

## Why the structural materials of a reactor become dangerously radioactive

*After irradiated fuel (“high-level radioactive waste”) is removed from a nuclear reactor, the empty structures themselves remain radioactive for thousands of years. Here’s why.*

*During normal operation subatomic projectiles called neutrons are flying in all directions inside the reactor core, originating from the atoms that are being split. Stray neutrons bombard any nearby materials, including metal, concrete, water and air, making them dangerously radioactive by a process called “neutron activation”.*

*When a non-radioactive atom (the “target”) absorbs a stray neutron, it is destabilized and is transformed into a radioactive atom (the “activation product”). This happens outside the fuel, in the core area. Here is a partial list of long-lived activation products.*

### Long-Lived Activation Products with Half-Lives Greater Than 5 Years

Radioactive Activation Product	Half-life (years)	Non-radioactive Target
Hydrogen-3 (aka tritium)	12.3	Lithium-6 Hydrogen-2 (aka deuterium)
Beryllium-10	1 million 600 thousand	Beryllium-9 Boron-10
Carbon-14	5 thousand 730	Nitrogen-14
Aluminum-26	720 thousand	Aluminum-27
Chlorine-36	301 thousand	Chlorine-35 Potassium-39
Argon-39	269	Potassium-39
Calcium-41	103 thousand	Calcium-40
Manganese-53	3 million 700 thousand	Iron-54
Nickel-59	80 thousand	Nickel-58 Copper-58
Cobalt-60	5.3	Cobalt-59
Nickel-63	100	Nickel-62 Copper-62
Selenium-79	377 thousand	Selenium-78 or -80 Bromine-79
Krypton-81	210 thousand	Strontium-84 Rubidium-81-
Krypton-85	10.7	Rubidium-85
Zirconium-93	1 million 530 thousand	Zirconium-92
Niobium-92m	27 million	Niobium-93
Niobium-93m	12	Niobium-93
Molybdenum-93	3 thousand 500	Molybdenum-92
Niobium-94	20 thousand	Niobium-93 Molybdenum-94
Technetium-97	2 million 600 thousand	Rubidium-96
Technetium-98	4 million 200 thousand	Rubidium-98

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Activation Product	Half-life (years)	Target
Technetium-99	213 thousand	Molybdenum-98
Palladium-107	6 million 500 thousand	Palladium-106
Silver-108m	130	Silver-107
Cadmium-113m	14.6	Cadmium-113
Tin-121m	50	Tin-120 Antimony-121
Iodine-129	15 million 700 thousand	Tellurium-128
Barium-133	10.4	Barium-132
Cesium-135	2 million 300 thousand	Barium-135
Cesium-137	30.1	Barium-137
Lanthanium-137	50 thousand	Cerium-136
Praesodymium-145	18	Samarium-144
Samarium-146	100 million	Samarium-147
Europium-150m	36	Europium-151
Gadolinium-150	1 million 800 thousand	Europium-151
Samarium-151	93	Samarium-150
Europium-152	13	Europium-151
Europium-154	8.6	Europium-153
Terbium-158	150	Terbium-159
Holmium-163	33	Erbium-164
Holmium-166m	1 thousand 200	Holmium-165
Hafnium-178m	30	Hafnium-177
Iridium-192m	241	Iridium--191
Platinum-193	50	Platinum-192 or -194
Lead-205	14 nillion	Lead-204 or -206
Bismuth-208	368 thousand	Bismuth-209
Bismuth-210m	24 thousand 390	Bismuth-209

*Source: Long-Lived Activation Products in Reactor Materials, 1984, NRC FIN 82296*

Of these 47 activation products created inside the core area of a nuclear reactor,

10 have a half -life of over a MILLION YEARS

18 have a half-life of over a HUNDRED THOUSAND YEARS

26 have a half-life of over a THOUSAND YEARS

31 have a half-life of over a HUNDRED YEARS

The radioactive waste materials in a defunct nuclear reactor shell  
**EXCLUDING IRRADIATED NUCLEAR FUEL**  
 will remain dangerous for many hundreds of thousands of years.

[www.cnr.org/activation\\_products.pdf](http://www.cnr.org/activation_products.pdf)