SAND2007-5110P

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.

Radiation Basics

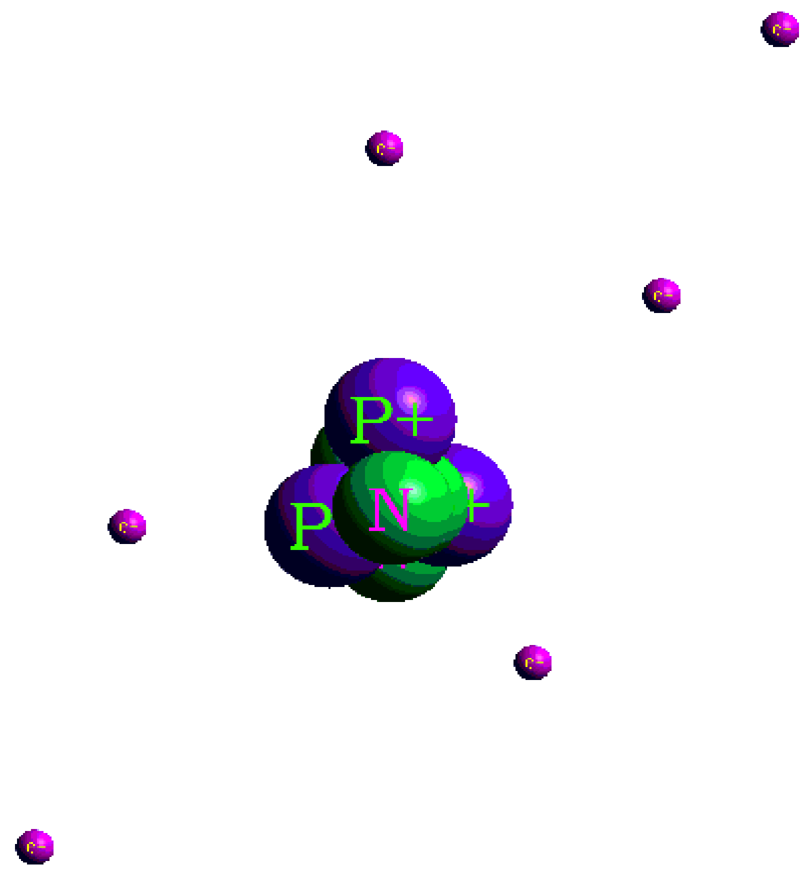
- Atoms, Ions, and Ionizing Radiation
- Ionizing Radiation
- Radiological Terminology and Units
- Radioactivity & Radioactive Decay (alpha, beta, gamma, neutron)
- Radioactive Material
- Radioactive Contamination

Atomic Structure

Protons (positive)

Neutrons (neutral)

Electrons (negative)



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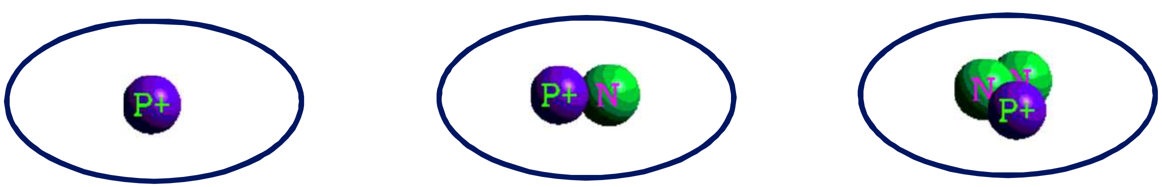
Elements & Isotopes

Elements: Identified by the number of Protons

hydrogen   helium

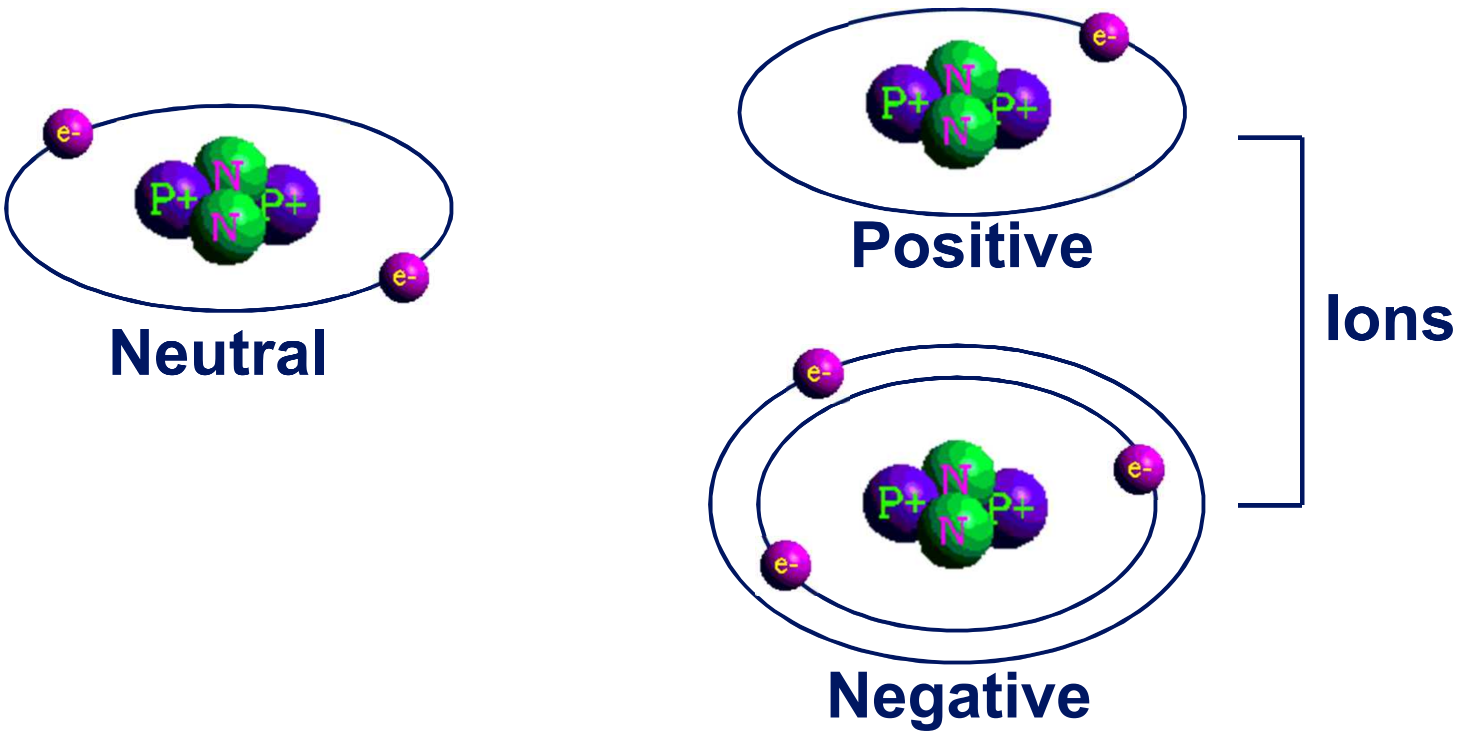
Isotopes: Atoms of the same element with different numbers of Neutrons



