CALCULATIONS of THE MAIN FREE PATH on NEUTRON EMISSION CROSS-SECTION for SPALLATION REACTION of TARGET and FUEL NUCLEI

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INTRODUCTION

Nowadays, nuclear reactors can be classified four group:

1. Fission Reactors
2. Fusion Reactors
3. Fusion –Fission (Hybrıd) Reactors
4. Accelator Driven Systems(ADS)

Today, only Fission reactors can run for obtained nuclear energy. The others reactors are resarching and devoloping. Probably, they will run in the future.

The hybrid is a combination of the fusion and fission processes (Şahin et al., 1986, 2002a, 2002b) . The fusion plasma is surrounded with a blanket made of the fertile materials (U238 or Th232) to convert them into fissile materials (Pu239 or U233) by transmutation through the capture of the high yield fusion neutrons. The fertile materials may also undergo a substantial amount of nuclear fission, especially, under the irradiation of the high energetic 14 MeV- (D,T) neutrons. In addition to that some of the breed fissile material burns in the hybrid blanket "*in situ* (Şahin et al., 2003, 2005; Übeyli and Tel, 2003).

In the ADS systems the heavy target elements are surrounded by a blanket assembly of nuclear fuel (Uranium, Thorium or Plutoinium etc..). There is a possibility of sustaining fission reaction (Rubbia, et al., 1995,1996)., Thorium, like uranium is a nuclear fuel, but the use of thorium fuel, unlike the use of uranium, has nearly been forgotten. However 232Th is important as fissile material in the new generation reactors. World thorium reserves are estimated to be about three times more abundant than the natural uranium reserves. The process of the main-breeding of the 233U from the 232Th by using the neutrons,

$$232Th + n \rightarrow 233Th \rightarrow 233Pa + \gamma \rightarrow 233U + \beta^-$$

lIt has been investigated in detail for 232Th (*n,xn*), 238U(n,xn) and some target nucleus in previous papers (Tel, et al., 2004,2006; Han,
2006; Demirkol et.al.2004; Şarer et al, 2006). In the present study, the experimental neutron-emission spectra for 232Th nuclei have been compared with experimental 238U(n,xn) neutron-emission spectra at the bombarding energies 6, 14 and 18 MeV. Equilibrium cross sections in neutron induced reactions on targets 232Th have been calculated at the bombarding energies at 14 MeV. The calculation results of the differential cross sections at 14 MeV for target nucleus 184W, 207Pb and 209Bi have been given.

EQUILIBRIUM AND PRE-EQUILIBRIUM NUCLEAR REACTION MODELS

For many years, Nuclear reactions have been divided into two extreme categories. First, there are very fast, direct reactions which on a time scale comparable to the time (10^{-22} s) necessary for the projectile to traverse a nuclear diameter, involve simple nuclear excitations, and are non-statistical in nature. At the other extreme we have the compound nucleus reactions which occur on a very much longer time scale (10^{-16} to 10^{-18} s) and are statistical means. This process can be described adequately by the Weisskopf and Ewing (Weisskopf and Ewing, 1940); Hauser and Feshbach (Hauser and Feshbach, 1952) compound nucleus theories. Compound nucleus wave function is very complicated, In these theories, the spectra of the emitted particles are approximately Maxwellian, and the angular distributions of emitted particles are symmetric about 90 degrees.

During the nineteen-fifties and sixties, It was seen that some nuclear reactions are not possible to understand for all emission process by using only compound nucleus and direct processes. The different shape for the emission spectra were observed for intermediate to high emission energies. The first developments were made to understand these observations by Griffin (Graffin, 1966) (in 1966). Griffin proposed the pre-equilibrium 'exciton model'. Pre-equilibrium processes are important mechanisms in nuclear reactions induced by light projectiles with incident energies above about 10 MeV.

The equilibrium emission is calculated according to the Weisskopf-Ewing and The reaction cross section for incident channel *a* and exit channel *b* can be written as;

$$\sigma_{ab}^{WE} = \sigma_{ab}(E_{inc}) \frac{\Gamma_b}{\sum_{b'} \Gamma_{b'}}$$

