INNOVATING BEYOND ZERO

AN INTRODUCTION TO:

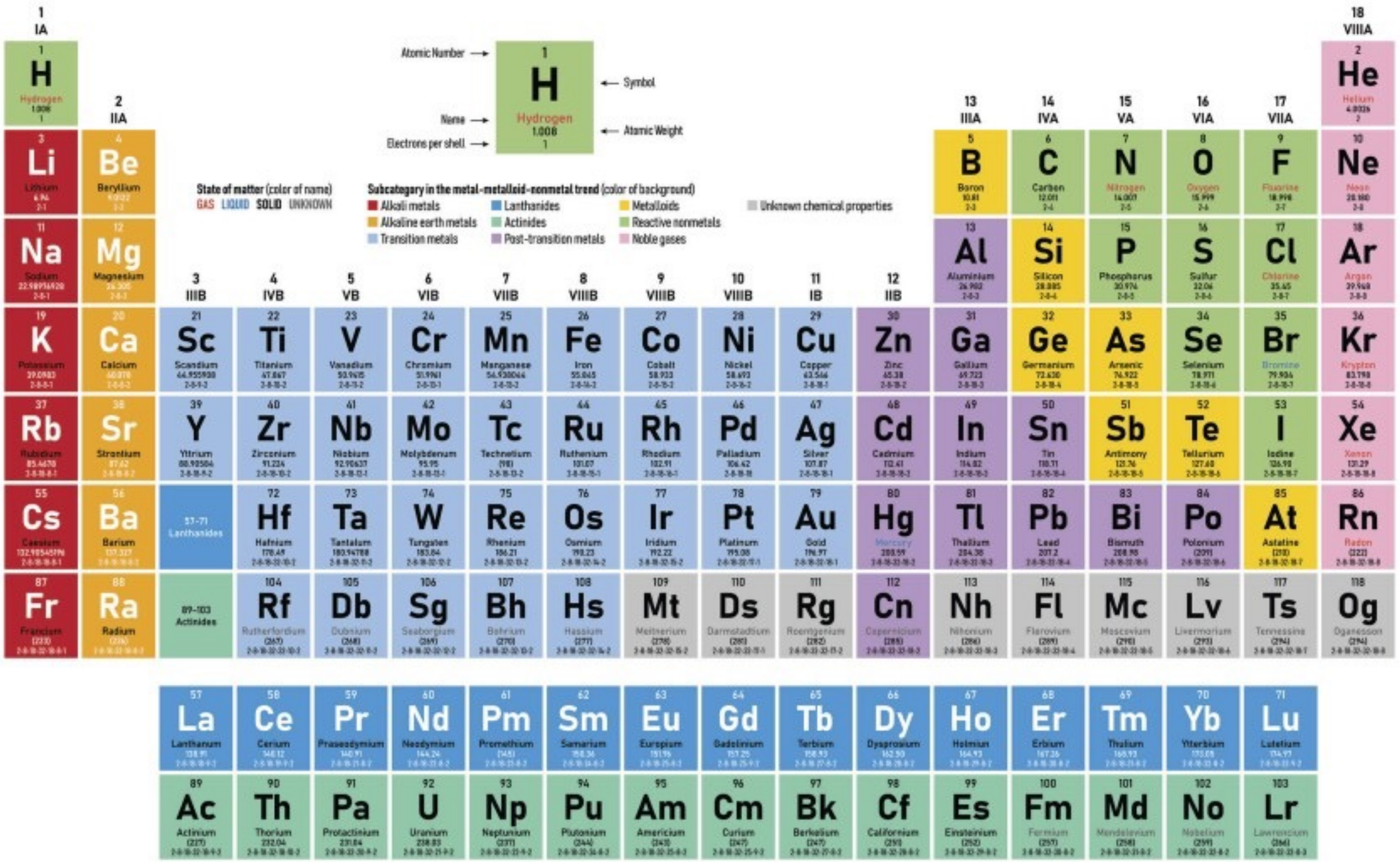
RADIOACTIVITY

RADIATION

EFFECTS OF RADIATION ON THE HUMAN BODY

LEGAL LIMITS FOR RADIATION EXPOSURE

Periodic Table of the Elements



WHICH ELEMENTS ARE RADIOACTIVE?

- Virtually all elements have unstable (radioactive) isotopes.
- 38 elements have no stable isotopes (Atomic Number 43, 61, & >83).

RADIOACTIVE ISOTOPES DECAY (CHANGE THEIR ATOMIC NUMBER AND MIGHT CHANGE MASS) BY ONE OF FOUR PROCESSES.

