LIVING IN A RADIOACTIVE WORLD

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Public Education Seminar Outline

- Session I

- Introduction to basic Terminology!
- What is radioactivity?
- How do we detect and measure it?
- Natural Background: What is it and where do we find natural radioactive materials?
- Introduction of Exposure, Dose & Dosimetery.

GLOSSARY OF RADIOLOGICAL TERMS

- **Absolute risk:** the proportion of a population expected to get a disease over a specified time period.
- **Absorbed dose:** the amount of energy deposited by ionizing radiation in a unit mass of tissue. It is expressed in units of joule per kilogram (J/kg), and called "gray" (Gy) or rad (radiation absorbed dose).
- **Activity (radioactivity):** the rate of decay of radioactive material expressed as the number of atoms breaking down per second measured in units called becquerels or curies.
- **Acute exposure:** an exposure to radiation that has occurred instantaneous or in a matter of seconds or minutes rather than in longer, continuing exposure over a period of time, e.g., hours, days, weeks or longer.
- **Acute Radiation Syndrome (ARS):** a serious illness caused by receiving a dose greater than 50 rads of penetrating radiation to the body in a short time (usually minutes). The earliest symptoms are nausea, fatigue, vomiting, and diarrhea. Hair loss, bleeding, swelling of the mouth and throat, and general loss of energy may follow. If the exposure has been approximately 1,000 rads or more, death may occur within 2 – 4 weeks.
- **Alpha particle:** the nucleus of a helium atom, made up of two neutrons and two protons with a charge of +2. Certain radioactive nuclei emit alpha particles. Alpha particles generally carry more energy than gamma or beta particles, and deposit that energy very quickly while passing through tissue. Alpha particles can be stopped by a thin layer of light material, such as a sheet of paper, and cannot penetrate
- the outer, dead layer of skin. Therefore, they do not damage living tissue when outside the body. When alpha-emitting atoms are inhaled or swallowed, however, they are especially damaging because they transfer relatively large amounts of ionizing energy to living cells.
- **Americium (Am):** a silvery metal; it is a man-made element whose isotopes Am-237 through Am-246 are all radioactive. Am-241 is formed spontaneously by the beta decay of plutonium-241. Trace quantities of americium are widely used in smoke detectors, and as neutron sources in neutron moisture gauges.
- **Atom:** the smallest particle of an element that can enter into a chemical reaction.
- **Atomic number:** the total number of protons in the nucleus of an atom.

- **Background radiation:** ionizing radiation from natural sources, such as terrestrial radiation due to radionuclides in the soil or cosmic radiation originating in outer space.
- **Becquerel (Bq):** the amount of a radioactive material that will undergo one decay (disintegration) per second.
- **Beta particles:** electrons ejected from the nucleus of a decaying atom. Although they can be stopped by a thin sheet of aluminum, beta particles can penetrate the dead skin layer, potentially causing burns. They can pose a serious direct or external radiation threat and can be lethal depending on the amount received.
- They also pose a serious internal radiation threat if beta-emitting atoms are ingested or inhaled.
- **Chain reaction:** a process that initiates its own repetition. In a fission chain reaction, a fissile nucleus absorbs a neutron and fissions (splits) spontaneously, releasing additional neutrons. These, in turn, can be absorbed by other fissile nuclei, releasing still more neutrons. A fission chain reaction is self-sustaining
- when the number of neutrons released in a given time equals or exceeds the number of neutrons lost by absorption in non-fissile material or by escape from the system.
- **Chronic exposure:** exposure to a substance over a long period of time, possibly resulting in adverse health effects.
- **Contamination (radioactive):** the deposition of unwanted radioactive material on the surfaces of structures, areas, objects, or people where it may be external or internal.
- **Cosmic radiation:** radiation produced in outer space when heavy particles from other galaxies (nuclei of all known natural elements) bombard the earth.
- **Criticality:** a fission process where the neutron production rate equals the neutron loss rate to absorption or leakage. A nuclear reactor is "critical" when it is operating.
- **Critical mass:** the minimum amount of fissile material that can achieve a self-sustaining nuclear chain reaction.
- **Curie (Ci):** the traditional measure of radioactivity based on the observed decay rate of 1 gram of radium. One curie of radioactive material will have 37 billion disintegrations in 1 second.
- **Decay, radioactive:** disintegration of the nucleus of an unstable atom by the release of radiation.

- **Dirty bomb:** a device designed to spread radioactive material by conventional explosives when the bomb explodes. A dirty bomb kills or injures people through the initial blast of the conventional explosive and spreads radioactive contamination over possibly a large area—hence the term “dirty.” Such bombs could be miniature devices or large truck bombs. A dirty bomb is much simpler to make than a true nuclear weapon.
- **Dose (radiation):** radiation absorbed by person’s body. Several different terms describe radiation dose.
- **Dose rate:** the radiation dose delivered per unit of time.
- **Dosimeter:** a small portable instrument (such as a film badge, thermoluminescent dosimeter [TLD], or pocket dosimeter) for measuring and recording the total accumulated dose of ionizing radiation a person receives.
- **Dosimetry:** assessment (by measurement or calculation) of radiation dose.
- **Effective half-life:** the time required for the amount of a radionuclide deposited in a living organism to be diminished by 50% as a result of the combined action of radioactive decay and biologic elimination.
- **Electron:** an elementary particle with a negative electrical charge and a mass 1/1837 that of the proton. Electrons surround the nucleus of an atom because of the attraction between their negative charge and the positive charge of the nucleus. A stable atom will have as many electrons as it has protons. The number of electrons that orbit an atom determine its chemical properties. *See also* neutron.
- **Electron volt (eV):** a unit of energy equivalent to the amount of energy gained by an electron when it passes from a point of low potential to a point one volt higher in potential.
- **Element:** 1) all isotopes of an atom that contain the same number of protons. For example, the element uranium has 92 protons, and the different isotopes of this element may contain 134 to 148 neutrons. 2) In a reactor, a fuel element is a metal rod containing the fissile material.
- **Enriched uranium:** uranium in which the proportion of the isotope uranium-235 has been increased by removing uranium-238 mechanically.
- **Epidemiology:** the study of the distribution and determinants of health-related states or events in specified populations; and the application of this study to the control of health problems.

- **Exposure (radiation):** a measure of ionization in air caused by x-rays or gamma rays only. The unit of exposure most often used is the roentgen.
- **Exposure pathway:** a route by which a radionuclide or other toxic material can enter the body. The main exposure routes are inhalation, ingestion, absorption through the skin, and entry through a cut or wound in the skin.
- **Exposure rate:** a measure of the ionization produced in air by x-rays or gamma rays per unit of time (frequently expressed in roentgens per hour).
- **External exposure:** exposure to radiation outside of the body.
- **Fallout, nuclear:** minute particles of radioactive debris that descend slowly from the atmosphere after a nuclear explosion.
- **Fissile material:** any material in which neutrons can cause a fission reaction. The three primary fissile materials are uranium-233, uranium-235, and plutonium-239.
- **Fission (fissioning):** the splitting of a nucleus into at least two other nuclei that releases a large amount of energy. Two or three neutrons are usually released during this transformation.
- **Fusion:** a reaction in which at least one heavier, more stable nucleus is produced from two lighter, less stable nuclei. Reactions of this type are responsible for the release of energy in stars or in thermonuclear weapons.
- **Gamma rays:** high-energy electromagnetic radiation emitted by certain radionuclides when their nuclei transition from a higher to a lower energy state. These rays have high energy and a short wave length. All gamma rays emitted from a given isotope have the same energy, a characteristic that enables scientists to identify which gamma emitters are present in a sample. Gamma rays penetrate tissue farther than do beta or alpha particles, but leave a lower concentration of ions in their path to potentially cause cell damage. Gamma rays are very similar to x-rays.
- **Geiger counter:** a radiation detection and measuring instrument consisting of a gas-filled tube containing electrodes, between which an electrical voltage but no current flows. When ionizing radiation passes through the tube, a short, intense pulse of current passes from the negative electrode to the positive electrode and is measured or counted. The number of pulses per second measures the intensity of the radiation field. Geiger counters are the most commonly used portable radiation detection instruments.
- **Gray (Gy):** a unit of measurement for absorbed dose. It measures the amount of energy absorbed in a material. The unit Gy can be used for any type of radiation, but it does not describe the biological effects of the different radiations.
- **Half-life:** the time any substance takes to decay by half of its original amount.
- **Health physics:** a scientific field that focuses on protection of humans and the environment from radiation. Health physics uses physics, biology, chemistry, statistics, and electronic instrumentation to help protect individuals from any damaging effects of radiation.

