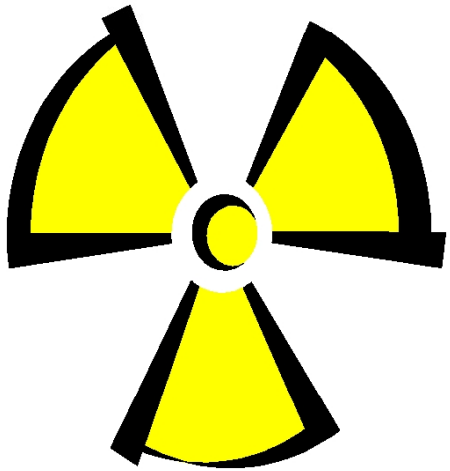
The Hazardous Environment Detection Solutions

Understanding Radiation

November 2010

Topics

- Introduction to Radiation
- Types of Radiation
- Measuring Radiation
- Radiation Safety
- Detecting Radiation
- Why We Need to Measure Radiation Today
- Ref: TN-176



Introduction to Radiation

- Radiation can be non-ionizing or ionizing.
- Non-ionizing radiation is generally a low energy electromagnetic wave
  - Sunlight
  - Radio waves
  - Microwaves
  - Infrared waves
- Mostly harmless

Ionizing Radiation

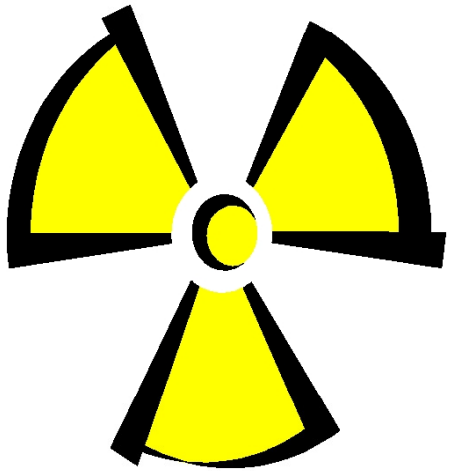
- Ionizing radiation has enough energy to ionize the atoms and molecules it interacts with.
  - Particles: alpha, beta, neutron
  - Waves: gamma
- Because it can ionize, it can cause biological damage

Introduction to Radiation

- Ionizing Radiation is all around us
  - Natural Sources:
    - Cosmic radiation from space
    - Radioactive material in the ground: Uranium, Radon gas
    - Other people!
  - Man-made Sources
    - Isotopes for medical and industrial imaging, oncology, agriculture
    - Coal-fired and nuclear power plants
    - Spent nuclear fuel from reactors
    - Nuclear warheads
  - Most of your annual dose of radiation comes from Radon gas in your house!

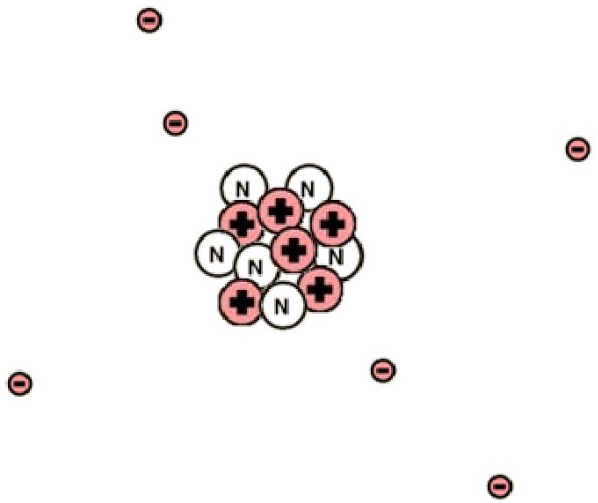
Topics

- Introduction to Radiation
- Types of Radiation
- Measuring Radiation
- Radiation Safety
- Detecting Radiation
- Why We Need to Measure Radiation Today
- Ref: TN-176