E_{inc}= incident energy
Γb =decay –width for exit b particle
σ_{ab}= reaction cross section for incident E_{inc} energy channel *a* and exit channel b

$$-q(n, t=0) = \lambda^{+}(E, n+2)\,\tau(n+2) + \lambda^{-}(E, n-2)\,\tau(n-2) - \left[\lambda^{+}(E,n) + \lambda^{-}(E,n) + W_{l}(E,n)\right]\tau(n)$$

where q (n, t = 0) is the initial condition

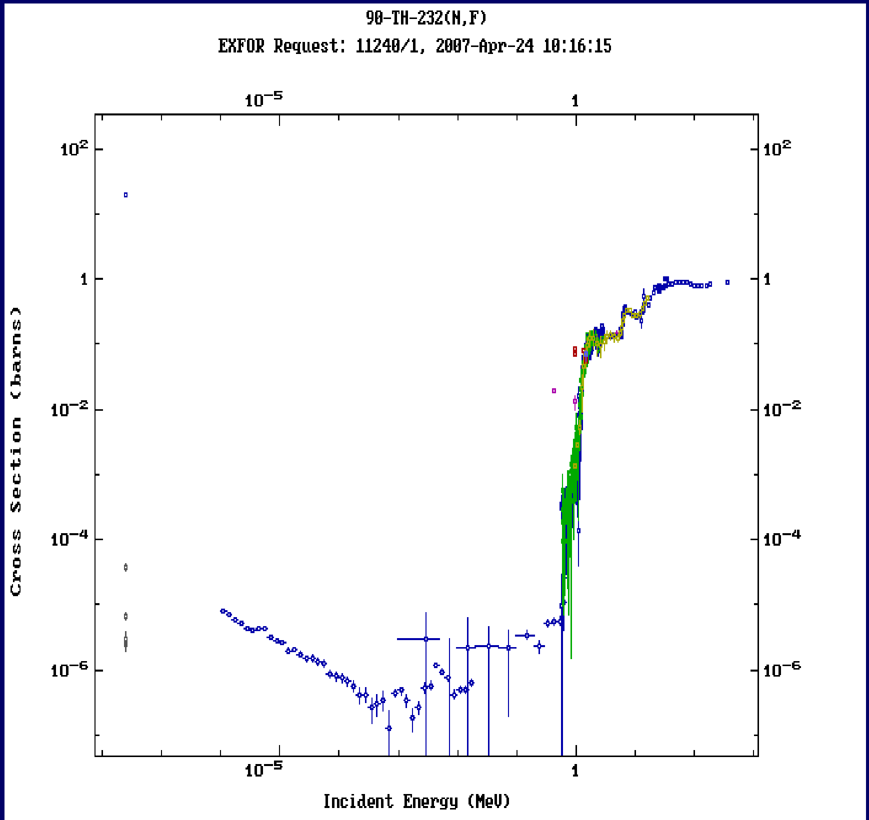
$\tau(n)$ is the time during which the system remains in a state of *n* excitons, W_l is the total particle decay probability of the *n* excitons state per unit time, E is the excitation energy of the compound nucleus

