Po-Be Neutron Check Source

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One question that arises over and over when working with neutron detectors is how to test and calibrate them. Obviously one has to have some kind of a neutron source in order to verify the detector operation. In this regard there are two general misconception about neutron sources:

1. *Neutron sources are expensive and complex devices akin to fusion reactors.* This is false. Many neutron sources are extremely simple and easy to make.
2. *One must have a neutron source in order to verify a neutron detector operation.* Also false. There is a background flux of neutrons that any operational neutron detector must register.

(α, n) Neutron Sources

When asked about neutron sources most researchers think about a DD or DT fusion reactions, e.g. D + D -> ^{3}He + n or D + T -> ^{4}He + n. These reactions are not difficult to effect, and many researchers have built their own thermonuclear fusion reactors with Farnsworth fusors being most popular among enthusiasts. But building a thermonuclear reactor is not a small task by any account. Fortunately, there is another nuclear reaction that yields neutrons without any effort whatsoever: I am talking about the (α, n) reaction. To make the (α, n) reaction happen you need a vigorous alpha source such as ^{210}Po, ^{239}Pu, ^{241}Am, or ^{226}Ra and a material (such as beryllium) that can readily capture the energetic alpha particles (i.e. ^{4}He nuclei) emitted by the alpha source and produce neutrons in the process.

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In the case of beryllium the reaction is $^{8}Be + ^{4}He \rightarrow ^{12}C + n$. Other materials such as lithium and boron can produce a similar reaction.

The key to make the (α, n) reaction happen is to have a *vigorous* source of high-energy alpha particles or an *alpha emitter*. Many common materials such as natural uranium and natural thorium are alpha emitters and they emit high-energy alpha particles. But the trouble with the natural uranium and natural thorium is that these alpha-emitters are not vigorous in the sense that the half-life of these elements is in the billions of years and therefore the resulting flux of alpha particles is extremely weak. What we need is a relatively short-lived alpha-emitting isotope that decays fast and therefore emits billions and trillions of alpha particles per second. Polonium-210 with the half life of ~4 months is a perfect candidate.

^{210}Po Alpha Source

Because ^{210}Po is a very short-lived isotope it is deemed 'dangerous' because it gives up its energy very fast. For that matter all short-lived isotopes (such as ^{137}Cs or ^{226}Ra) are deemed 'dangerous' as opposed to long-lived isotopes (such as natural uranium and natural thorium) that are deemed 'benign' as they are for the most part stable and give off their energy very reluctantly. If that is the case, so how on Earth one can get sufficient quantities of ^{210}Po to make a neutron source?

Fortunately, ^{210}Po alpha sources are commercially available for purchase as they are widely used in the industry for static electricity elimination. E.g. a Nuclespot alpha ionizer can be purchased from Amstat Industries for $262. The Nuclespot model P2042 is a little larger than a quarter, has the activity of 5 mCi and comes in a durable metal package.

And the beauty of this product is that anyone residing in the United States can buy this product by placing an online order at www.amstat.com, and the ionizer will be delivered to you via mail. In other words, Nuclear Regulatory Commission (NRC) grants one a compulsory license for owning and operating this product.

There is a slight catch, however. In order to comply with the terms of the compulsory NRC license one must register the source with the local NRC branch by filling out and mailing a special form, and paying a small processing fee ($30 in the state of Florida). By the same token, when the source looses its activity (in a year it will have just 1/8 of its original power left) it must be returned back to the manufacturer and the local NRC branch once again must be notified that you no longer own the source. That's all.

So, when you purchase the ^{210}Po source from Amstat they will notify the local NRC branch about the transaction and you will receive the paperwork from them automatically. Technically you do not own the source, you lease it, and the term of the lease is one year. At the end of the lease you can either renew the lease and get a new source or simply terminate the lease. In both cases Amstat will send you the paperwork with the instructions on how to properly package and mail the source back to them (you pay for the shipping, of course). And of course you will need to send a form to the NRC indicating that you have returned your old source to the manufacturer and have gotten a new source in it's place (or not).

Thank god for common sense and for the democracy that we enjoy in this great country of the United State of America! We are allowed to buy and mail all sorts of radioactive materials with minimum bureaucratic overhead. Try this in Europe or China. The truth is that most sources that one needs for research are benign due to very small activity (you need only microcuries to get a gamma spectrum line). And for sources in the millicurie range you can get a compulsory license. For even larger sources (in the curies) you can get a license too, although the process will be a bit more tedious. But my point is that you can get it done if you fill out the paperwork, pay the fees and implement the required safekeeping and tracking procedures.