- Alpha Decay
- Beta Decay
- Positron Emission
- Electron Capture

- Radioactive decay may or may not be accompanied by a Gamma ray.

ALPHA DECAY

- Helium atom ejected.
- Atomic Number decreases by 2.
- Mass decreases by 4.

BETA DECAY

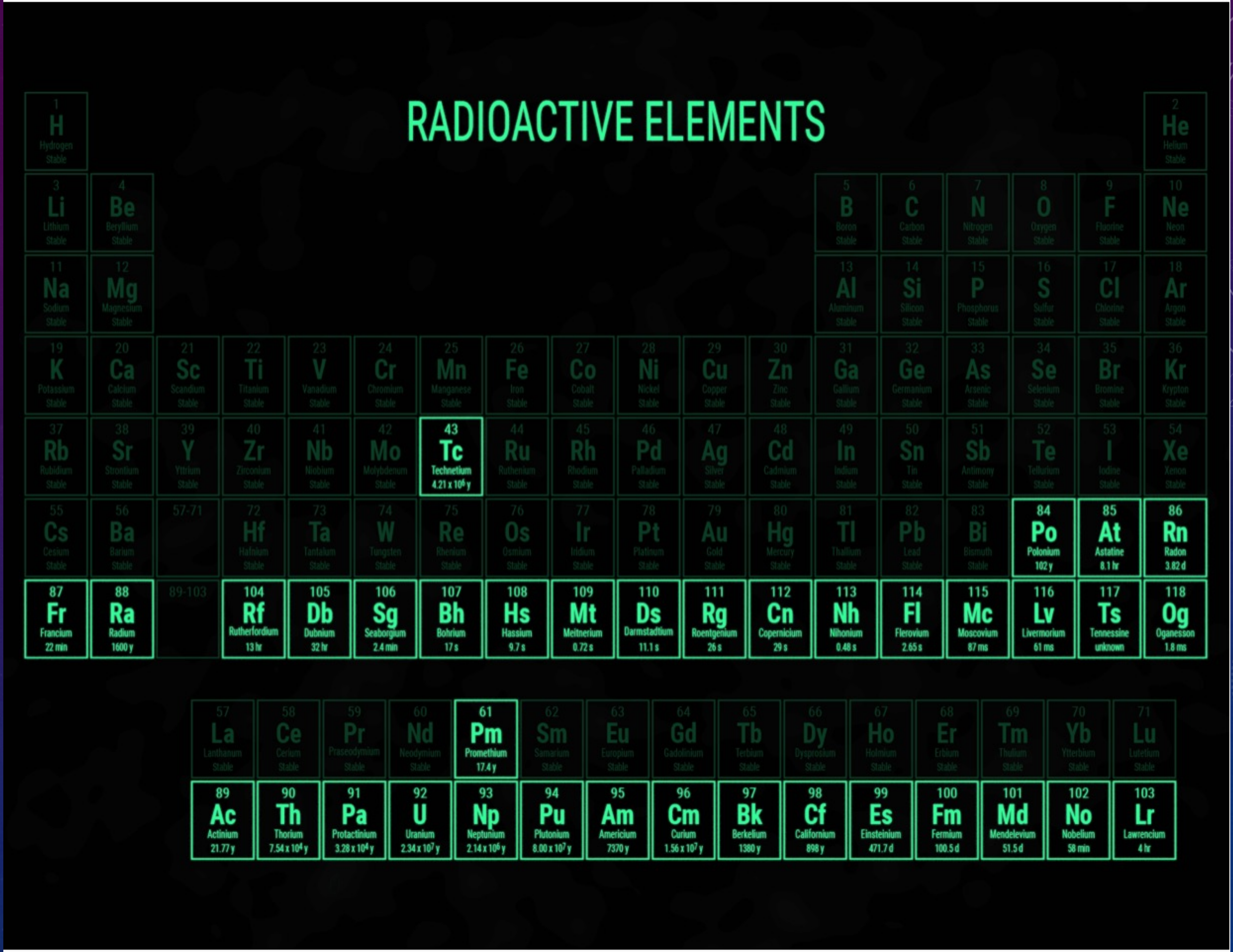
- An electron is ejected from a neutron.
- The neutron becomes a proton.
- Atomic number increases by 1.
- Mass remains the same.

POSITRON EMISSION

- A positron is ejected from a proton.
- The proton becomes a neutron.
- Atomic number decreases by 1.
- Mass remains the same.

