Activity and self-shielding coefficient Calculations of Europium oxide (Eu_2O_3) in a hypothetical nuclear reactor

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Abstract

The elements are generally characterized by various cross-sections for interaction with particles and the effect of this reaction shows the number of elements with large cross-sections for interaction with neutrons in particular, so this effect must be studied on the materials that make up the core of the nuclear reactor, especially the elements with large cross-sections. Theoretical studies The characteristics of Europium oxide (Eu2O3) have been widely researched. Europium-153 makes up 52 percent of natural europium, with europium-151 accounting for the other 48 percent. Because of its ability to absorb neutrons, europium is primarily used in nuclear reactor control rods. Other usage have been limited due to its scarcity and high cost. This research included mainly to study the activity of Europium oxide for different Thickness of Radius in radial and axial distribution. Calculations of self-shielding coefficients and its effects clarify that this material wildly uses in a nuclear reactor as control rod elements, in particular the compound with large absorption cross-sections of the neutron. It is critical that it is compatible with its cladding alloy.

Keywords: *Activity, self-shielding coefficient, Europium oxide, nuclear reactor, large cross-section.*

النشاط الإشعاعي لأوكسيد اليوربيوم ($Eu_2 O_3$) في مفاعل نووي افتراضي وحساب معامل الحجب الذاتي

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الخلاصة

تتميز العناصر بصورة عامة باختلاف المقاطع العرضية للتفاعل مع الجسيمات وتاثير هذا التفاعل يظهر عدد العناصر ذات المقاطع العرضية الكبيرة للتفاعل مع النيترونات خاصة ,لذا يجب دراسة هذا التاثير على المواد المكونة لقلب المفاعل النووي وبصورة خاصة العناصر ذات المقاطع العرضية الكبيرة .

تمت دراسة الدراسات النظرية لأكسيد اليوروبيوم (Eu2O3) على نطاق واسع لخصائصه الهامة. يمثل اليوروبيوم -153 52٪ من اليوروبيوم الطبيعي ، ويشكل اليوروبيوم -151 النسبة المتبقية 48٪ ، والاستخدام الأساسي لليوروبيوم هو في قضبان التحكم في المفاعلات النووية ، بسبب فعاليته في امتصاص النيوترونات. كانت الاستخدامات الأخرى محدودة لأنها نادرة وبالتالي باهظة الثمن. تضمن هذا البحث بشكل أساسي دراسة نشاط أكسيد اليوروبيوم لسماكات مختلفة من نصف القطر في التوزيع الشعاعي القطري والمحوري. توضح حسابات معاملات التدريع الذاتي وتأثيراتها أن هذه المادة تستخدم بشكل كبير في المفاعلات النووية كعناصر قضيب تحكم ، ولا سيما المركب. مع المقاطع العرضية لامتصاص كبير من النيوترون. التوافق مع سبائك الكسوة له أهمية كبيرة.

الكلمات المفتاحية : *النشاط ، معامل الحجب الذاتي، اوكسيد اليوربيوم، مفاعل نووي، مقطع عرضي كبير .*

Introduction

Europium Oxide (Eu_2O_3) is a synthetic compound made up of europium and oxygen Europium is a silvery-white metal with a high melting point. It is the lanthanide series' softest, least dense, and most volatile member, igniting in air at high temperatures (150 to 180°C). Europium is found in nature as two stable isotopes. (Isotopes are various versions of an element with the same number of protons but differing numbers of neutrons in the nucleus.) Europium-153 makes up 52 percent of natural europium, while europium-151 makes up the other 48%. [1].

The curie, named for Pierre and Marie Curie, is an ancient unit. One curie equals (exactly) 3.7 x 1010 Becquerel and is equivalent to the activity of 1 gram of radium. The number of decays per second determines the activity, not the kind of decay, the energy of the decay products, or the biological consequences of the radiation [2]. The hetero structure device will have unique electrical and optical features due to the combination of nanoparticles of europium oxide (n-type) with various organic and inorganic semiconductors (p-type). Red electroluminescence was seen in a Eu2O3/p+-Si device, and performance was increased by adding a Tb2O layer [3].

