SAND2007-0624P

# Lesson 1
# Radiation Basics

Sandia is a multiprogram laboratory operated by Sandia Corporation, a Lockheed Martin Company,
for the United States Department of Energy's National Nuclear Security Administration
under contract DE-AC04-94AL85000.

# Lesson 1
# Radiation Basics

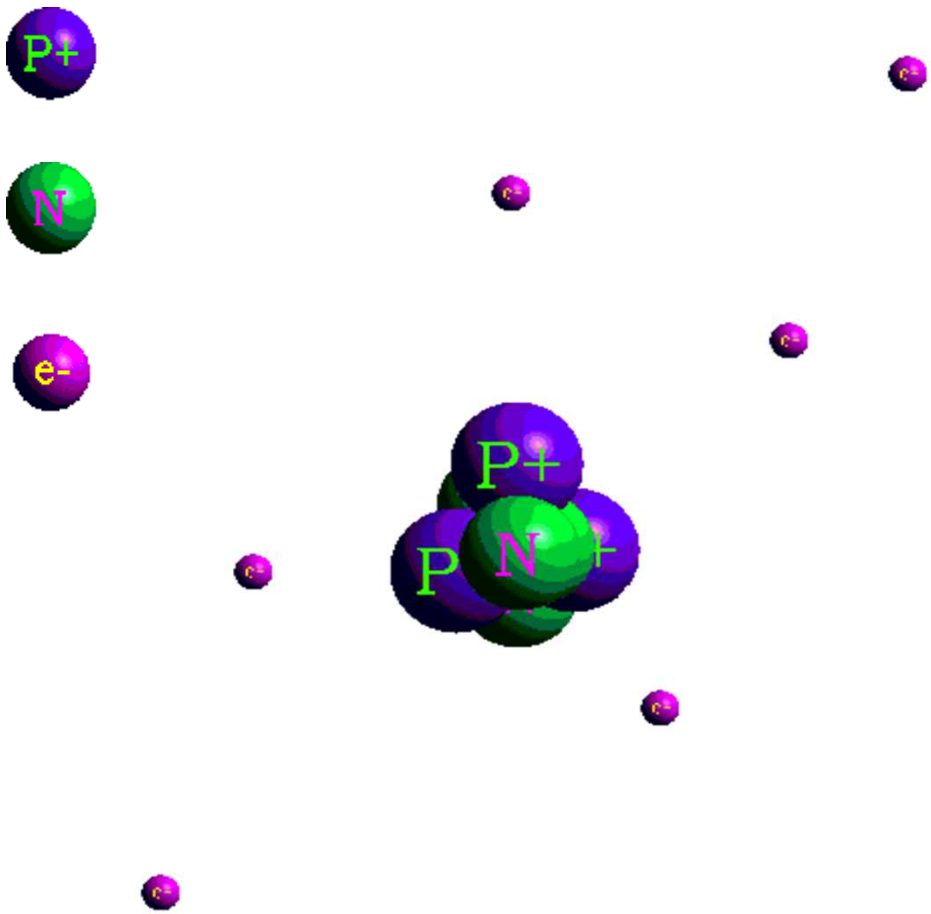
- Atoms, Ions, and Ionizing Radiation
- Ionizing Radiation
- Radiological Terminology and Units
- Radioactivity & Radioactive Decay (alpha, beta, gamma, neutron)
- Radioactive Material
- Radioactive Contamination

# Atomic Structure

Protons (positive)

Neutrons (neutral)

Electrons (negative)



