

Study of a Li doped CsI scintillator crystal as a neutron detector

This content has been downloaded from IOPscience. Please scroll down to see the full text.

2015 J. Phys.: Conf. Ser. 630 012010

(<http://iopscience.iop.org/1742-6596/630/1/012010>)

View [the table of contents for this issue](#), or go to the [journal homepage](#) for more

Download details:

IP Address: 143.107.255.190

This content was downloaded on 29/02/2016 at 17:28

Please note that [terms and conditions apply](#).

Study of a Li doped CsI scintillator crystal as a neutron detector

T Madi Filho, M C C Pereira, J R Berretta and J P N Cárdenas

Instituto de Pesquisas Energéticas e Nucleares – IPEN/CNEN-SP
Av. Prof. Lineu Prestes 2242 Cidade Universitária
CEP: 05508-000– São Paulo-SP – Brasil
tmfilho@usp.br, macoper@ipen.br, jrretta@ipen.br, ahiru@ipen.br

Corresponding author: tmfilho@usp.br

Abstract. The radiation monitoring system is an important requirement in the premises of a nuclear reactor. A variety of types of radiation (neutrons, gamma, beta and fission products) exist in a reactor, associated to the broad energy spectrum of these radiations, implying the need of detectors to be used in the reactor system and security, as well as radiation monitoring. As the neutron sources are associated to gamma radiation, it is necessary that the neutron detecting system may be capable to discriminate the gamma interference. In our work environment, there are two Nuclear Research Reactors and a neutron irradiator with two AmBe sources (592GBq of Am, each). These conditions warrant the development of new types of detectors. Due to the absence of charge in the neutron, it is necessary to use a converter material that generates radiations capable to produce signals in the detector. Materials with high cross section, like Li or B, are used for this purpose. The CsI crystal doped with ${}^6\text{Li}$ has been studied. The concentration of the lithium doping element (Li) studied was 10^{-3}M . The detector test was done using an AmBe source (37GBq) and gamma sources. The crystal was coupled to a photomultiplier.

Key words: neutron detector, CsI scintillator, ${}^6\text{Li}$.

1. Introduction

In the design and installation of a system of measurement, it is necessary to understand the processes of interaction of radiation with the detector in order to select the one that best suits the work to be performed.

What makes neutron distinctive is the null action with electromagnetic fields, making its interaction with matter, practically, by means of a strong nuclear interaction.

Neutrons cross electronic layers without any major disruption and do not feel the Coulomb barrier that interferes with charged particles, as they approach the nucleus.

Due to the lack of electric charge, the interaction of the neutron with the atomic electric field is negligible; therefore, the interaction of neutrons with matter occurs, essentially, through direct interaction with the nuclei.

The detection of neutrons is not trivial due to lack of charge of these particles and the peculiarity of their interaction with matter. The neutron sources, also, generate gamma radiation, which may interfere with their measurement. It is necessary that the detector system may be able to discriminate these interferences.

Steven M. Grimes [1] presents the neutron detector types:



Detectors Based on Elastic Scattering, Detectors Based on Capture Reactions, Detectors Based On Fission, based on Inelastic Scattering Counters, Detectors Based on (n, p) or (n, α) Reactions.

These detectors have, internally, a converter for neutrons to produce ionizing radiation. The converters are based on nuclear reactions of the type:

Neutron + Converter → ionizing radiation

The converter is a material with a high probability of interaction with the neutron (high cross section). The cross section is a parameter that expresses the probability of neutron interaction with the target. It is dependent on the energy of the incident neutron [2].

For each of the incident neutron energy, the probability that a conversion reaction may occur depends on the cross section of the converter nuclide. The ratio between the cross sections of various nuclides used as converters, in function of the incident neutron energy, is shown in Figure 1. [2, 5]