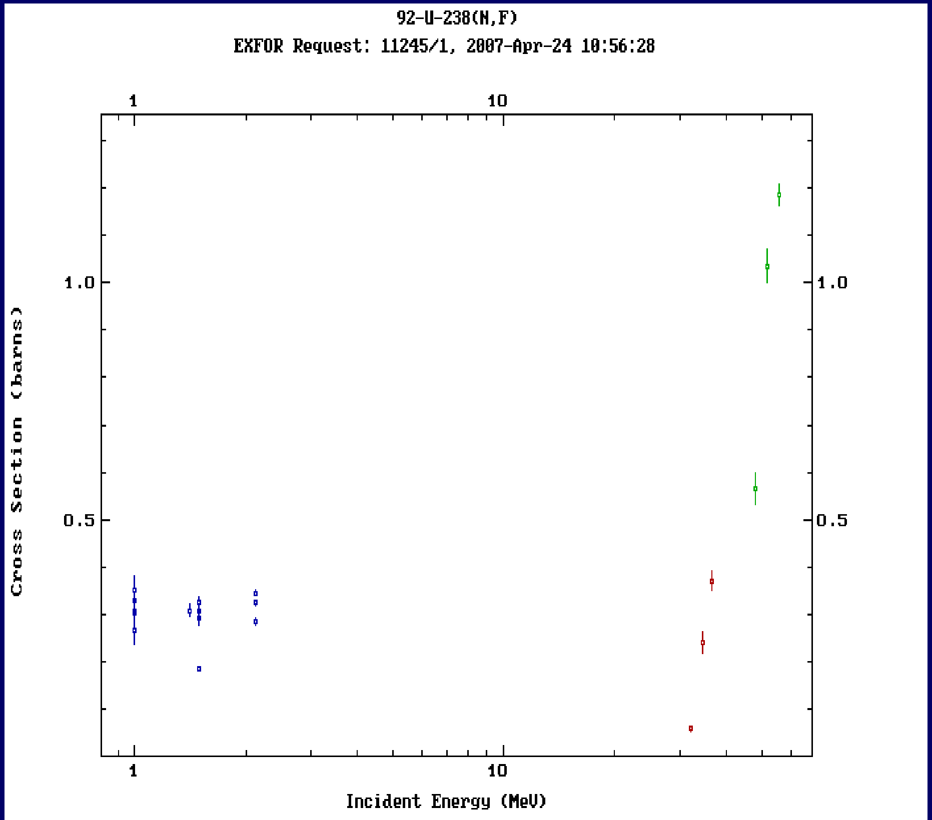
λ is the probability of transition

λ^{+} is the transition rate of $n \rightarrow n+2$

λ^{-} is the transition rate of $n \rightarrow n-2$

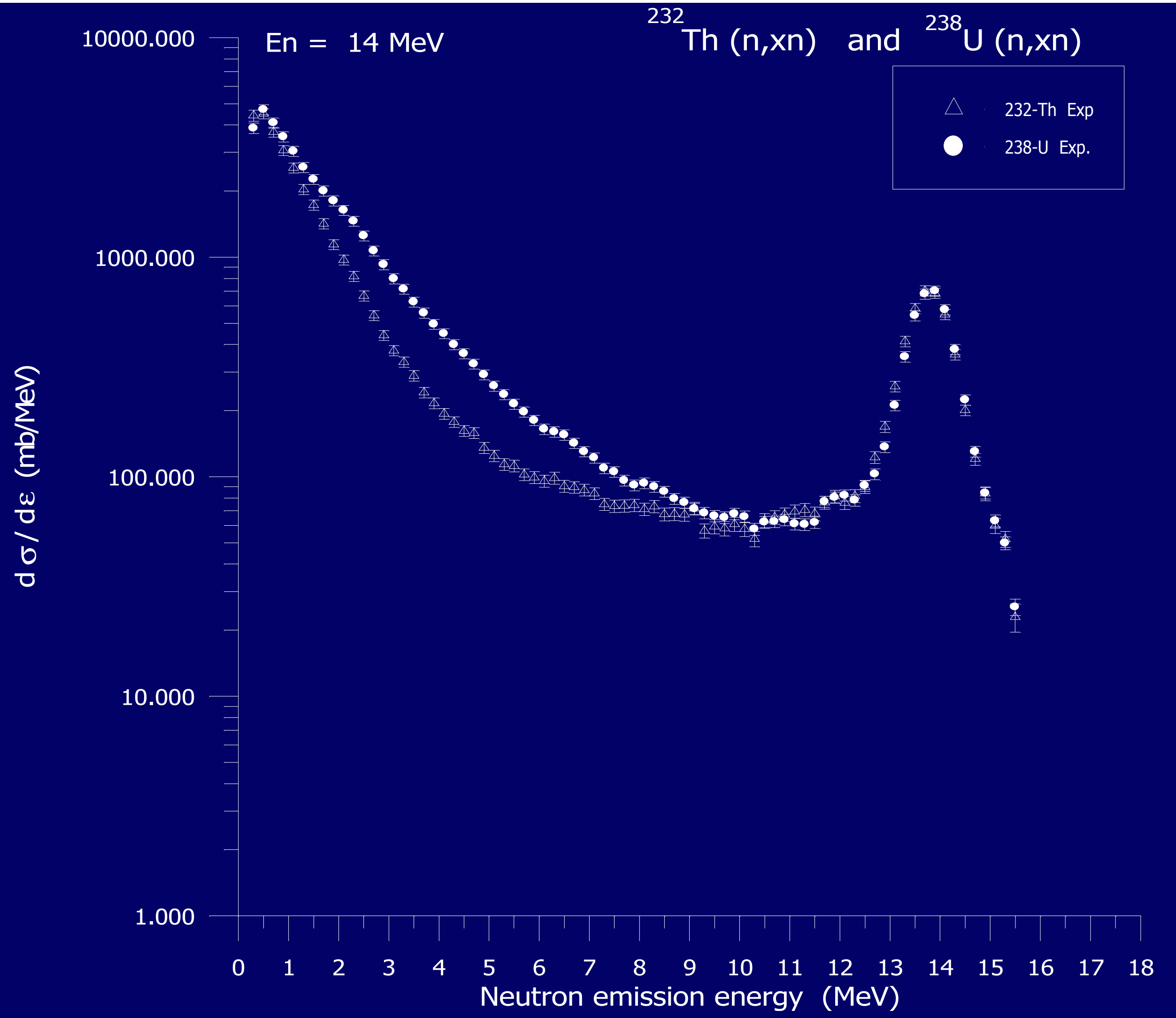
RESULTS AND DISCUSSION