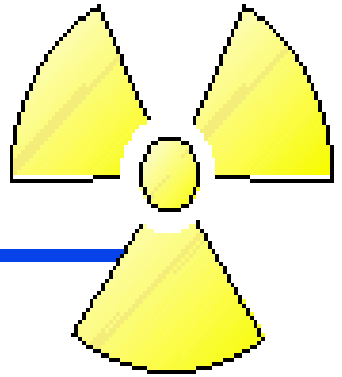
- **High-level radioactive waste:** the radioactive material resulting from spent nuclear fuel reprocessing. This can include liquid waste directly produced in reprocessing or any solid material derived from the liquid wastes having a sufficient concentration of fission products. Other radioactive materials can be designated
- as high-level waste, if they require permanent isolation. This determination is made by the U.S. Nuclear Regulatory Commission on the basis of criteria established in U.S. law.
- **Iodine:** a nonmetallic solid element. There are both radioactive and non-radioactive isotopes of iodine. Radioactive isotopes of iodine are widely used in medical applications.
- **Ion:** an atom that has fewer or more electrons than it has protons causing it to have an electrical charge and, therefore, be chemically reactive.
- **Ionization:** the process of adding one or more electrons to, or removing one or more electrons from, atoms or molecules, thereby creating ions. High temperatures, electrical discharges, or nuclear radiation can cause ionization.
- **Ionizing radiation:** any radiation capable of displacing electrons from atoms, thereby producing ions. High doses of ionizing radiation may produce severe skin or tissue damage.
- **Irradiation:** exposure to radiation.
- **Isotope:** a nuclide of an element having the same number of protons but a different number of neutrons.
- **Kiloton (Kt):** the energy of an explosion that is equivalent to an explosion of 1,000 tons of TNT. One kiloton equals 1 trillion (1012) calories.
- **Low-level waste (LLW):** radioactively contaminated industrial or research waste such as paper, rags, plastic bags, medical waste, and water-treatment residues. It is waste that does not meet the criteria for any of three other categories of radioactive waste: spent nuclear fuel and high-level radioactive waste; transuranic radioactive waste; or uranium mill tailings. Its categorization does not depend on the level of
- radioactivity it contains.
- **Megaton (Mt):** the energy of an explosion that is equivalent to an explosion of 1 million tons of TNT. One megaton is equal to a quintillion (1018) calories.
- **Molecule:** a combination of two or more atoms that are chemically bonded. A molecule is the smallest unit of a compound that can exist by itself and retain all of its chemical properties.
- **Neutron:** a small atomic particle possessing no electrical charge typically found within an atom's nucleus. Neutrons are, as the name implies, neutral in their charge. That is, they have neither a positive nor a negative charge. A neutron has about the same mass as a proton.
- **Non-ionizing radiation:** radiation that has lower energy levels and longer wavelengths than ionizing radiation. It is not strong enough to affect the structure of atoms it contacts but is strong enough to heat tissue and can cause harmful biological effects. Examples include radio waves, microwaves, visible light, and infrared from a heat lamp.

- **Nuclear fuel cycle:** the steps involved in supplying fuel for nuclear power plants. It can include mining, milling, isotopic enrichment, fabrication of fuel elements, use in reactors, chemical reprocessing to recover the fissile material remaining in the spent fuel, reenrichment of the fuel material refabrication into new fuel elements, and waste disposal.
- **Nucleus:** the central part of an atom that contains protons and neutrons. The nucleus is the heaviest part of the atom.
- **Nuclide:** a general term applicable to all atomic forms of an element. Nuclides are characterized by the number of protons and neutrons in the nucleus, as well as by the amount of energy contained within the atom.
- **Penetrating radiation:** radiation that can penetrate the skin and reach internal organs and tissues. Photons (gamma rays and x-rays), neutrons, and protons are penetrating radiations. However, alpha particles and all but extremely high-energy beta particles are not considered penetrating radiation.
- **Photon:** discrete "packet" of pure electromagnetic energy. Photons have no mass and travel at the speed of light. The term "photon" was developed to describe energy when it acts like a particle (causing interactions at the molecular or atomic level), rather than a wave. Gamma rays and x-rays are photons.
- **Pitchblende:** a brown to black mineral that has a distinctive luster. It consists mainly of urananite (UO2), but also contains radium (Ra). It is the main source of uranium (U) ore.
- **Proton:** a small atomic particle, typically found within an atom's nucleus, that possesses a positive electrical charge. Even though protons and neutrons are about 2,000 times heavier than electrons, they are tiny. The number of protons is unique for each chemical element.
- **Quality factor (Q):** the factor by which the absorbed dose (rad or gray) is multiplied to obtain a quantity that expresses, on a common scale for all ionizing radiation, the biological damage (rem) to an exposed person. It is used because some types of radiation, such as alpha particles, are more biologically
- damaging internally than other types.
- **Rad (radiation absorbed dose):** a basic unit of absorbed radiation dose. It is a measure of the amount of energy absorbed by the body. The rad is the traditional unit of absorbed dose. It is being replaced by the unit gray (Gy), which is equivalent to 100 rad. One rad equals the dose delivered to an object of 100 ergs of energy per gram of material.
- **Radiation:** energy moving in the form of particles or waves. Familiar radiations are heat, light, radio waves, and microwaves. Ionizing radiation is a very high-energy form of electromagnetic radiation.
- **Radiation sickness:** *See also* acute radiation syndrome (ARS). **Radiation warning symbol:** a symbol prescribed by the Code of Federal Regulations. It is a magenta or black trefoil on a yellow background. It must be displayed where certain quantities of radioactive materials are present or where certain doses of radiation could be received.
- **Radioactive contamination:** the deposition of unwanted radioactive material on the surfaces of structures, areas, objects, or people. It can be airborne, external, or internal.
- **Radioactive decay:** the spontaneous disintegration of the nucleus of an atom.

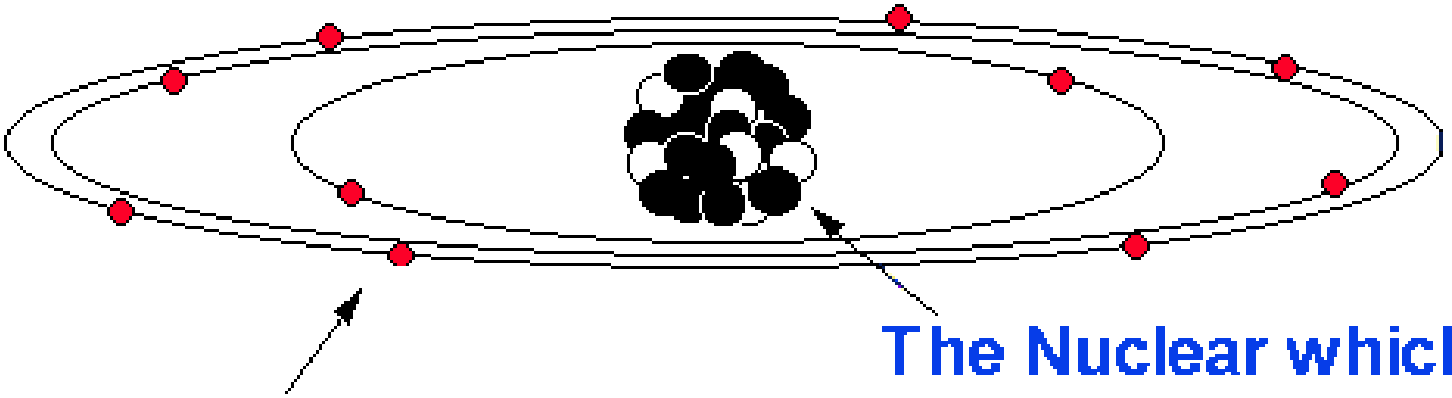
- **Radioactive half-life:** the time required for a quantity of a radioisotope to decay by half. For example, because the half-life of iodine-131 (I-131) is 8 days, a sample of I-131 that has 10 mCi of activity on January 1, will have 5 mCi of activity 8 days later, on January 9.
- **Radioactive material:** material that contains unstable (radioactive) atoms that give off radiation as they decay.
- **Radioactivity:** the process of spontaneous transformation of the nucleus, generally with the emission of alpha or beta particles often accompanied by gamma rays. This process is referred to as decay or disintegration of an atom.
- **Radiography:** 1) *medical:* the use of radiant energy (such as x-rays and gamma rays) to image body systems. 2) *industrial:* the use of radioactive sources to photograph internal structures, such as turbine blades in jet engines. A sealed radiation source, usually iridium-192 (Ir-192) or cobalt-60 (Co-60), beams gamma rays at the object to be checked. Gamma rays passing through flaws in the metal or incomplete welds strike special photographic film (radiographic film) on the opposite side.
- **Radioisotope (radioactive isotope):** isotopes of an element that have an unstable nucleus. Radioactive isotopes are commonly used in science, industry, and medicine. The nucleus eventually reaches a stable number of protons and neutrons through one or more radioactive decays. Approximately 3,700 natural and artificial radioisotopes have been identified.
- **Radiological or radiologic:** related to radioactive materials or radiation. The radiological sciences focus on the measurement and effects of radiation.
- **Radiological dispersal device (RDD):** a device that disperses radioactive material by conventional explosive or other mechanical means, such as a spray. *See also* dirty bomb.
- **Radionuclide:** an unstable and therefore radioactive form of a nuclide.
- **Radium (Ra):** a naturally occurring radioactive metal. Radium is a radionuclide formed by the decay of uranium (U) and thorium (Th) in the environment. It occurs at low levels in virtually all rock, soil, water, plants, and animals. Radon (Rn) is a decay product of radium.
- **Radon (Rn):** a naturally occurring radioactive gas found in soils, rock, and water throughout the United States. Radon causes lung cancer and is a threat to health because it tends to collect in homes, sometimes to very high concentrations. As a result, radon is the largest source of exposure to people from naturally occurring radiation.
Relative risk: the ratio between the risk for disease in an irradiated population to the risk in an unexposed population. A relative risk of 1.1 indicates a 10% increase in cancer from radiation, compared with the "normal" incidence.
- **Rem (roentgen equivalent, man):** a unit of equivalent dose. Not all radiation has the same biological effect, even for the same amount of absorbed dose. Rem relates the absorbed dose in human tissue to the effective biological damage of the radiation. It is determined by multiplying the number of rads by the quality factor, a number reflecting the potential damage caused by the particular type of radiation. The rem is the traditional unit of equivalent dose, but it is being replaced by the sievert (Sv), which is equal to 100 rem.