ELECTRON CAPTURE

- An orbital electron is captured by a proton.
- The proton becomes a neutron.
- Atomic number decreases by 1.
- Mass remains the same.


RADIOACTIVE ELEMENTS
1 H Hydrogen Stable
2 He Helium Stable
3 Li Lithium Stable
4 Be Beryllium Stable
5 B Boron Stable
6 C Carbon Stable
7 N Nitrogen Stable
8 O Oxygen Stable
9 F Fluorine Stable
10 Ne Neon Stable
11 Na Sodium Stable
12 Mg Magnesium Stable
13 Al Aluminum Stable
14 Si Silicon Stable
15 P Phosphorus Stable
16 S Sulfur Stable
17 Cl Chlorine Stable
18 Ar Argon Stable
19 K Potassium Stable
20 Ca Calcium Stable
21 Sc Scandium Stable
22 Ti Titanium Stable
23 V Vanadium Stable
24 Cr Chromium Stable
25 Mn Manganese Stable
26 Fe Iron Stable
27 Co Cobalt Stable
28 Ni Nickel Stable
29 Cu Copper Stable
30 Zn Zinc Stable
31 Ga Gallium Stable
32 Ge Germanium Stable
33 As Arsenic Stable
34 Se Selenium Stable
35 Br Bromine Stable
36 Kr Krypton Stable
37 Rb Rubidium Stable
38 Sr Strontium Stable
39 Y Yttrium Stable
40 Zr Zirconium Stable
41 Nb Niobium Stable
42 Mo Molybdenum Stable
43 Tc Technetium 4.21 x 10^6 y
44 Ru Ruthenium Stable
45 Rh Rhodium Stable
46 Pd Palladium Stable
47 Ag Silver Stable
48 Cd Cadmium Stable
49 In Indium Stable
50 Sn Tin Stable
51 Sb Antimony Stable
52 Te Tellurium Stable
53 I Iodine Stable
54 Xe Xenon Stable
55 Cs Cesium Stable
56 Ba Barium Stable
57-71
72 Hf Hafnium Stable
73 Ta Tantalum Stable
74 W Tungsten Stable
75 Re Rhenium Stable
76 Os Osmium Stable
77 Ir Iridium Stable
78 Pt Platinum Stable
79 Au Gold Stable
80 Hg Mercury Stable
81 Tl Thallium Stable
82 Pb Lead Stable
83 Bi Bismuth Stable
84 Po Polonium 102 y
85 At Astatine 8.1 hr
86 Rn Radon 3.82 d
87 Fr Francium 22 min
88 Ra Radium 1600 y
89-103
104 Rf Rutherfordium 13 hr
105 Db Dubnium 32 hr
106 Sg Seaborgium 2.4 min
107 Bh Bohrium 17 s
108 Hs Hassium 9.7 s
109 Mt Meitnerium 0.72 s
110 Ds Darmstadtium 11.1 s
111 Rg Roentgenium 26 s
112 Cn Copernicium 29 s
113 Nh Nihonium 0.48 s
114 Fl Flerovium 2.65 s
115 Mc Moscovium 87 ms
116 Lv Livermorium 61 ms
117 Ts Tennessine unknown
118 Og Oganesson 1.8 ms
57 La Lanthanum Stable
58 Ce Cerium Stable
59 Pr Praseodymium Stable
60 Nd Neodymium Stable
61 Pm Promethium 17.4 y
62 Sm Samarium Stable
63 Eu Europium Stable
64 Gd Gadolinium Stable
65 Tb Terbium Stable
66 Dy Dysprosium Stable
67 Ho Holmium Stable
68 Er Erbium Stable
69 Tm Thulium Stable
70 Yb Ytterbium Stable
71 Lu Lutetium Stable
89 Ac Actinium 21.77 y
90 Th Thorium 7.54 x 10^4 y
91 Pa Protactinium 3.28 x 10^4 y
92 U Uranium 2.34 x 10^7 y
93 Np Neptunium 2.14 x 10^6 y
94 Pu Plutonium 8.00 x 10^7 y
95 Am Americium 7370 y
96 Cm Curium 1.56 x 10^7 y
97 Bk Berkelium 1380 y
98 Cf Californium 898 y
99 Es Einsteinium 471.7 d
100 Fm Fermium 100.5 d
101 Md Mendelevium 51.5 d
102 No Nobelium 58 min
103 Lr Lawrencium 4 hr

HOW LONG DO RADIOACTIVE ISOTOPES LAST?