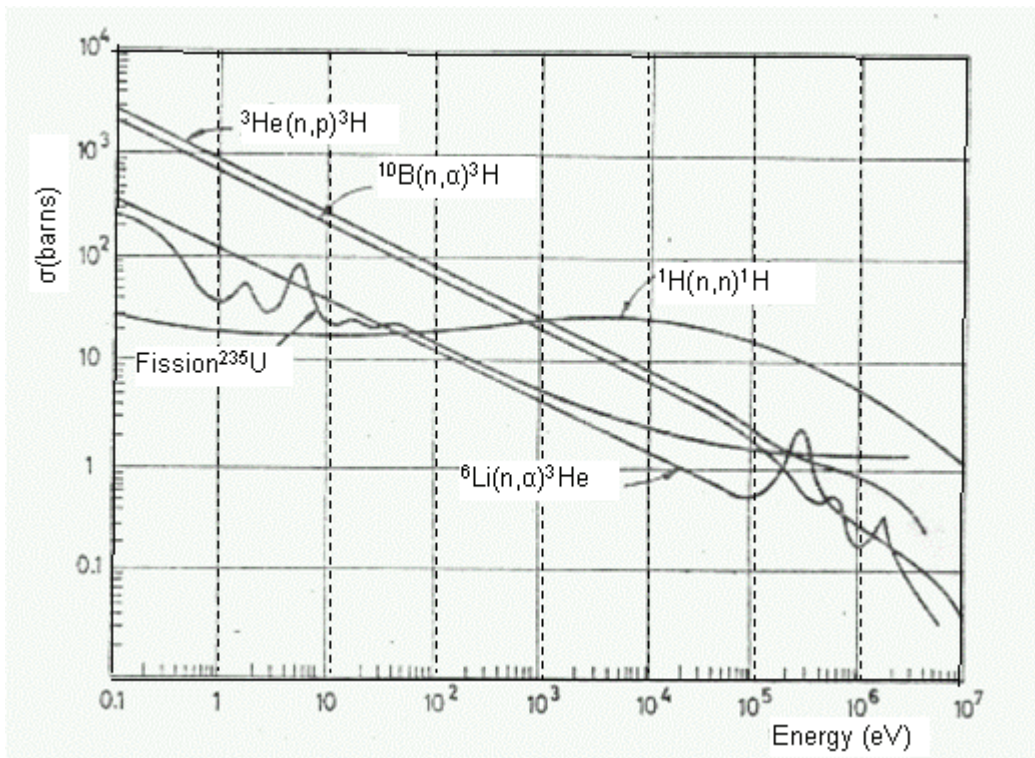
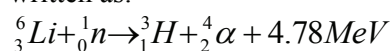


Figure 1. - Cross section of some converters as a function of incident neutron energy. (Figure adapted from Tanarro [3])

⁶Li is an element used as a converter for detecting thermal neutrons. It features cross section of 940 barns, for thermal neutrons. The reaction of thermal neutrons with ⁶Li used in detectors can be written as:



In this reaction, the emitted tritium has kinetic energy $E = 2.73 \text{ MeV}$, while α particle is emitted with $E_\alpha = 2.05 \text{ MeV}$ [5]

2. Materials and methods

Lithium doped CsI crystals were grown using the vertical Bridgman technique at the Instituto de Pesquisas Energéticas e Nucleares IPEN/CNEN-SP, [6].

In order to study the response to neutron radiation, the crystals were polished with ethylene glycol and directly coupled to the photomultiplier tube (RCA Model 8575, 21 pins), using silicon (Dow Corning), viscosity of 1.0McStokes, for the optical coupling. This procedure ensured uniform refractive index across the contact surface between the crystal and the photomultiplier. The sides of the crystal, which were not in contact with the photo-sensor, were covered with white Teflon tape to ensure good reflection of light. The electronic modules used for the processing of signals from the photomultiplier tube are shown in Fig. 2

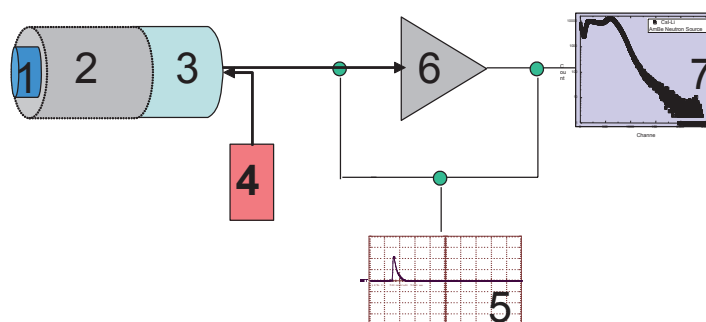


Figure 2. – Schematic of the measurement system, detector and electronics used: 1) Detector, 2) Photomultiplier, 3) Photomultiplier base, 4) HV (1900 V), 5) Oscilloscope, 6) Amplifier, 7) Multi-channel (Spectrum Master ORTEC Model 919 + computer).