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

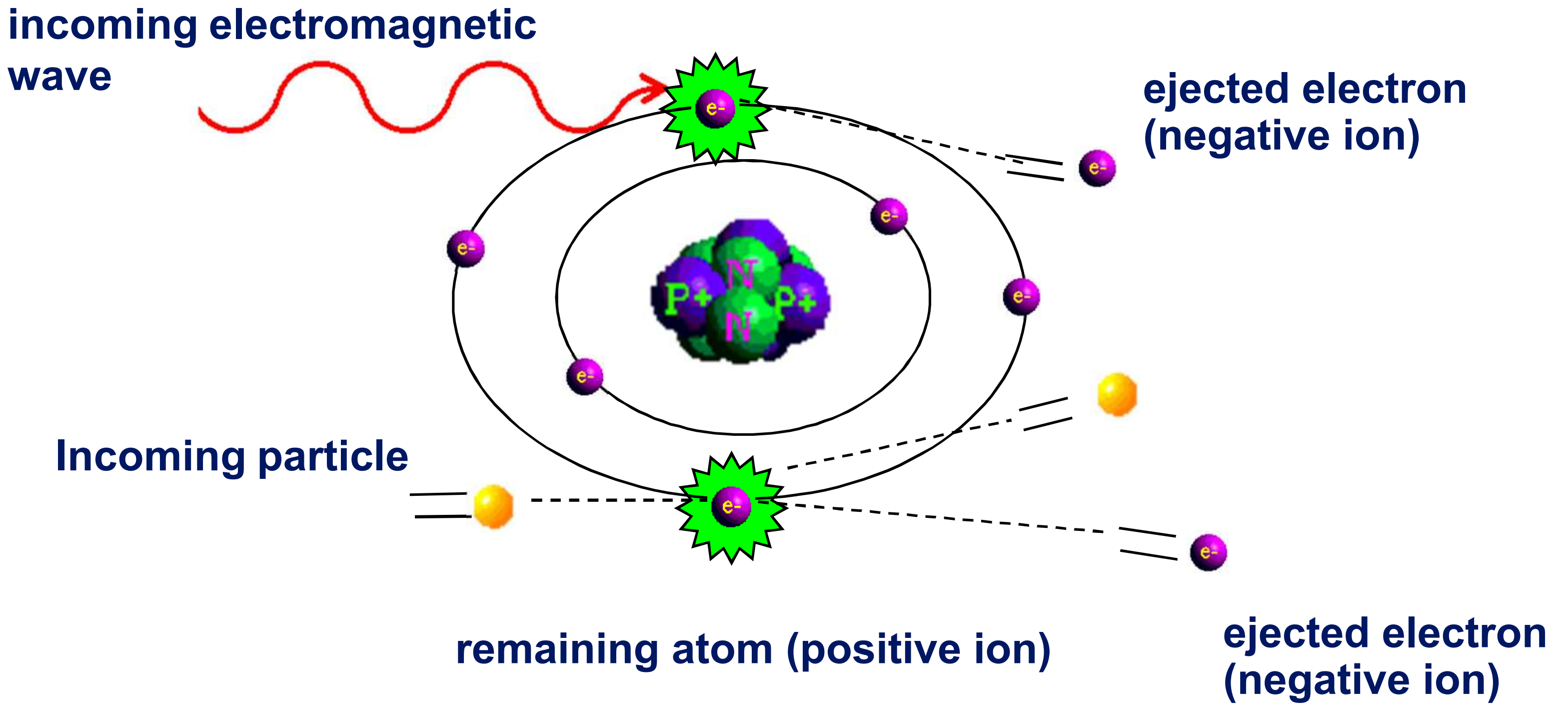
Ions

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



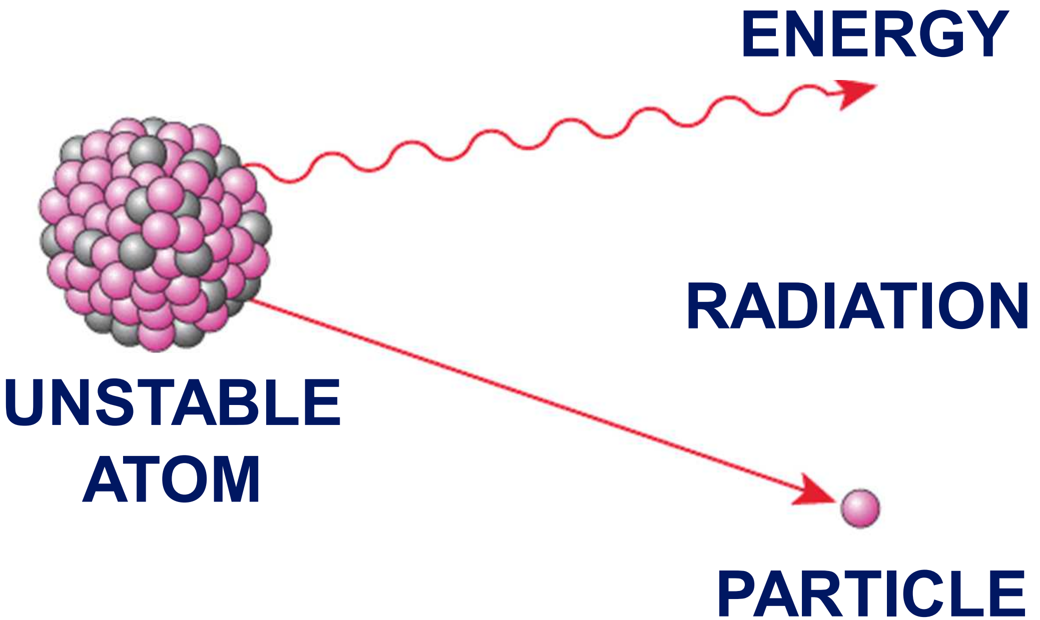
Ionization

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**

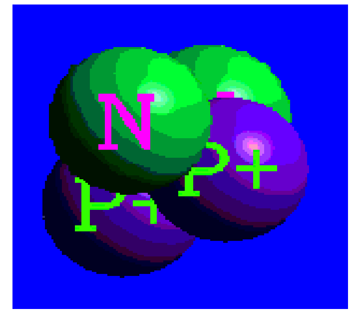
Ionizing Radiation

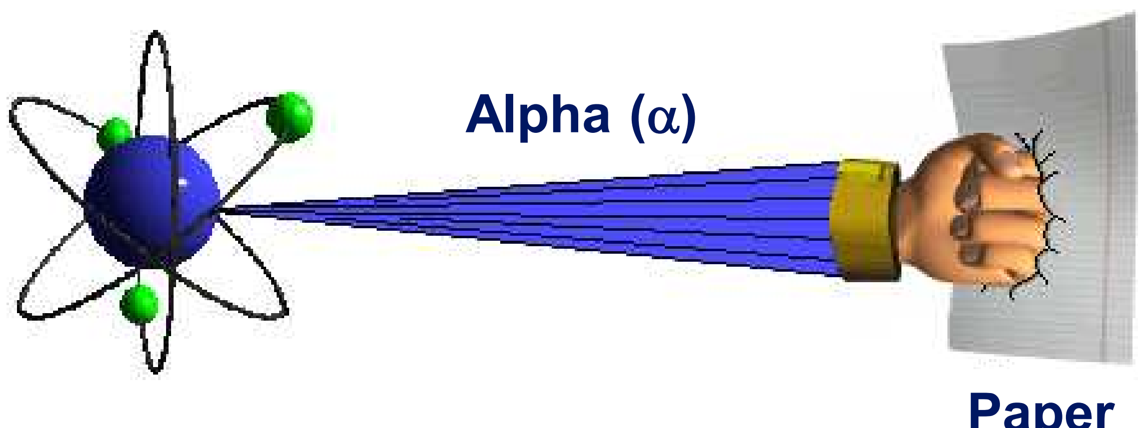
- Radiation that possesses enough energy to <u>cause ionization</u> in the atoms with which it interacts
- Released from unstable atoms and some devices in the form of rays or particles
- Examples:
  - Alpha (particle) α 

  - Beta (particle) β 
  - Gamma/x-ray (ray) γ 
  - Neutron (particle) η 

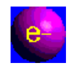
Alpha Radiation (α)

- 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)

