

DU vs. Natural Uranium?

by George Dowell

Q:

Can you explain the difference between Uranium 238 and Depleted Uranium 238?

Short answer:

Natural uranium ore contains about .72 percent of U-235, the fissionable variety, and the rest is U-238 and a little of the daughter U-234. Uranium which has been purified, but the U-235 removed (leaving only U-238) is called Depleted Uranium, or DU. Depleted Uranium is that material left over when U-235 has been chemically (or mechanically) separated so that the U-235 can be isolated for scientific uses.

During the Manhattan Project, the separation of U-235 occurred at the Oak Ridge K-25 plant.



The U-shaped K-25 building measures half a mile by 1,000 feet, and at the time was the largest building in the world.



Here is a summary of facts and ideas concerning Depleted Uranium VS Natural Uranium

***Natural* uranium is 99.284% U-238 isotope, with U-235 only 0.72 % by weight. U-235 is the only isotope existing in nature in any amount that is *fissionable*.**

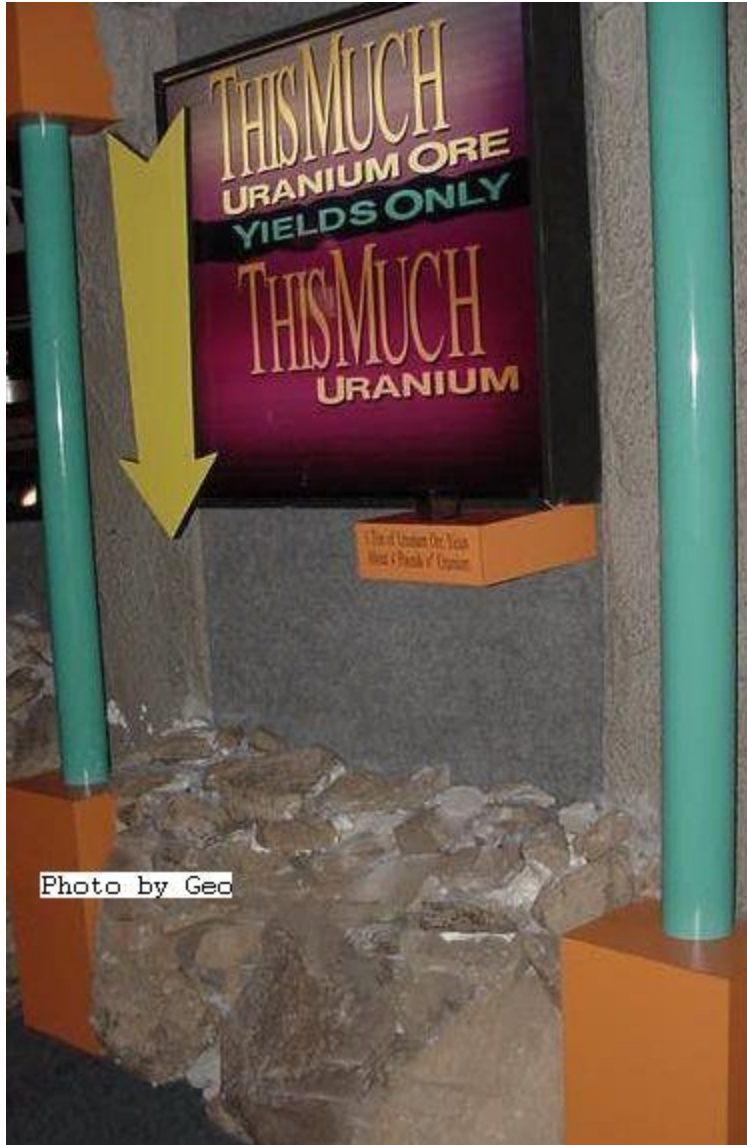


Photo by Geo

about a ton of ore is required to extract two pounds of uranium

First let's review the term "equilibrium". Uranium 238 and 235 are both naturally occurring and are both the head of a decay chain (note 1). In U ore, the natural state of Uranium there is a mixture of U-238 (99.3%) and U-235 (.72%) along with all the decay progeny (formerly called "daughters") that have grown in over the billions of years. This equalized state is called "equilibrium". In nature, there are many things that can disturb equilibrium, possibly the most noteworthy is the fact that one of the progeny, RADON is a gas and can in some circumstances be removed from the parent material by normal means. Not all escapes of course, but there is

a significant release of some percentage. By and large though, equilibrium can be assumed to be pretty close to normal. Uranium element can be found in chemical combination with other elements, giving rise to all kinds of Uranium bearing rocks, some having an economical concentration, others much less. It is a fact of chemistry that all isotopes of a given element are chemically the same, that is they combine with other chemicals the same, have the same melting temperatures etc. The variances are in the weight of the nucleus.



