Generating Metastable Isotopes of Short Half-Life in the Home Lab

By George Dowell

"METASTABLE" -

"m", small case m, when appended to an isotope name, means metastable. An isotope that is in a metastable state has pent up energy inside that WILL be released at some time, but all *normal* quantum transitions are forbidden. This energy comes about from normal nuclear decay of the metastable isotope's parent atom. Usually when an atom decays, there is an immediate rearrangement of the energy levels quite quickly in the daughter. So much so, that we often think of the Gamma ray that is released as part of the decay. It is not. Radioactive decay involves the transformation of the nucleus in terms of physical particles, into a new nuclide. Gamma radiation usually comes from the nucleus of the daughter nuclide as it rebalances its own energy to a ground state or more stable state.
In some instances, the new atom holds the energy for a finite period of time, sometimes microseconds, sometime hours. This final release of energy is called Isometric Transition (abbrev. IT), and allows the nucleus to fall to the stable state or nearer to a stable state. Thus, Ba-137m has the same weight, number of nucleons etc. as stable Ba-137. Ditto Tc-99m > Tc-99, although they have vastly different properties as far as radiation and half-life.
Iso*MER*s are two or more nuclides that have same atomic and mass numbers, but differing in other properties. Iso*TOPES* have the same atomic numbers, but different atomic weights and energy (different number of Neutrons), while Iso*TONES* are nuclides with the same number of Neutrons, but different numbers of Protons.

Sometimes the Gamma process involves the released photon smacking into an inner shell electron, disappearing but imparting its energy to the electron, which takes off from the atom- these are the IC or INTERNAL CONVERSION electrons. This void is filled from another shell, and that process alone creates a characteristic X-ray photon, whose energy is equal to the difference of the two electron's binding energy. If the excitation energy to the escaping electron comes from the atomic region rather than the nucleus, it is called an Auger Electron.

If a photon comes from the nucleus, it is called Gamma, if it comes from outside the nucleus, it is called an X-ray. The origin is the ONLY difference. Likewise, electrons, be they regular ones or antiparticle positrons, that come from the nucleus are called Betas. If they come from outside the nucleus (shell area, or atomic area) they are called electrons. These is some disagreement among

scientists about calling EC a Beta decay, since the electron goes into the nucleus, not out of it. Even the folks at Oak Ridge who make my Fe-55 disagree about this.

Pa-234m Generator

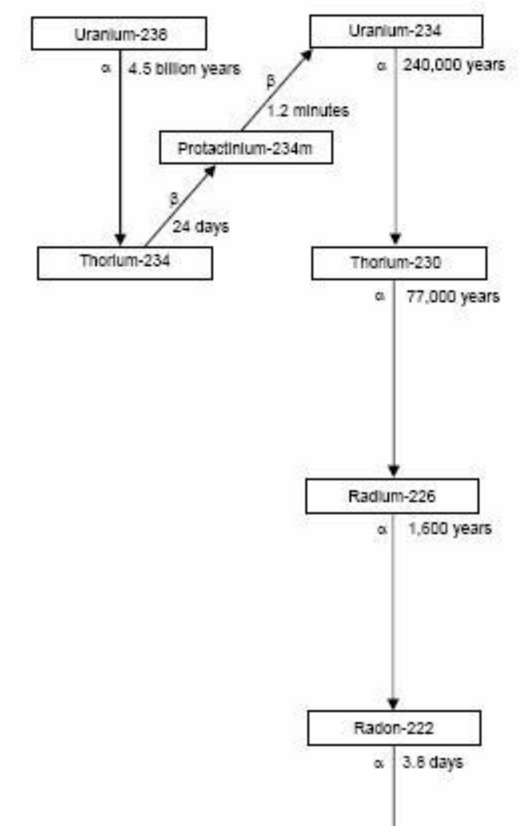
This seemed like a good idea at the time. Personally I won't recommend the procedure, as liquids in the home lab are messy and can be dangerous.

