Radiation Safety Principles

An Overview of

Basic Radiation Fundamentals

Source:
Mirion Technologies
www.mirion-hp.com/radiationsafety.asp

Note: the information provided is designed to familiarize individuals with basic theories and terminology commonly associated with radiological detection instrumentation and software. This module should not be used in place of formal radiation safety training.

Exposure to Radiation:
What is out there…

Where we encounter sources of radiation:

Industrial – Can Be Used for Good

- Radiography/density gauges
- Medical, lab, pharmaceutical facilities
- Nuclear power plant
- Vehicular transportation of radioactive waste/material
- Food irradiation processing facility

Accidents

- A passing radioactive cloud or smoke (plume from a nuclear power plant)
- A large point source emitting a strong radioactive beam
- Exposure from contamination deposited on the ground

Misuse and Terrorism – Bad Stuff

- Exposure of public to a radiation source
- Disperse radioactive material using conventional means (aircraft, ventilation, etc.)
- RDD (Incendiary/explosive or dirty bomb)
- Detonate a nuclear weapon (tactical backpack device)

Radiation Principles
Atom –

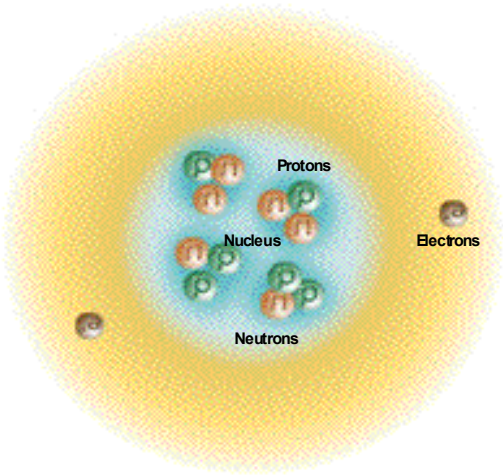
The smallest component of an element, which still retains the physical properties of that element. An atom is comprised of three particles:

- Protons
- Neutrons

These are in the central nucleus

- Electrons

These orbit the nucleus



Radiation Principles (continued)

Radiation –

Energy in the form of particles or waves, emitted from the nucleus of an unstable atom. When an unstable atom decays, it *transforms* into another atom and releases its excess energy in the form of radiation.

Types of Radiation

- Ionizing: removes electrons from atoms
  - Particulate form (alphas and betas)
  - Wave form (gamma and X-rays, also known as photons)
- Non-ionizing (electromagnetic): can't remove electrons from atoms
  - Infrared, visible, microwaves, radar, radiowaves, lasers

Radiation is expressed in terms of "dose" or activity", or

- Dose: Rem, milliRem, microRem (uRem/hr)
- Activity: counts or disintegrations per second/minute; curies, becquerels

Basic Interaction with Matter

- Ionization: an interaction in which the radiation gives up enough energy to one of the atom's electrons to completely remove it from the atom
- Excitation: an interaction in which the radiation gives up energy to one of the atom's electrons, raising the atom to a higher energy level
- Radiation deposits small amounts of energy, or "heat" in matter
  - alters atoms
  - changes molecules
  - damages cells
  - similar effects may occur from chemicals

Gamma

Electromagnetic waves or photons emitted from the nucleus of an atom.

Beta

A beta is a high speed particle, identical to an electron, that is emitted from the nucleus of an atom.

Alpha

An alpha is a particle emitted from the nucleus of an atom, that contains two protons and two neutrons. It is identical to the nucleus of a helium atom, without the electrons.

Neutron

Neutrons are neutral particles that are normally contained in the nucleus of all atoms and may be removed by various interactions or processes like collision and fission. Typically found near an operating reactor or nuclear detonation.

X-rays

X-rays are electromagnetic waves or photons not emitted from the nucleus, but normally emitted by energy changes in electrons. These energy changes are either in electron orbital shells that surround an atom or in the process of slowing down, such as in an X-ray machine.

Radiation Principles (continued)

Radiation –

Particulate Radiation

- *Alpha Particles*
  - – High mass (4 amu) and high charge (+2)
  - – Travel an inch or two in air
  - – **Stopped by a sheet of paper or skin**
- *Beta Particles*
  - – Low mass (0.0005 amu) and low charge (+/– 1)
  - – Travel 10-20 feet in air
  - – **Stopped by a book, cardboard, wood or plastic**
- *Neutron*
  - – Moderate mass (1 amu) and no charge (+2)
  - – Travel many feet in air
  - – **Stopped by water or hydrogen (low Z material)**