The main reason to mine Uranium is the ultimate recovery of the U-235 which is the isotope needed for power plants and weapons. The concentration must be increased from .72% to at least 5% for reactors and >85% for weapons.



During the chemical refinement of the U ore, much but not all of the U-235 (now called “ Enriched Uranium” EU, slightly enriched uranium (SEU) has a ^{235}U concentration of 0.9% to 2%, “ Low Enriched Uranium” LEU <20% U-235, or even “ Highly Enriched Uranium” (HEU) >20%.

Once the desirable U-235 is mostly removed, leaving predominately chemically pure U-238 and a little U-234.

Here is the raw data from the IAEA:

Natural Uranium:

U-238 = 99.28%

U-235 = 0.72%

U-234 = 0.0057%

Depleted Uranium

U-238 = 99.8%

U-235 = 0.2%

U-234 = 0.001%

U-235 is still present at .2 or .3 % concentration, with the former being "waste", while the latter is stockpiled for future consideration. Any Uranium which has less than .72% of U-235 is technically considered Depleted, or DU.

DU is the material of most interest to us in the home lab along with natural U ore and the various natural U chemical materials.



As mentioned, that variety of DU with .2% or less is considered a waste product to be disposed of in any economical and safe manner.



Since there are huge amounts of the "waste" product (presently estimated at 500,000 tons in the US), it is literally given away for some other use. We know of projectiles and armor plating, as well as radiation shielding as

some of those uses. Since DU is weighty or dense (1.7 times heavy as lead), it also finds use as ballast weight in ships and airplanes. Another use was in the coloring glaze used on red/orange ceramic dishware, with Fiesta Ware being the most well known brand. This practice has been abandoned in recent years but much of the material is still collected and traded.



In the days before WW2, Fiesta Ware was made with natural U. After the war, it was made with DU.

It has been said (note 2) that DU is 40% less radioactive than natural U. There are two reasons for this. The first is that the U-235, even though only less than 1% of the natural mix, is

more radioactive in terms of disintegrations per second by virtue of its much shorter half-life. Short half-life isotopes

"burn up" at a faster rate, that's why they last a shorted time.

Secondly, we must consider the equilibrium status of chemically purified U-238, which is the majority isotope in DU. At the moment of purification, all the atoms are only U-238. Non of the rest of the decay chain are any longer represented. Now with a half life of 4.5 billion years, you might think that it stays as only pure U-238 for a long time. Truth is, even after a few weeks (note 3) the first progeny (Thorium 234, HL= 24 days) are already