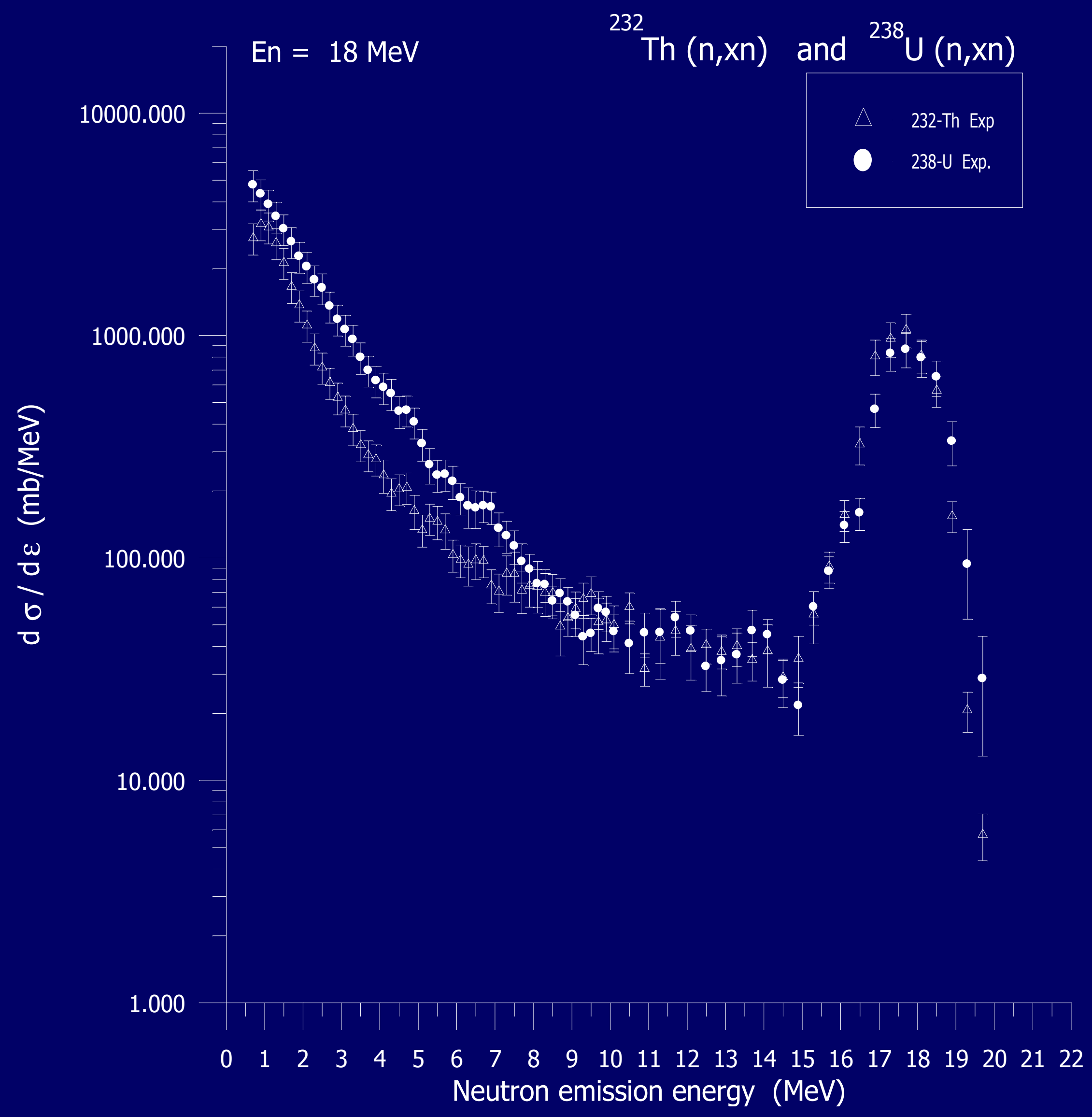
The experimental (n,f) fission cross section of the 232Th nuclei is similar to (both of them can be make a fission with fast neutrons) so, 232Th nuclei is important as fissile material in the new