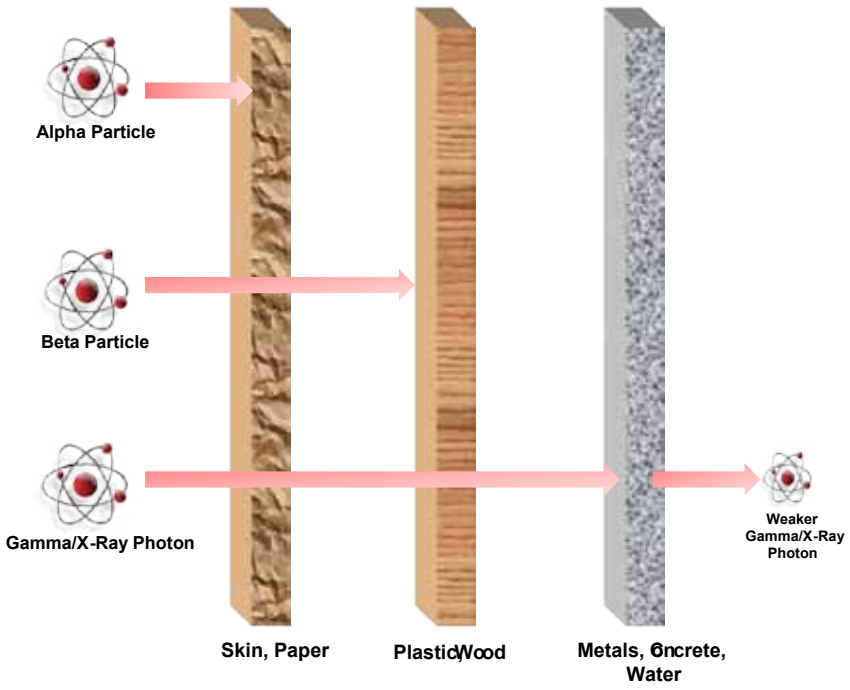
Wave (Photon) Radiation

- *Gamma Rays*
  Electromagnetic Waves produced in the nucleus of unstable atoms
  - – No mass and no charge
  - – Travels many feet in the air
  - – **Lead or steel used as shielding**
- *X-Rays*
  Electromagnetic waves produced when orbiting electrons transition to lower energy levels
  - – **Same characteristics as gamma rays**

Radiation Interactions

Radiation particles differ in mass and energy, and can be stopped or shielded by various types of material.

This graphic demonstrates the basic methods in which particle radiation can be effectively shielded.



Radiation Principles (continued)

Radiation Dose

- Human dose measured in ***rem*** or ***millirem*** *(also indicated as mR)*
  – 1000 mrem = 1 rem
  – 1 rem poses the **same risk** for any type of ionizing radiation (alpha, beta, gamma, X-ray) for ...
    – internal exposure
    – external exposure
- External radiation exposure measured by dosimetry (TLD, film badge, or electronic device)
- Internal radiation exposure measured using bioassay (e.g. urine/fecal sample analysis)

Radiation Units

Rad — Unit used to measure a quantity of absorbed dose (Radiation Absorbed Dose)

Rem — Used to derive a quantity called equivalent dose; 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.
– Typical units: mRem, mRem/hr, mRem (mR), mR/hr

Dose — The quantity of radiation or energy absorbed. Dose is affected by the TYPE of radiation, the amount of radiation and the physical properties of the material itself.

Dose Rate — The dose delivered per unit of time; used to indicate the level of hazard from a radioactive source per unit of time.

– Dose rate = dose x time

Example: 100 mRem/hr = 100 mRem x 60 minutes

Radiation and Contamination

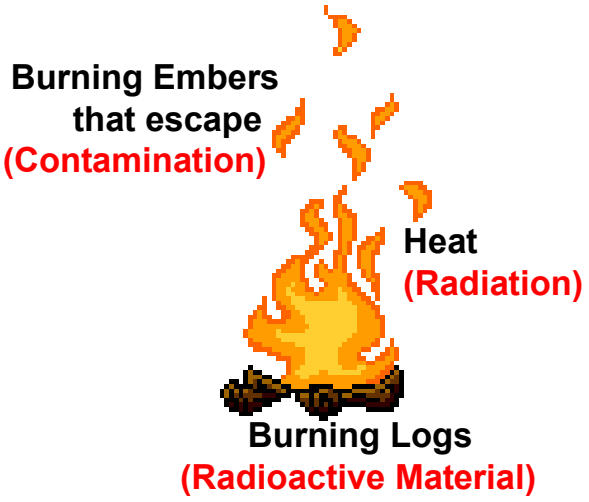
Radioactivity

A process where a collection of unstable atoms of a particular element decay, resulting in atoms of a different element. The degree of radioactivity is given by the number of decays that occur per unit time (i.e. decays per minute).

