Radiation Exposure Principles

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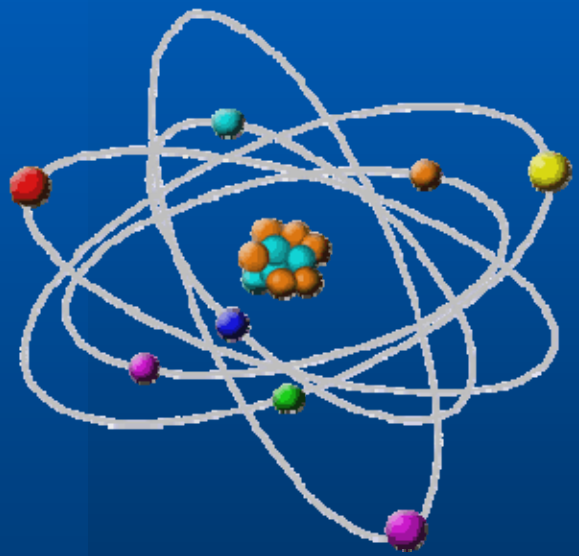
Radiation Physics

- Ionization
- Radiation Types
  - Ionizing
  - Nonionizing
- Radioactivity and Radioactive Decay
- Types of Ionizing Radiation
- Radiation and Radioactivity Units
- Radiation
  - Levels
  - Protection
  - Measurement

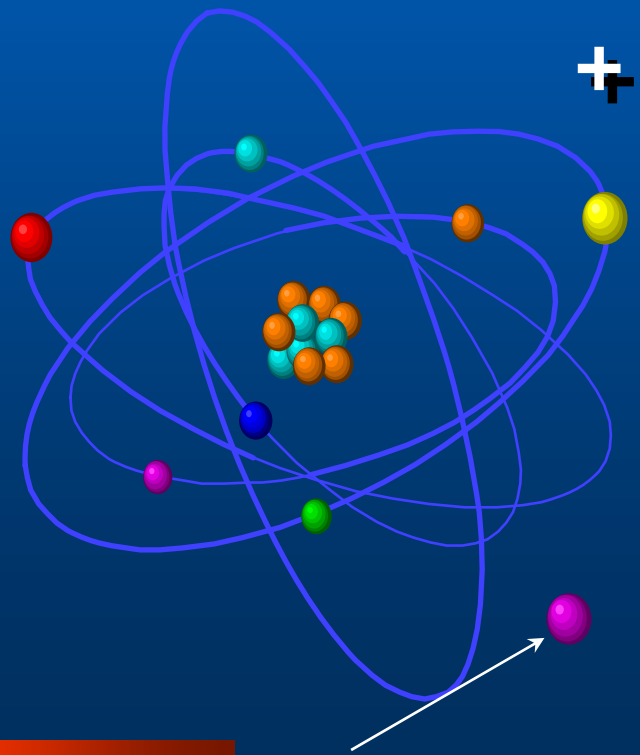
What is Radiation?



Radiation is energy transported in the form of particles or waves.

Ionization

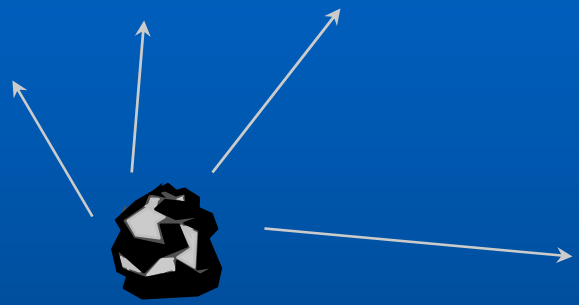
The Process by which a Neutral Atom or Molecule Acquires a Positive or Negative Charge



Examples of Radiations

Ionizing	Non-Ionizing
Grentz Rays	Sound
X-Rays	Ultrasound
Gamma Rays	Heat
Beta Radiation	Infrared Light
Alpha Radiation	Light
Neutron Radiation	UV Light
Positron Radiation	Radiowaves (RF)
Proton Radiation	Microwaves (RF)
	Ultrasound

Radioactive Material



U-238

A Material which Spontaneously Emits Radiation (Particles or Photons) is Said to be Radioactive

Note: the atomic nuclei of these materials have excess mass and/or energy which they get rid of by emitting ionizing radiation