# Radiological Fundamentals
## *REVIEW*

**Elements:** Identified by the number of Protons

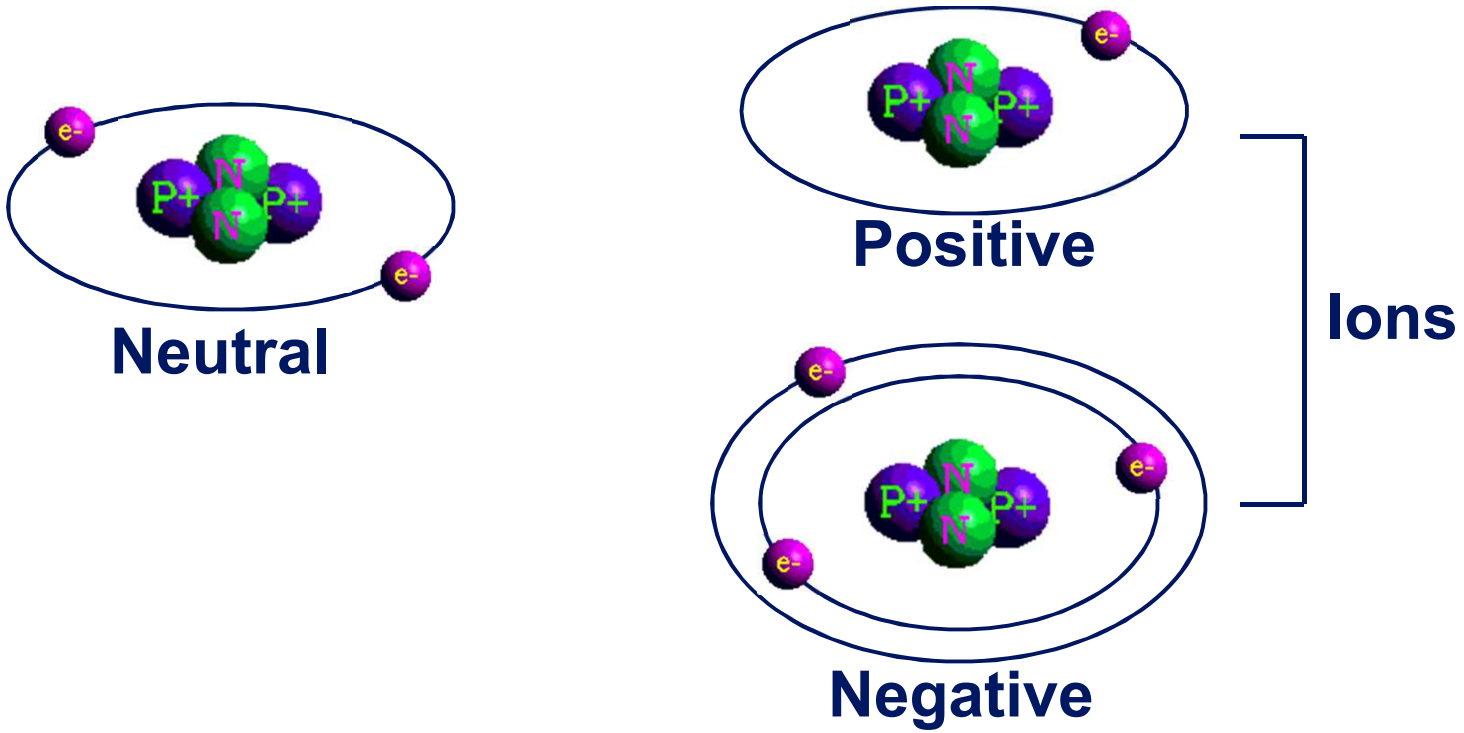

hydrogen helium

**Isotopes:** Atoms of the same element with different numbers of Neutrons


hydrogen (protium) hydrogen (deuterium) hydrogen (tritium)