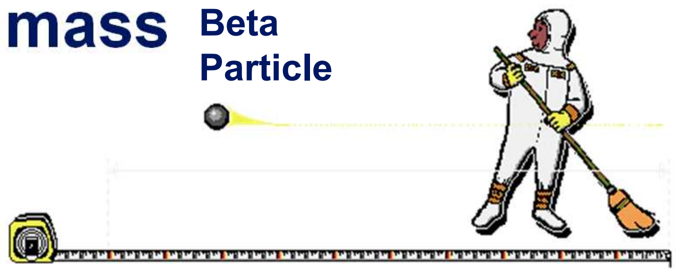


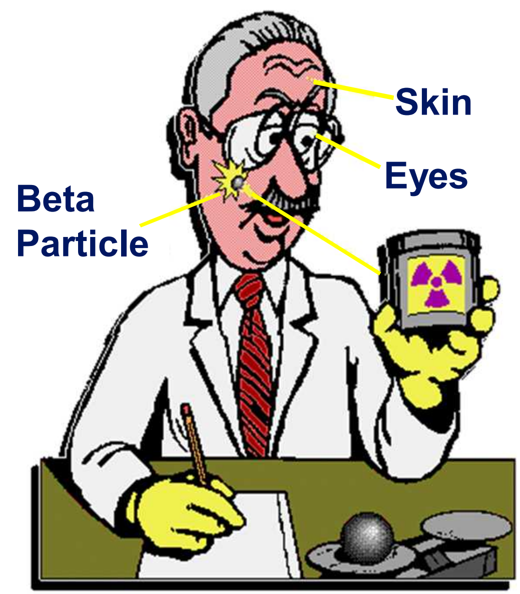


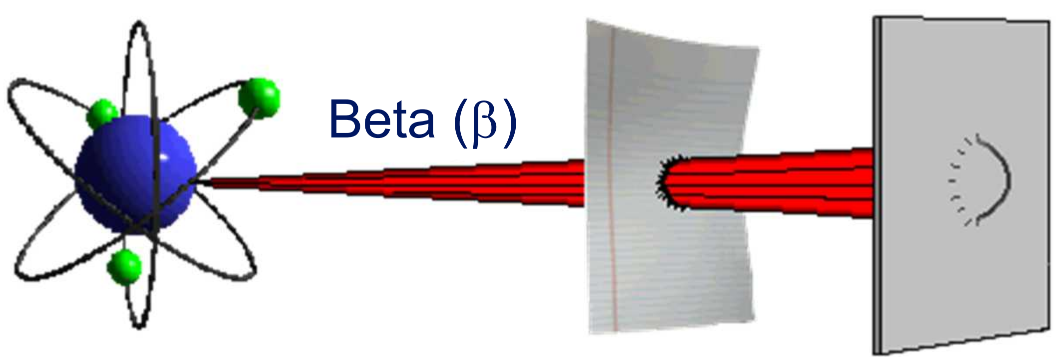
Beta Radiation (β)

- 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

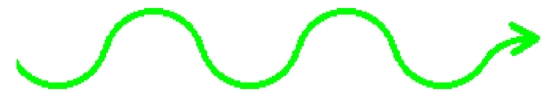


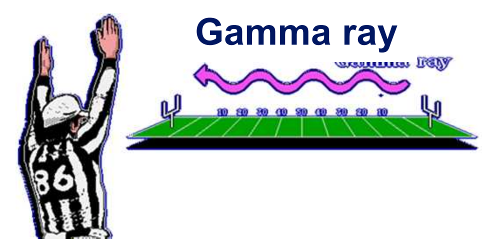


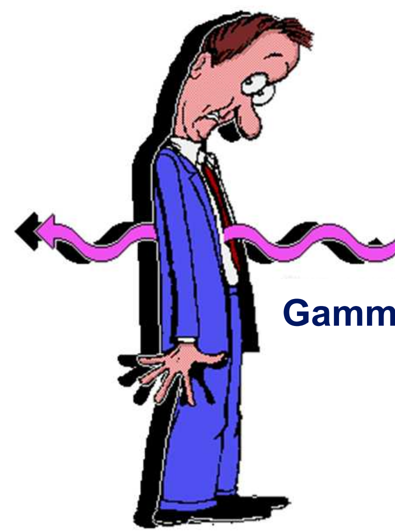


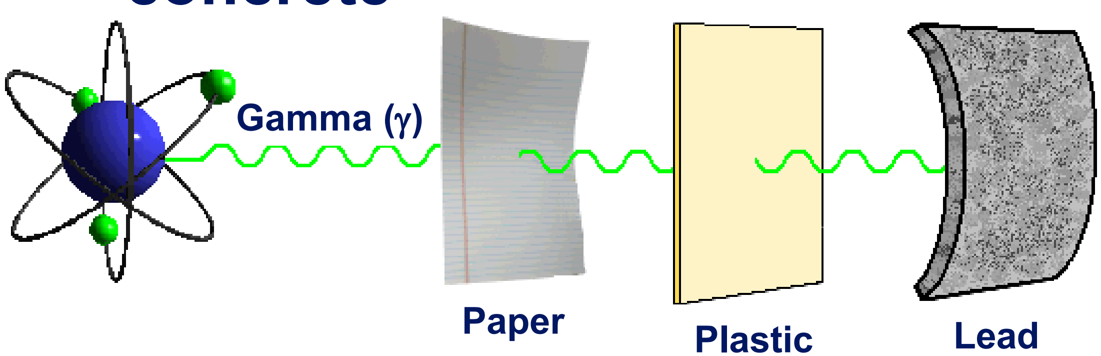
Gamma Rays (γ) and X-Rays

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

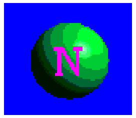


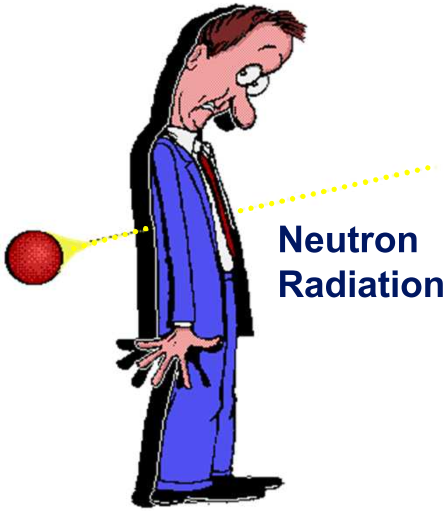


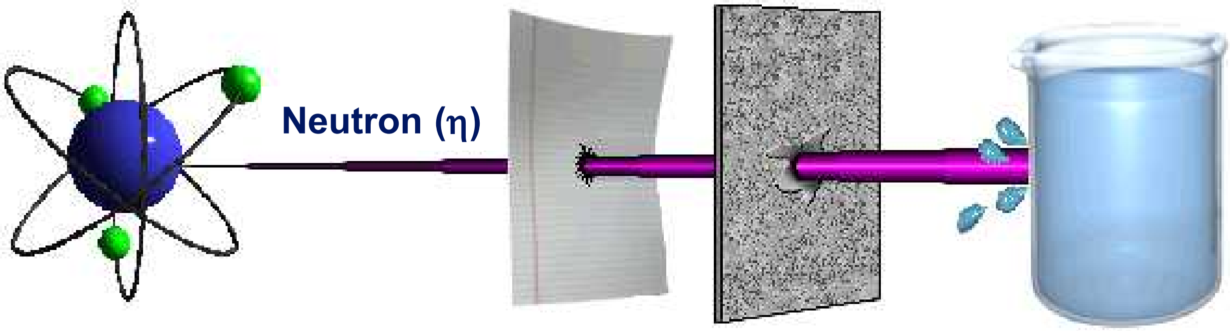




Neutron Radiation (η)