Radioactive Decay

- Why Does it Occur?
  - Unstable Atomic Nuclei Become more Stable when a Loss of Mass and/or Energy Occurs (i.e., with the Emission of Particulate and/or Electromagnetic Radiation)
- Nuclear Change
  - Change in the Mass Number, Atomic Number, or Both, of the Product Nucleus usually Occurs
- Daughter (Product) Atom may be Stable or Unstable

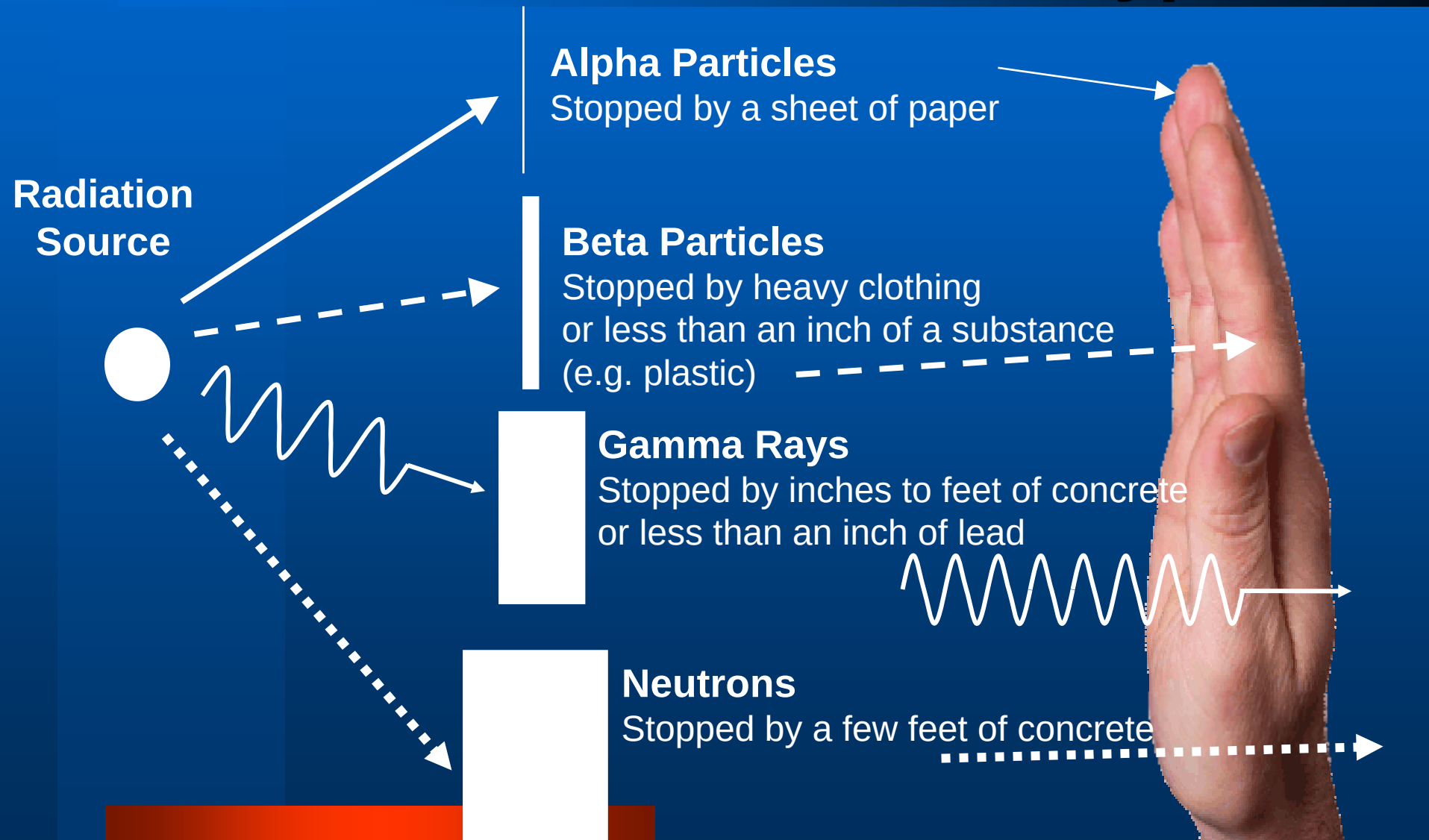
Atomic Structure

- **Atomic Number** - The Number of Protons in Nucleus of an Atom
- **Atomic Mass** - The Total Number of Protons and Neutrons in Nucleus
- **Isotopes** - Atoms of Same Element that have Different Numbers of Neutrons

Radiations Types

- Alpha Particles - Helium Ion
- Beta Particles - Energetic Electron
- Gamma Rays - Photon from Nucleus
- X-Rays - Photon from Electron Shell
- Neutrons - Neutral Particle from Nucleus

Penetration of Radiation Types



Relative Biological Effectiveness (RBE)

- All radiations are not created equal!