While fission products such as europium-152, europium-154, and europium-155 are the most common, europium-152 can also be created by neutron activation of nuclear reactor control rods. When a fissile nuclide, such as uranium-235, fissions, it usually divides asymmetrically into two big pieces, each of which can include one of the three europium isotopes, as well as two or three neutrons [1-4]. Because of its ability to absorb neutrons, europium is most commonly used in nuclear reactor control rods. Other applications have been limited due to its scarcity and high cost. Laser materials made of europium-doped polymers have been employed, and europium oxide has been employed as a phosphor activator. For example, europium has been used to activate yttrium vanadate for use in color television tubes' red phosphors [5].

Calculation of The Radioactivity of Erbium Oxide

The Radioactivity of the Models Is Calculated to Be Irradiated In A Neutron Flood In A Hypothetical Nuclear Reactor Applying The Following Relationship.

$A = N \sigma_a \phi (1-e^{-\lambda T}) e^{-\lambda \Delta t}$ ……………………….(1)

where

$N = mK N_{av.} / a.w$……………….(2)

Substituting in equation (2) by in to yields the following:

$A=[Nav.mK \sigma a \phi /(a.w)(3.7\times10^{10})] (1-e-\lambda T) e-\lambda\Delta t$ ………..(3)

A- The radioactivity after The irradiation process, measured in curie units.

m- The weight of the model in (gm)

K - The ratio of isotope nuclei in the model to be irradiated

a.w _ atomic weight of sample

Φ_ neutron flux(n/cm2 .Sec)

σa_ cross-section of absorbance microscopy

T_ irradiation time (Sec)

Δt_ cooling time (Sec)

λ_ decay constant (Sec-1)

The relationship (3) has been used to calculate the radioactivity of different erbium oxide models. Tables (1) show the most important values used in the calculations. Assuming the height of the models for all cases is constant and the variable is the radius of the cylindrical model only, that is, the change of mass and volume together, and that The height stabilization is intended to be exposed to the same unchanged neutron flood for all models.

Tables (2),(3),(4) shows the radial radioactivity change for the radius 0.25,0.5 and 1 cm of Erbium oxide respectively . The graphical relationships were drawn showing the radioactivity as a function of the radius of erbium oxide, which inferred the large drop of the neutron flood due to the large absorption of neutrons and the self-blocking of that substance. Figures (1), (2), (3) are show how the change in show the change in of the radius (1, 0.5,0.25) cm. According to the radioactivity horizontally (axially) for these models, Table (5) shows the change in the axial radioactivity, while Figure (4) shows the increase in the value of the radioactivity in the middle of the model and its decrease when moving away from the center of the neutron flood in the middle of the model. Basic language program was used to calculate the radioactivity diagonally and axially of the model.

Table (1): The most important values used in the calculation of radioactivity of Erbium oxide

Molt.wt	**352gm**
K	**0.9164**
Density	**7.42gm/cm3**
$T_{1/2}$	**0.41×10^{9} sec**
Hight	**5cm**

Table (2): Values of radial radioactivity for the radius 0.25cm of Erbium oxide

Radius (Cm)	**Activity (Curie)**
0.0	412.093
0.05	1.660199
0.1	6.22×10^{-3}
0.15	2.42×10^{-8}
0.2	9.41×10^{-8}
0.25	3.66×10^{-10}

