

NUCLEONICS: The science and technology of nuclear physics and nuclear engineering.

by George Dowell

Or:

Using Exempt, Unlicensed or Generally Licensed RADIOACTIVE sources in the Home Rad lab and School Lab (USA 2007 Version)

To kick off our series of **Home Rad Lab** articles, it was decided to first delineate the legal parameters of owning and using radioactive sources.

Unfortunately since 9/11 the issue of what is legal and what is not legal has been in flux, as the US Federal government, especially the Nuclear Regulatory Commission, has been tightening up the rules and regulations concerning radioactive materials in general. Many of the regulations issued by the NRC stem from the Atomic energy Act of 1954, Energy Reorganization Act of 1974, and Uranium Mill Tailings Radiation Control Act of 1978.

In 2005, the Energy Policy Act of 2005 was passed. Prior to this law, the NRC had jurisdiction over certain types of radioactive material, and States over other types. Surprisingly, the NRC had no jurisdiction over Radium! Up until 2005, Radium was regulated only by the individual STATES. This to say the least was confusing to the lay person, lab operator, and even NRC employees. Not that an amateur scientist can truly understand all the laws and regulations totally, we will endeavor to create a safe and sane legal outline that will assure the instructor or hobbyist at least a basic understanding of the allowable procedures and experiments.

While the Energy Policy Act of 2005 was AUTHORITY, until *RULES* were instituted, the *LAW* had nothing to enforce.

<http://www.nrc.gov/reading-rm/doc-collections/news/2007/07-052.html>

Finally in April 2007 a definitive set of new rules has emerged, from which we may now derive guidelines for safe and currently legal radioactive experiments.

Of particular concern was the eminent reclassification and strict regulation of the most common radioactive source, the common radium painted watch hand. Serious consideration was given to restricting the ownership of radium watch hands to only 50 units at any one location. This of course would have reduced the ability of any institution to own a reasonable amount of that valuable material. Fortunately after long and contentious debate, much input from the public and industrial entities, it has been decided to delete the quantity restrictions on radium watch hands altogether. Currently

NRC regulations prohibit manufacturing any article, device or apparatus from Radium (Ra-226), and the use of pre existing material has its restrictions as well, but basically a vial of Radium watch hands is still OK to own at this time, subject to the general license provided in 10CFR-31.12.

NRC rules are very different for

- A) Individuals
- B) Educational institutions
- C) Business entities.

Before we get into the particulars we must understand some of the basic terminology used in the radiation lab.

PERSONS -Means (1) any individual, corporation, partnership, firm, association, trust, estate, public or private institution, group or Government agency. 10CFR-40.4

ISOTOPE – Normal atoms have the same number of Neutrons and Protons in their nucleus. Isotopes include all variations of the same chemical element that have the same number of Protons, but different numbers of Neutrons in the nucleus. All isotopes of a particular element have nearly identical chemical properties, but can have very different radioactive qualities. All variations of the same element are isotopes, but not all are radioactive. There are a vast number of radioactive isotopes, many of common elements like carbon, gold, silver or sodium. Once an atom increases or decreases the number of Protons in the nucleus, it is no longer the same element, but has transmuted into a different element altogether. That new element may have several isotopes all of its own. This fact of nuclear transmutation is evidenced by careful study of the nuclear decay chains in the link provided. Uranium-238 literally turns into Thorium which turns into Protactinium which turns into a different isotope of Uranium, and so on until stable Lead is the only thing left.

<http://www.ead.anl.gov/pub/doc/natural-decay-series.pdf>

SOURCE MATERIAL -“ SOURCE” in this case means “ natural source” . There are three decay chains that exist in nature. These are headed by Uranium-238, Uranium-235 and Thorium-232. Decay chain starts with the parent material and over time, decays into other radioactive material, until after a great deal of time, the final residue is stable lead (Pb). The exact type of stable lead depends on the originating parent material. Radium and Radon are some of the intermediate daughters or *PROGENY* of these decay chains. Uranium as found in nature, that is un enriched in U-235 is source material, and Depleted Uranium, uranium which has had a portion of the U-235 removed comes under the “ source” definition. Any kind of *ENRICHED URANIUM*- that is uranium with more than .7% U-235 is no longer considered “ source” , but is “ special nuclear material” - which is forbidden to own by individuals.

10cfr-40.4 Source Material means: (1) Uranium or thorium, or any combination thereof, in any physical or chemical form or (2) ores which contain by weight one-twentieth of one percent (0.05%) or more of: (i) Uranium, (ii) thorium or (iii) any combination thereof. Source material does not include special nuclear material.