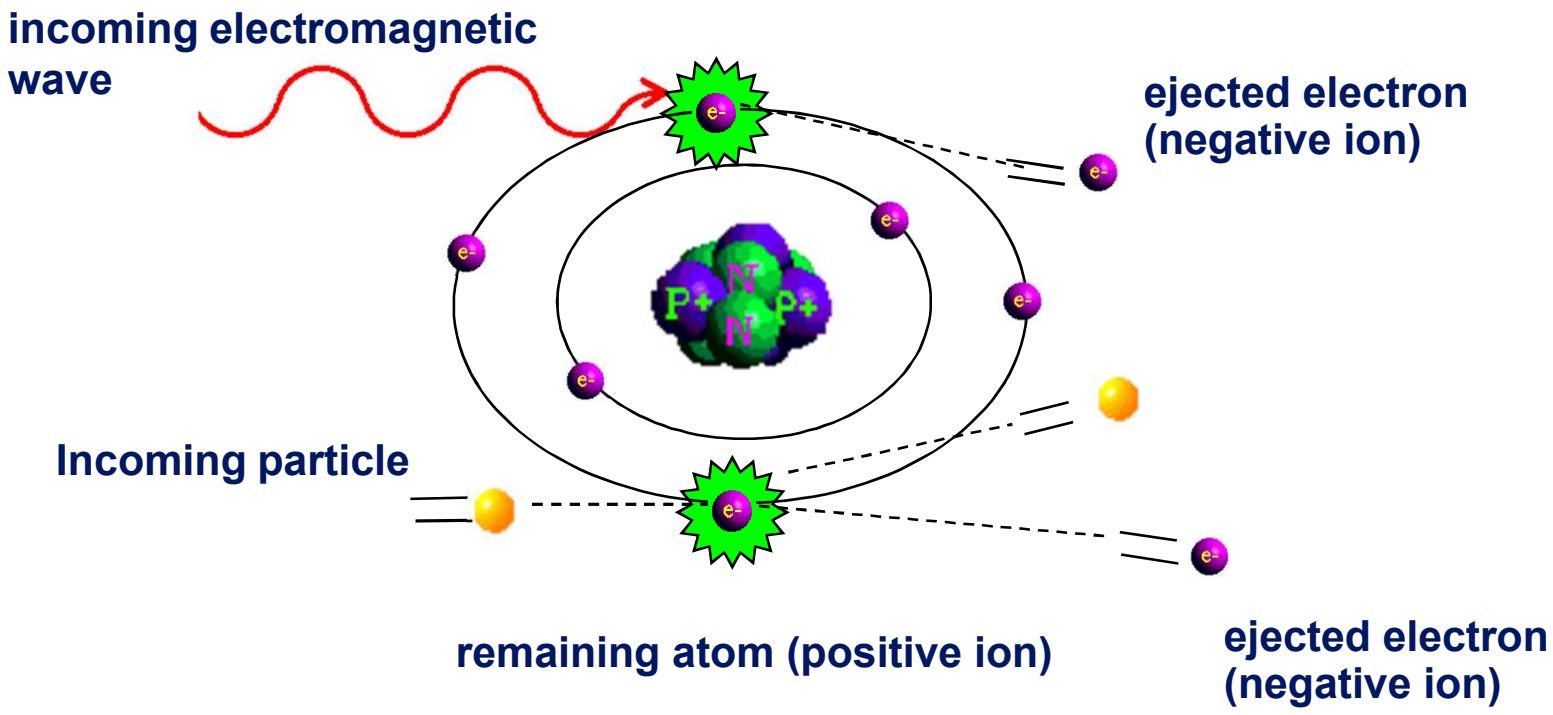
# Ions

Ions are atoms with *positive* or *negative* charge



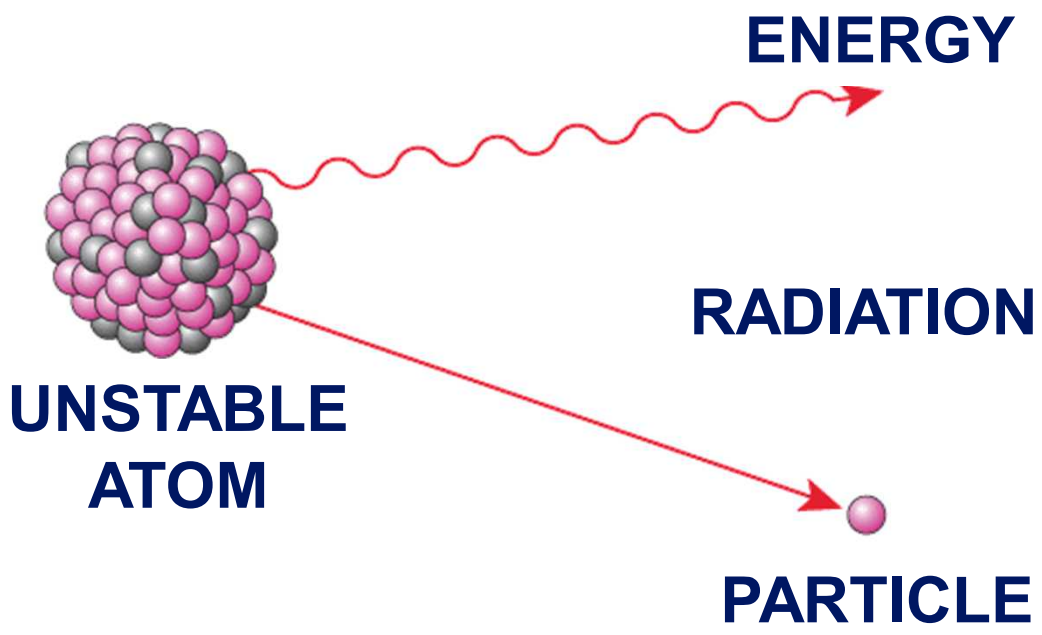
# Ionization

The process of removing electrons from atoms



# Ionizing Radiation

- Radiation is energy released from unstable (radioactive) atoms in the form of rays or particles.
- Ionizing Radiation causes a physical change in atoms by making them electrically charged (ionization).



# Non-Ionizing Radiation

- Radiation that does *not* have enough energy to ionize atoms with which it interacts
- Examples:
  - radio waves
  - infrared radiation
  - visible light
  - radar waves
  - microwaves



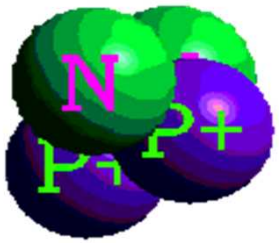


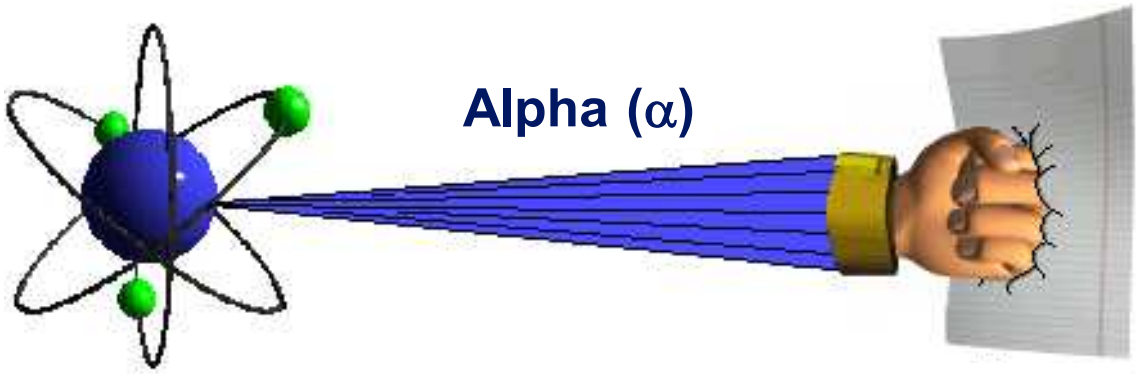
# Ionizing Radiation

- Radiation that possesses enough energy to cause ionization in the atoms with which it interacts
- Released from unstable atoms and some devices in the form of rays or particles
- Examples:
  - Alpha (particle) $\alpha$ 
  - Beta (particle) $\beta$ 
  - Gamma/x-ray (ray) $\gamma$ 
  - Neutron (particle) $\eta$ 

# Alpha Radiation (α)

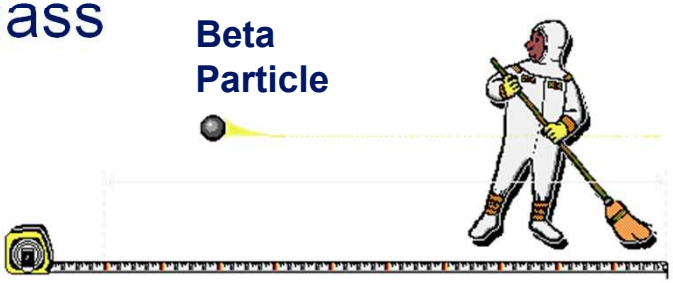
- Particle with a large mass
- Highly charged (+2 charge)
- Short range (2-5 cm in air)
- Significant internal hazard
- Easy to shield (paper, outer layer of skin)