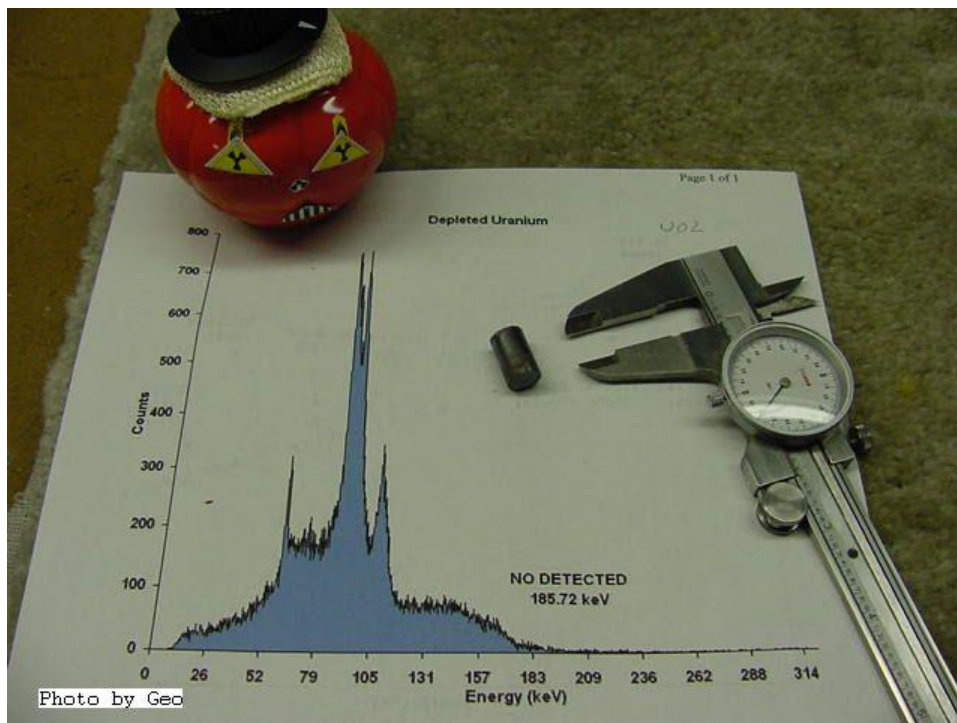
starting to grow in. Within a few months, the mix is now U-238 + Th-234 +Pa-234M +U-234. The last isotope mentioned , U-234 has a 240,000 year HL, so it is unlikely that anything from below this in the decay chain exists, unless contributed by contamination (very likely, from what I have read).

None of these first four isotopes are known for their high probability of energetic Gamma emissions, but have copious Alphas and Betas.

In the home lab we have easy access to both natural U and DU. The many U ores abound, and any one would have the equilibrium signature.

For DU, we select a late version of Fiesta Ware, fuel pellets, U-308 chemicals or DU metal..

Performing Gamma spectrum analysis on each would show the different spectrum signatures due to the lack of lower progeny in DU.



Radium-226 from parent U-238 and U-235 both have Gamma Rays in the 185 keV region, but the one from Radium is seldom noticed. Use the 185.7 keV peak from U-235 to identify that isotope, and use the presence or absence of the lower progeny Bi-214 @ 1.76 MeV to indicate the presence of U-238.

Another easily detected and non ambiguous marker is 351 keV from Pb-214, also a lower daughter of U-238.

If it either is present, we can assume that the U has at least partial equilibrium and is therefore in a state that would preclude any prior enrichment activities.



Mere chemical purification would leave all the isotopes of U in their natural balance, but remove the lead, polonium etc from the ore.

Bi-214 Gammas corresponds to the U channel on geological Gamma Ray Spectrometers, as it is a unique signature, and can be detected at long ranges. A rather thick section NaI (Tl) would be the preferred detector, 2" or 3" being superior to smaller crystals.



We know from historical documentation that Fiesta Ware was once made from both purified natural and DU. It may be assumed that other types of civilian goods follow a similar pattern, with DU being the cheap and abundant material by the 1950's. It would be interesting to run similar tests on "depression glass", marbles, beads, and other such items from the two different eras, as well as "Uranium" test spots on antique Geiger Counters.

Determining Natural U in equilibrium, Natural U *NOT* in equilibrium, DU, Using the Ratios

Method of Gamma Spectroscopy.

Natural U = has all natural isotopes, U-234, U-235, U-238, same ratios as in nature

DU = U-235 reduced by separation, leaving only U-238

Equilibrium = has lower daughters

NOT in Equilibrium = Lower daughters NOT present

Using a single channel analyzer and a 2" X 1/2" NaI crystal a technique was developed to measure the ratio of 100 keV X-Rays from U-238 and 185 keV Gamma rays from U-235, thereby determining the absence of U-235, an indication of DU.

Depleted Uranium is that material left over when U-235 has been chemically (or mechanically) separated so that the U-235 can be isolated for scientific uses.

Natural U contains .72 % of U-235, most of the remainder being U-238. Technically speaking, any U that has less than .72% of U-235 is called DU, but in practical terms the materials that we see that has been passed down to commercial uses contains .2%. U-235. A slightly less depleted material, with .3% is retained in stockpiles for future refining. U-235 is more radioactive than the U-238 counterpart, and contributes probably 50% of the radiation in natural samples.