generation reactors

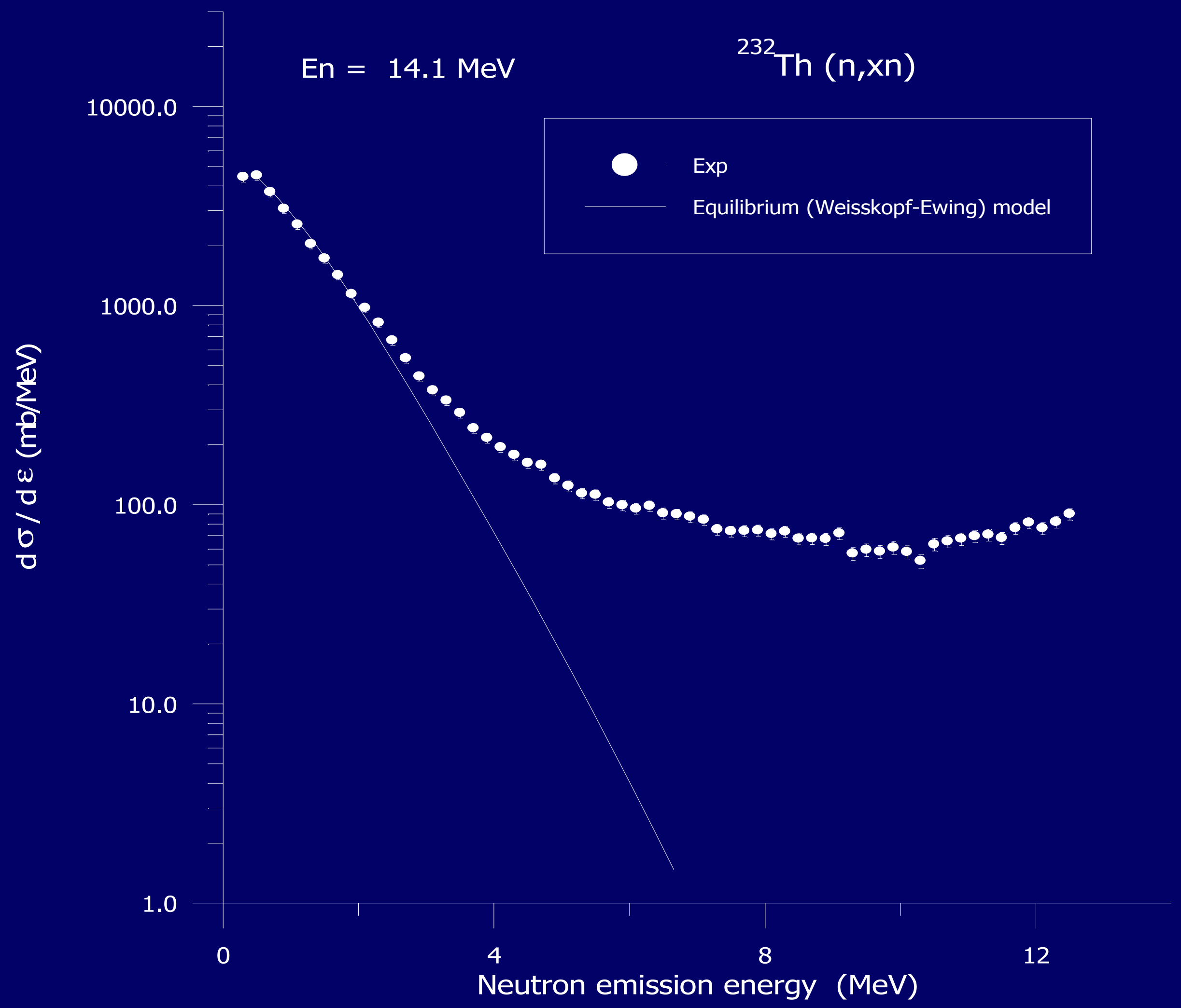


The experimental neutron-emission spectra cross section of the 232Th nuclei has been lower than nuclei at the bombarding energies 14 MeV. However, these experimentalspectral shapes of the neutron-emission spectra are very similar to each