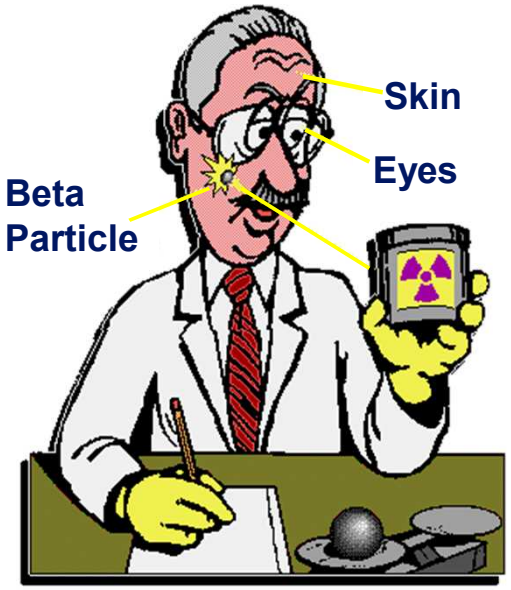


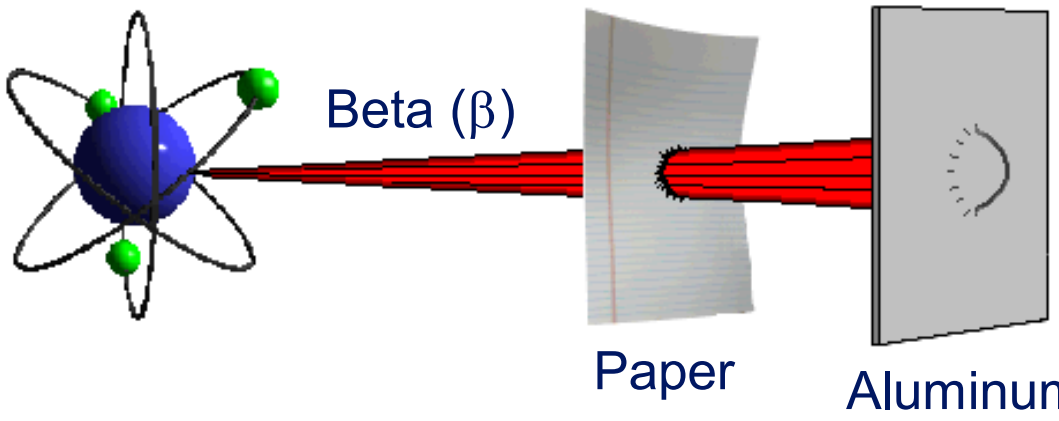



# Beta Radiation (β)

- Particle with a relatively small mass
- Charged (-1 charge)
- Mid-range (3.5 meters/Mev)
- Potential internal and external hazard (skin, eyes)
- Shielding – plastic, glass, aluminum, wood

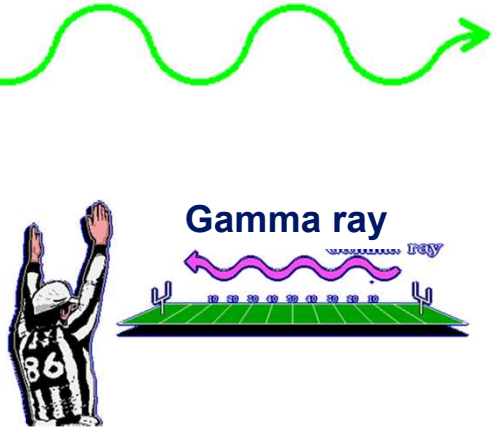


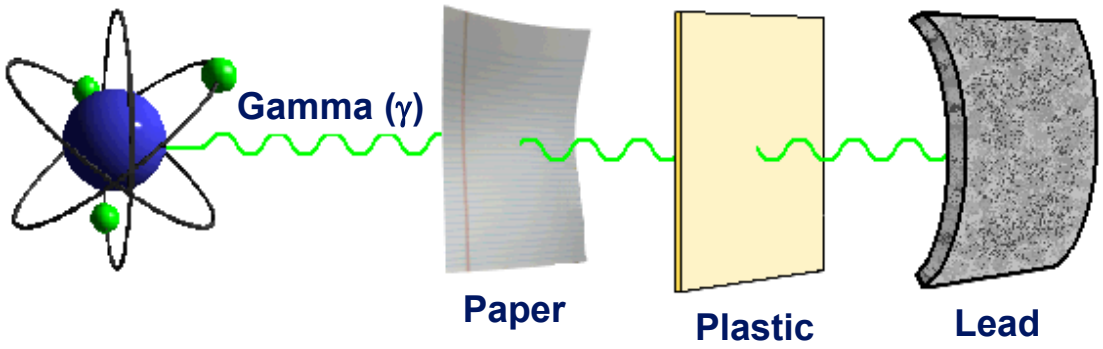



# Gamma Rays (γ) and X-Rays

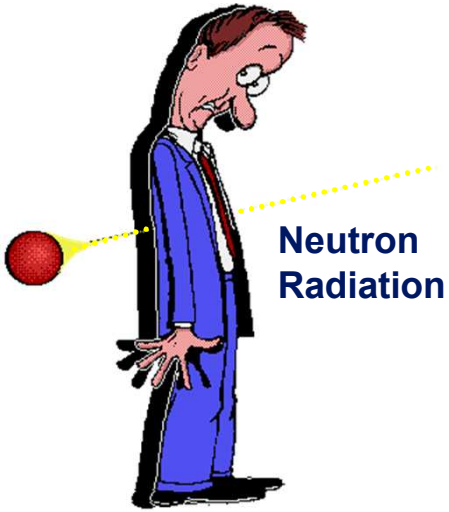
- Electromagnetic energy (ray)
- No mass, no charge
- Very long range
- Penetrating, whole body exposure hazard
- Difficult to shield – lead, steel, concrete