The neutron radiation response of the AmBe source was measured, with pure crystal, with doped crystal and without crystal.

The AmBe reaction neutron source (α,n) was acquired in August 17, 1970, with a nominal activity of $3.7 \cdot 10^{10}$ Bq (1.0Ci) of ^{241}Am and neutron emission rate (rate neutrons flux) of $2.6 \cdot 10^6$ n s $^{-1}$, calibrated in July 2, 1970. For the purpose of correcting the loss by radioactive decay, the activity was calculated for the date of the experiments, yielding a neutron emission rate of $2.42 \cdot 10^6$ n s $^{-1}$ neutrons per second.

The operating voltage of the photomultiplier tube was 1900 V; the accumulation time in the counting process was 1800s. The scintillator crystals used were cut with dimensions of 20 mm diameter and 20 mm height

3. Results

Measurements to assess the ^6Li doped neutron detector response were performed. Therefore, a neutron source of AmBe, already described, a Co-60 source and a Cd foil of 0.5 mm thickness were used. The Co-60 source was used to verify the response in the gamma field. To verify if the photomultiplier was contributing to the neutron response, measurements with only the photomultiplier and the AmBe source were performed. Measurements with pure CsI crystal and with the crystal doped with ^6Li , using the neutron source, were carried out. In order to verify the response to fast and thermal neutrons, a block of 50.0 mm of paraffin was used. A Cd foil was placed around the detector and the photomultiplier to avoid the scattered neutrons contribution. Fig. 3 shows the array used in that measurements.

Fig.4 shows the results only for the photomultiplier with neutron source and for the CsI + Li crystal using the Co-60 source. In Fig 5, it is shown of measurements performed using the neutron source for a pure CsI crystal and for the crystal doped with ^6Li . A paraffin block to slowing down the neutron and a Cd foil to cut neutron with energy below 0.4eV, were used.