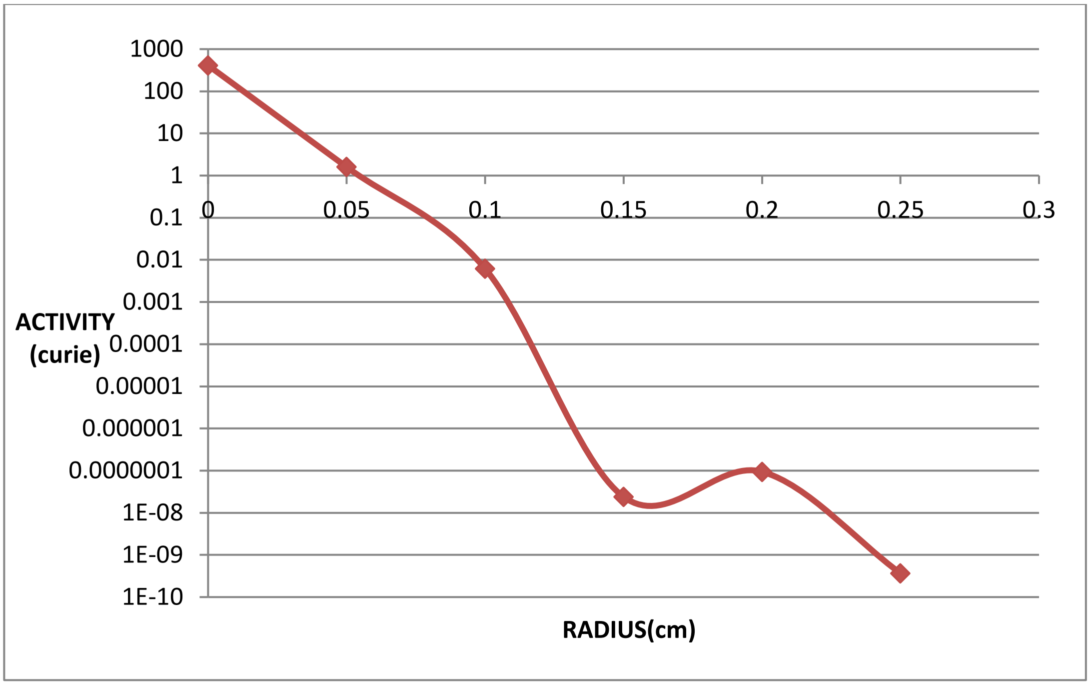

Figure (1): The graphical relationship of change Radial Radioactivity for the Radius 0.25cm of Erbium Oxide.

Table (3): Values of radial radioactivity for the radius 0. 5cmof Erbium oxide

Radius (Cm)	Activity (Curie)
0.0	1649
0.1	0.0246
0.2	3.7×10^{-7}
0.3	5.7×10^{-12}
0.4	8.6×10^{-17}
0.5	1.3×10^{-21}