- RBE = 1 - photon, electron, proton (usually described as “Low-LET” radiation)
- RBE > 1 - alpha, neutron (usually described as “High-LET” radiation)

Decay Series

Half-Life and Biological Systems

- **Effective Half-Life** - Time Required for Radionuclide Contained in a Biological System, to Reduce Its Activity by Half, as a Combined Result of Radioactive Decay and Biological Elimination
  - **Physical Half-Life** - Time Required for Radioactive Substance to Lose Half of Its Material by Decay.
  - **Biological Half-Life** - Time Required for Biological System to Eliminate, by Natural Processes, Half the Amount of Substance, (e.g., Radioactive Material) that Entered It.

Some Transuranic Half-Lives

Transuranic	Primary Radiation	Physical Half-Life
Plutonium-238	Alpha (~5MeV)	86 yr
Plutonium-239	Alpha (~5MeV)	24,000 yr
Plutonium-240	Alpha (~5MeV)	6580 yr
Plutonium-241	Beta (0.21 MeV)	13 yr
Americium-241	Alpha (~5MeV) Beta (26 - 722 KeV)	458 yr

Isotope Examples

Isotope		Atomic Number	Atomic Mass	Element
^{5}Li	3 Protons 2 Neutrons	3	5	Lithium
^{6}Li	3 Protons 3 Neutrons	3	6	Lithium
^{7}Li	3 Protons 4 Neutrons	3	7	Lithium
^{8}Li	3 Protons 5 Neutrons	3	8	Lithium
^{9}Li	3 Protons 6 Neutrons	3	9	Lithium

Units of Radioactivity (Activity Units)

- **Curie (Ci)**
  - The Traditional/Conventional Unit of Activity
  - Equals about 2 Trillion Atomic Nuclei Undergoing Radioactive Decay (Transformation/Conversion) Per Minute
  - Equals 37 Billion Atoms Transformed per Second
- **Becquerel (Bq)**
  - The SI (International System) Unit of Radioactivity
  - Equals One Atom Decaying/Sec

