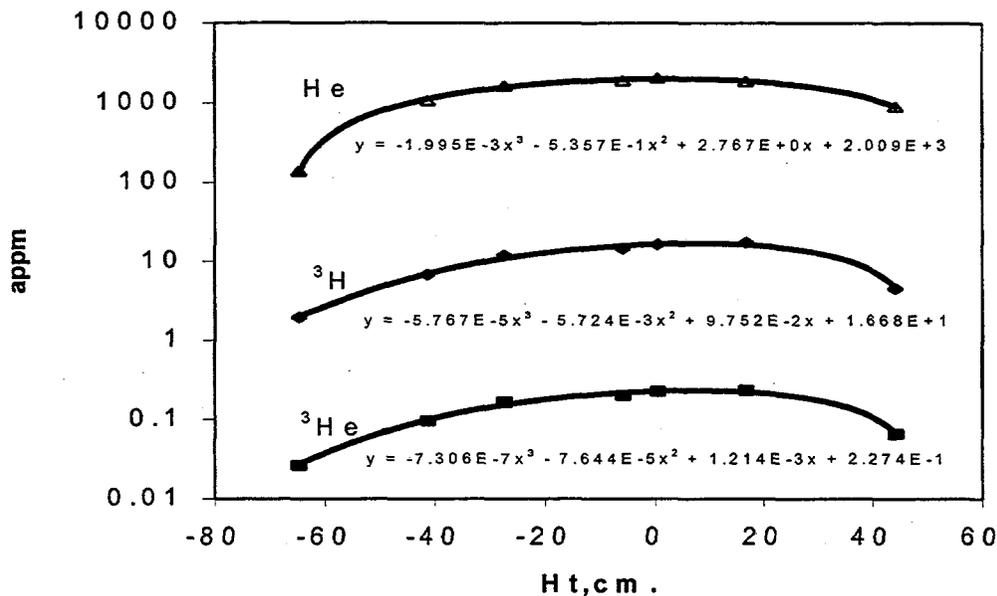
The present calculations for the production of He and tritium assume that both species remain trapped in the beryllium close to the point of generation. Although this is a good assumption for helium, the tritium may be subject to significant diffusion and possible loss from the beryllium at the irradiation temperatures of 370°C (BCA-1), 425°C (4B1), and 550°C (2B2 and 2B4). Consequently, comparisons of these calculations with measured tritium evolution from the beryllium must consider the possible diffusion and loss of tritium from the subcapsules.

Table 3. Calculated ^4He , ^3H , ^3He , and ^6Li results for MOTA-2B (EOI = 3/19/92)

Height,cm:	Production in Be, appm						
	-64.7	-41.2	-27.3	-5.8	0.5	16.8	44.3
^4He	138	1071	1640	1916	2066	1873	911
^3H	1.95	6.79	12.0	14.6	16.5	17.4	4.56
^3He	0.026	0.096	0.166	0.201	0.226	0.234	0.065
^6Li	34.8	196	287	342	360	326	168

Table 4. Calculations for Be cylinders in MOTA-2B (at 12/1/97)

Sample	Cylinder Length	Ht,cm.	^4He appm	^3He appm	^3H appm	Fluence $\times 10^{22}$ n/cm 2		Be dpa
						> 1 MeV	>0.1 MeV	
V310/311	0.25"	-61.7	267	0.91	1.52	0.20	1.77	11.8
	0.80"	-60.4	328	1.00	1.65	0.22	1.86	12.4
V489-490	0.25"	24.2	1734	5.61	9.36	0.87	5.41	33.5
	0.80"	25.5	1697	5.53	9.11	0.85	5.32	32.9
V491	1.20"	25.4	1701	5.58	9.14	0.85	5.33	33.0
V568	0.25"	-21.0	1733	4.91	7.96	0.85	4.88	30.5
	0.80"	-19.7	1762	5.05	8.17	0.86	4.97	31.0
V569	0.25"	-27.3	1574	4.11	6.87	0.78	4.44	27.8
	0.80"	-26.0	1610	4.18	7.10	0.79	4.53	28.4

Figure 2. Production of ^4He , ^3He and ^3H as a function of reactor elevation

It is important to note that the calculated values in Table 3 are given at the end of irradiation time, March 19, 1992. Tritium decays with a half-life of 12.32 years, which amounts to 5.5% per year. The tritium and ^3He values shown in Table 4 are corrected for decay to December 1, 1997.

FUTURE WORK

Measurements of the tritium and helium content of the beryllium cylinders are planned.

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