- **Risk:** the probability of injury, disease, or death under specific circumstances and time periods. Risk can be expressed as a value that ranges from 0% (no injury or harm will occur) to 100% (harm or injury will definitely occur). Risk can be influenced by several factors: personal behavior or lifestyle, environmental exposure to other material, or inborn or inherited characteristic known from scientific evidence to be associated with a health effect. Because many risk factors are not exactly measurable, risk estimates are uncertain.
- **Risk assessment:** an evaluation of the risk to human health or the environment by hazards. Risk assessments can look at either existing hazards or potential hazards.
- **Roentgen (R):** a unit of exposure to x-rays or gamma rays. One roentgen is the amount of gamma or xrays needed to produce ions carrying 1 electrostatic unit of electrical charge in 1 cubic centimeter of dry air under standard conditions.
- **Sievert (Sv):** a unit used to derive a quantity called dose equivalent. This relates the absorbed dose in human tissue to the effective biological damage of the radiation. Not all radiation has the same biological effect, even for the same amount of absorbed dose. Dose equivalent is often expressed as millionths of a
- sievert, or micro-sieverts (μSv). One sievert is equivalent to 100.
- **Terrestrial radiation:** radiation emitted by naturally occurring radioactive materials, such as uranium (U), thorium (Th), and radon (Rn) in the earth.
- **Thorium (Th):** a naturally occurring radioactive metal found in small amounts in soil, rocks, water, plants, and animals. The most common isotopes of thorium are thorium-232 (Th-232), thorium-230 (Th-230), and thorium-238 (Th-238).
- **Transuranic:** pertaining to elements with atomic numbers higher than uranium (92). For example, plutonium (Pu) and americium (Am) are transuranics.
- **Tritium:** (chemical symbol H-3) a radioactive isotope of the element hydrogen (chemical symbol H). **Uranium (U):** a naturally occurring radioactive element whose principal isotopes are uranium-238 (U-238) and uranium-235 (U-235). Natural uranium is a hard, silvery-white, shiny metallic ore that contains a minute amount of uranium-234 (U-234).
- **Uranium mill tailings:** naturally radioactive residue from the processing of uranium ore. Although the milling process recovers about 95% of the uranium, the residues, or tailings, contain several isotopes of naturally occurring radioactive material, including uranium (U), thorium (Th), radium (Ra), polonium (Po), and radon (Rn).
- **X-ray:** electromagnetic radiation caused by deflection of electrons from their original paths, or inner orbital electrons that change their orbital levels around the atomic nucleus. X-rays, like gamma rays can travel long distances through air and most other materials. Like gamma rays, x-rays require more shielding to reduce their intensity than do beta or alpha particles. X-rays and gamma rays differ primarily
- in their origin: x-rays originate in the electronic shell; gamma rays originate in the nucleus.

The Atom



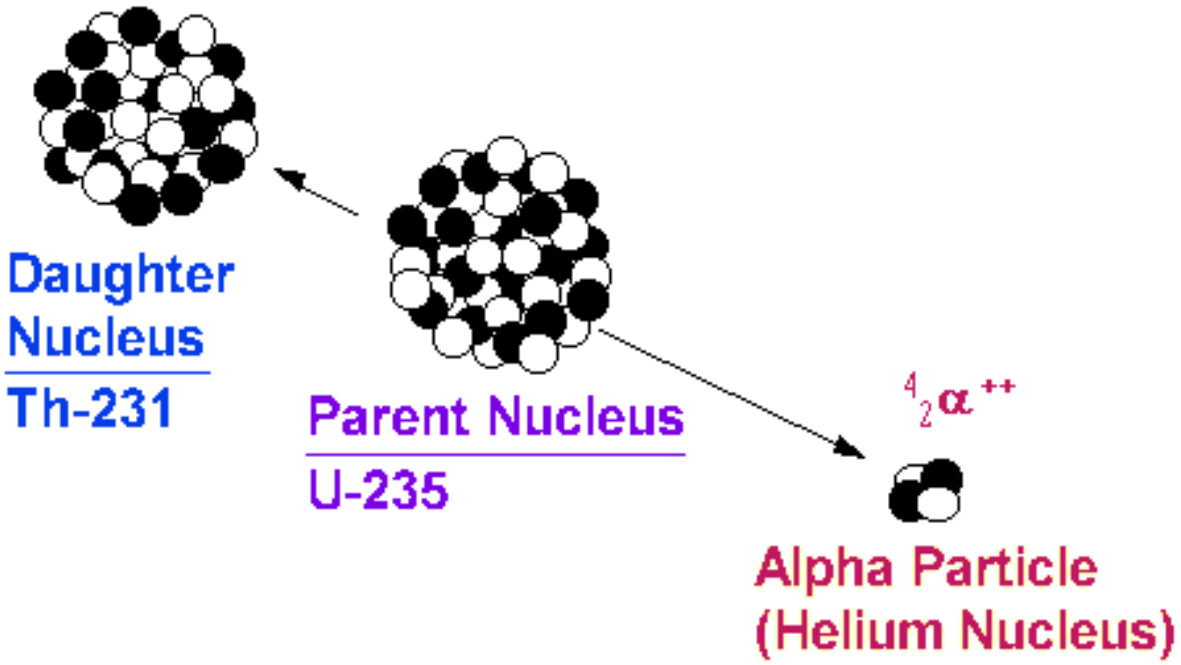
Example - Neon-20



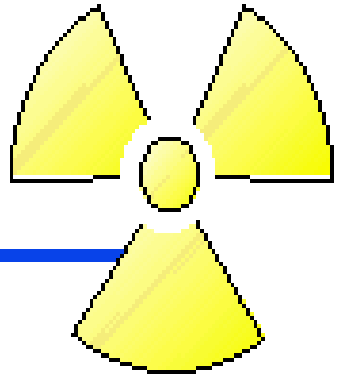
Electrons

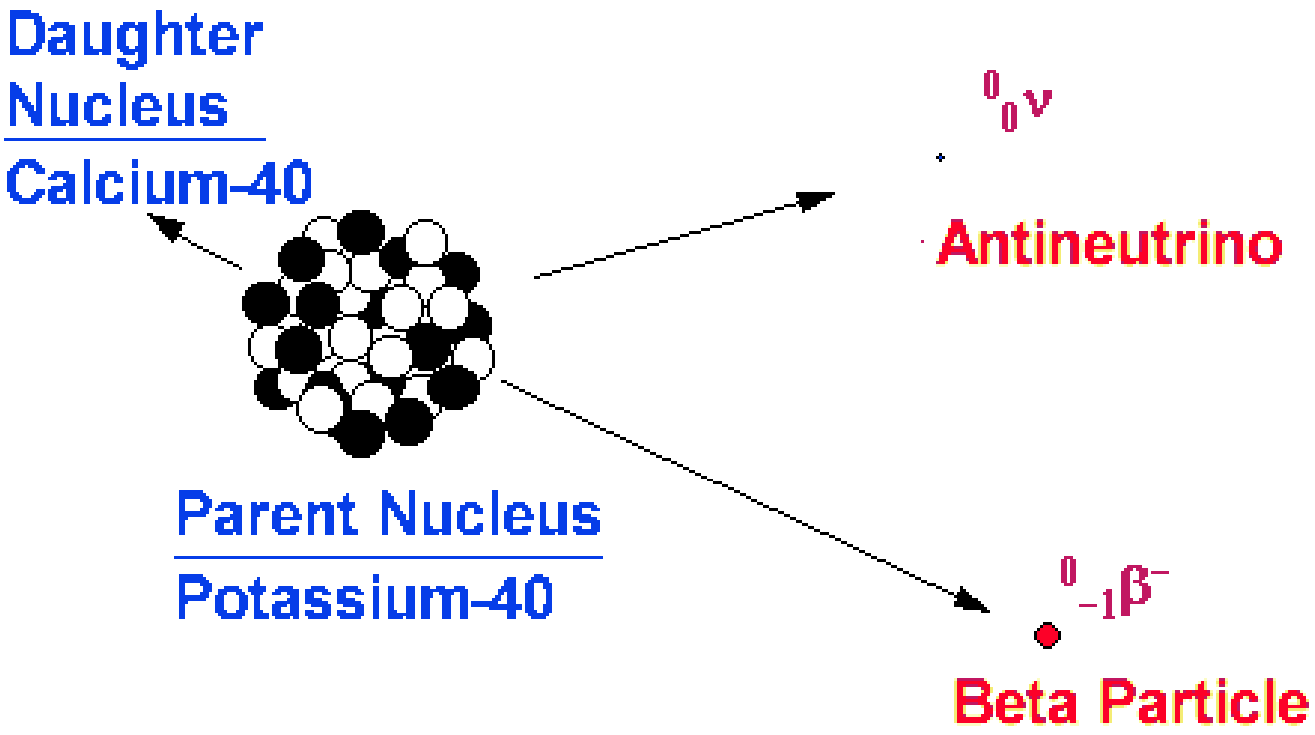
The Nuclear which contains neutrons and protons