Under the new NRC rules, Radium is now included in this category,
<http://www.ead.anl.gov/pub/doc/natural-decay-series.pdf>

<http://www.nrc.gov/materials/srcmaterial.html>

BYPRODUCT MATERIAL- As defined by NRC regulations includes any radioactive material (except enriched [uranium](#) or [plutonium](#)) produced by a [nuclear reactor](#). It also includes the [tailings](#) or [wastes](#) produced by the [extraction](#) or concentration of uranium or thorium or the [fabrication of fuel](#) for nuclear reactors. Additionally, it is any material that has been made radioactive through the use of a particle accelerator or any discrete source of [radium-226](#) used for a commercial, medical, or research activity. In addition, the NRC, in consultation with the EPA, DOE, DHS and others, can designate as byproduct material any source of naturally-occurring radioactive material, other than [source material](#), that it determines would pose a threat to public health and safety or the common defense and security of the United States. For additional detail, see [Byproduct Material](#). Under the new NRC rules, Radium and Uranium plant tailing piles are now included in this category.

<http://www.nrc.gov/reading-rm/doc-collections/fact-sheets/byproduct-materials.html>

BYPRODUCT MATERIAL Exempt Sources: Those man made (Byproduct) radioactive materials that are exempt from licensing in certain quantities, usually supplied to the Home Lab by companies such as Spectrum Techniques in safe SEALED SOURCES.

<http://www.spectrumtechniques.com/>

No man made materials that is not on this list are allowed to be owned except under license. This includes Plutonium, Americium, and Californium, basically any element heavier than Uranium on the Periodic Chart of Elements.

Check out the full list of approved materials and the allowable quantities under Schedule B at:

<http://www.nrc.gov/reading-rm/doc-collections/cfr/part030/full-text.html>

ALL materials supplied by Spectrum Techniques are of *exempt quantity*, therefore no license or special handling is needed.

NRC- US Nuclear Regulatory Commission, the primary regulator of radioactive materials in the USA.

Click here for the NRC' s Public Reading Room:

<http://www.nrc.gov/reading-rm.html>

NRC AGREEMENT STATES- Those states that have elected to take primary authority of radiation matters under their own control. State rules must be at least as restrictive as the NRC' s version. There are currently 34 Agreement States with others in consideration. Click here to review your state' s current status:

<http://nrc-stp.ornl.gov/>

Non AGREEMENT STATES - States which prefer the NRC to be the primary authority in radiation matters. Even these states have certain responsibilities that they must enforce. Click here to review your state' s current status:

<http://nrc-stp.ornl.gov/>

Misuse- The use of any radioactive material for other than its intended or licensed purpose. Removing a radioactive Am-241 from a smoke detector for use as a test source is considered a grievous misuse. Penalties are far beyond any benefit.

General License- A type of license automatically granted to and end user to own and operate some devices containing radioactive materials. The license is granted for the intended use of these devices only, and does not convey permission to use the device in an unintended manner (see Misuse). Transfer of such devices is generally forbidden between unlicensed persons, as is any alteration, removal of radioactive material or manufacture for sale. A generally licensed device usually consists of radioactive material contained in a sealed source within a shielded device

“ The general licenses provided in this part are effective without the filing of applications with the Commission or the issuance of licensing documents to particular persons. Specific licenses are issued to named persons upon applications filed pursuant to the regulations in this part” :

<http://www.nrc.gov/reading-rm/doc-collections/cfr/part040/part040-0020.html>

Perfect examples are: Smoke Detectors (Am-241), Tritium Lights (H3) and Signs, Static Brushes (Po-210). Depending upon the isotope involved, the only avenue of transferring the device is through disposal in a landfill. Some devices must be returned to the manufacturer for proper disposal. Again, an individual cannot sell, resell or transfer Generally Licensed material without a Specific License to do so.

<http://www.nrc.gov/materials/miau/general-use.html#7>

Specific License- The type of license required to manufacture, process and distribute regulated radioactive material. A University Lab would require a Specific License to own and use certain types or quantities of radioactive materials. This type license is not within the reach of the Home or small School Lab. “ Specific licenses are issued to named persons upon applications filed pursuant to the regulations in this part” :

<http://www.nrc.gov/reading-rm/doc-collections/cfr/part040/part040-0020.html>

We will deal with only Unlicensed, Generally Licensed, or Exempt sources.

PART 2- Radioactive Lab Sources.