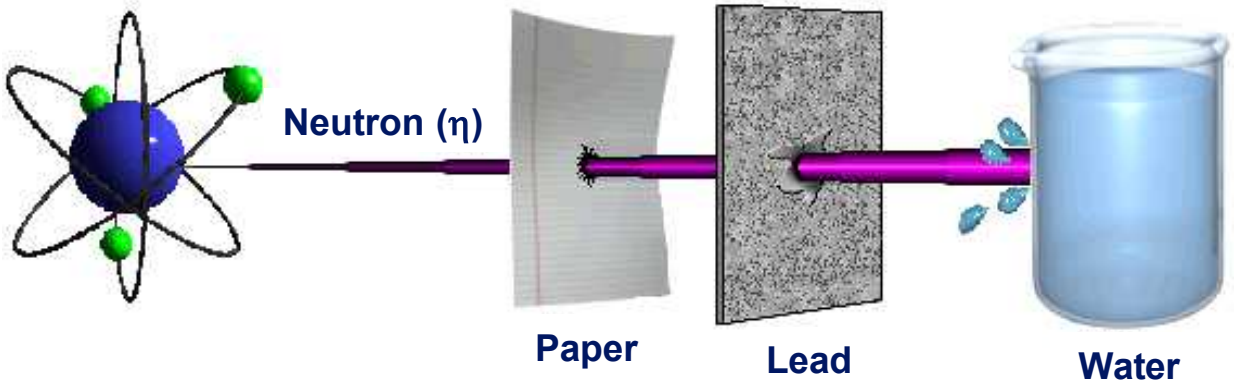



# Neutron Radiation (η)

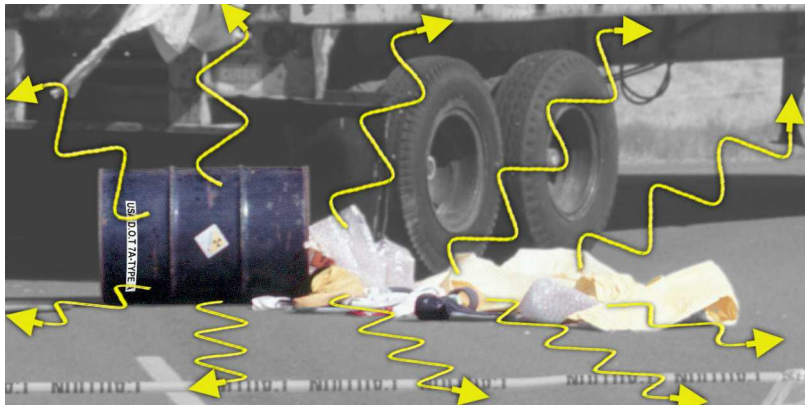
- Particle with no charge
- Very long range
- Penetrating, whole body exposure hazard
- Shielding – water, polyethylene

# Radioactive Material and Radioactive Contamination

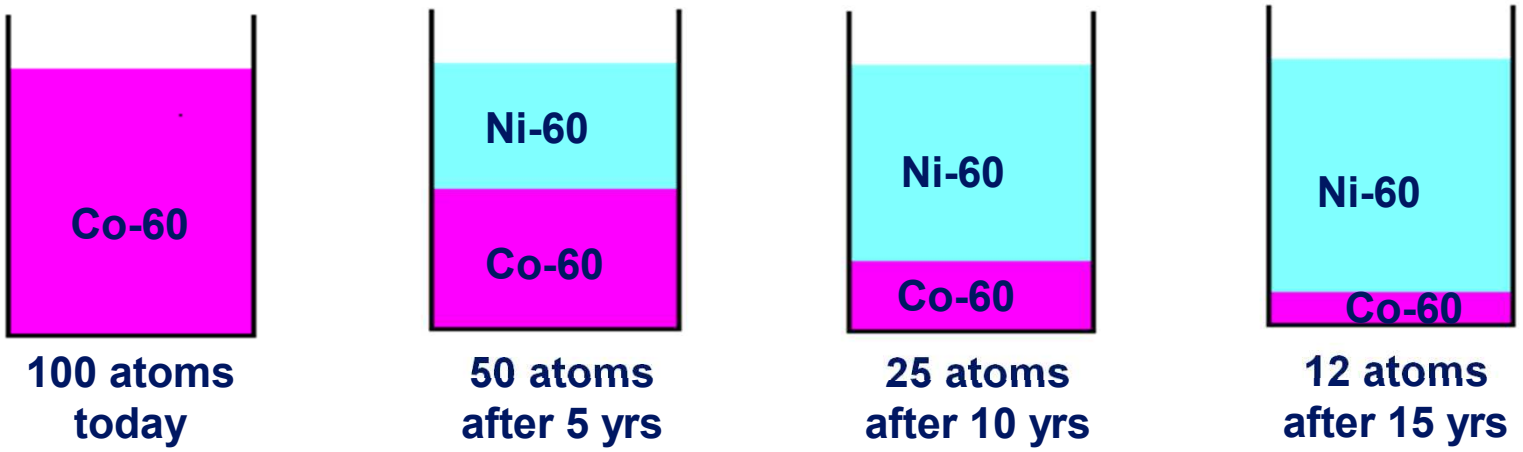
- Radiation is energy
- **Radioactive Material** - the physical material emitting the radiation (energy)
- **Radioactive Contamination** - radioactive material that is uncontained and in an unwanted place
- Exposure to radiation will not cause you to become contaminated