Ever since I saw the experiment here:

http://www.uni-regensburg.de/Fakultaeten/nat_Fak_IV/Organische_Chemie/Didaktik/Keusch/cassy_pa_hwz-e.htm

I just had to try it for myself. Most of the materials are readily available, save the MIBK (Hexone, isobutyl methyl ketone) which is a non-miscible organic solvent.

The idea is to dissolve Uranyl Nitrate in acid+water, then top it off with a layer of MIBK. When shaken, the Pa-234m which is a natural part of the Uranium 238 decay series , will dissolve in the solvent, which then floats back to the top. Physical separation of the Pa-234m from the parent allows the short half life of 1.2 minutes to be examined.



http://www.qsl.net/k0ff/index_files/Radon-222.jpg

As mentioned, MOST but not all the ingredients are readily available.

Sulfuric acid came from a bottle of left over dry charge battery juice.

Research into various substitutes for the MIBK lead me to plain old WD-40. An organic solvent that is not soluble in water. Bingo.

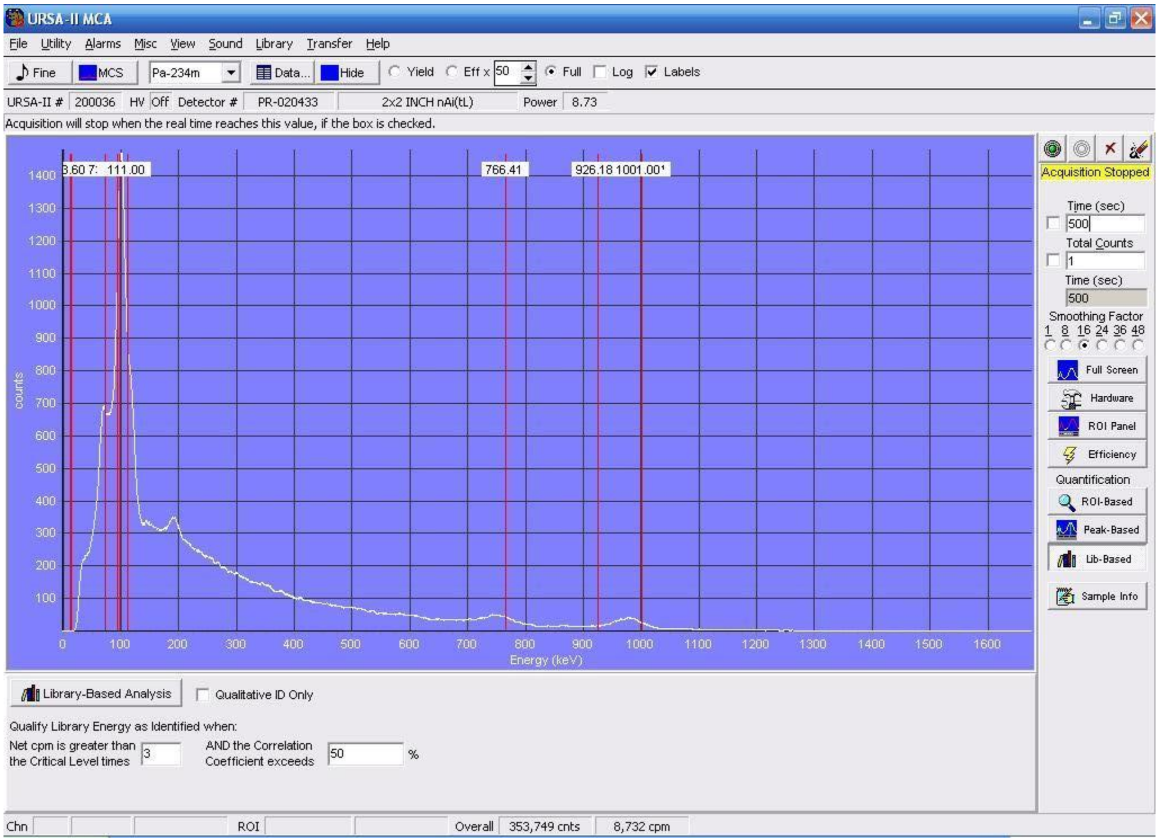
Using a hypo canister for the tube and a vinyl cap-plug as a stopper, a quickie isotope generator was hacked together.