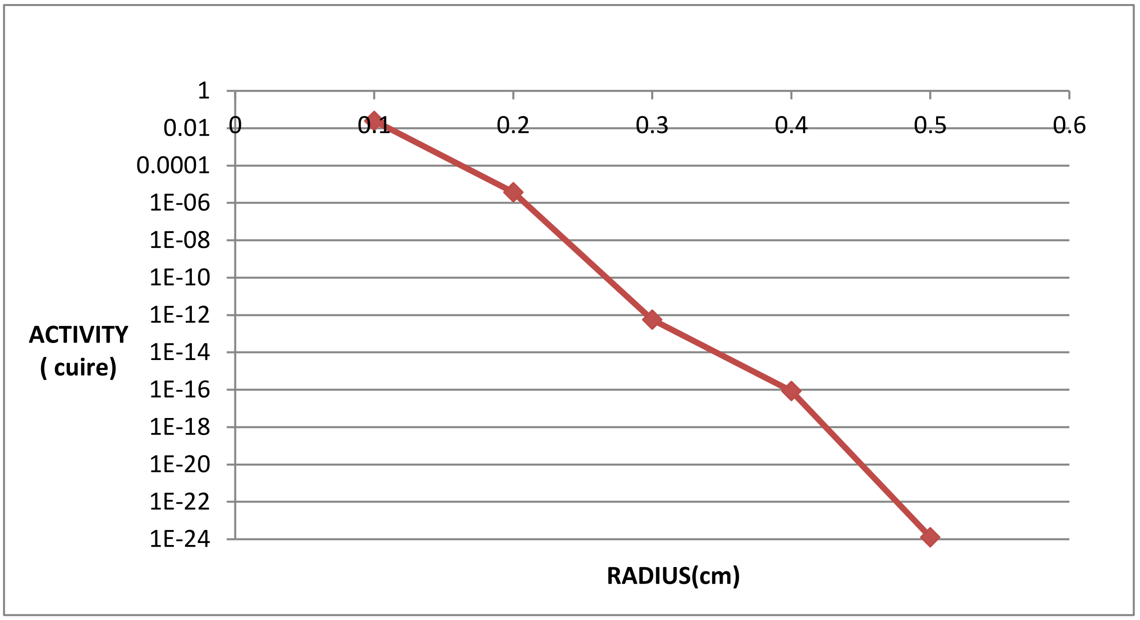

Figure (2): The graphical relationship of change Radial Radioactivity for The Radius 5cm of Erbium Oxide

Table (4): Values of radial radioactivity for the radius 1 cm of Erbium oxide

Radius (Cm)	Activity (Curie)
0.0	6.595×10^{-3}
0.2	1.5060×10^{-6}
0.4	3.439×10^{-16}
0.6	7.856×10^{-35}
0.8	$1.794\times10\text{-}^{35}$
1.0	$4.097\times10\text{-}^{45}$

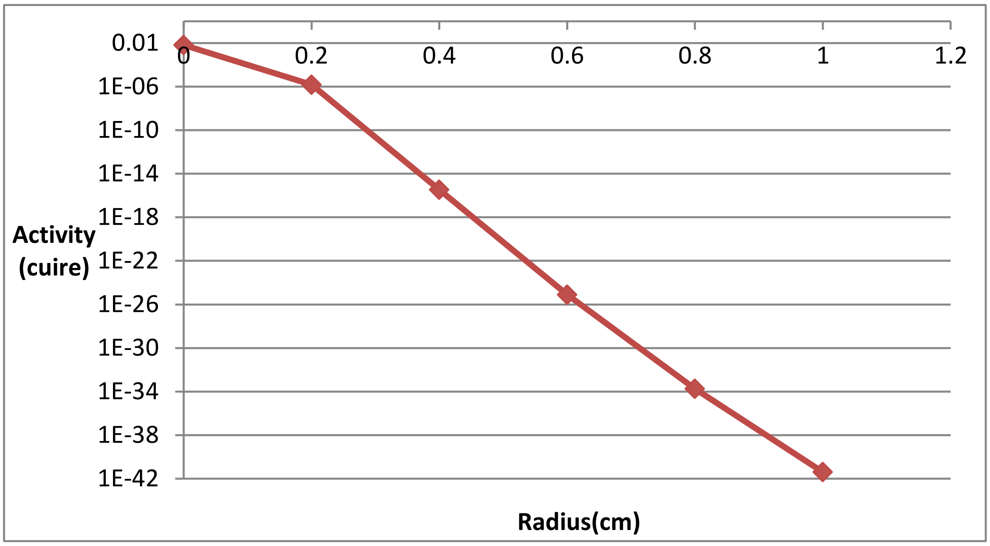

Figure (3): The graphical relationship of change Radial radioactivity for the radius 1 cm of Erbium oxide.

Table (5): the axial radioactivity values for 0.25cm radius of Erbium oxide

Radius (Cm)	**Activity (Curie)**
0.25	412
	3.73×10^{-15}
	4.6×10^{-15}
	3.19×10^{-36}
	8.41×10^{-48}
	1.45×10^{-59}