Po-Be Neutron Source

OK, you have gotten a ^{210}Po alpha source, now what? To turn the alpha emitter into a neutron source all you need is beryllium window to cover the source and absorb the alpha particles – Fig. 1.

Fig. 1. A Po-Be neutron check source.

Simply buy a piece of beryllium beryllium foil, cut out a circle and place it over your source as close to the ^{210}Po material as possible as any kind of air gap between the source and the window will make a significant number of alpha particles loose their energy and thus considerably reduce the neutron yield. The source on Fig. 1 uses a cardboard plug to hold the beryllium foil in place in point-blank contact with the ^{210}Po material.

The shape and thickness of beryllium does not matter. Alpha particles will bombard the metal at point blank and the resulting high-energy neutrons will travel through metal without noticing it. I recommend using beryllium foil rather than grinding beryllium into powder. Beryllium powder is a health hazard and you will not gain anything by using it. Literally any chunk of beryllium metal will do.

Now you can use your 5 mCi Po-Be source to test your neutron tubes. A good ^{3}He proportional counter should report hundreds of CPM with a new source. Obviously, fast (α, n) neutrons must be thermalized using a moderator (such as HDPE, oil, water, wax, etc.) in order to be detected with a ^{3}He proportional counter.

Also, keep in mind that the resulting source is non-directional, i.e. the neutrons will be emitted isotropically in all directions.

Illegal Pu-Be and Am-Be Sources

It may come to you as a surprise, but most smoke detectors rely on small quantities of radioactive materials for air ionization. ^{241}Am is commonly used. ^{239}Pu (yes, plutonium!!!) was also commonly used in some old Russian smoke detectors. This is where the things get interesting. For some time one could buy hundreds of smoke detectors for next to nothing on eBay, and quite a few enthusiasts did. The by taking apart the detectors (you probably need 100 of them or so) and extracting the radioactive materials one could get enough plutonium or americium to make a Pu-Be or an Am-Be source. Needless to say, such practice is illegal. NRC does monitor eBay and they do casual crackdowns on enthusiasts that overstep the boundaries of common sense. At this level NRC does not send anybody to jail and may not even issue a fine, but they will collect your radioactive material excess that was obtained without a license e.g. by taking apart a third-party device. The law on this subject is clear: you can own radioactive substances no problem; depending on the quantity you may need a compulsory license; for larger quantities you will need a special license; but you are not allowed to take apart third-party devices that come with radio isotopes; you can own them, sure, but if you take stuff apart and start hording sources NRC will likely to pay a visit and take your toys away.

Natural Neutron Background

Lastly, I want to mention that one does not have to have a neutron source to test a neutron detector. There is natural / cosmic neutron background that any detector must register. Outer space is full of high-energy particles. These particles strike Earth's atmosphere causing nuclear reactions. The nuclear reaction product shower down on earth, and some of these products are neutrons. So day or night neutrons (and gamma rays for that matter) rain down on us. Fortunately, the flux is small and harmless, but large enough to be detected. Thunderstorms are also known to produce neutrons, but these are rare and difficult to detect.

So, if you do not want to mess with a neutron source and you want to test your neutron detector – simply let it count the background. You should be getting a handful (1-5) neutrons per minute on a good tube. If you are getting less than 1 and more than 5 then something could be wrong: either the tube is not working (less than 1 CPM) or you are picking up gamma rays or noise (more than 5 CPM). In all cases the tube needs to be enclosed in HDPE moderator as most neutron detectors are meant to detect only thermal neutrons. Also, if you leave the tube counting background for a long time (few days) you should be able to recover the thermal neutron spectrum. This would be an excellent test to determine if your neutron detector is operating properly.

Then what is the advantage of a neutron source? Well, with a neutron source you can do it a whole lot quicker, in just one minute.

Conclusion

If you are serious about neutron detection or when you need to count neutrons in your nuclear science experiment you pretty much must have a neutron source to verify your detector. Fortunately, a Po-Be source is easy to put together for this purpose. Without the source it may take hours or days to verify the detector operation using the natural neutron background. To get work done quick one needs the source.

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