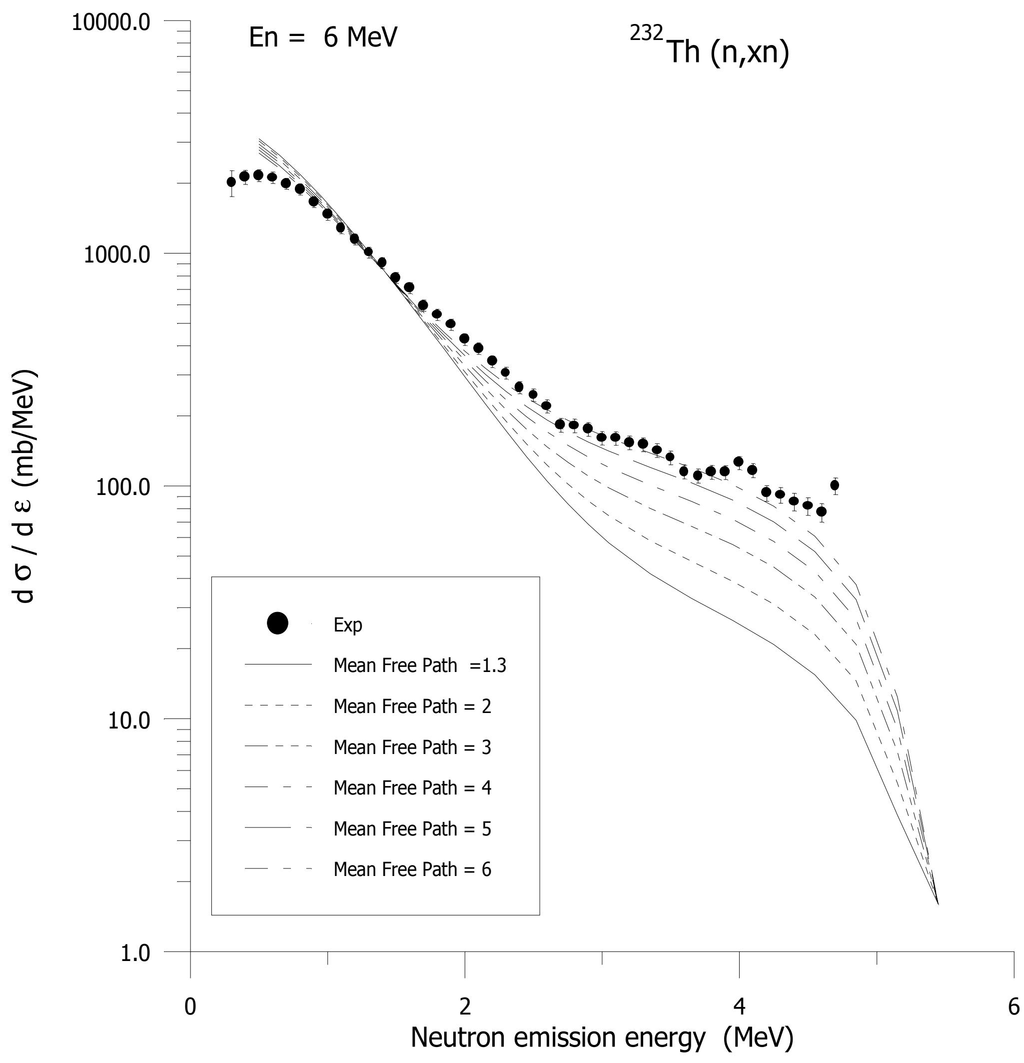
other



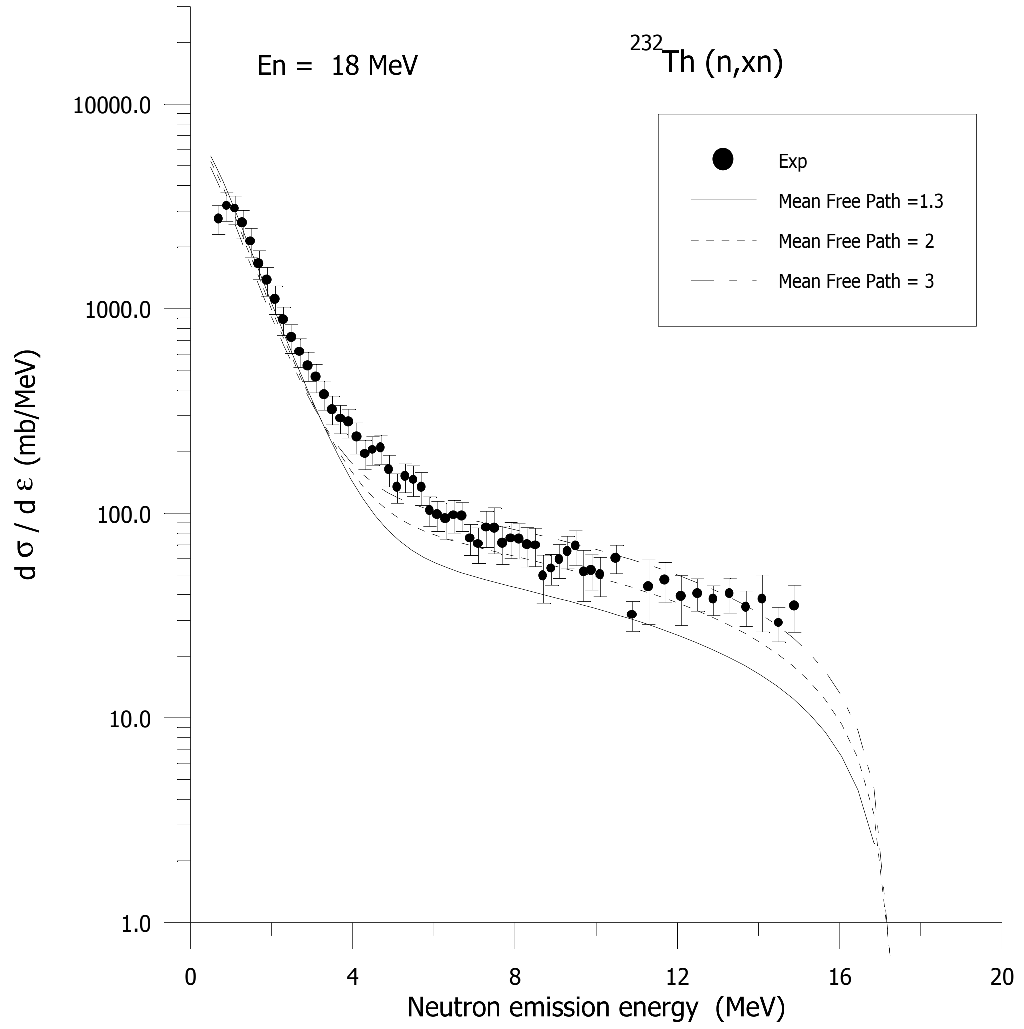
The experimental neutron-emission spectra cross section of the 232Th nuclei has been lower than nuclei at the bombarding energies at 18 MeV. However, these experimental spectral shapes of the neutron-emission spectra are very similar to each other