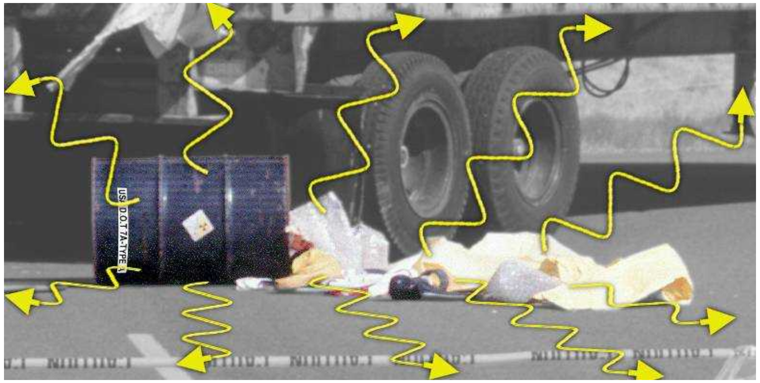
- Particle with no charge 
- Very long range
- Penetrating, whole body exposure hazard
- Shielding – water, polyethylene





Radioactive Material and Radioactive Contamination

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



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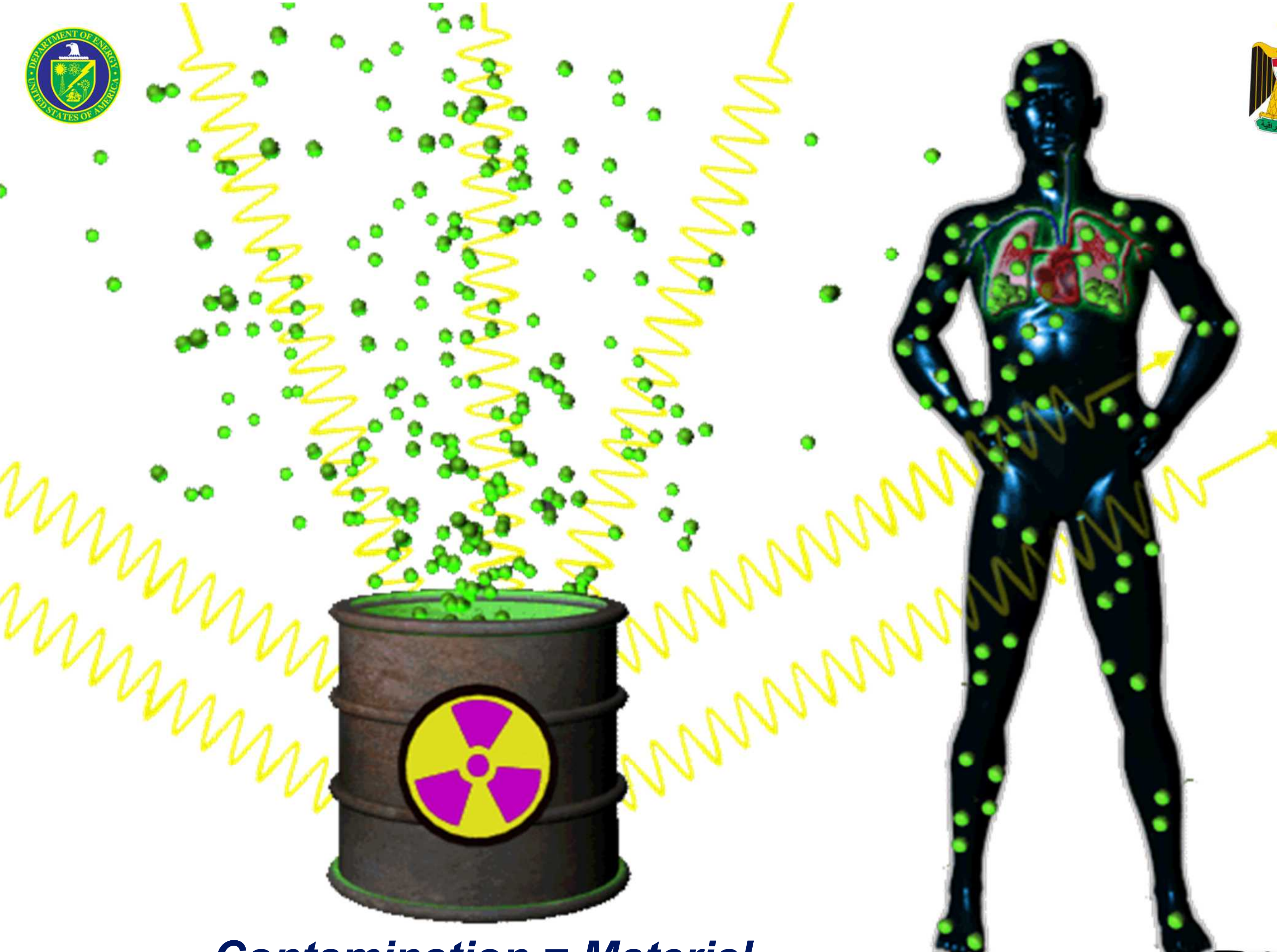
Radiation = Energy