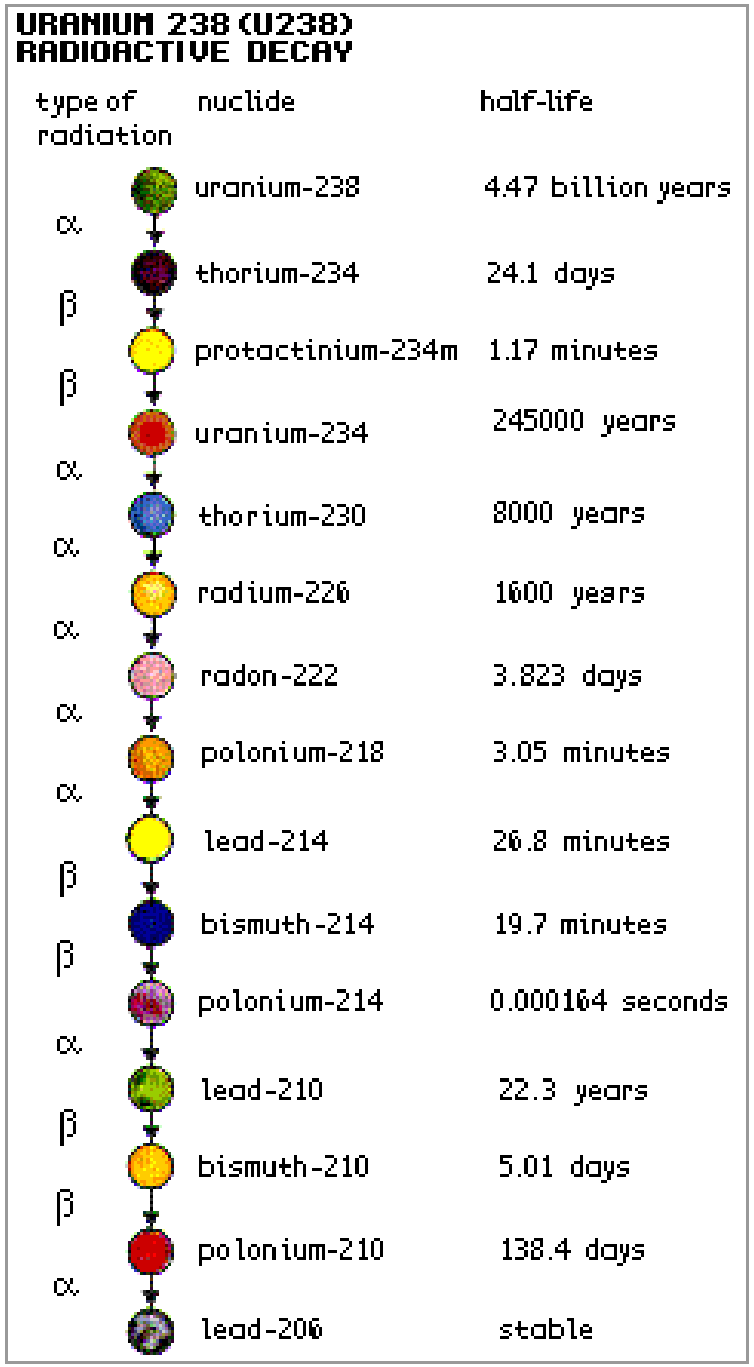



# Radioactivity and Radioactive Half-Life

- **Radioactivity** - the *process* of unstable atoms becoming stable by emitting radiation
- **Radioactive Half-Life** - the time it takes for one half of the radioactive atoms present to decay

  Example: Cobalt-60 half-life = 5.27 years




URANIUM 238 (U238)
RADIOACTIVE DECAY
type of radiation
nuclide
half-life
uranium-238
4.47 billion years
α
thorium-234
24.1 days
β
protactinium-234m
1.17 minutes
β
uranium-234
245000 years
α
thorium-230
8000 years
α
radium-226
1600 years
α
radon-222
3.823 days
α
polonium-218
3.05 minutes
α
lead-214
26.8 minutes
β
bismuth-214
19.7 minutes
β
polonium-214
0.000164 seconds
α
lead-210
22.3 years
β
bismuth-210
5.01 days
β
polonium-210
138.4 days
α
lead-206
stable

# UNITS OF MEASURE

- **Radiation ⟶ Energy**

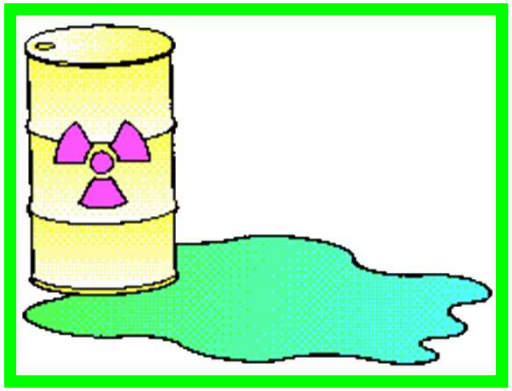
  Roentgen, Gray / RAD, Sievert / REM

- **Radioactivity ⟶ Rate**

  dpm, dps, becquerel, Curie

- **Contamination ⟶ Spread**

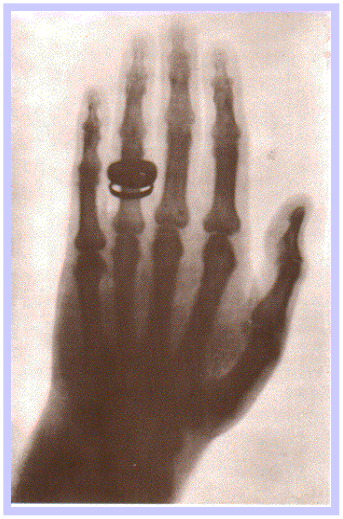
$$\frac{\text{Radioactivity}}{\text{Area or volume}}$$

# Measuring Radiation Energy
# ROENTGEN (R)

- Unit for measuring exposure
- Defined only for ionization in air
- Applies only to gamma and x-rays
- Not related to biological effects

Wilhelm Roentgen
1845 -1923
Discovered X-rays



# Measuring Radiation Energy
## GRAY / RAD

- SI Unit = GRAY (Gy) an absorbed dose of 1 joule/kilogram.
- Unit for measuring absorbed dose in any material
- Applies to all types of radiation
- Does not take into account the potential effect that different types of radiation have on the body
- Special Unit = RAD = Radiation Absorbed Dose
- 1 Gy = 100 RAD