- Some last billions of years.
- Some only last a fraction of a second.
- The half-life of an isotope is the time it takes for half the mass of a sample to decay to other isotopes.

EXAMPLE HALF-LIVES

- Nitrogen-16: 7.13 seconds.
- Cesium-133: 2 years.
- Cobalt-60: 5.3 years.
- Plutonium-239: 24,100 thousand years.
- Technium-99: 211,000 years.
- Uranium-235: 700 million years.
- Uranium-238: 4.5 billion years

TYPES OF RADIATION FROM NUCLEAR POWER PLANTS

1. Neutron – average of 2.4 high energy neutrons per fission of U-235, with 2 “fission fragments” one about 3/5 mass of U-235 the other about 2/5 (ie CS-133 and Tc-99).
2. Gamma – from fission and decay of fission products & activated structural materials.
3. Beta – from decay of fission products & activated structural materials.
4. Alpha – from decay of fission products.

PARTICLE RADIATION EFFECTS ON THE BODY

- High energy ionized particles (Alpha or Beta)passing through a cell strip electrons from atoms in the cell creating free radicals.
- Free radicals are very reactive chemically.
- Subsequent chemical reactions damage cells in various ways.

GAMMA RADIATION EFFECTS ON THE BODY

- Gamma rays are not physical particles.
- Gamma rays interact with atoms along their path releasing high energy electrons.
- These electrons behave like Alpha and Beta particles.

NEUTRONRADIATION EFFECTS ON THE BODY

- Neutrons collide with the nucleus of atoms causing them to recoil and loose their electrons (they become ionized).
- These ionized particles behave like Alpha and Beta particles.

RADIATION MEASUREMENT UNITS

- RAD – Radiation Absorbed Dose, a measurement of how much energy absorbed by a gram of material.
- There is a difference between how much biological damage is done by 1 RAD depending on the type of radiation. This is accounted for by a “Quality Factor” (QF).

ROENTGEN EQUIVALENT IN MAN

- REM –Roentgen Equivalent in Man. 1REM = 1RAD x QF.
- Quality Factors:
  - Gamma and Beta = 1.
  - Alpha = 20.
  - Neutron = 10.

LEGAL LIMITS FOR RADIATION OCCUPATIONAL RADIATION WORKER EXPOSURE

• Whole body:	5 REM per year
• Any organ:	50 REM per year
• Skin:	50 REM per year
• Extremity:	50 REM per year
• Lens of eye:	15 REM per year

LEGAL LIMITS FOR OCCUPATIONAL RADIATION EXPOSURE TO THE PUBLIC

- Whole body: 0.1 REM per year

Background Annual Average Radiation Doses to the U.S. Population

Radiation Source		Average Annual Whole Body Dose (mrem/year)
Natural:	Cosmic	26
	Terrestrial	29
	Radon	200
	Internal (K-40, C-14, etc.)	40
Manmade:	Diagnostic X-Ray	39
	Nuclear Medicine	14
	Consumer Products	11
	All Others (fallout, nuclear power plants, air travel, occupational, etc.)	2
	Average Annual Total	**361 mrem/year**

Tobacco (If You Smoke, Add ~ 280 mrem)

The tobacco in cigarettes contains lead-210. Lead-210 is a naturally occurring radionuclide that precipitates out of the atmosphere and deposits on the leaves of tobacco. When the tobacco is inhaled, the smoker receives a dose from the inhaled lead-210 as well as polonium-210, the decay product of lead-210. Lead-210 is deposited on the surfaces of bones and polonium-210 is deposited in the liver, kidney and spleen.

Table 11.9.2: The Effects of a Single Radiation Dose on a 70 kg Human

Dose (rem)	Symptoms/Effects
< 5	no observable effect
5–20	possible chromosomal damage
20–100	temporary reduction in white blood cell count
50–100	temporary sterility in men (up to a year)
100–200	mild radiation sickness, vomiting, diarrhea, fatigue; immune system suppressed; bone growth in children retarded
> 300	permanent sterility in women
> 500	fatal to 50% within 30 days; destruction of bone marrow and intestine
> 3000	fatal within hours

Radiation doses of 600 rem and higher are invariably fatal, while a dose of 500 rem kills half the exposed subjects within 30 days. Smaller doses (≤ 50 rem) appear to cause only limited health effects, even though they correspond to tens of years of natural radiation. This does not, however, mean that such doses have no ill effects; they may cause long-term health problems, such as cancer or genetic changes that affect offspring. The possible detrimental effects of the much smaller doses attributable to artificial sources (< 100 mrem/yr) are more difficult to assess.