Worry about annual output a few of kg neutrons in nuclear power station?

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Abstract

It is important to investigate how many neutrons are produced and where fissional neutrons are going in uranium fuel reactor, as hazard assessment on nuclear wastes does need reliable data, but it seems hard to find a pie chart depicting different percentages for all possible destinies of neutrons, so some calculations herein need correction in future.

An isotope U235 fuel atom will averagely release 200MeV heat energy, 2.5 neutrons and 2 smaller nuclei in random species, during nucleus fission induced by thermal neutron tender massage.

In other words, if 80MeV heat is generated, then 1 neutron will pop up as one of many fission crumbs.

Given 1MeV = $1.6*10^{-13}$J, neutron mass = $1.67*10^{-27}$kg, and to make engineering sense, it's better to convert it to heat/weight ratio $7.66*10^{15}$J/kg, or approximately 8 petajoules per kilogram neutrons.

Let me take a sample nuclear power station to calculate neutrons productivity.

Japan Fukushima Daiichi nuclear power plant: 6 reactors, total power 4546MW.

As a reasonable estimation, the efficiency of heat to electricity is about 35%, so the thermal power must be larger than 4546/35% = 12989MW.

Theoretical max yearly heat energy = 365*24*12989*1000 = $114*10^9$kwh.

Because night energy consumption is far less than day time, and equipment also need maintenance time, thus above data should be discounted by a factor of duty cycle.

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As per statistics, duty cycle 0.6 is reasonable, so the yearly real heat output = $68*10^9$kwh.

Given 1kwh = 3.6MJ, therefore heat yield = $245*10^{15}$J/year.

By afore calculated $7.66*10^{15}$J/kg, now I get result of neutrons total mass = 245/7.66 = 32kg/year.

Yes, a few of kilograms neutrons per year, that is it.

Neutron’s density is extremely high, even a spoon of neutrons may have more weight than the Himalaya Mountain.

Imagining these 32kg neutrons tightly packed together, it’s still so tiny, that you have to see it with help of a microscope.

There are many possibilities for neutrons destiny:

1. Hit a hydrogen nucleus in water molecule, then fused to deuterium;

2. Hit a generated deuterium, fused to tritium;

3. Absorbed by power adjusting control bar, which is made of cadmium;

4. Absorbed by U238, the major component of fuel-escorting material, then decayed to Np239 after 23 minutes, then decayed to Pu239 after 2.4 days (by the way, Pu or plutonium is excellent igniter for nuke hydrogen bomb);

5. Absorbed by whatever miscellaneous atoms in structure or containers;

6. Beta decay to a hydrogen atom, if no other destiny after about 15 minutes;

Supposedly, scientific community should produce a pie chart to depict percentages of all possible destinies, so public can be well informed and have a good judge about any potential risks, but unfortunately there is no such chart.

The tritium has 12 years half-life beta decay to helium, with a radioactive energy release up to 18KeV, and usually renders average 5.7KeV electron projectile, because the ghost particle neutrino takes away quite a portion of energy.

Its energetic electron projectile can destroy some cells if inside human body, though short fly distance down to a few of centimeters, nevertheless tritium is still harmful to human if too much exposure.

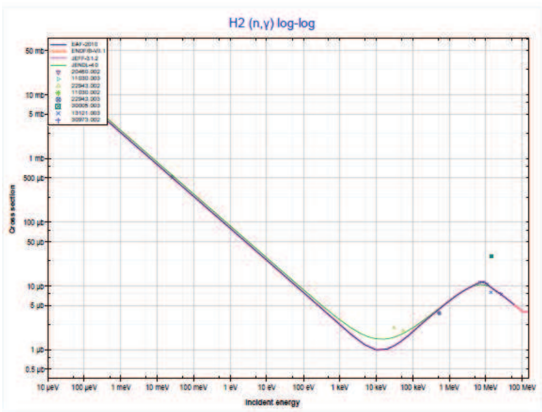
In contrast, medical X-ray render far higher energy and deeper penetration, up to 150KeV; however, accurate comparison should depend on dose condition.

As nuclear wastewater may contain significant tritium, of course, public is worry about its discharge.

Although no reliable data of neutrons destinies, we can assume all neutrons go for tritium, so a water H_2O can consume 2 neutrons, or say, 1 kg neutrons can make up 10kg or 10 liters water, then the said power plant, at max, it could produce 320kg pure tritium-water per year.

OECD NEA Data Bank

<< 1-H-1	1-H
<< MT16 (n,2n)	MT102 (n,γ) or MT



Library	Sig(2200 m/s)	Sig(25.3 meV)	Avg-Sig(thermal)
EAF-2010	5.05737E-4 b	5.0537E-4 b	5.054E-4 b
ENDF/B-VII.1	5.05866E-4 b	5.05503E-4 b	5.056E-4 b
JEFF-3.1.2	5.05866E-4 b	5.05503E-4 b	5.056E-4 b
JENDL-4.0	5.50191E-4 b	5.50191E-4 b	5.5071E-4 b

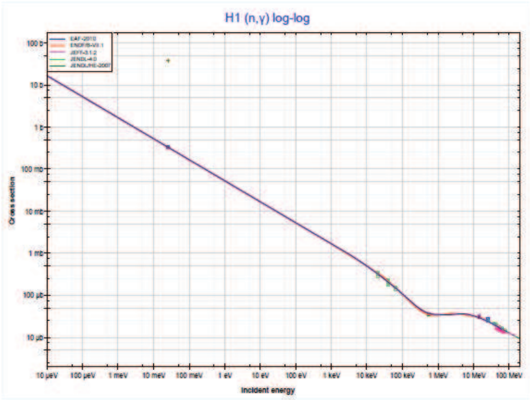
Figure 1: cross section of tritium production

I believe above estimation is super exaggerated, and the real tritium productivity may be just a very small fraction, because the published cross section curve of neutron absorption by deuterium is very low, as illustrated in figure 1.