# Measuring Radiation Energy
## SIEVERT / REM

- SI Unit = Sievert (Sv) unit for measuring dose equivalence
- Pertains to the human body
- Takes into account the energy absorbed (dose) and the biological effect on the body due to the different types of radiation
- Special Unit = REM = Roentgen Equivalent Man
- 100 REM = 1 Sv

# CONVERTING REM TO MILLIREM

**1 Rem = 1000 milliRem (mRem)**

## Fill in the blanks

500 mRem = **0.5** Rem

0.8 Rem = **800** mRem

0.25 Rem = **250** mRem

# CONVERTING SIEVERT TO REM

**1 Sievert = 100 REM**

## Fill in the blanks

0.02 Sv = **2** Rem

1.40 mSv = **140** mRem

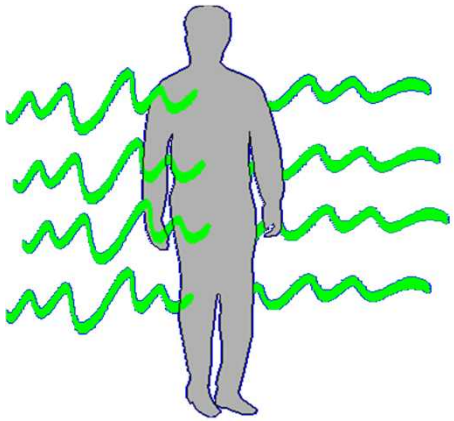
4.0 mSv = **0.4** Rem

210 ☞SV = **21** mRem

# DOSE VS. DOSE RATE

- Dose rate is the *rate* at which you receive the dose.
- Dose rate = dose divided by time (mGray/hr, ☞Gray/hr, Rad/hr, mRad/hr).
- Dose is the *amount* of radiation you receive.

Dose = Dose Rate X Time



200 mrad/hr

Question: How much dose would this individual receive in 2 hours?

Answer: 400 mrad

# MEASURING RADIOACTIVITY

- A measure of the number of spontaneous disintegrations radioactive material undergoes in a certain period of time
- We measure the rate of decay, which leads us to the quantity of radioactive material present

# RADIOACTIVITY UNITS

Basic Unit

- Becquerel (Bq)
- 1 Bq = 1 disintegration per second (dps)
- dps = derived from instrument counts and counting efficiency

Larger unit

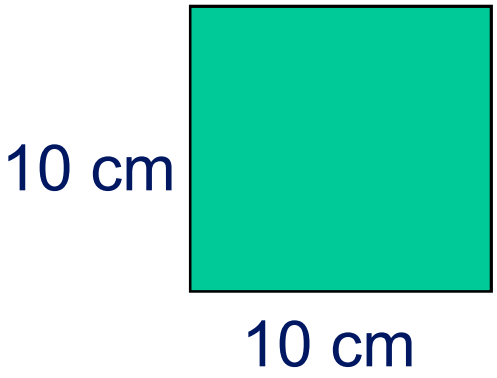
- Curie (Ci)
- 1 Ci = $3.7 \times 10^{10}$ dps

**Marie Curie**
**1867 - 1934**
**Discovered**
**radium & polonium**

# CONTAMINATION UNITS

How spread out is the radioactive material?

$$\frac{\text{Radioactivity}}{\text{Area or Volume}}$$



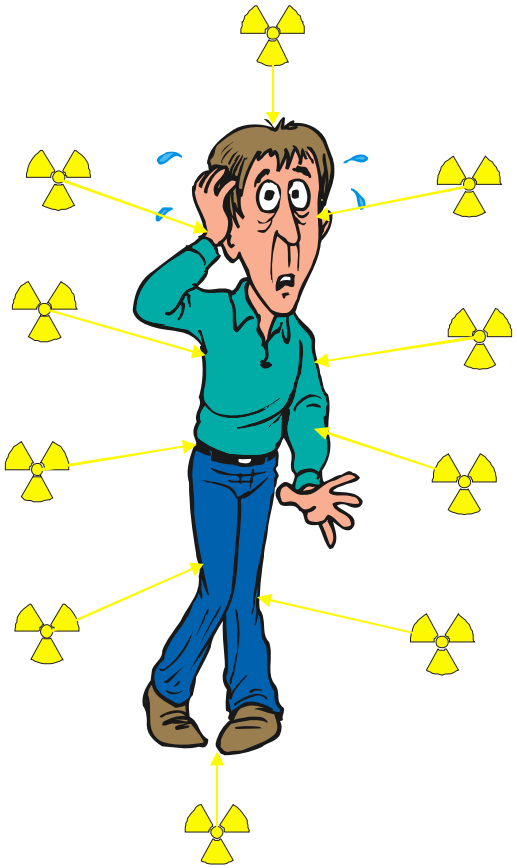

$$\frac{\text{dpm}}{100\ \text{cm}^2}$$

dpm = disintegrations per minute

# Background Sources of Ionizing Radiation

**Background = natural + man-made**

We are *constantly* exposed to background radiation, from both natural and man-made sources