Contamination = Material

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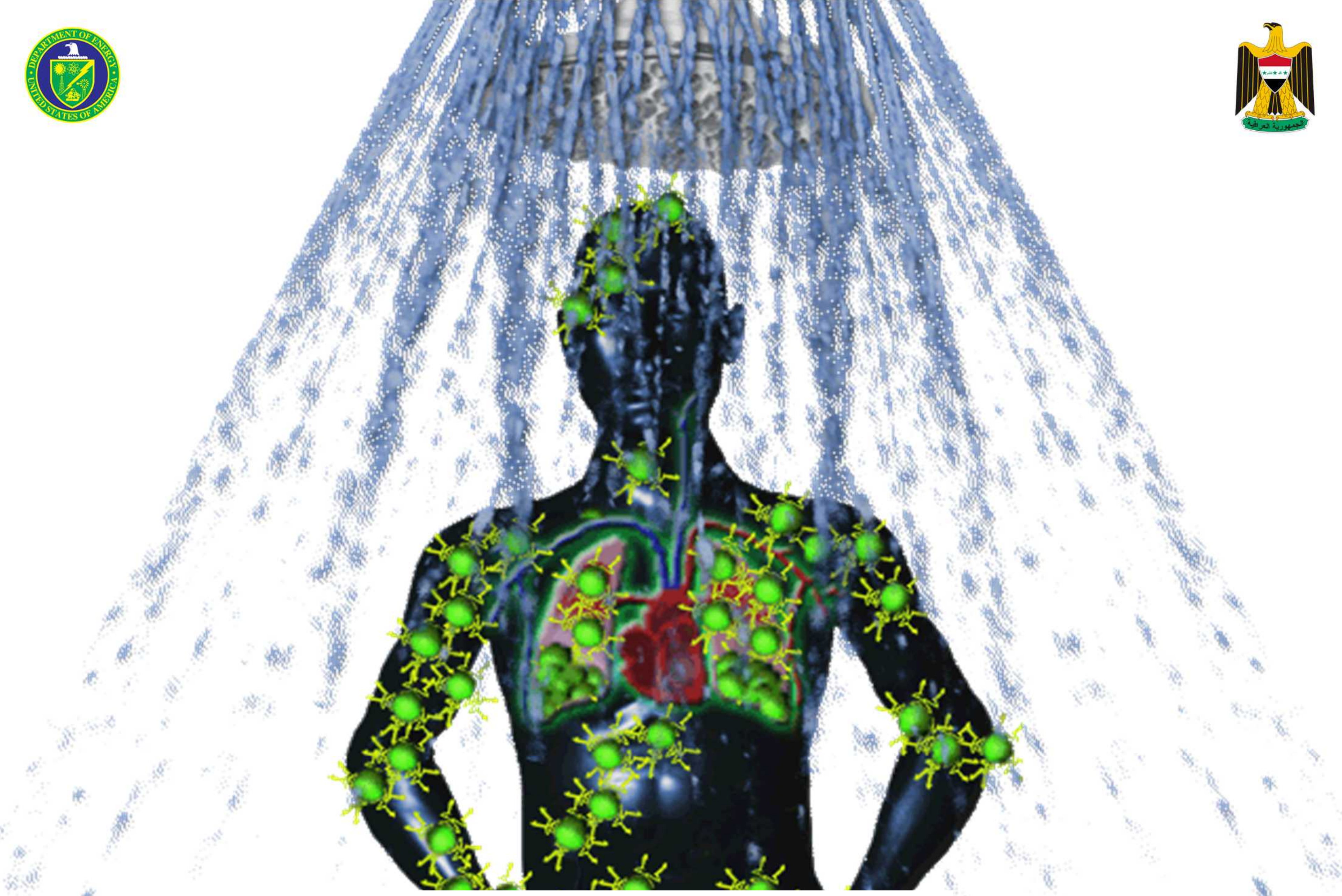