In contrast, the probability of absorption by proton is far bigger by almost 3 orders of magnitude, therefore the major component of heavy water must be harmless and safe deuterium water. Comparing figure 2 & 1 can prove it.

OECD NEA Data Bank

	1-H
<< MT2 (n,el)	MT102 (n,γ) or MT



Library	Sig(2200 m/s)	Sig(25.3 meV)	Avg-Sig(thermal)
EAF-2010	0.332002 b	0.331761 b	0.33177 b
ENDF/B-VII.1	0.332128 b	0.33189 b	0.33199 b
JEFF-3.1.2	0.332094 b	0.331855 b	0.33196 b
JENDL-4.0	0.332128 b	0.332128 b	0.33224 b
JENDL/HE-2007	0.332106 b	0.331868 b	0.33197 b

Figure 2: cross section of deuterium production

Still clueless about the data contrast? look at the principle cross section data of the fuel element uranium U235 isotope, as shown in figure 3.

It implies the possibility of tritium creation is just a tiny millionth of fuel fission.

Now the plant said they have accumulated 1 million tons of waste water, if the imagined one year product of pure tritium-water is mixed, then the dilution ratio is about 1:3,125,000.

Japan government approved the discharge in sea on a long span of 30 years.

How is the risk to our health and ecology? Judge it by yourself with common sense and herein scientific analysis data.

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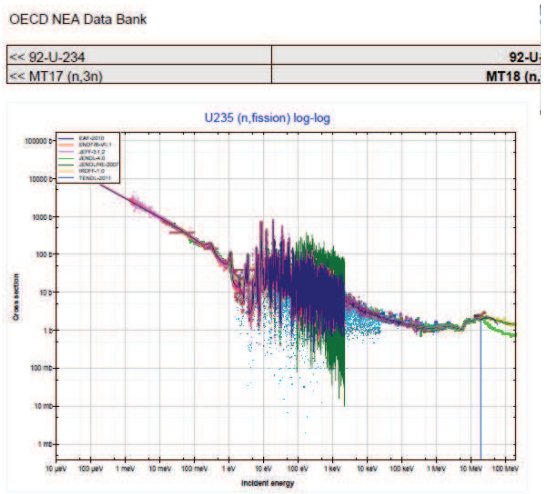

Library	Sig(2200 m/s)	Sig(25.3 meV)	Avg-Sig(thermal)
EAF-2010	583.199 b	582.709 b	568.7 b
ENDF/B-VII.1	584.977 b	584.512 b	570.79 b
JEFF-3.1.2	584.977 b	584.512 b	570.79 b
JENDL-4.0	584.977 b	584.977 b	571.28 b
JENDL/HE-2007	584.977 b	584.512 b	570.79 b
IRDFF-1.0	584.989 b	577.656 b	563.63 b
TENDL-2011	584.977 b	584.512 b	570.79 b

Figure 3: cross section of U235 fission

Nobody worry about tritium when they enjoy luxury watch with luminous convenience, even many consumers never know its lighting material made of radioactive tritium.

Figure 4: illuminating watch

Thinking nuclear power is dirty? No, don't be scared or frustrated by some rare nuclear disasters, believe me, it is even cleaner than most other energy sources.

Outlook for future evolution of potential new nuclear fuels

Anyway, roaming neutron is nasty, but why leave me alone and not fund me to explore next generation of clean nuclear fuel?

My research is focusing on the isotope Lutetium 176, and my revolutionary invention can drive it to release most cleanest yet huge beta decay power by catalysis of artificial extreme tiny "neutron star" weighed under 1 gram.

Lutetium 176 is deemed as the only half-baked element in the long time process of star nucleosynthesis, so I believe humankind can continue bake the left 50% for energy.

The abundance of Lu176 amongst all Lutetium isotopes is 2.6%, obviously far larger than 0.72% of U235 amongst uranium, thus purification Lu176 by centrifuges is far cheaper than U235 extraction.

Following figure presents the energy level of isomer Lu176:

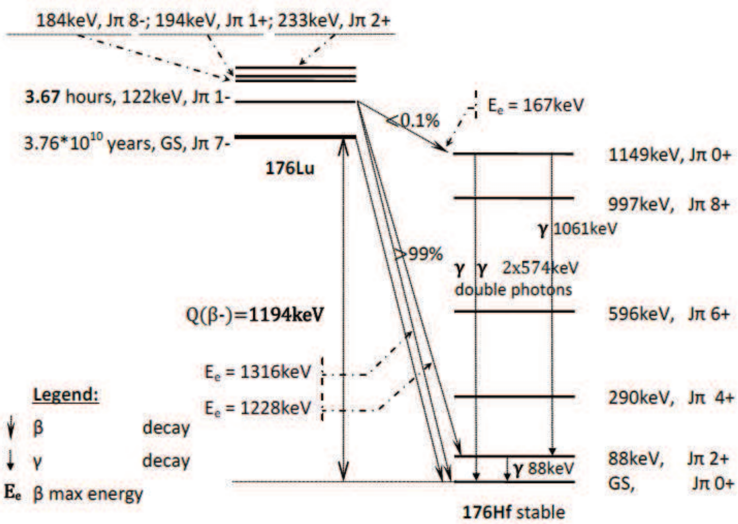

Figure 5: Lu176 energy levels & decay paths

As this new fuel is a by-topic in situ, so more details have to not be disclosed. If still interested, readers can contact me by yan@kiwaho.com.