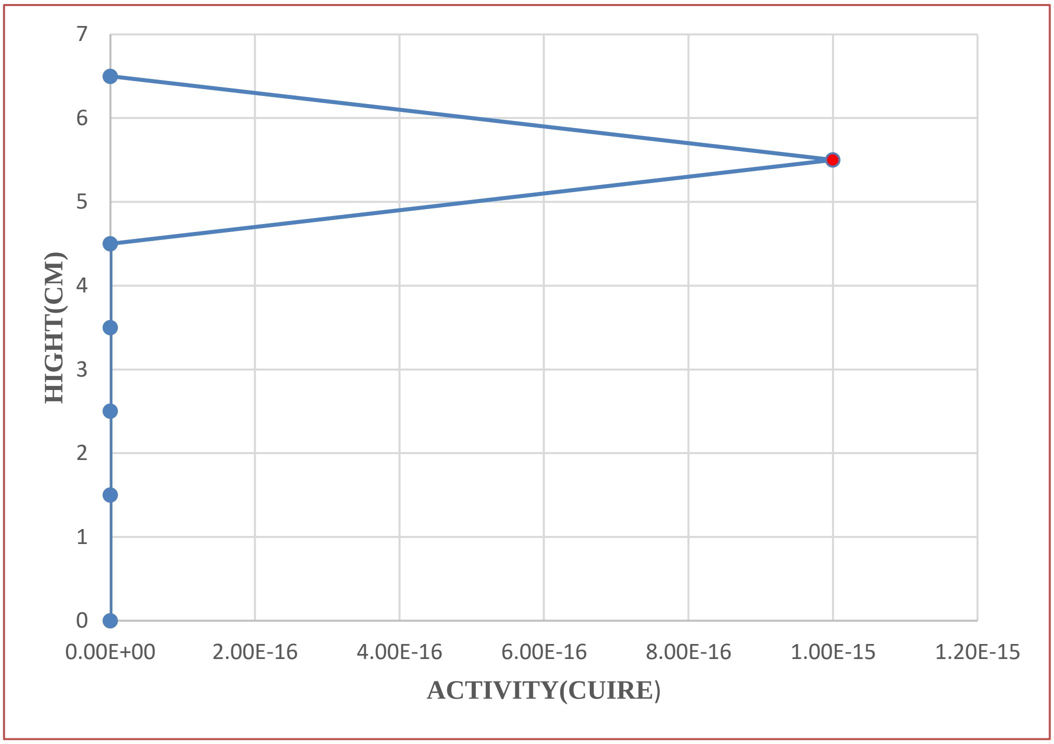

Figure (4): The change the axial radioactivity values for 0.25cm cm radius of Erbium oxide.

2. Calculation of the self-blocking coefficient of different forms of erbium oxide

The self-shielding coefficients were calculated for different radii of erbium oxide using the equation (4-1).

$$\rho = k.eff - 1 / k.eff \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots.(4)$$

Table (5) shows the self-shielding values of the thermal zone and the results show the inverse relationship between the mass of the material and the self-shielding coefficient as shown in figure (5). The self-shielding coefficient is defined as the amount of the ratio between the neutron flux in the case of a model to the neutron flux in the absence of a model that has a significant impact on the calculations of nuclear reactors, especially for materials with large absorption cross-sections for thermal neutrons. The effect on the chain reactions and their measurements, because of their effect on the reactivity of the reactor, called the hazardous parameter measurements.

Table (6): The values of the self-shielding coefficient for the thermal region of the nitron flood and the mass and radius of the Erbium oxide

Radius(cm)	Mass of Eu_2o_3	s.s.s of Eu_2o_3
0.1	13.5200	0.342311697
0.2	54.0810	0.091357167
0.3	121.681	0.050503297
0.4	216.322	0.020985760
0.5	338.003	0.013856290