External contamination is easily removed

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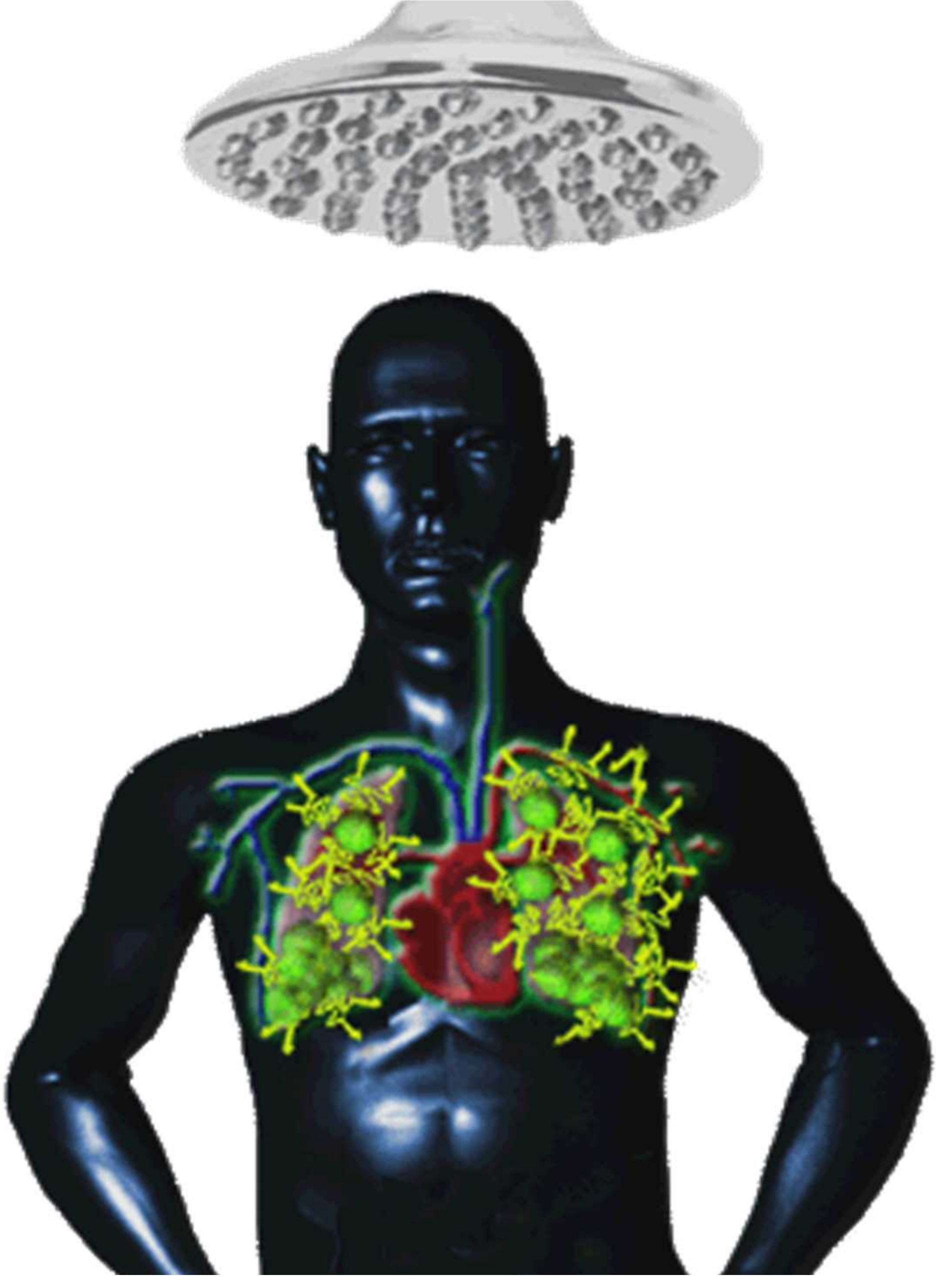
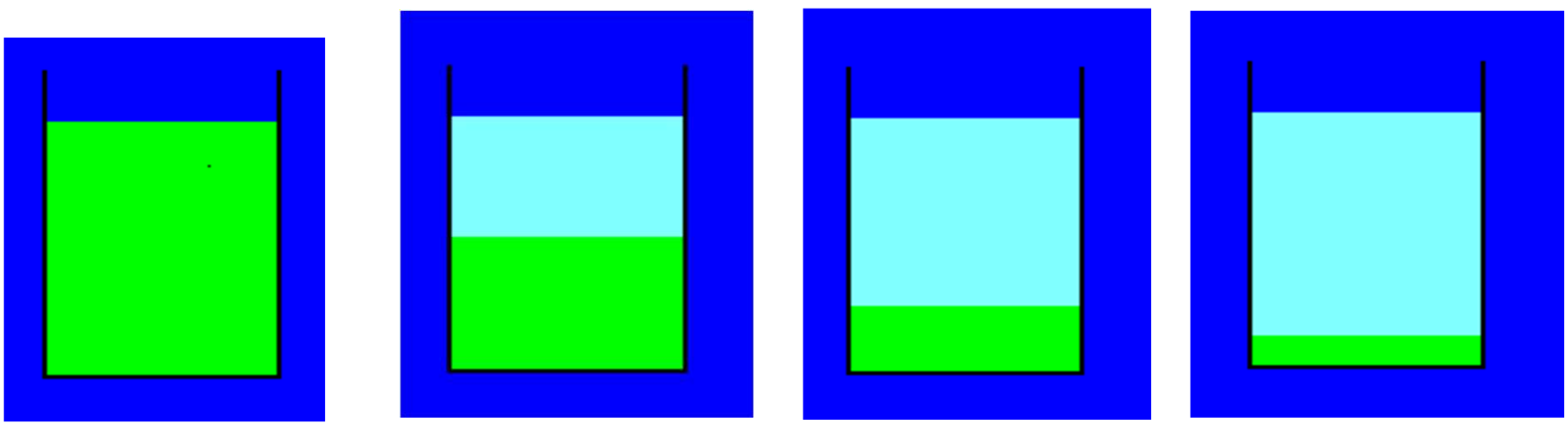


Internal contamination
is NOT easily removed

Radioactivity and Radioactive Half-Life

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

Example: Cobalt-60 half-life = 5.27 years



100 atoms today | 50 atoms after 5 yrs | 25 atoms after 10 yrs | 12 atoms after 15 yrs

Decay Chain

After 18 decays we arrive at stable:

$$^{206}_{82}Pb$$

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

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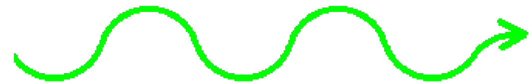
Units of Measure

- **Radiation ⟶ Energy**

  Roentgen, Gray / RAD, Sievert / Rem

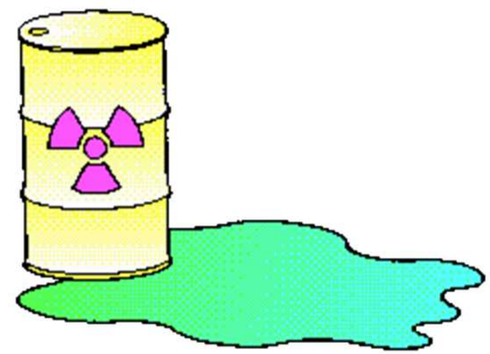


- **Radioactivity ⟶ Rate**

  dpm, dps, Becquerel, Curie

- **Contamination ⟶ Spread**

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



Measuring Radiation Energy
- Roentgen (R) -

- Unit for measuring <u>exposure</u>
- Defined only for <u>ionization in air</u>
- Applies only to <u>gamma</u> and <u>x-rays</u>
- <u>Not</u> 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 <u>any material</u>
- Applies to <u>all types of radiation</u>
- Does <u>not</u> take into account the potential effect that different types of radiation have on the body
- Special Unit = <u>R</u>adiation <u>A</u>bsorbed <u>D</u>ose (RAD)
- 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 = Roentgen Equivalent Man (Rem)
- 100 Rem = 1 Sv

Converting Rem to milliRem

1 Rem = 1000 milliRem (mRem)

Fill in the blanks

500 mRem = **0.5** Rem
(5 mSv)