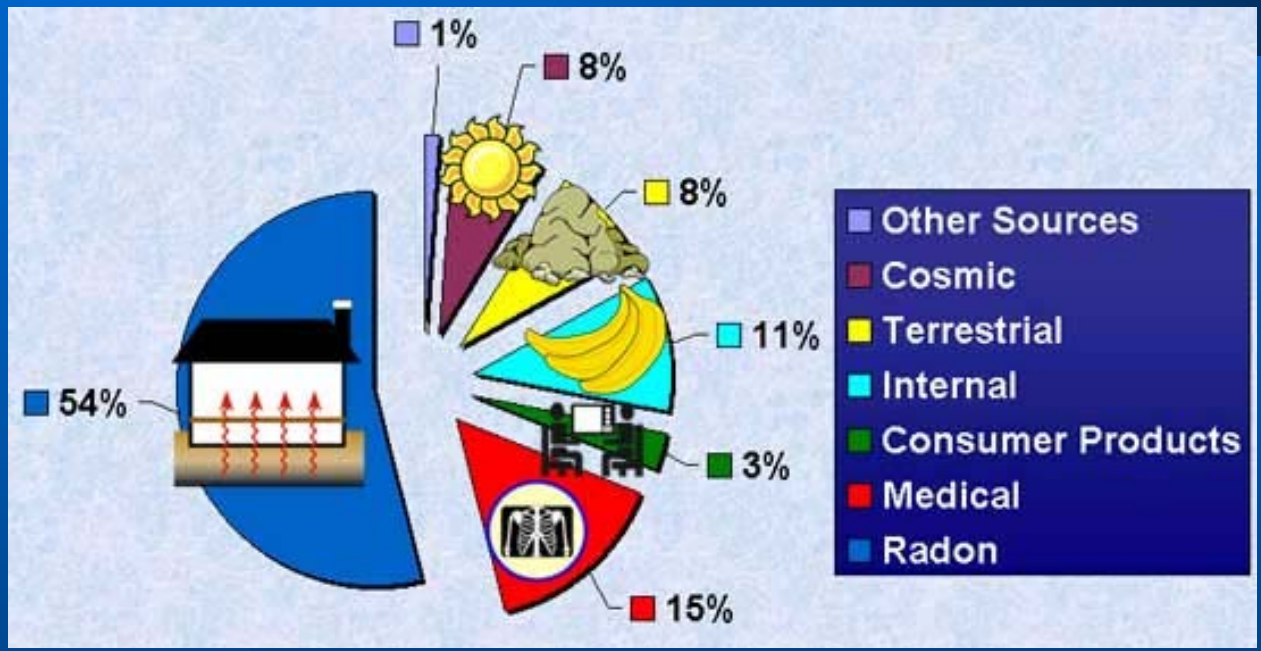
Radiation Quantities

- **Activity** [Curie (Ci), Becquerel (Bq)]
- **Exposure** [Roentgen (R); Coulomb/kg]
- **Dose** [rad (Radiation Absorbed Dose); Gray (Gy)]
- **Dose Equivalent** [rem (Roentgen Equivalent Man); Sievert (Sv)]

Traditional vs. S.I. Units

	Traditional (Conventional)	S.I.
Activity	Ci	Bq
Exposure	R	Coul/Kg
Dose	rad	Gy
Dose Equivalent	rem	Sv

Background Dose in US



Graphic: INEEL

Cosmic – 27 mrem (0.27 mSv)
Terrestrial – 28 mrem (0.28 mSv)
Internal – 39 mrem (0.39 mSv)
Consumer Products – 10 mrem (0.1 mSv)
Medical – 43 mrem (0.43 mSv)
Radon – 200 mrem (2 mSv)
Other – 1 mrem (0.01 mSv)

Total = 360 mrem (3.6 mSv) / yr

Source: NCRP 94

Representative Medical Radiation Exposures

Chest X-Ray	10 mrem	(0.1 mSv)
IVP	160 mrem	(1.6 mSv)
CT - Head	200 mrem	(2 mSv)
CT – Abdomen	1000 mrem	(10 mSv)
Bone Scan	440 mrem	(4 mSv)

(Effective Radiation Dose)

Source: ACR, HPS

External Beam Therapy	250-300 rad (2.5 – 3 Sv) locally

Annual Limits of Exposure (NRC)

Exposure	Radiation Worker
Whole Body	0.05 Gy
Lens of Eye	0.15 Gy
Extremities	0.50 Gy
Skin	0.50 Gy
(Pregnancy)	0.005 Gy
Minor	10% of above
Public	0.001 Gy