A strange blue color was produced in the acid phase, probably from some impurities in the Uranium.

Shaking does mix the components well, and the separate back rather quickly.

Photon Emission Products: Pa-234m
Fraction Energy(MeV)
0.000136 0.073920
0.000597 0.013300
0.000873 0.111000
0.001157 0.094665
0.001875 0.098439
0.002067 0.766410
0.003739 0.926180
0.004433 0.013600
0.005891 1.001000

Scan details:
URSA II MCA, Ludlum 44-10 probe >2" x 2" NaI(Tl)



http://www.qsl.net/k0ff/Pa-234m%20Generator/Pa-234m%20scan.jpg

The Spectrum Techniques Ba-137m generator is nice, and affordable.

The generator contains 10uCi. of Cs-137 and can produce up to 1000 small aliquots of the short lived Ba-137m isotope with a half-life of 2.6 minutes.

The parent isotope Cs-137 with a half-life of 30.1 years beta decays (94.6%) to the metastable state of Ba-137m. This further decays by gamma emission (662 keV) with a half-life of 2.6 min. to the stable Ba-137 element. During elution using a solution of0.9% NaCl,, the Ba-137m is selectively "milked" from the generator leaving behind the Cs-137 parent. Regeneration of the Ba-137m occurs as the Cs-137 continues to decay, re-establishing equilibrium in less than 1 hour.

Those short half-life isotopes are fun to chart. It is quite true that Cs-137 is actually a pure beta emitter, but is always found in the presence of the progeny Ba-137m, which gives the typical gamma signature we look for in spectrum analysis.