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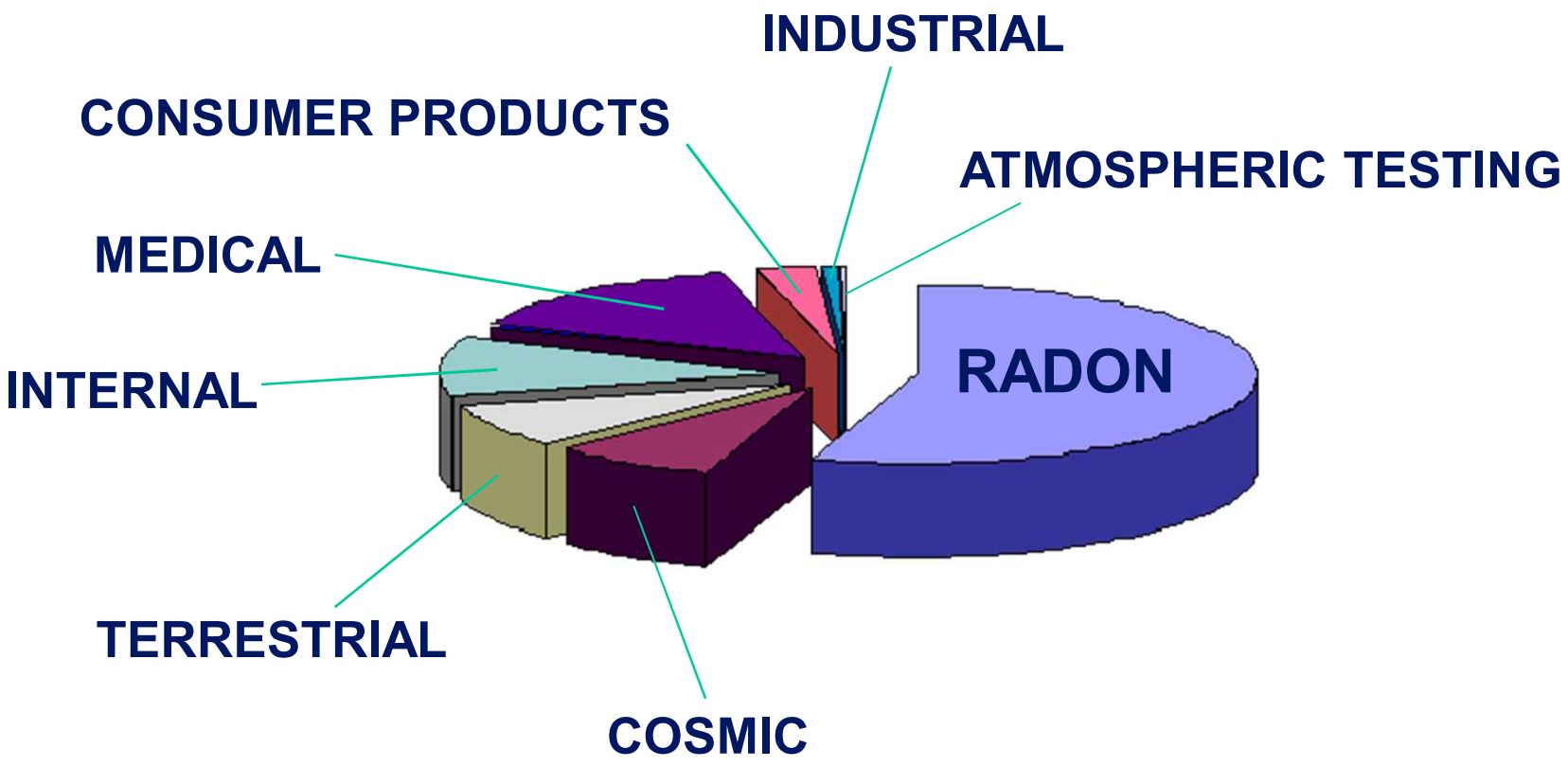
# Background Radiation Sources

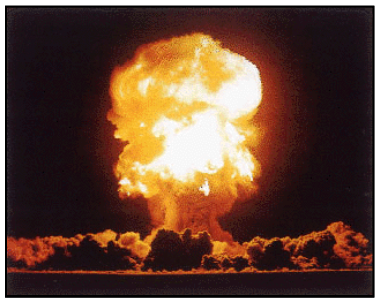


# Natural Radiation Sources

| SOURCE | AVG DOSE |
|---|---|
| COSMIC - sun & outer space | 20-40 mrem/yr |
| TERRESTRIAL - Earth's crust | 20-50 mrem/yr |
| INTERNAL - our own bodies | 30-40 mrem/yr |
| RADON - Uranium in the Earth | 120-200 mrem/yr |

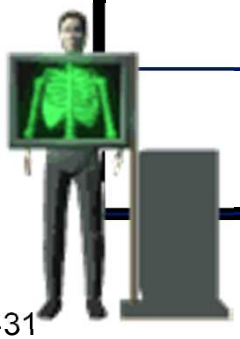
# Man-Made Radiation Sources

| SOURCE | AVG DOSE |
|---|---|
| Medical | 40-54 mrem/yr |
| Consumer Products | 10 mrem/yr |
| Industrial Uses | < 3 mrem/yr |
| Atmospheric Testing | < 1 mrem/yr |



# Radiation Doses
# - Medical Procedures -

| | |
|---|---|
| Radiation Therapy | 600,000 mrem - tumor |
| CAT Scan | 5,800 mrem - head<br>1,500 mrem - lower spine |
| Fluoroscope | 5,000 mrem/min. - skin |
| Mammogram | 400 mrem - breast<br>0.2 mrem (low-dose screen) |
| Dental X-Ray | 55 - 65 mrem/shot - mouth |
| Chest X-Ray | 20 - 50 mrem/shot - chest |



# Radiation Doses
# - Consumer Products -

| PRODUCT | AVG DOSE |
|---|---|
| Cigarettes (1.5 packs/day) | 8,000 mrem/yr - lungs |
| Dental Porcelain | 60 rem/yr - gums |
| Tinted Glasses | 4 rem/yr - eyes |
| Building Materials | 7 mrem/yr - whole-body |
| Radium Dial Watch | 6 mrem/yr - whole-body |
| Smoke Detector | 1 mrem/yr - whole-body |

# World Average

The average annual doses to the world population from all sources of radiation is estimated to be **280 mrem/year (2.8 mSv/year).** (IAEA Report)