Alpha Particle Radiation

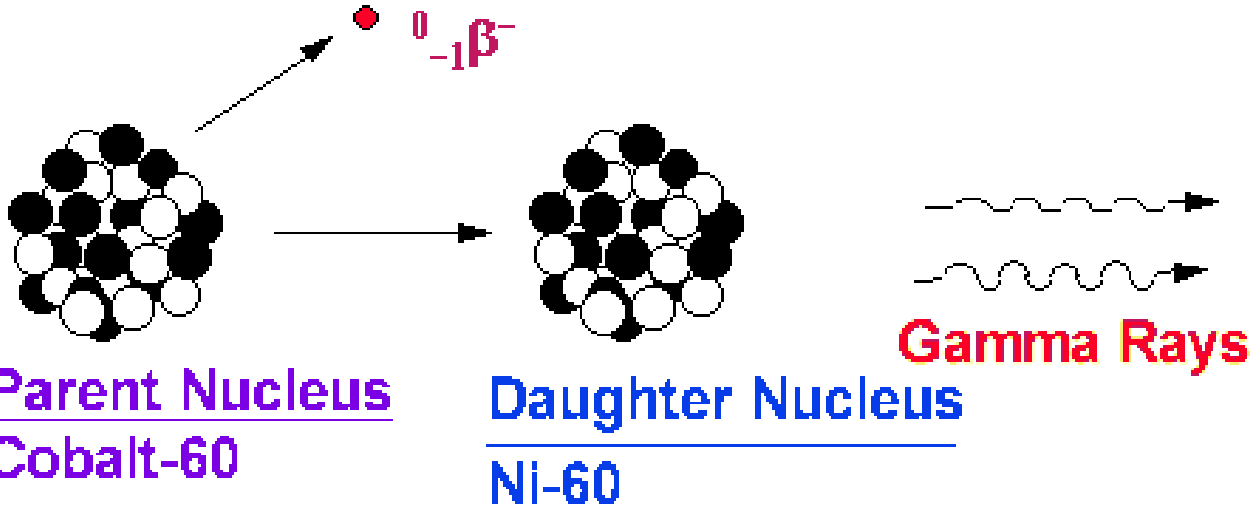


Beta Particle Radiation

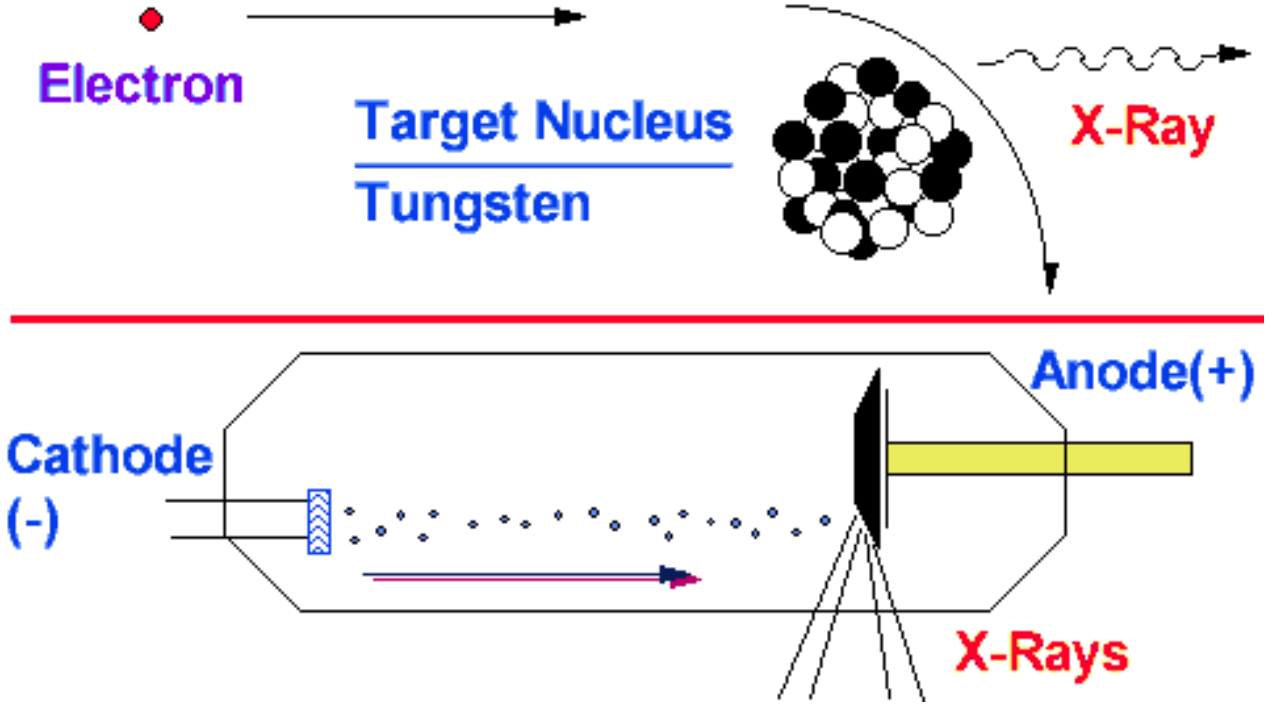




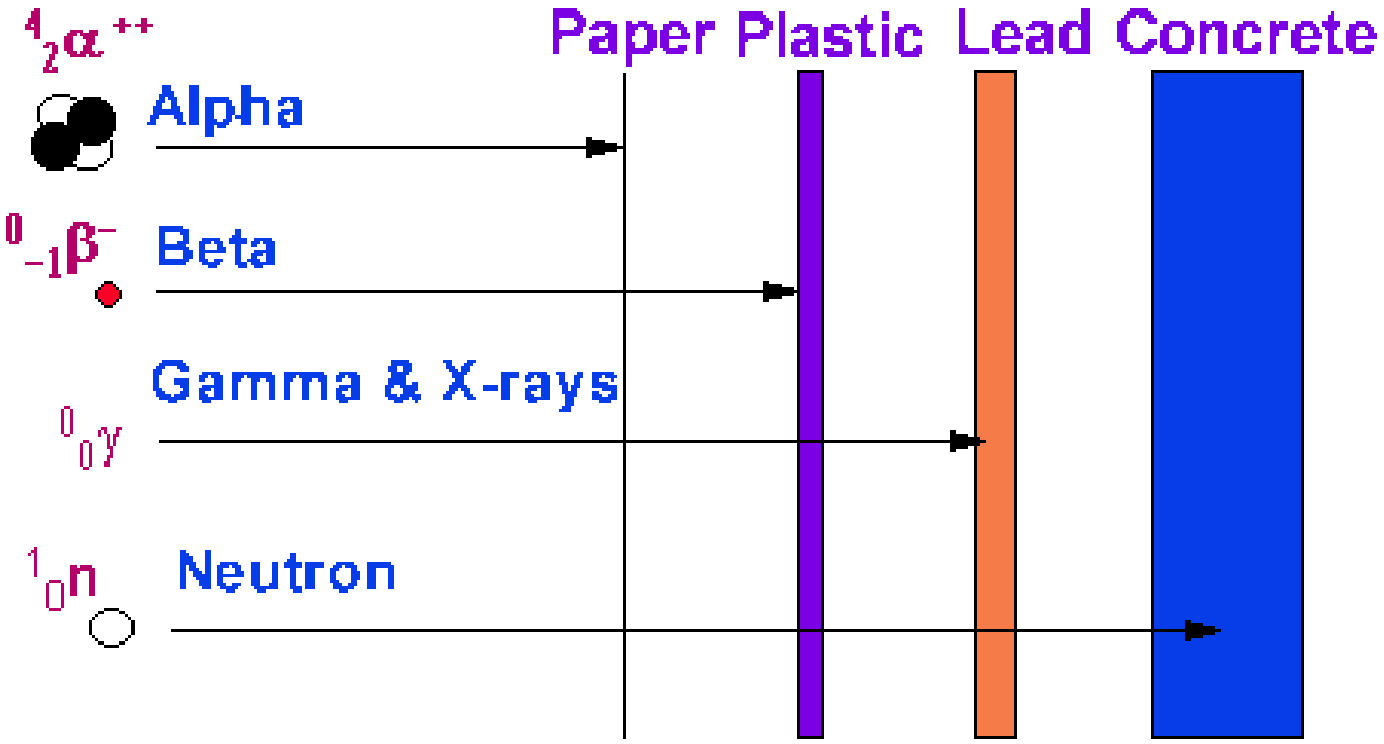
Gamma-Ray Radiation



X-Ray Production (Bremsstrahlung)