Being a chemical process, the lower daughter is U are removed from DU, and must grow back in from the moment of separation. Problem being that the 3rd daughter, U-234 has a half life of 22,000 years, so for practical purposes, real DU only consists of the Parent U 238, Thorium 234, Protactinium 234M and U 234, and a tiny bit of the remaining U-235 left from the imperfect separation.

U-238 has a nice X-Ray at 100 keV as well as some other peaks in that general area. The U-235 main peak is at 185 keV.

With a suitable probe, these two peaks can be measured independently. There is a little interference in the 185 keV channel from artifacts of U-238 also, but these are of low occurrence and can either be deleted electronically, or in this case ignored.

A 2 inch by 1/2 inch NaI scintillator was chosen as having the proper characteristics for this test, namely a good response to low and medium energies, and a rejection of high energies (for a good signal-to-noise ratio).

Charting the 100 keV \pm 10 keV channel, then the 185 keV channel, then subtracting the background from each, then determine the 100/185 ratio by mathematics.

Some Fiesta Ware is Nat U (before 1943), some (after 1959) is DU.

Torbernite = 2:1

Atunite = 2.4:1

.5% U ore = 1.6:1

2% U ore = 1.8:1

Fiesta Plate = 2.13:1

Fiesta Platter = 2.4:1

Fiesta Bowl = 2.3:1

Uranium Glass (modern) = 9.4:1

It is obvious that of all the items tested so far, only the U glass bead from BlackcatSystems is DU.

After studying the ratios of U-238 and U-235 to determine the presence of DU in the previous post, I took things a bit farther and looked at the lower U daughters. Detecting the 351 keV Gamma from the Radium B or Lead-214 gives an

instant insight into the equilibrium status of the Uranium. It was found that my Fiesta Ware samples were of normal U238/235 ratio, as in natural U, but there is an absence of lower daughters. This leads me to believe that the Uranium glaze was made from a purified form of U, not just ground-up U ore. The modern Uranium Glass bead also showed missing Pb-214, but the ore samples show a full load of it, with about 1/3 as many counts at 351 as from the 100 keV channel. All the ore and other mineral samples showed a large 351 contribution as expected, indicating some level equilibrium. Atunite and U ore showed a 1:5 ratio but Torbernite was more like 1:3, my guess is that this is due to natural chemical purification at some time in the distant geological past, where the U was brought into compound by natural forces, but the polonium's, bismuths, leads etc. were not.

Uranium that has been chemically separated from the ore by man can still be natural U, but is purified, that is, removed from the other chemicals (polonium, bismuth, lead) that would exist along with the U if left undisturbed for thousands of years. This purified U would be just Uranium, with the ratio of U-238 and U-235 intact.

Simple chemical processes can yield Yellowcake, UO₂, UO₃ and U₃O₈.



The daughter ingrowths would of course start right away after purification, but U-238's 3rd daughter, U-234 has a very long half life, @ 240K years so could be considered a "stopper". The "stopper" in the naturally occurring U-235 portion would be the 2nd daughter, Protactinium-231 @ 33K years. Chemically purified natural Uranium would never reach equilibrium again in human terms.

Perhaps we can look at Uranium as at least 3 different products from here on out:

- A) Natural U in equilibrium
- B) Natural U *NOT* in equilibrium (purified U)
- C) Depleted U

If you have a Depleted Uranium fuel pellet and IF you have a spectrum analyzer or even an SCA, look far above the expected 100 keV X-Rays for the gamma signature of Pa-234M. A strong peak at 766 and another at 1001 keV indicates the ingrowths of this daughter. The more counts in those peaks compared to the X-Ray peaks, the older is the pellet (or other DU source). Since U-238 has a 4.5 Billion year half life, there will be no chance of any of us seeing this process through to equilibrium.

At the moment of processing, the DU contains only Uranium. Immediately the daughters start to grow in, albeit slowly.