As stewards of the SAFETY of our students, more importantly, the PERCEIVED SAFETY, we must first and foremost be adamant about using only materials that are PERFECTLY SAFE UNDER EVERY CIRCUMSTANCE. All the sealed sources from Spectrum Techniques meet this criteria and I will suggest a few more that should be suitable. Any items such as Uranium Ore and Gas lantern Mantles that can leave debris behind should not be taken into a classroom. These materials are perfectly safe in the Home Lab with only a modicum of caution and common sense.

Radiation dose to humans is a subject best address by health professionals, but certain guidelines have been set by the NRC and can be found here:

<http://www.nrc.gov/reading-rm/doc-collections/cfr/part020/>

Sealed Sources Suitable for classroom- unrestricted. >HIGHLY recommended classroom source<

Listed in order of priority:

These first three	are basic and are the	first three any lab should	obtain.	
Cs137S5	5uCi.	30.1 years	Gamma, Beta	32, 661.6, B511.6, B1173.2
Sr-90S	0.1uCi.	28.8 years	Beta	B546
Po-210S	0.1uCi.	138 days	Alpha	5407.5
These Isotopes	are very useful	in slightly advanced	to advanced experiments	
Co-60S1	1uCi.	5.27 years	Gamma, Beta	1173.2, 1332.5, B317.9
Tl-204S1	1uCi.	3.78 years	Beta	B763.7
Na-22S1	1uCi.	2.6 years	Gamma	1274.5, 511
Ba-133S1	1uCi.	10.7 years	Gamma	81.0, 276.3, 303.7, 355.9, 383.7
Fe-55S100	100uCi.	2.73 years	X-ray, Beta	5.9, 6.5, B231.4
Cd-109S1	1uCi.	453 days	Gamma	88.0
Eu-152S1	1uCi.	13.5 Years	Gamma, Beta	Multiple energies

Cs/ZnS	1uCi.	Mixed	"Unknown"	32, 661.6, 1115.5
Co-57S1	1uCi.	270 days	Gamma	122.1, 136.4
Mn-54S1	1uCi.	312 days	Gamma, Beta	834.8, 8542.2
C-14S10	10uCi.	5730 years	Beta	8156.5
Zn-65S1	1uCi.	244 days	Gamma, Beta	1115.6, 8236.34 81351.9

Sealed sources may be purchased, owned, used and discarded without a license. It takes a license to transfer sealed sources, so you cannot resell or even give them away.



Uranium Ore > OK in classrooms if contained <

Any number of experiments will be discussed using this basic radioactive material. At this time simply owning ore in any quantity is no problem.

Business or educational entities can own and process any amount of uranium ore, yielding up to 15 pounds in one session and 150 pounds in any one year of Yellowcake or concentrated uranium. Per Mr. Charles Cain, Senior Materials Analyst, NRC office,

Arlington TX, the office in charge of uranium milling. The US NRC does not regulate mining of uranium ore.

Ownership:

Individuals OK

Educational OK

Business OK



Any number of experiments will be discussed using this basic radioactive material. At this time simply owning ore in any quantity is no problem.

Ownership:

Individuals OK

Educational OK

Business OK

10CFR-40.13D

“ b) Any person is exempt from the regulations in this part and from the requirements for a license set forth in section 62 of the act to the extent that such person receives, possesses, uses, or transfers unrefined and unprocessed ore containing source material; provided,

that, except as authorized in a specific license, such person shall not refine or process such ore.”

Processing ore to yellowcake i.e. concentrating:

§ 40.22 Small quantities of source material.

“ (a) A general license is hereby issued authorizing commercial and industrial firms, research, educational and medical institutions and Federal, State and local government agencies to use and transfer not more than fifteen (15) pounds of source material at any one time for research, development, educational, commercial or operational purposes. A person authorized to use or transfer source material, pursuant to this general license, may not receive more than a total of 150 pounds of source material in any one calendar year.”

Mr. Charles Cain, Senior Materials Analyst at the NRC office in charge of uranium milling and processing indicates that the NRC does not regulate the mining operation of uranium ore, and defines the words "source material" in section 40.22 as the end result of processing, in other words yellowcake. In a telephone conversation of 26 Ap 2007, he answered some direct questions for me:

Q: How much ore may a person own? A: Any amount. As much as your dump truck will hold, then go back for some more.

Q: May an individual who is part of an educational or commercial entity process i.e. concentrate uranium ore.? A: Yes, up to 15 pounds of yellow cake per session, 150 pounds per year.