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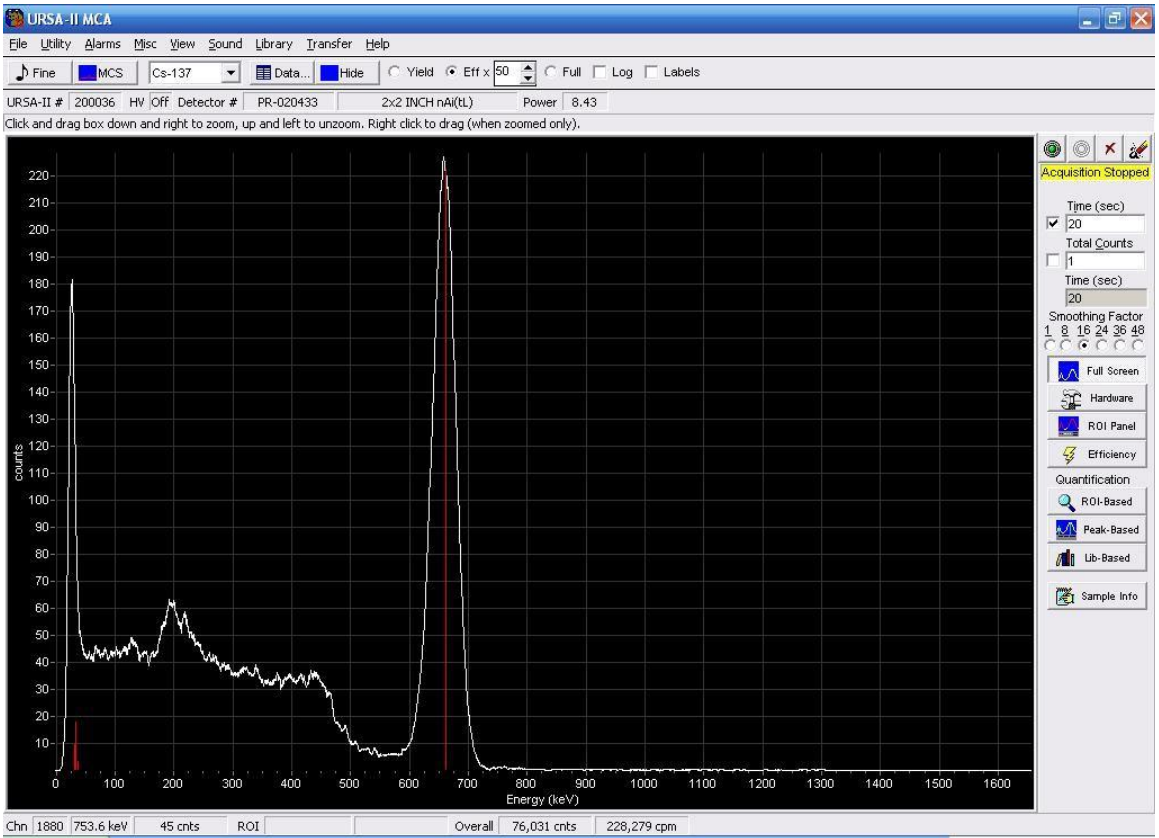
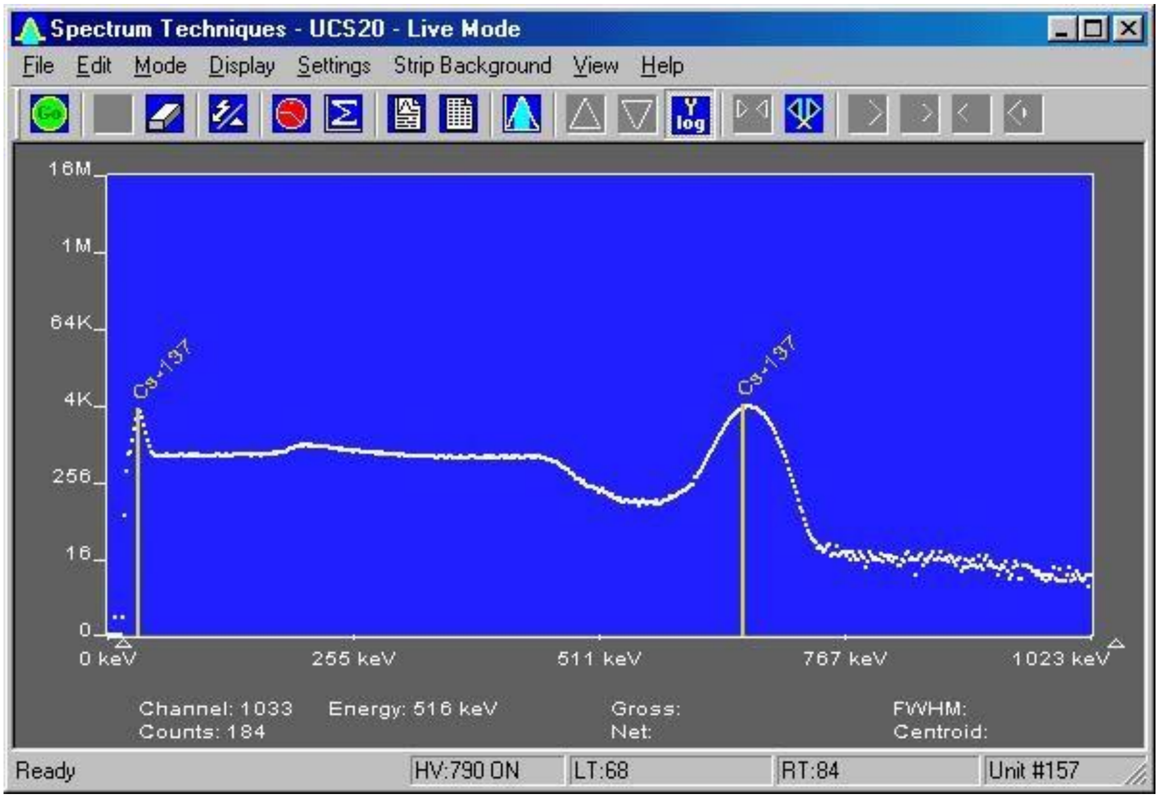
URSA II MCA, Ludlum 44-10 probe >2" x 2" NaI(Tl)