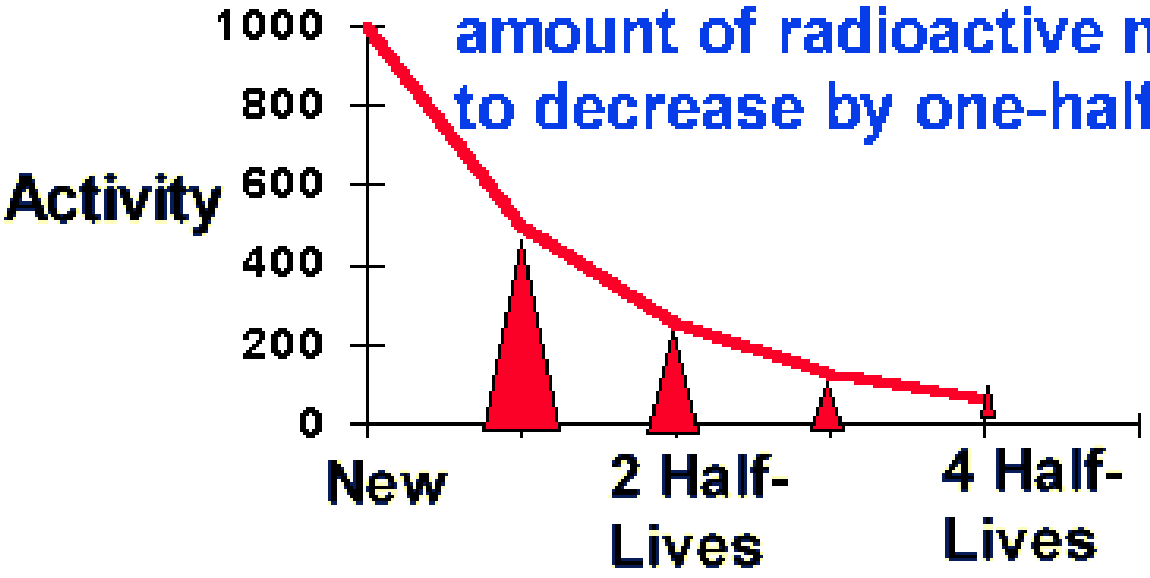


Penetrating Distances

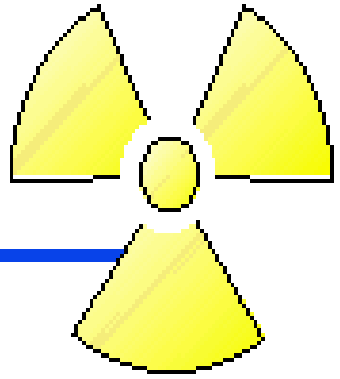


Half-Life

The time required for the amount of radioactive material to decrease by one-half



Measures of Radioactivity



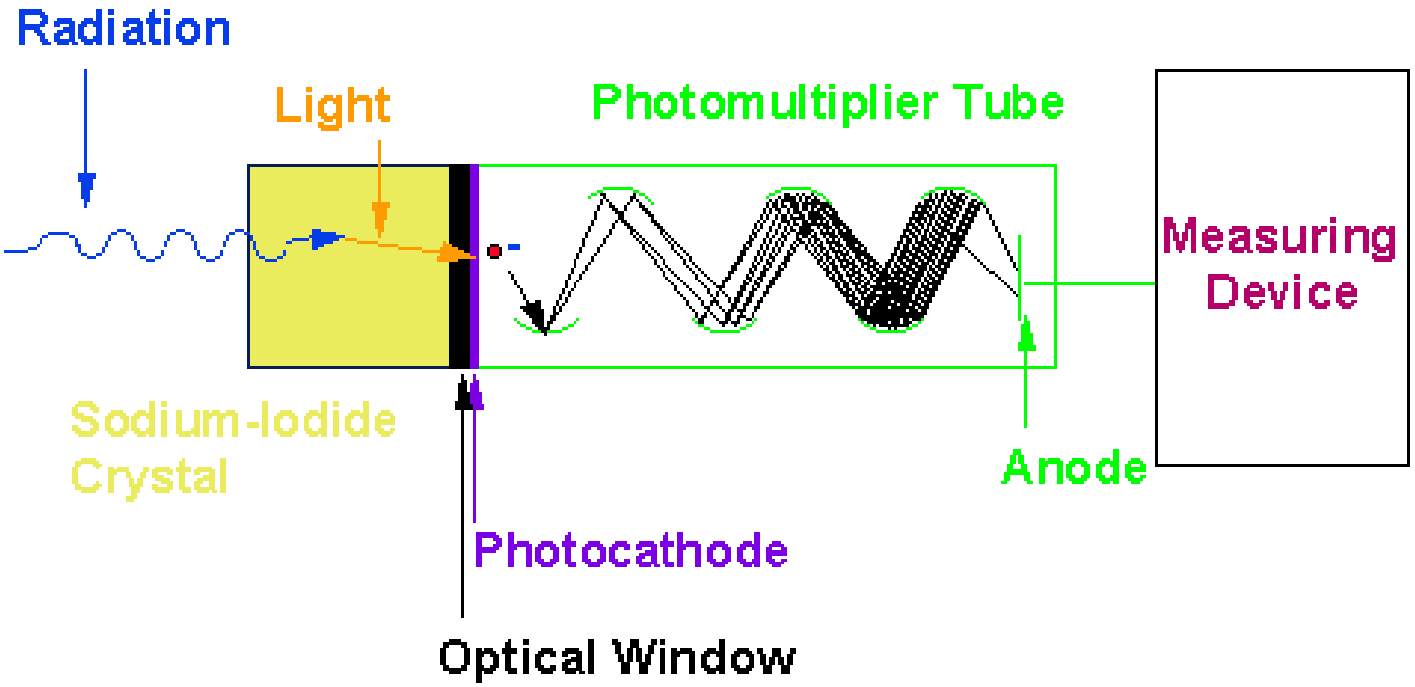
Activity: The quantity of radioactive material at a given time:

- Curie(Ci): 3.7 10^{10} disintegrations per second(dps)

or

- Becquerel (Bq): 1 dps

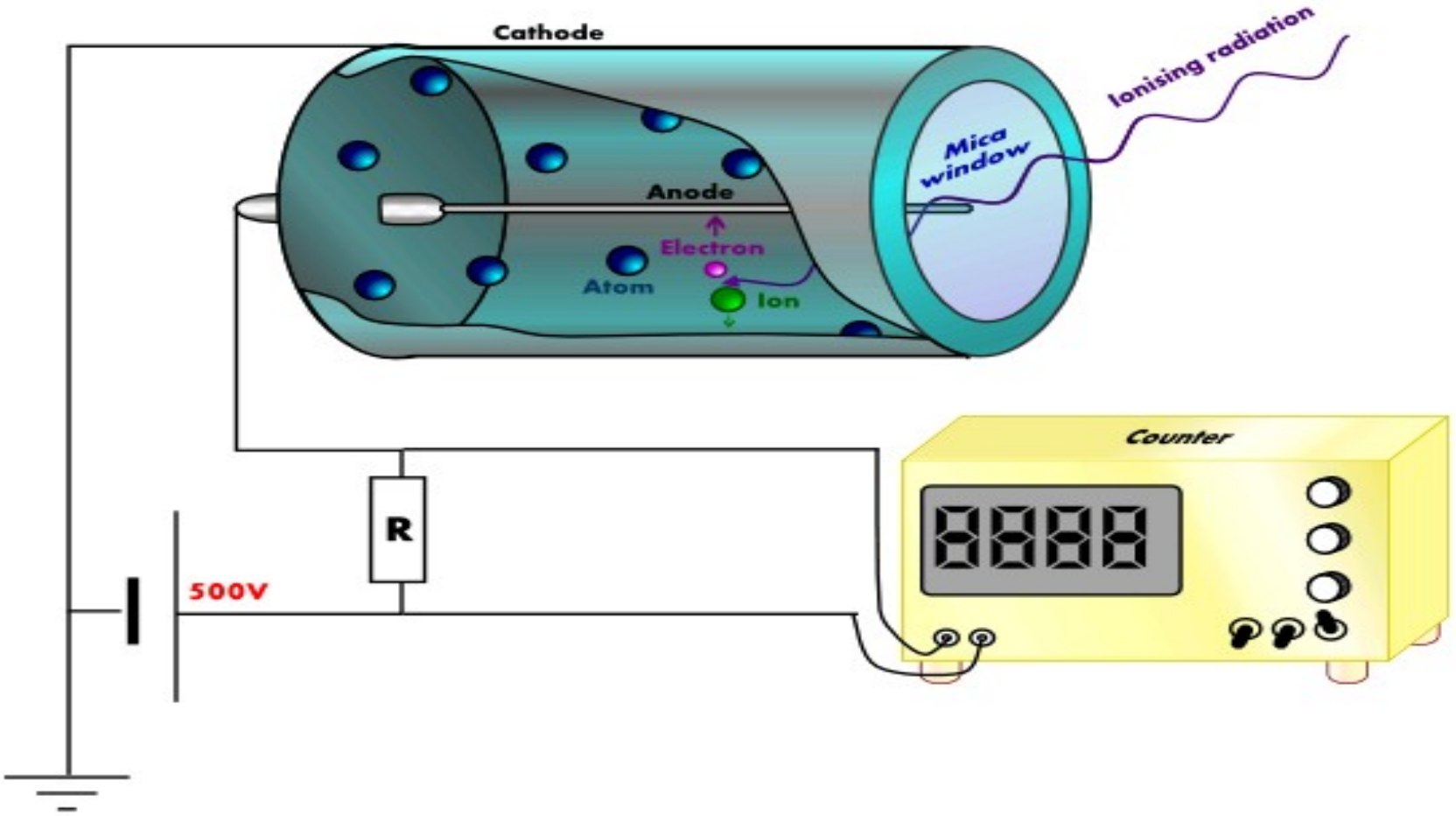
Radiation Detection
Scintillation Detectors



Scintillation Detectors

- A **scintillator** is a device or substance that absorbs high energy (ionizing) electromagnetic then in response, fluoresces photons at a characteristic Stokes-shifted (longer) wavelength (light), releasing the previously absorbed energy. Scintillators are defined by their short fluorescence decay times and optical transparency at wavelengths of their own specific emission energy, characteristics which set them apart from phosphors. The lower the decay time of a scintillator, that is, the shorter the duration of its flashes of fluorescence are, the less so-called "dead time" the detector will have and the more ionizing events per unit of time it will be able to detect.
- A example of a scintillator is a thallium doped sodium iodide crystal used in many ways to measure gamma ray sources. One common use is for radioisotope imaging.
- Scintillators are used in many physics research applications to detect electromagnetic waves or particles. There, a scintillator converts their energy to light of a wavelength which can be detected by inexpensive or easy to handle detectors such as photomultiplier tubes (PMTs).