ALARA – As Low as Reasonably Achievable

- Radiation Work Environment Policy

Principles of Radiation Protection

- Time
- Distance
- Shielding
- Quantity

Radiation Accidents

- Exposure is rarely uniform

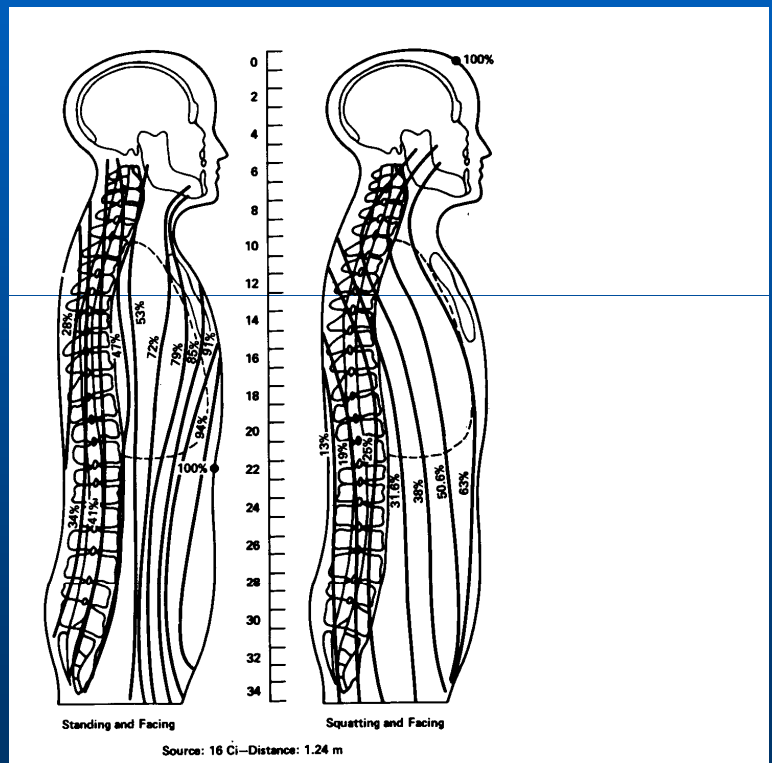
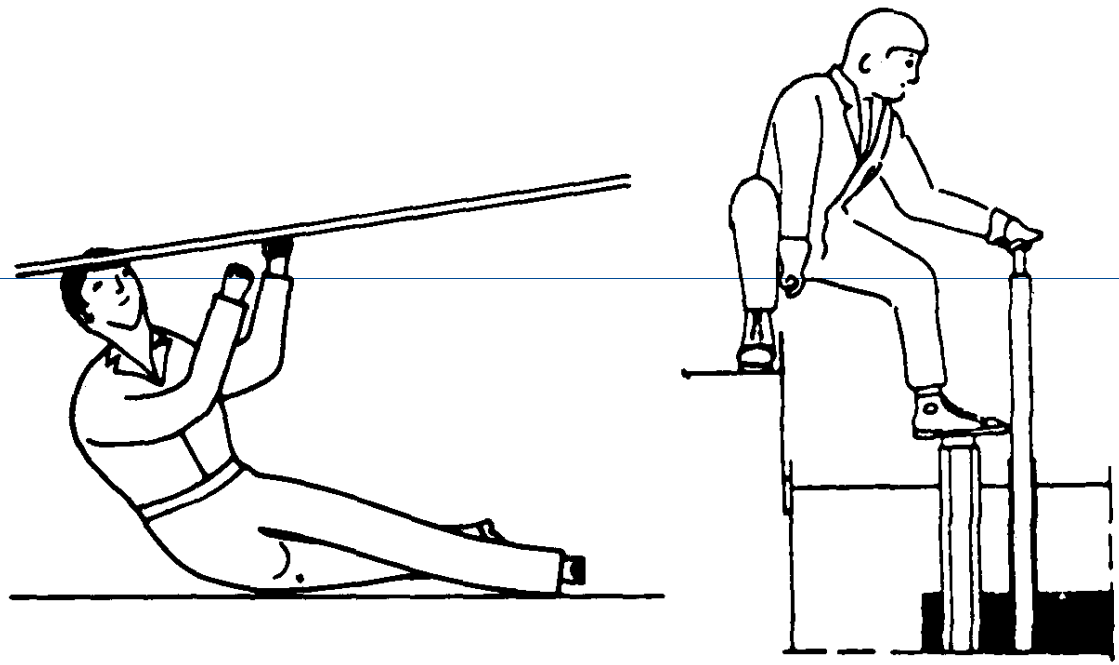


Figure 2A. Isodose map from reconstruction in a human phantom for the standing position. **2B.** Isodose map from reconstruction in a human phantom for the squatting position.

Hubner KF, Fry SA, *The Medical Basis for Radiation Accident Preparedness*, New York: Elsevier, 1980, p 116.

Exposure Geometry

Figure 1. Position of workers during exposure. The Belgian is on the right, the Italian on the left.



Hubner KF, Fry SA, *The Medical Basis for Radiation Accident Preparedness*, New York: Elsevier, 1980, p 106.

Accident Details are Important to Evaluate Dose

- Radionuclides
  - Amount (Max Amount – Search for Lab License)
  - Chemical, Physical Form
- External Beam
  - Radioactive Source
  - Exposure Time(s)
  - Distance from Source
  - Dose Rate
  - Exposure Geometry

Summary

- Different Types of Radionuclides
- Different Types of Radiation
- R, rad, rem, are essentially equivalent units for clinicians
- SI units becoming more common
- Exposure Details are important in prognosis of morbidity and mortality

References

- Hubner KF, Fry SA, *The Medical Basis for Radiation Accident Preparedness*, New York: Elsevier, 1980