Through a special specific grant from the NRC, I have obtained permission to encapsulate Autunite from a particular mine into a particular kind of acrylic, providing the only legal source of SAFE AUTUNITE to the instructor. Autunite is particularly attractive as a demo source since it also glows under UV light.



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Ownership:

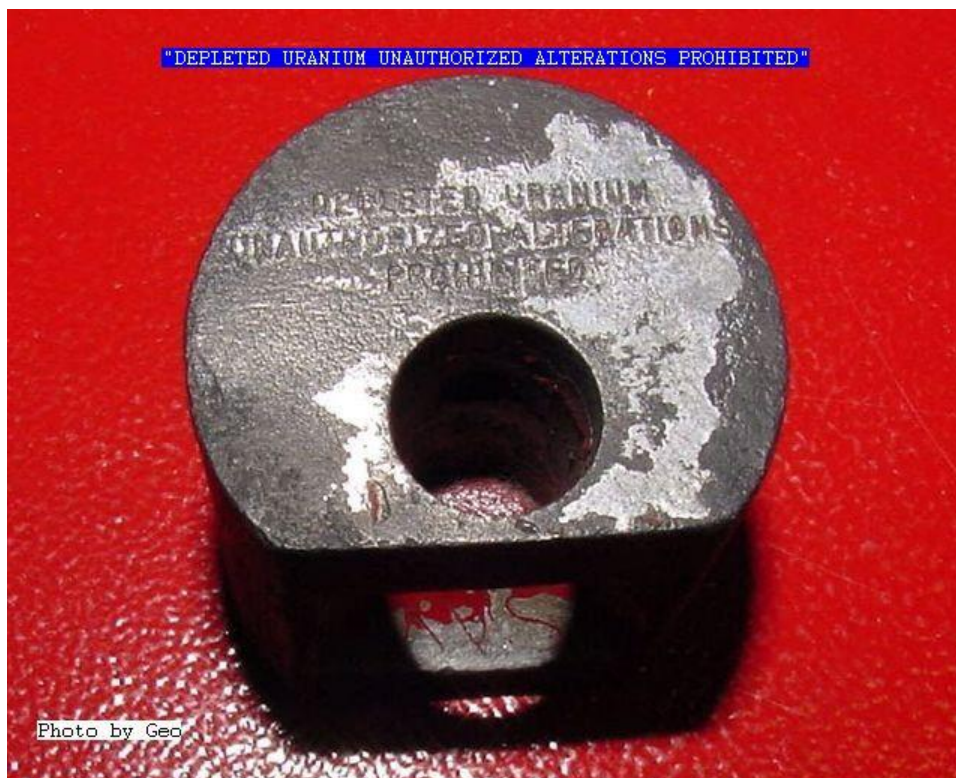
Individuals OK

Educational OK

Business OK

Depleted Uranium Metal (DU) > NOT suitable for classroom. An excellent radioactive material for numerous experiments in the HOME LAB environment< DU is any uranium with less than .711% by weight of U-235. DU metal is usually about .2% U-235, the rest is low radioactivity U-238.

Ownership: Depending on the item see: <http://www.nrc.gov/reading-rm/doc-collections/cfr/part040/full-text.html>



Individuals No

Educational OK up to 15 pounds

Business OK up to 15 pounds

Subject to rules under 10CFR-40.25 see:

<http://www.nrc.gov/reading-rm/doc-collections/cfr/part040/full-text.html>

Radium/ Ra-226 > NOT suitable for classroom. <An *excellent* radioactive material for numerous experiments in the HOME LAB environment, radium watch hands may be used, but only with care. Handling any Radium painted object WILL transfer Ra-226 to the skin and surroundings. In the school lab, an intact watch, clock or compass is the ONLY approved source. All glass covering must be undamaged and full shield the items inside. Never let a student handle the item. Only qualified instructors should be allowed to handle the item. Cleanup after a dropped/broken clock could be a financial burden. Far better to use one of the proven safe test discs from Spectrum Techniques in the classroom environment. Let me suggest videotaping actual experiments using any radium painted device. Redefined in 2007 as a BYPRODUCT MATERIAL.



LINK MR WIZARD

<http://www.mrwizardstudios.com/store.htm>

“ Everyday Radioactivity” episode.

Ownership: Exempted see- <http://www.nrc.gov/reading-rm/doc-collections/news/2007/07-052.html>

Individuals OK

Educational OK

Business OK

Thorium/ Th-232 >OK in classroom if sealed in a container. <

Thorium has been used in many consumer products in the past. It is still used in an abundance of everyday items, as it has certain unique characteristics that make it invaluable. All isotopes of Thorium are radioactive, the most common one being Th-232, found in many kinds of rocks.