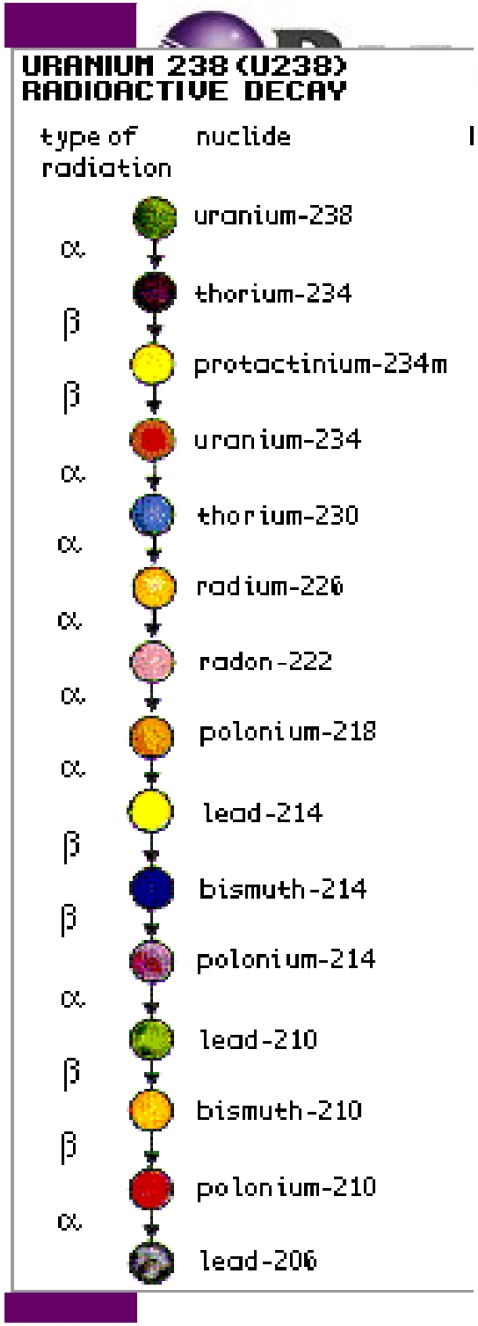
Carbon-12:

- 6 Protons
- 6 Neutrons
- 6 Electrons



Particle		Location	Charge	Relative Mass
⊕	Proton	Nucleus	+1	1
N	Neutron	Nucleus	neutral	1
⊖	Electron	Orbit	-1	1/1837

Unstable Atoms Decay

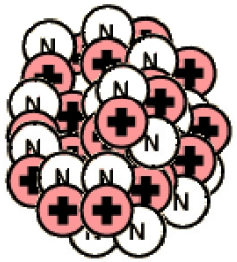


- Certain atoms are radioactive because their nuclei are unstable
  - They have too few or too many neutrons, which creates an imbalance
- To get stable, the atom "decays" and transforms into a new atom by emitting radiation in 4 forms:
  - Alpha particle (α)
  - Beta particle (β)
  - Gamma wave (γ)
  - Neutron particle (n)
- Sometimes the new atom is also unstable, and it decays too, creating a "decay chain"

UCRL-PRES-149818. Understanding Radiation and it's Effects.

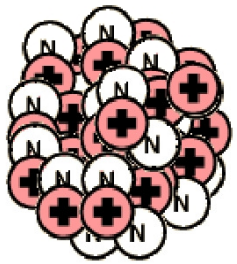
Alpha Decay

- A +2 charged helium nucleus with 2 protons and 2 neutrons
- Relatively heavy particle with a big charge
- Travels 2-5 cm in air
- Stopped by a piece of paper, or the top layer of your skin
- Difficult to detect
- Dangerous if inhaled– will cause localized severe damage to a thin layer of tissue in the lungs and respiratory tract- possible precursor to lung cancer
- Radioactive “beach ball”



Beta Decay

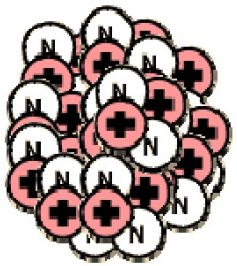
- Negatively (or positively) charged electron
- Relatively light particle, but still charged
- Travels ~10 meters in air
- Stopped by aluminum foil, glass plate or 2.5 cm of virtually anything
- Difficult to detect
- Dangerous if inhaled– will cause localized severe damage to a thin layer of tissue in the lungs and respiratory tract- possible precursor to lung cancer
- Radioactive “golf ball”