Geiger-Müller tube



Geiger-Müller tube (or **GM tube**)

- A **Geiger-Müller tube** (or **GM tube**) is the sensing element of a Geiger counter instrument that can detect a single particle of ionizing radiation, and typically produce an audible click for each. It was named for Hans Geiger who invented the device in 1908, and Walther Müller who collaborated with Geiger in developing it further in 1928.
- It consists of a tube filled with an inert gas such as helium, neon or argon and an organic vapor. The tube contains electrodes, between which there is an electrical voltage of several hundred volts, but no current flowing. The walls of the tube are either metal or the inside coated with metal to form the cathode whilst the anode is a wire passing up the centre of the tube.
- When ionizing radiation passes through the tube, it ionizes some of the gas molecules, creating positively charged ions, and electrons. The strong electric field created by the tube's electrodes accelerate the ions towards the cathode and the electrons towards the anode. The ion pairs gain sufficient energy to ionise further gas molecules through collisions on the way, creating an avalanche of charged particles.
- This results is a short, intense pulse of current which passes (or *cascades*) from the negative electrode to the positive electrode and is measured or counted. To prevent the current from flowing continuously there are several techniques to stop, or *quench* the discharge. Quenching is important because a single particle entering the tube is counted by a single discharge, and so it will be unable to detect another particle until the discharge has been stopped, and because the tube is damaged by prolonged discharges.

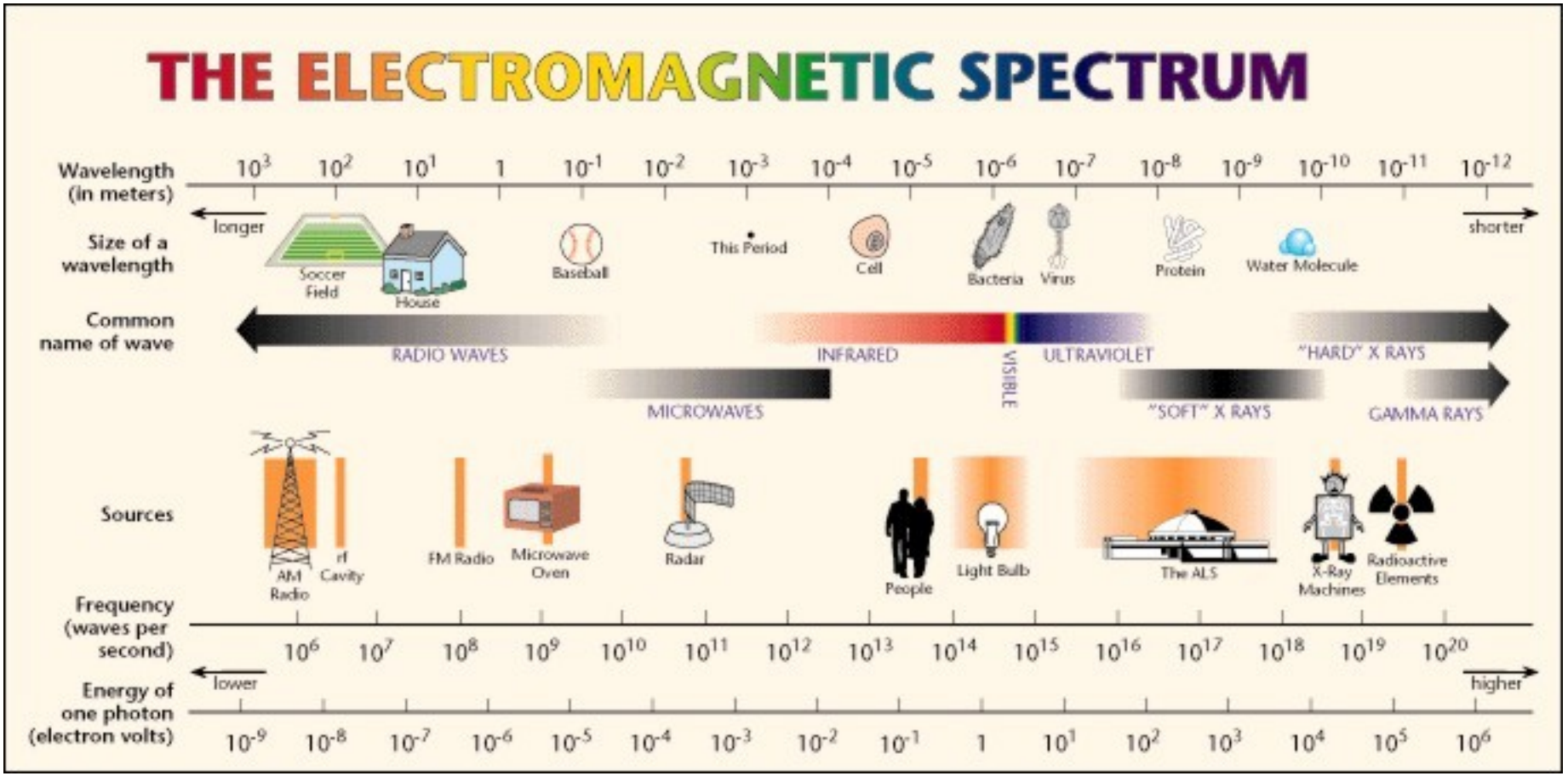
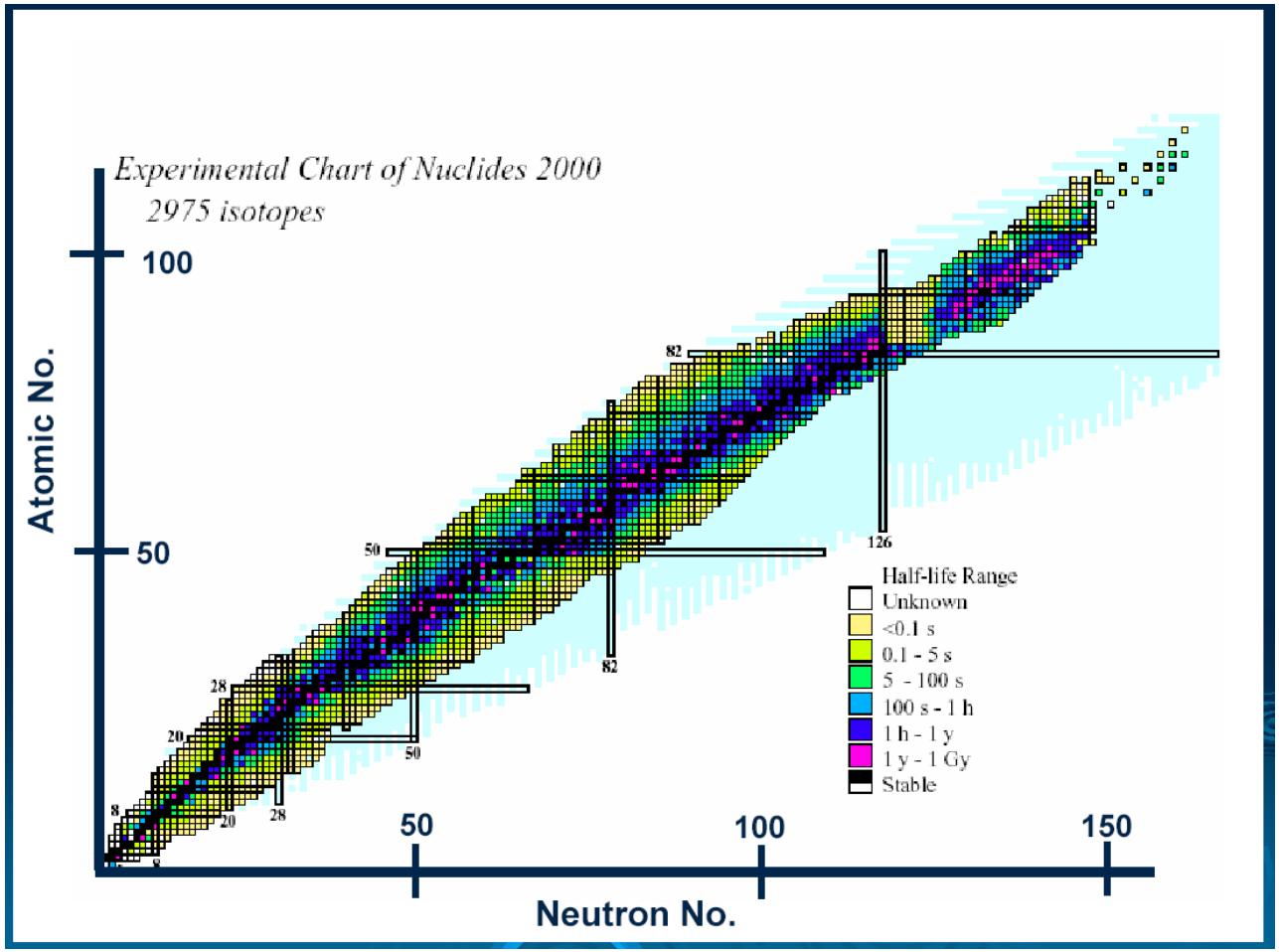
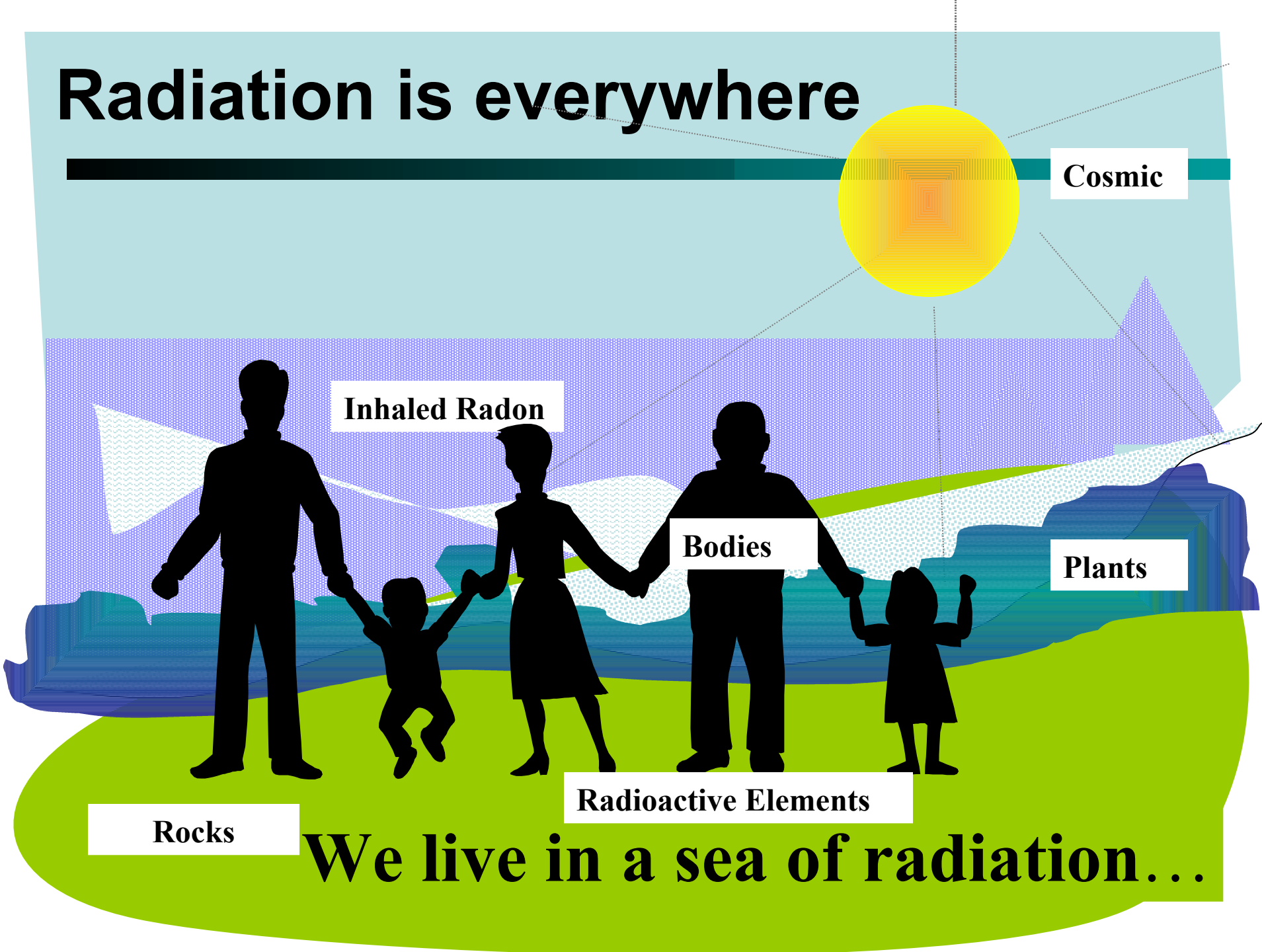