Th-232 is the head of one of the three natural decay chains, while Thorium-230, 231, 234, and 228 are progeny of decay chains.

Some of the many uses include: alloying metals for extra strength, used to provide a better filament in high power radio transmitting tubes, added to welding rods, and making high temperature ceramics. The most ubiquitous use in the recent past has been in the form of Thorium Dioxide, ThO₂ in the making of Welsbach Gas lantern mantles.

http://en.wikipedia.org/wiki/Gas_mantle

Although the use of Thorium in Gas Mantles has been superseded by Cerium Oxide, many previously manufactured mantles are still around and may be purchased at a nominal fee.



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Ownership: Exempted see- <http://www.nrc.gov/reading-rm/doc-collections/cfr/part040/part040-0013.html>

Individuals OK

Educational OK

Business OK

Radioactive Potassium-40 /K-40 > *Suitable for classrooms-unrestricted.*
Highly recommended>

Sounds intimidating, but it is in virtually all soil, most rocks, and fertilizer, cleaning products, even your own bones. K-40 is not only everywhere; we eat it in the form of salt-substitute. The food product is actually a useful Home Rad Lab source! Other foods such as bananas and nuts have a fairly high concentration too.



Ownership: unrestricted in the natural state

Individuals OK

Educational OK

Business OK

Uranium Glass > Suitable for classroom - *unrestricted*. **HIGHLY** recommended classroom source.<

“ Depression glass” , uranium glass marbles, other green colored glass items. Perfectly safe, use a small amount of uranium in the manufacturing process. Also glows under UV light.

Ownership: Exempted under <http://www.nrc.gov/reading-rm/doc-collections/cfr/part040/part040-0013.html>

PICTURE COMING SOON!

Individuals OK

Educational OK

Business OK

FiestaWare, Bauer ceramic dishware, many other ceramics coated with the “ radioactive red” glaze > Suitable for classroom - *unrestricted*. **HIGHLY** recommended classroom source.<

Red or orange dishware has the most radiation, some other colors, especially crème contain lesser amounts. Pre WW2 contained natural pure uranium, lacking lower progeny but with the full U-238/U-235 ratio intact. Dishes made after WW2 were made with purified depleted uranium, mostly U-238, have reduced levels of U-235, and no lower progeny.

Ownership: Exempted under: <http://www.nrc.gov/reading-rm/doc-collections/cfr/part040/part040-0013.html>

PICTURE COMING SOON!

Individuals OK

Educational OK

Business OK

Future articles will highlight some of the many everyday items that happen to be radioactive, such as ceramic dishware, uranium glass dishes and objects, granite countertops, building materials, soil and many more.

Besides Uranium (Ore or Autunite in Acrylic), Radium and Thorium samples, I highly recommend the Home Rad Lab be equipped with at least a Cesium-137 disc (Gamma and Beta radiation), Strontium-90 disc (Beta only), and a Polonium Disc (Alpha only).

<http://www.spectrumtechniques.com/disc%20sources.htm>

Most school science supply houses carry the Spectrum Techniques products.

As our series of experiments evolve and get more complex, other test discs will be used, such as Cobalt-60, Sodium-22, Cadmium-109 and Barium-133. The culmination of the series involves “milking” one radioactive product from another, Ba-137m from Cs-137 using a Spectrum Techniques “Isotope Generator”.

PICTURE COMING SOON!

Recap of important points:

Do not remove radioactive material from smoke detectors.

Do not use any radioactive material in a way inconsistent with the intent of the object.

PART 3-Home Rad lab Instrumentation

During the course of this series of articles, will be using nuclear instrumentation from the simplest home made apparatus to very sophisticated analytical equipment. I promise that there will be something of interest for everyone.

PART 4- Human Rad Dose

Radiation dose to humans is a subject best address by health professionals, but certain guidelines have been set by the NRC and can be found here:

<http://www.nrc.gov/reading-rm/doc-collections/cfr/part020/>

No materials used in the Home Rad lab have enough radioactivity to be of any concern.

Have Fun

George Dowell, “ Geo”

NLNL/ New London Nucleonics Laboratory

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Comments, criticism and questions will be appreciated and may be directed to

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"Our progress as a nation can be no swifter than our progress in education" -- J. F. Kennedy

"You do not really understand something unless you can explain it to your grandmother." - Albert Einstein (1879-1955)