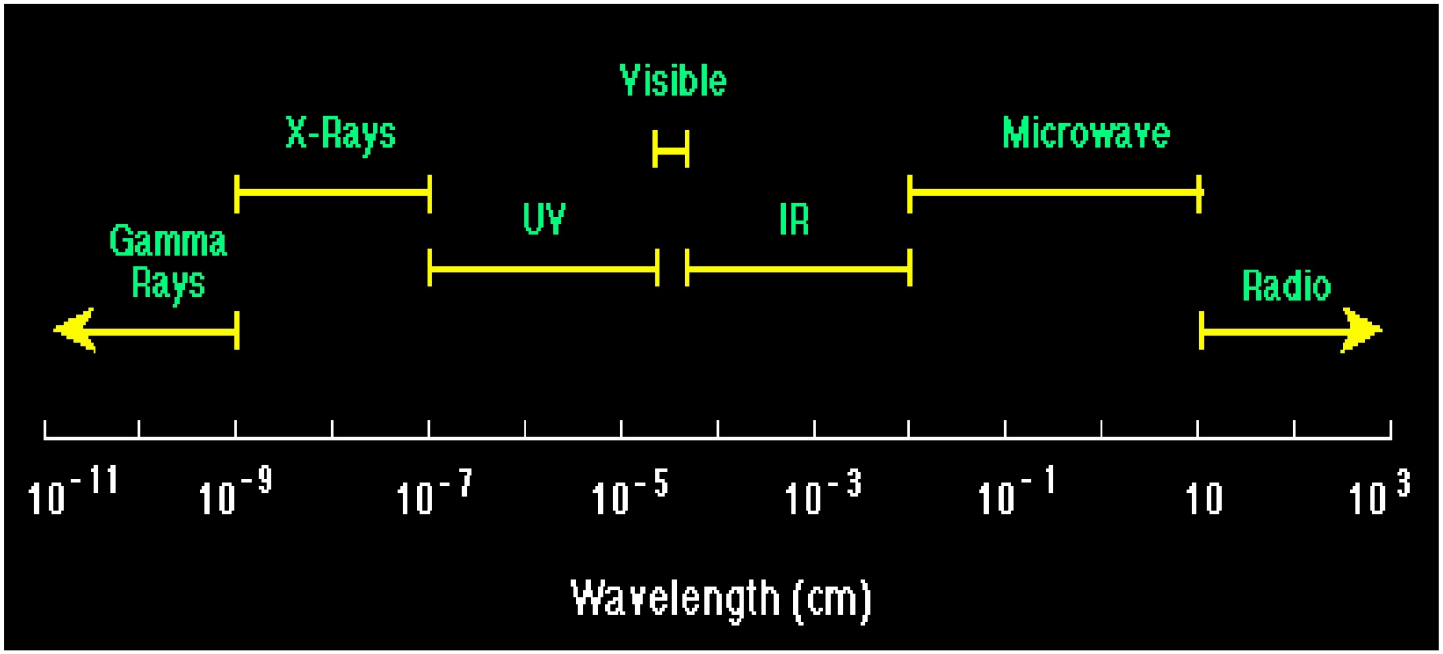
Gamma Decay

- Energetic electromagnetic wave (photon) with no charge
- Travels many kilometers/miles in air
- Stopped by lead or concrete 10+ cm thick
- Relatively easy to detect and direct exposure is likely
- Normal to be exposed to small amounts everyday from ground radiation and cosmic rays
- γ rays vs. x-rays
  - γ rays are emitted from the nucleus of an atom
  - X-rays are emitted from the orbital electrons of an atom
- Radioactive

  "9mm bullet"

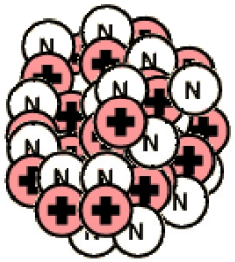


The electromagnetic spectrum



Neutron Decay

- Small, neutral particles (same size as a proton)
- Travels many kilometers in air
- Stopped by 30+ cm of water, polyethylene or paraffin
  - Spent fuel rods are stored in water
- Self-fissioning radioactive materials (Plutonium, Californium) give off neutrons
- Large doses can do significant damage to people