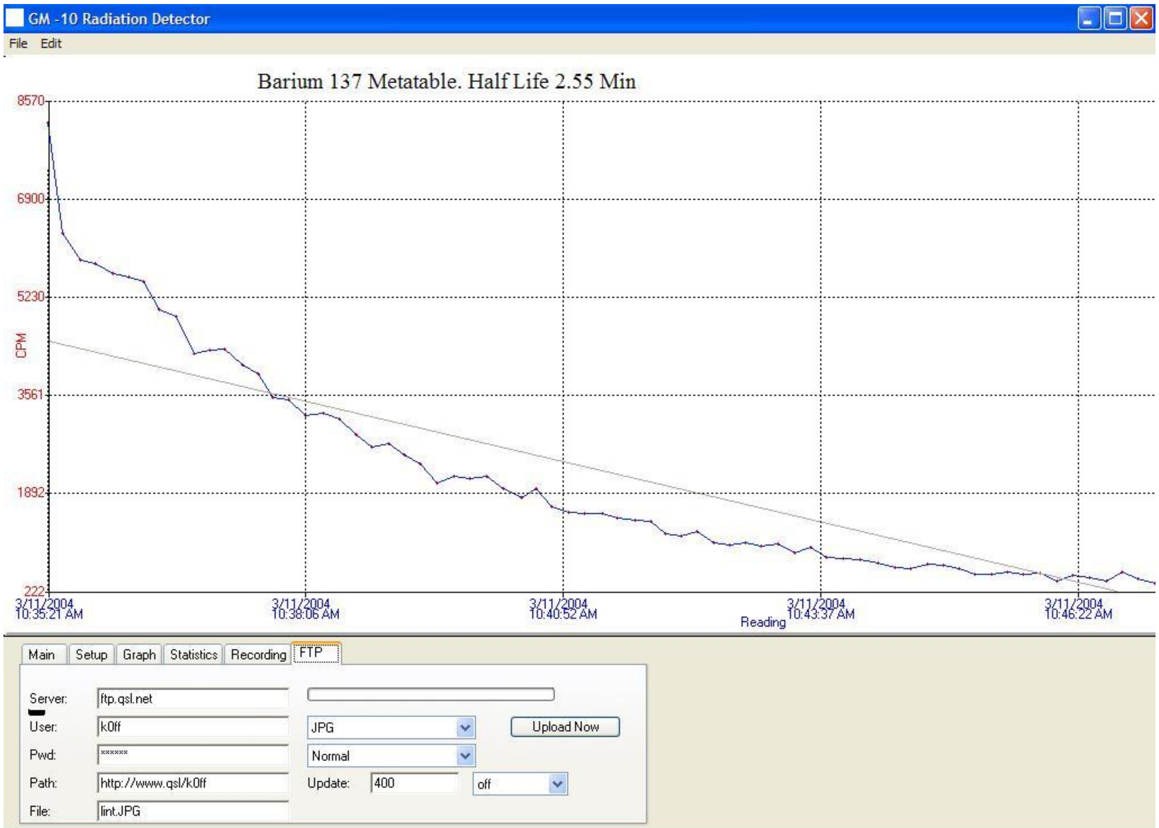


Only a few isotopes are truly gamma free beta minus emitters, H3, C-14, Ni-63 Tc-99, Tl-204, Pm-147 Sr-90/Y-90 and P-32 being the most common. Any time betas are flying about, X-rays are also being created by them. These can be bremsstrahlung or of the "characteristic" type, so there is always a lot of "noise" on the scan. Setting up a NaI(Tl) probe for spectrum analysis includes adding a beta shield to the source holder for this reason.
We have a small group of spectrum analysis enthusiasts at:
http://groups.yahoo.com/group/GammaSpectrometry/

Scan details:
Setup:
3M3 3" x 3" Nai(Tl), Canberra 2007P base, Canberra 727 lead shield-graded to copper. USC-20 set as MCS= Multi Channel Scaler mode, HP laptop



Scan Details:
Black Cat Systems GM-45 using GM-10 Software



Note: after 7 half-lives of any isotope, 99.2% of the original activity is lost.

Have Fun

Geo

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Comments, criticism and questions will be appreciated and may be directed to
the author by email to GEOelectronics@netscape.com