- Units of Measure: cpm, cps, dpm, dps, or Curie
  – Curie (Ci): 1C = 37,000,000,000 dps (3.7E10 dps)
- Sub-multiples of the Curie:
  – millicurie; 1 mCi = 37,000,000 dps
  – microcurie;1 uCi = 37,000 dps
  – nanocurie; 1 nCi = 37 dps
  – picocurie; 1 pCi = .037 dps
- SI Unit – Bequerel
  – 1 Bq = 1 dps

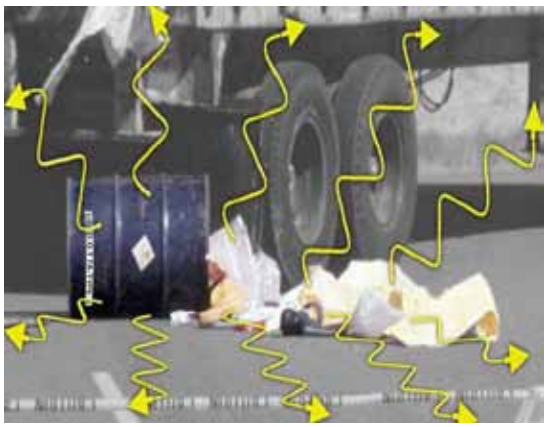
Radioactive Material

- Material that is unstable and emits radiation; any material that contains radioactive atoms. Items that become contaminated with radiation become radioactive material.



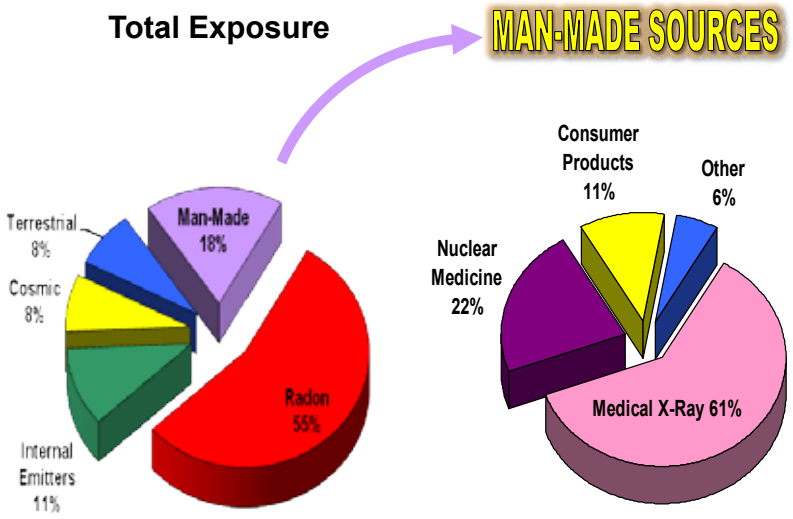
Contamination

- Radioactive material in any place where it is not desired, particularly where its presence can be harmful (for example, a spill from a drum or material dispersed from an RDD)
- Radioactive contamination emits radiation
- Exposure to radiation will not contaminate an individual
- Contact with radioactive contamination can contaminate people and other materials



Radiation and Contamination (continued)

Background Radiation Exposure



Total US Average Dose Equivalent = 360 mRem/year

Radiation Exposure

Exposure to Radiation

There are two (2) types of radiation exposure: **ACUTE** and **CHRONIC**

ACUTE – Large doses received in a short time period

- Accidents
- Nuclear war
- Cancer therapy
- Short term effects (Acute Radiation Syndrome: 150 to 350 rad whole body)
  - Anorexia
  - Nausea
  - Erythema (skin reddening)
  - Fatigue
  - Vomiting
  - Hemorrhage
  - Epilation (hair removal)
  - Diarrhea
  - Mortality

CHRONIC – Doses received over long periods

- Accidents
  - Background radiation exposure
  - Occupational radiation exposure
- 50 rem acute vs. 50 rem chronic
  - Acute: no time for cell repair
  - Chronic: time for cell repair
- Average US will receive 20-30 rem lifetime
- Long term effects
  - Increase risk of cancer
  - 0.07% per rem lifetime exposure
  - Normal risk: 30% (cancer incidence)

Radiation Exposure (continued)

Effects of Acute Exposure to Radiation

Dose (R)	Effects
25-50	First sign of physical effects (drop in white blood cell count)
150 - 350	Nausea, vomiting, fatigue, hair loss (epilation), skin reddening (erythema) ~ 50% die within 60 days with minimal care
450 – 600 LD 50/30	~50 % die within 60 days with medical care ~50% die within 30 days without medical care
1,000 LD 100/60	~ 100% die within 30-60 days

** For common external exposures 1Rad or Rem = 1,000 mRem*

Summary

Understanding Radiation and Its Effects

- Radiation is energy given off by unstable atoms and some machines.
- Radioactive material contains unstable atoms that give off radiation when they “decay.”
- Contamination is radioactive material spread someplace where you don’t want it.
- Radiation damages our cell’s DNA. Fortunately, our body has very efficent repair mechanisms.
- Large, acute doses of radiation can cause sickness or even death. The severity of the effects are proportional to the dose.
- All exposures are presumed to increase the risk of cancer. The amount of “increased risk” is proportional to exposure.

• Very Small DOSE = Very Small RISK