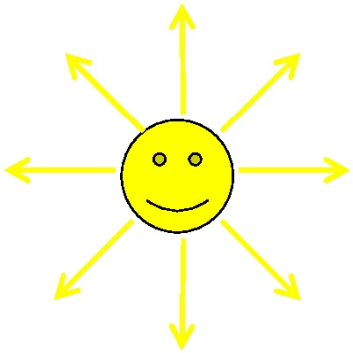


Types of Radiation

Type of Radiation	*Physical Structure*		*Travel Distance in Air & Means of Attenuation*
Alpha Particles	Positively charged Helium nucleus (2 protons & 2 neutrons)		2-5 cm Stopped by a single sheet of paper
Beta Particles	Positively or negatively charged electrons		~10 meters Stopped by aluminum foil, glass plate, ~2.5 cm of anything
Gamma Rays (Photons)	Neutral, energetic electromagnetic wave		Many kilometers Stopped by thick lead (10+ cm) or very thick concrete
Neutrons	Small, neutral particles with mass very near a proton		Many kilometers Stopped by 30+ cm of water, polyethylene, paraffin

Radiation Sources - Source Activity

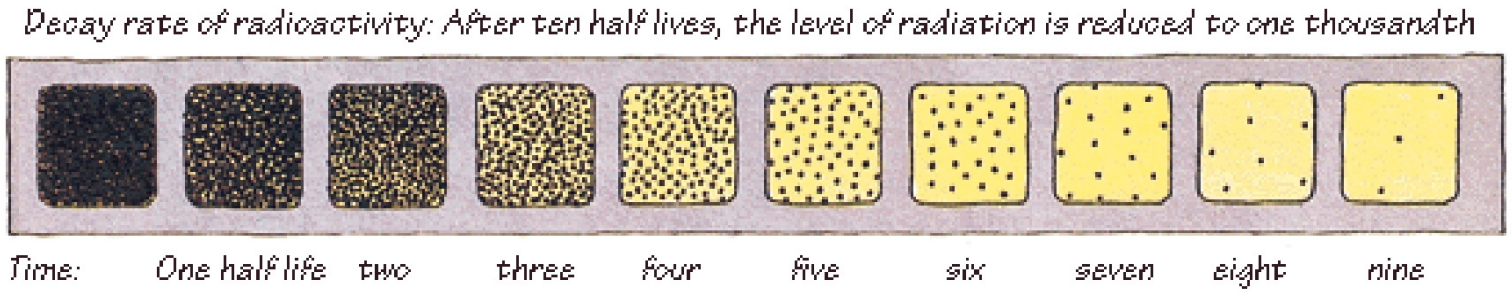
- The number of decays per unit time tell us how radioactive a source is. This is called **activity**.
- Measured in **Curies** (**Ci**) or **Becquerels** (**Bq**)
  - 1 **Becquerel** = 1 **Bq** = 1 decay per second
  - 1 **Curie** = 1 **Ci** = 3.7 x 10^{10} **Bq**
  - 1 **Ci** = the activity of 1 gram of Radium-226
- Visualize the amount of light emitted by the sun



Radiation Sources - Half Life

- The **half life** of a radioactive material tells us how quickly it decays away
- **Half life** = how long it takes for ½ of the radioactive atoms in a sample to decay away
- Measured in units of time
- Some examples:
  - Some natural isotopes (like Uranium and Thorium) have half lives that are billions of years
  - Most medical isotopes (like Technicium-99m) last only a few days

UCRL-PRES-149818. Understanding Radiation and it's Effects.



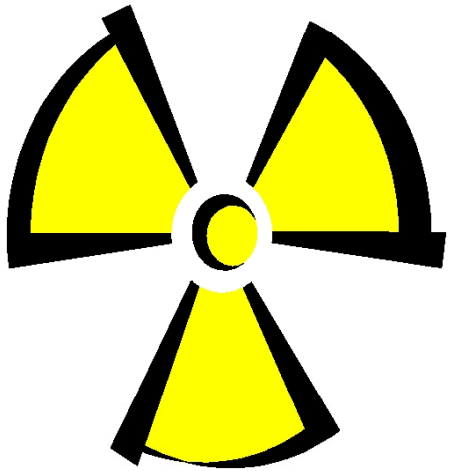
Some Isotopes & Their Half-Lives

Isotope	Half-Life	Applications
Uranium	billions of years	Natural uranium is comprised of several different isotopes. When enriched in the isotope of U-235, it's used to power nuclear reactor or nuclear weapons.
Carbon-14	5730 y	Found in nature from cosmic interactions, used to "carbon date" artifacts and as radiolabel for detection of tumors.
Cesium-137	30.2 y	Blood irradiator, tumor treatment through external exposure. Also used for industrial radiography.
Hydrogen-3	12.3 y	Labeling biological tracers.
Iridium-192	74 d	Implants or "seeds" for treatment of cancer. Also used for industrial radiography.
Technicium-99m	6 h	Brain, heart, liver, lungs, bones, thyroid, and kidney, regional cerebral blood flow imaging.