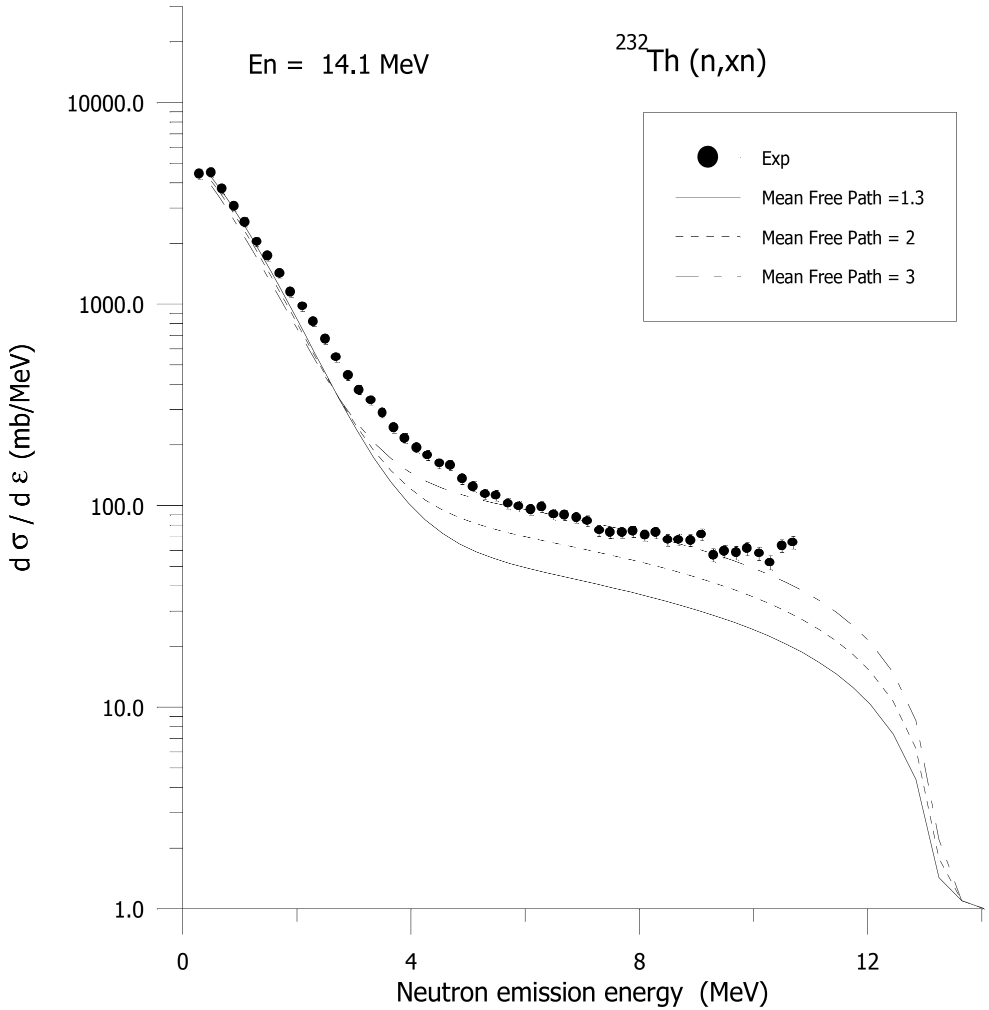
For the 232Th neutron-emission spectra, the equilibrium calculations of the Weisskopf-Ewing have shown only good agreement with the experimental data up to 4 MeV