THE ELECTROMAGNETIC SPECTRUM
Wavelength (in meters)
10^{3} 10^{2} 10^{1} 1 10^{-1} 10^{-2} 10^{-3} 10^{-4} 10^{-5} 10^{-6} 10^{-7} 10^{-8} 10^{-9} 10^{-10} 10^{-11} 10^{-12}
longer
shorter
Size of a wavelength
Soccer Field
House
Baseball
This Period
Cell
Bacteria
Virus
Protein
Water Molecule
Common name of wave
RADIO WAVES
INFRARED
VISIBLE
ULTRAVIOLET
"HARD" X RAYS
MICROWAVES
"SOFT" X RAYS
GAMMA RAYS
Sources
AM Radio
rf Cavity
FM Radio
Microwave Oven
Radar
People
Light Bulb
The ALS
X-Ray Machines
Radioactive Elements
Frequency (waves per second)
10^{6} 10^{7} 10^{8} 10^{9} 10^{10} 10^{11} 10^{12} 10^{13} 10^{14} 10^{15} 10^{16} 10^{17} 10^{18} 10^{19} 10^{20}
lower
higher
Energy of one photon (electron volts)
10^{-9} 10^{-8} 10^{-7} 10^{-6} 10^{-5} 10^{-4} 10^{-3} 10^{-2} 10^{-1} 1 10^{1} 10^{2} 10^{3} 10^{4} 10^{5} 10^{6}

Chart of the Nuclides



Background Radiation

Radiation is everywhere



We live in a sea of radiation…

Normal annual exposure from natural radiation

About 240 mrem/yr

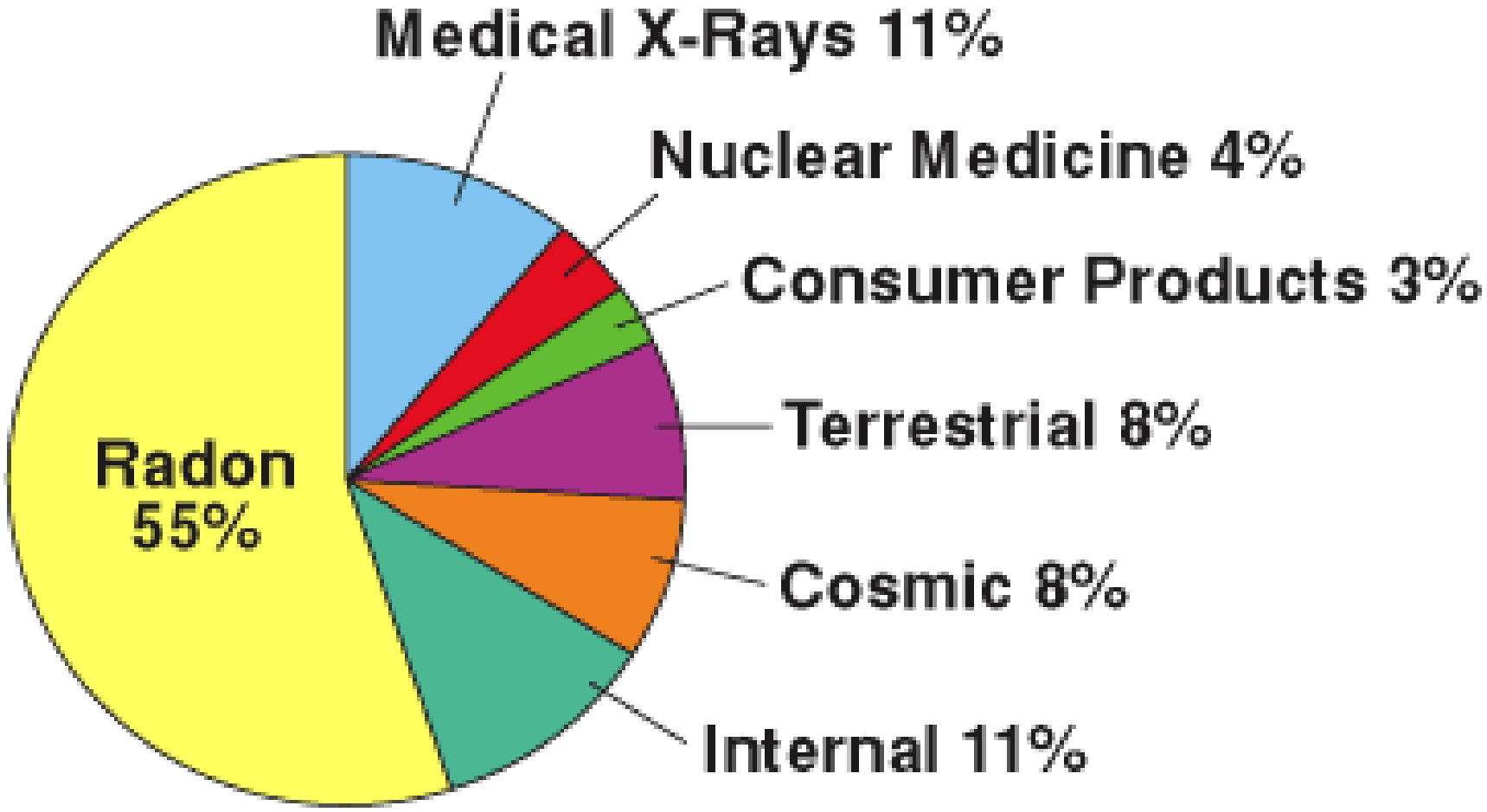
Radon gas	140 mrem
Human body	40 mrem
Rocks, soil	30 mrem
Cosmic rays	30 mrem