UCRL-PRES-149818. Understanding Radiation and it's Effects.

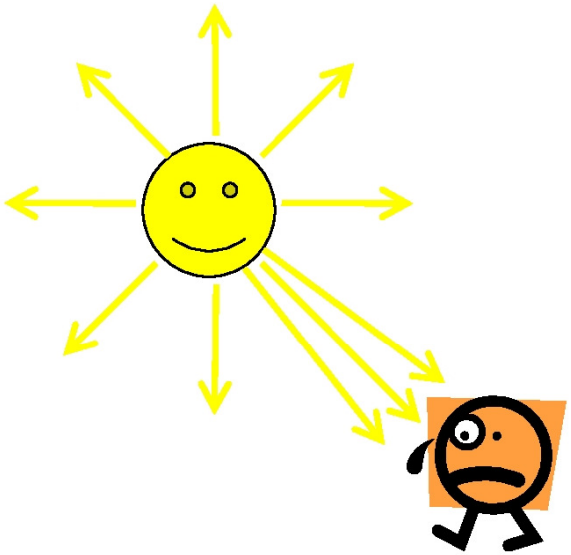
Topics

- Introduction to Radiation
- Types of Radiation
- Measuring Radiation
- Radiation Safety
- Detecting Radiation
- Why We Need to Measure Radiation Today
- Ref: TN-176



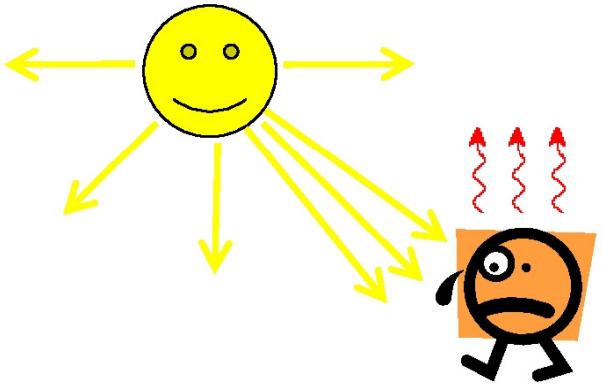
Exposure

- **Exposure:** how much radiation "hits" an object (or person)
- Measured in **Roentgens (R)**
- Visualize the amount of light emitted by the sun that hits you while sitting on the beach



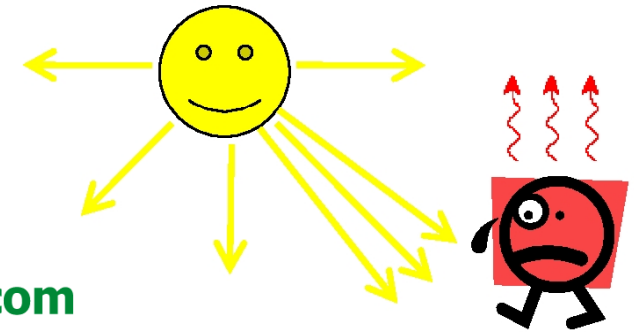
Absorbed Dose

- **Absorbed dose:** how much energy is imparted on/transferred to the object by the radiation
- Measured in **Rads (Radiation Absorbed Dose)** or **Grays (Gy)**
  - Units of energy/mass
  - 1 **Gy** = 100 **rad**
- Imagine how much your skin heats up from the sunlight hitting it



Biologically Equivalent Dose

- **Biologically equivalent dose:** Radiation-weighted dose to quantify the effects of radiation on biological tissue
- Measured in **Roentgen Equivalent Man (rem)** or **Sieverts (Sv)**
  - 1 **Sv** = 100 **rem**
- Imagine how sunburnt you get from sitting out in the sun



How Radiation Interacts

- Imagine you're relaxing on the beach on a sunny day:
  - The amount of light the sun emits is the "activity" of the sun
  - The amount of light that hits your skin is your exposure
  - The amount your skin heats up is your "absorbed dose"
  - The amount of sunburn you get is your "biologically equivalent dose"