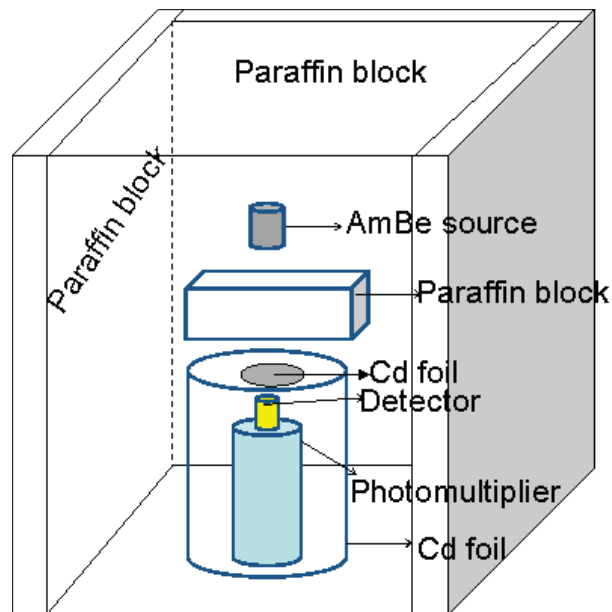


Figure 3. - Schematic of the array used for measurements

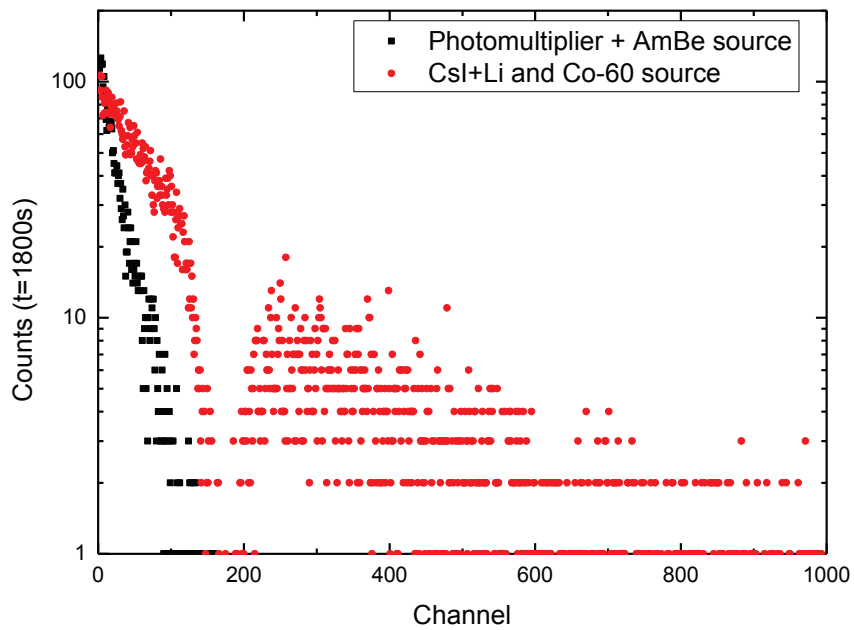


Figure 4. – Results of the measurements using neutron source and the photomultiplier without detector and CsI+Li detector with ^{60}Co source

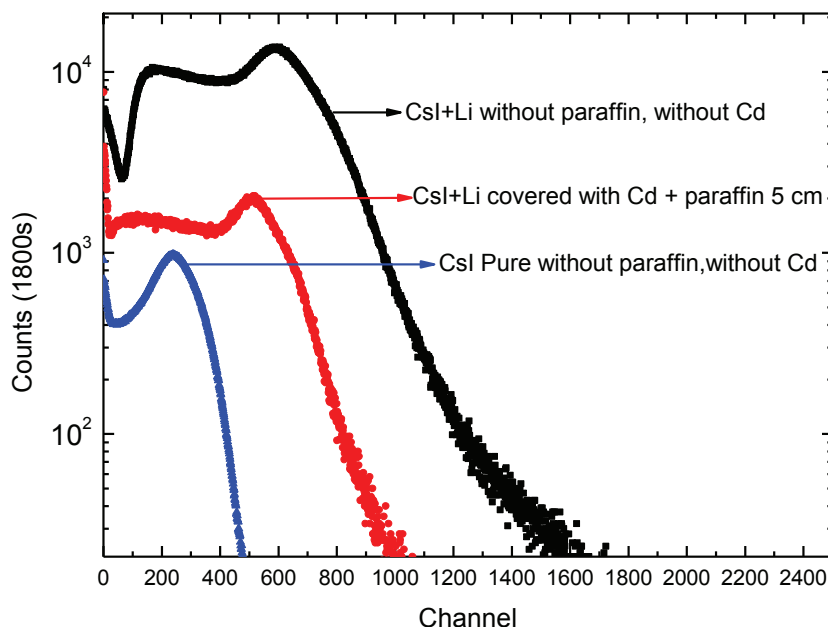


Figure 5. – Results for three different measurements conditions: (a) CsI pure and neutron source, (b) ^6Li doped crystal covered with paraffin and Cd foil and neutron source and (c) ^6Li doped crystal and neutron source.

4. Conclusions

It could be shown, experimentally that the addition of the Li to the CsI matrix resulted in crystals with promising results, when excited with neutron radiation. The crystals showed sensitive to fast and thermal neutron. Obviously, further work will have to be carried out on these materials, in particular on the concentration of dopants and crystal growth technique parameters. In our work environment can be use as area neutron detector and used in the personal dosimeter for the workers of the nuclear research reactor IEA-R1 and IPEN/MB-01.

The fast and thermal neutron were considered with energy above and below the cadmium cutoff energy (0.4 eV).

References

- [1] Neutron Measurement," Steven M. Grimes, Chapter 68 in *The Measurement, Instrumentation and Sensors Handbook*, edited by John G. Webster, CRC Press, 1999
- [2] CARLOS H. MESQUITA, TUFIC MADI FILHO, AND MARGARIDA M. HAMADA. *Development of Neutron Detector Using the PIN Photodiode with Polyethylene (n; p) Converter*. IEEE Transactions on Nuclear Science, Vol. 50, N. 4, August 2003
- [3] TANARRO, A. S. *Instrumentación nuclear*. Servicio de Publicaciones de La J.E.N.. Madrid1970
- [4] A.J. PEURRUNG. *Recent developments in neutron detection*. Nucl. Instrum. Meth. A 443 (2000).
- [5] KNOLL, G. F.; *Radiation detection and measurement*. 2 ed. John Wiley&Sons. 1986
- [6] Maria C. C. Pereira, Tufic M. Filho, Margarida M. Hamada, Development of crystals based on cesium iodide for measurements of gamma radiation and alpha particles. NUKLEONIKA 2009; 54(3):151–155.