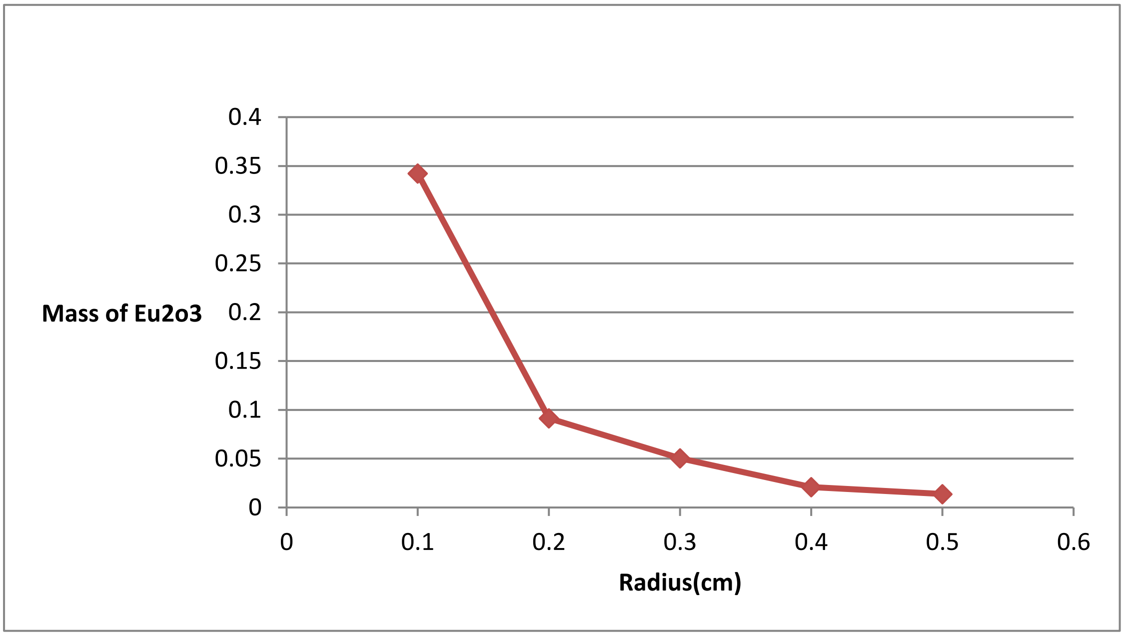

Figure (5): The graphical relationship between self-shielding coefficient and radius.

Conclusion

The activity of europium oxide for several radiuses declared that the self-shielding factor for material under this research had most absorption coefficient's because of the higher mass number and density.

The change in the neutron flux in the reactor during the irradiation process makes the values of the radioactivity approximate and needs to be corrected for the elements with short half-lives compared to the half-life irradiation period and since the Eurbium (0.4 × 109) is very large in relation to the irradiation period that it extends. Since it is assumed that the check and the neutron flux density are constant. The decrease in radioactivity in the central part of the capsules is due to the large decline in the neutron flux due to the large neutron absorption cross section that is characteristic of the two isotopes, Eu-153 and Eu-151. The absorption by the Eurbium took place in the outer and proximal shell of the surface and the inner nuclides were blocked from the neutron flux due to the great blocking of those external nuclides and the inability of the neutrons to penetrate them and reach the central parts.

The capsules opposite to the reactor core have been exposed to a neutron flood higher than the far side of the radiating channel due to the decrease in the neutron flux in the slightly opposite side of the gap on the proximal side in the core of the reactor. More fast breeder reactors and light water reactors uses the europium oxide as control rods and decreasing the higher neutron flux. Europium oxide is a potential neutron absorber material for fast reactors. It offers a lot of good qualities for this purpose, however it has a low heat conductivity. Pellet cracking occurs as a result of this during reactor operation [7]. The europium anomaly refers to the depletion or enrichment of europium in minerals in comparison to other rare earth elements [8].

The strong absorption of multi-reactions by europium oxide (Eu_2O_3) has been widely explored. Eu_2O_3 has a substantially greater radiation sensitivity than the other materials in this investigation [9]. These findings conflict with those of earlier studies in the field. future investigations Because of its ability to absorb neutrons, europium is primarily used in nuclear reactor control rods. Other applications have been limited due to its scarcity and high cost. Several groups are developing a wide spectrum of Eu_2O_3 consisting of various elements and their compounds as potential radio sensitizers [9,10].

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