You can't do this sort of measurement with natural U since the daughters are near equilibrium and the spectrum is jammed with all sorts of peaks from those progeny and the Compton scattering interference that they generate. The Pa-234M peaks are lost in the noise, but with real DU, they are the only peaks to be seen in that part of the spectrum

That 1001 keV makes a nice marker for calibrating systems too..

Uranium Assaying

When assaying Uranium Ore, it is important to check for

- 1) concentration of total U in the ore, and
- 2) the enrichment of the ore (U 235/U-238 ratio).

In order to check for concentration, kits were made available from large labs, to compare a sample you have weighed and crushed against the known concentrations. Viable concentrations were anything above 1/10th percent, the lowest grade the Government will purchase (at least back in the U-rush days). Some meters made in the 1950's were calibrated in "percent U" on the dial. Today special meters have a "grams" mode, which is about the same idea. In all cases a calibrated sample is needed to set up the instrument initially.



Today calibrated U-samples are still available from various labs, but the price has escalated to put it out of reach of the home lab for practical purposes (\$100.00 USD per each concentration), but still well within reason for a commercial endeavor.

See:

<http://www.nrcan.gc.ca/mms/canmet-mtb/mmsl-lmsm/ccrmp/pricesccrmp-e.htm>

The meter used in an assay is usually called a Stabilized Assay Meter, and the "stabilized" part refers to a feedback system in the NaI(Tl) probe that adjusts the system gain to compensate for temperature and other drift factors, to keep the output very accurate.

Ludlum makes such an instrument (It's the one I have) called a 2218 Assay Meter, and the probe in that system used an internal LED to adjust the gain.

Eberline has the SAM-2 and uses a built in radioactive source inside the probe (Am-241) in which the alphas create a false gamma channel, for setting the gain. Both systems are very stable, and the instrument itself is set up as a dual channel analyzer.

What you look for is the 185 keV signal given off by the U-235, and compare that to the total counts received from the U-238/U-235 mixture. Without the correct matching probe, the stabilizer must be switched off to use a standard probe. In such a case, the system is used as a standard meter but is no longer stabilizer.

Generally a 3/16th inch lead shield and a 1/32nd inch cadmium window are used to reduce background counts and limit the range of low energy Gammas and X-Rays allowed into the probe. Scintillation crystal are optimized to receive the 185 and reject higher energies by design, and a shape of 2" diameter by 1/2 in thickness*.

*High energy gammas penetrate further into a scintillation crystal, and indeed will pass right on through if the crystal is not thick enough to stop them. The many different shapes and thickness of crystals available in probes is a result of optimizing this effect to the best use. One wants to maximize the desired signal and minimize the undesired components, especially background radiation. Lower energy Gammas only penetrate a short distance into the crystal, so having any extra thickness just raises the perceived background without raising the desired

signal at all.

Probes made for Plutonium detection (main Gamma a very low @ 13.6 keV) have a 5 inch diameter but are only 1/10th inch thick. Similar smaller diameter probes are made by Ludlum and TA (PGS-22)



The above furthers our basic concept that only a minimum variety of electronics** is needed in the home lab,

but an abundance of different probes is crucial. I would like to add that a variety of known Gamma energy samples and a few Beta samples*** make setting up equipment and experiments a lot more enjoyable. Lastly a set of calibrated absorbers keeps will make a lot more experiments possible****. One would be far better off spending their monies on samples and probes than a "collection" of electronics. Keep it simple.

NOTES>

** Variable HV is a must, and a digital scaler (counter) comes next. Variable LLD (also called Gain, Lower Level Discriminator, and Threshold) is good to have, but a fixed gain system is fine if the lower level is around 30 mV.

*** Minimum: Cs-137 @ 1 or 5 uCi, Co-60 @ 1 uCi, Sr-90 @ .1 uCi in that order.

REFERENCES:

Note 1:

http://www.gsl.net/k/k0ff//7Manuals/ANL%20Sheets/DecaySeries_FactSheet_ANL.pdf

Note 2:

http://www.gulflink.osd.mil/du/du_tabkb.htm

Note 3:

<http://www.idust.net/Tutorial/DBish002.htm>

Note 4:

<http://groups.yahoo.com/group/GeigerCounterEnthusiasts/>

Have Fun

Geo

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