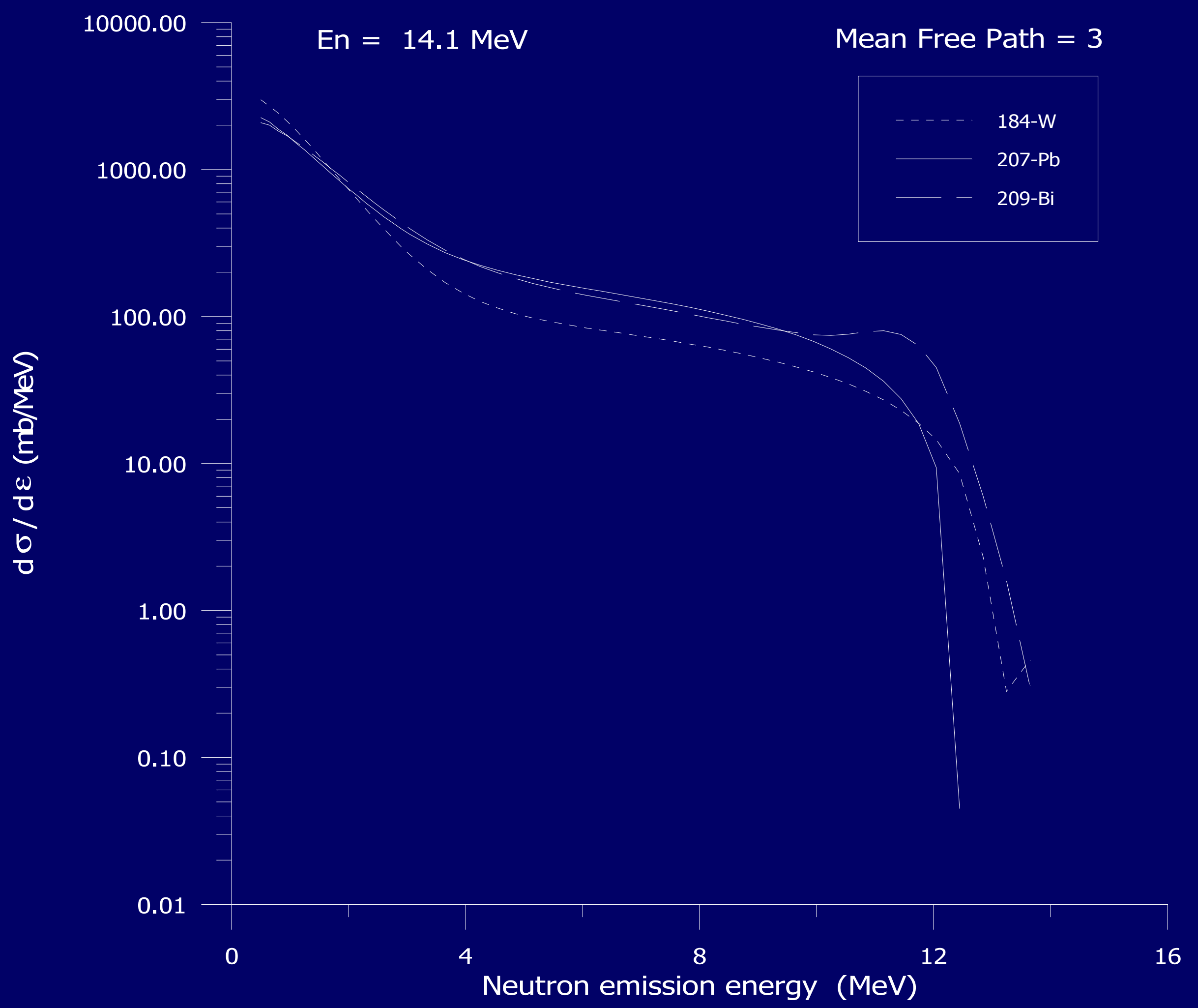
For the 232Th, the mean free path constant 5 and 6 good agreement with the experimental data for 6 MeV neutrons



For the 232Th, while the mean free path constant 2 and 3 good agreement with the experimental data for 14 and 18 MeV neutrons



The summation contribution consists of the equilibrium and pre-equilibrium contributions have shown good agreement with the experimental data



The pre-equilibrium neutron-emission spectra cross section values of 207Pb and 209Bi are higher than 184W. Therefore, 207Pb and 209Bi are good targets for using the spallation neutron sources

CONCLUSIONS

- 1. The experimental (n,f) fission cross section of the 232Th nuclei is similar to 238U (both of them can be make a fission with fast neutrons) so, 232Th nuclei is important as fissile material in the new generation reactors
- 2. The experimental neutron-emission spectra cross section of the 232Th nuclei has been lower than 238U nuclei at the bombarding energies 14 and 18 MeV. However, these experimental spectral shapes of the neutron-emission spectra are very similar to each other .
- 3. The experimental neutron-emission spectra cross section of the 232Th nuclei is very similar to 238U so, 232Th nuclei can be used as fissile material in the new generation reactors.
- 4. For the 232Th neutron-emission spectra, the equilibrium calculations of the Weisskopf-Ewing have shown only good agreement with the experimental data up to 4-6 MeV
- 5. The summation contribution consists of the Weisskopf-Ewing theory for equilibrium and exciton model for pre-equilibrium contributions have shown good agreement with the experimental data.
- 6. For the 232Th, while the mean free path constant 2 and 3 correspond to the experimental values for 14 and 18 MeV neutrons, the mean free path constant 6 and 7 correspond to the experimental values for 6 MeV neutrons.
- 7. The pre-equilibrium neutron-emission spectra cross section values of 207Pb and 209Bi are higher than 184W. Therefore, 207Pb and 209Bi are good targets for using the spallation neutron sources.

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