Normal annual exposure from man-made radiation

About 165 mrem/yr

Medical procedures	150 mre
Consumer products	10 mre
One coast to coast airplane flight	2 mrems
Watching color TV	1 mrem
Sleeping with another person	1 mrem
Weapons test fallout	less that 1 mrem
Nuclear industry	less than 1 mrem

The Background Pie



Natural Radioactivity in soil

- How much natural radioactivity is found in a volume of soil that is 1 square mile, by 1 foot deep? The following table is calculated for this volume (total volume is 7.894×10^5 m^3) and the listed activities. It should be noted that activity levels vary greatly depending on soil type, mineral make-up and density (~1.58 g/cm^3 used in this calculation). This table represents calculations using typical numbers.

Natural Radioactivity in soil

Natural Radioactivity in Soil (One Sq. Mile, 1 Foot Deep)

Nuclide	Activity used in calculation	Mass of Nuclide	Activity found in the volume of soil
• Uranium	0.7 pCi/g (25 Bq/kg)	2,200 kg	0.8 curies (31 GBq)
• Thorium	1.1 pCi/g (40 Bq/kg)	12,000 kg	1.4 curies (52 GBq)
• Potassium 40	11 pCi/g (400 Bq/kg)	2000 kg	13 curies (500 GBq)
• Radium	1.3 pCi/g (48 Bq/kg)	1.7 g	1.7 curies (63 GBq)
• Radon	0.17 pCi/g (10 kBq/m3) soil	11 µg	0.2 curies (7.4 GBq)
•	Total:		>17 curies (>653 GBq)

Natural Radioactivity in Building Materials

Material	Uranium (pCi/g)	Thorium (pCi/g)	Potassium (pCi/g)
Granite	1.7	0,22	32
Sandstone	0.2	0.19	11.2
Cement	1.2	0.57	6.4
Limestone concrete	0.8	0.23	2.4
Sandstone concrete	0.3	0.23	2.4
Dry wallboard	0.4	0.32	2.4
By-product gypsum	5	1.78	0.2
Natural Gypsum	0.4	0.2	4
Wood	0	0	90
Clay Brick	3	1.2	18

Natural Radioactivity in the Ocean

- How much natural radioactivity is found in the world's oceans?
- All water on the Earth, including seawater, has some radionuclides in it. In the following table, the oceans' volumes were calculated from the *1990 World Almanac*:
- Pacific = 6.549×10^{17} m^3
- Atlantic = 3.095×10^{17} m^3
- Total = 1.3×10^{18} m^3

Natural Radioactivity in the Ocean

Nuclide	Activity used in Calculation	Activity in Ocean		
		Pacific	Atlantic	All Oceans
Uranium	0.9 pCi/L	6 E +8 Ci	3 E +8 Ci	1.1 E+ 9 Ci
Potassium 40	300 pCi/L	2 E + 11 Ci	9 E + 10 Ci	3.8 E+11 Ci
Tritium	0.016 pCi/L	1 E + 7 Ci	5 E + 6 Ci	2 E +7 Ci
Carbon 14	0.135 pCi/L	8 E + 7 Ci	4 E + 7 Ci	1.8 E + 8 Ci
Rubidium 87	28 pCi/L	1.9 E+10 Ci	9 E+9 Ci	3.6 E+10 Ci

- The activities used in the table above are from 1971 *Radioactivity in the Marine Environment*, National Academy of Sciences:

Natural Radioactivity in Food

Food	40K (pCi/kg)	226Ra (pCi/kg)
Banana	3520	1
Brazil Nuts	5600	1,000-7,000
Carrot	3400	0.6-2
White Potatoes	3400	1-2.5
Beer	390	---
Red Meat	3000	0.5
Lima Bean (raw)	4640	2 to 5
Drinking water	---	0-0.17

- **Ref: Handbook of Radiation Measurement and Protection, Brodsky, A. CRC Press 1978 and Environmental Radioactivity from Natural, Industrial and Military Sources, Eisenbud, M and Gesell T. Academic Press, Inc. 1997.**

Natural Radioactivity in your Body

Nuclide	Total Mass of Nuclide Found in the Body (ug)	Total Activity of Nuclide Found in the Body (pCi)	Daily Intake of Nuclides (ug)
Uranium	90	30	1.9
Thorium	30	3	3
Potassium 40	17000	120000	390
Radium	3.1E-05	30	0.0023
Carbon 14	0.022	100000	0.0018
Tritium	6E-08	600	3E-06
Polonium	2E-07	1000	~6E-10

Areas of High Background Radiation

Background doses in some areas of the world are exceptionally high when compared to other regions. Specifically areas in Iran, India, Brazil and China are high because of geologic formations, deposits and/or geothermal activity. Monazite sands, high in natural thorium and radium are the large contributors to the values seen in the following table taken from UNSCEAR 2000.

Table 11
Areas of high natural radiation background

Country	*Area*	*Characteristics of area*	*Approximate population*	*Absorbed dose rate in air [a] (nGy h^{-1})*	*Ref.*
Brazil	Guarapari	Monazite sands; coastal areas	73 000	90–170 (streets) 90–90 000 (beaches)	[P4, V5]
	Minеas Gerais and Goias			110–1 300	[A17, P4]
	Pocos de Caldas Araxá	Volcanic intrusives	350	340 average 2 800 average	[V5]
China	Yangjiang Quangdong	Monazite particles	80 000	370 average	[W14]
Egypt	Nile delta	Monazite sands		20–400	[E3]
France	Central region	Granitic, schistous, sandstone area	7 000 000	20–400	[J3]
	Southwest	Uranium minerals		10–10 000	[D10]
India	Kerala and Madras	Monazite sands, coastal areas 200 km long, 0.5 km wide	100 000	200–4 000 1 800 average	[S19, S20]
	Ganges delta			260–440	[M13]
Iran (Islamic Rep. of)	Ramsar	Spring waters	2 000	70–17 000	[S21]
	Mahallat			800–4 000	[S58]
Italy	Lazio	Volcanic soil	5 100 000	180 average	[C12]
	Campania		5 600 000	200 average	[C12]
	Orvieto town		21 000	560 average	[C20]
	South Toscana		~100 000	150–200	[B21]
Niue Island	Pacific	Volcanic soil	4 500	1 100 maximum	[M14]
Switzerland	Tessin, Alps, Jura	Gneiss, verucano, ^{220}Ra in karst soils	300 000	100–200	[S51]

a Includes cosmic and terrestrial radiation.

RADIOLOGICAL UNITS

QUANTITY	NAME	SYMBOL	UNITS
Activity	Becquerel	Bq	1 d/s
Activity (old)	Curie	Ci	3.7 E10 d/s
Absorbed Dose	Gray	Gy	J/kg
Absorbed Dose (old)	rad	rad	100 ergs/g
Dose Equivalent	Sievert	Sv	J/kg x QF
Dose Equivalent (old)	rem	rem	100 ergs/g x QF
Exposure	Roentgen	R	2.58 E-4 C/kg

Fractions and Multiples commonly Used with Radiological Units

FACTOR	PREFIX	SYMBOL
10+9	giga	G
10+6	mega	M
10+3	kilo	k
10+2	hecto	h
10+1	deka	da
10-1	deci	d
10-2	centi	c
10-3	milli	m
10-6	micro	μ
10-9	nano	n
10-12	pico	p

EXPOSURE

- **Exposure (radiation):** a measure of ionization in air caused by x-rays or gamma rays only. The unit of exposure most often used is the roentgen.
- **Exposure rate:** a measure of the ionization produced in air by x-rays or gamma rays per unit of time (frequently expressed in roentgens per hour).

The concept of Dose

- **Dose** can refer to several things:
- *n* An amount of medication to be taken at one time.
- *n* An amount of radiation received.

  a. A specified quantity of a therapeutic agent, such as a drug or medicine, prescribed to be taken at one time or at stated intervals.
- **b.** The amount of radiation administered as therapy to a given site.

"THE POISON IS IN THE SIZE OF THE DOSE"

Dosimetry

- Assessment (by measurement or calculation) of radiation dose.