0.8 Rem = **800** mRem
(8 mSv)

0.25 Rem = **250** mRem
(2.5 mSv)

Converting Sievert to Rem

1 Sievert = 100 Rem
(0.01 Sv = 1 Rem)

Fill in the blanks

0.02 Sv =	**2**	Rem
1.40 mSv =	**140**	mRem
4.0 mSv =	**0.4**	Rem
210 μSV =	**21**	mRem

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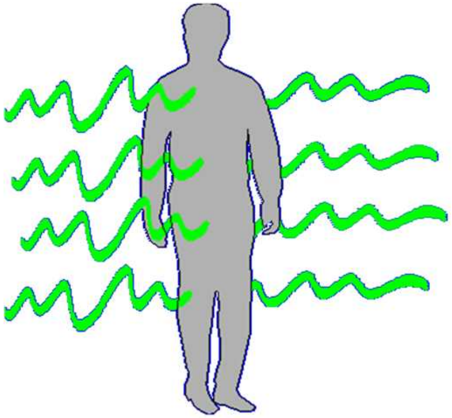
Dose vs. Dose Rate

- <u>Dose rate</u> is the *rate* at which you receive the dose.
- Dose rate = dose divided by time (Gray/hr, mGray/hr, RAD/hr, mRAD/hr).
- <u>Dose</u> is the *amount* of radiation you receive.

Dose = Dose Rate X Time



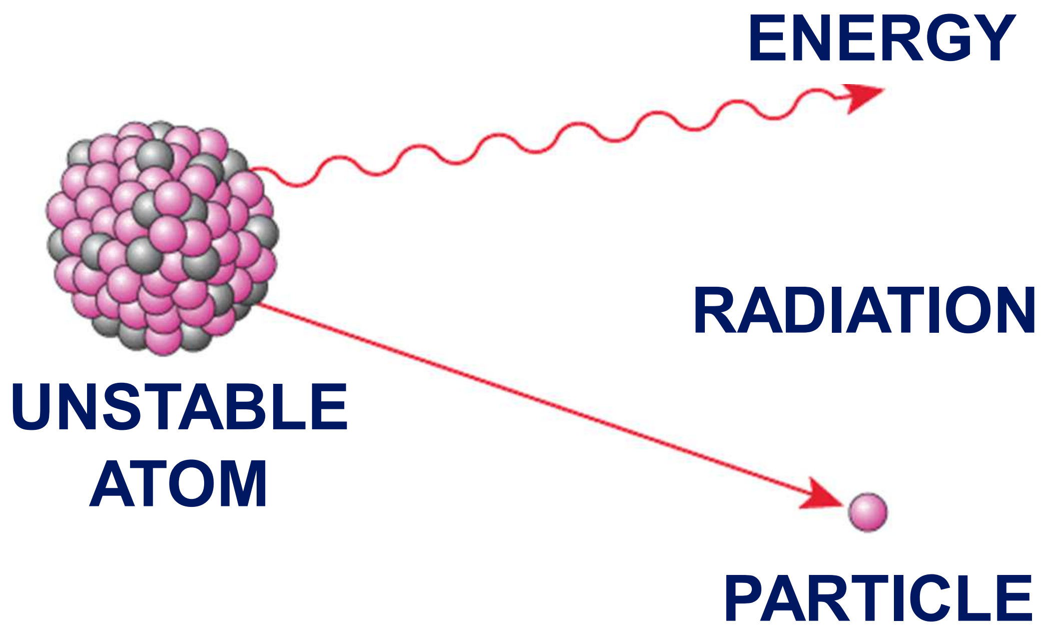
200 mRAD/hr

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

Answer: 400 mRAD (4 mGy)

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 <u>quantity</u> 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

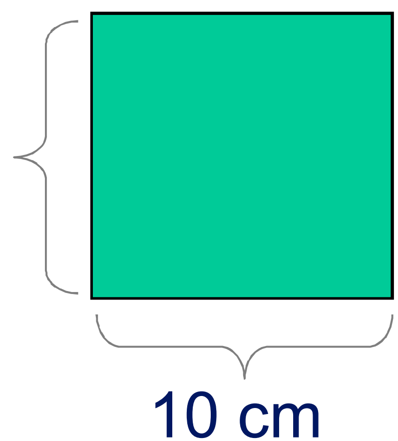
- **Curie (Ci)**
- **1 Ci = 3.7×10^{10} dps**

Marie Curie
1867 - 1934
Discovered radium & polonium

Contamination Units

How spread out is the radioactive material?

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



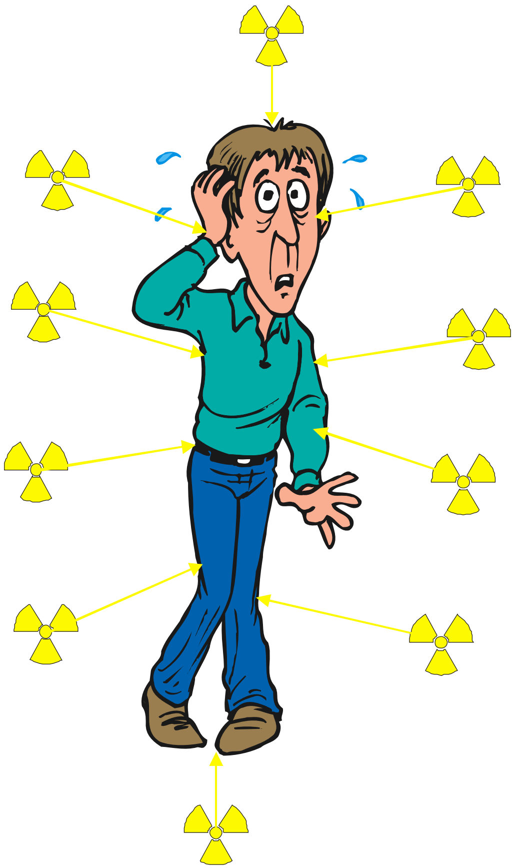
$$\frac{\text{dpm}}{100\ \text{cm}^2}$$

(dpm = disintegrations per minute)

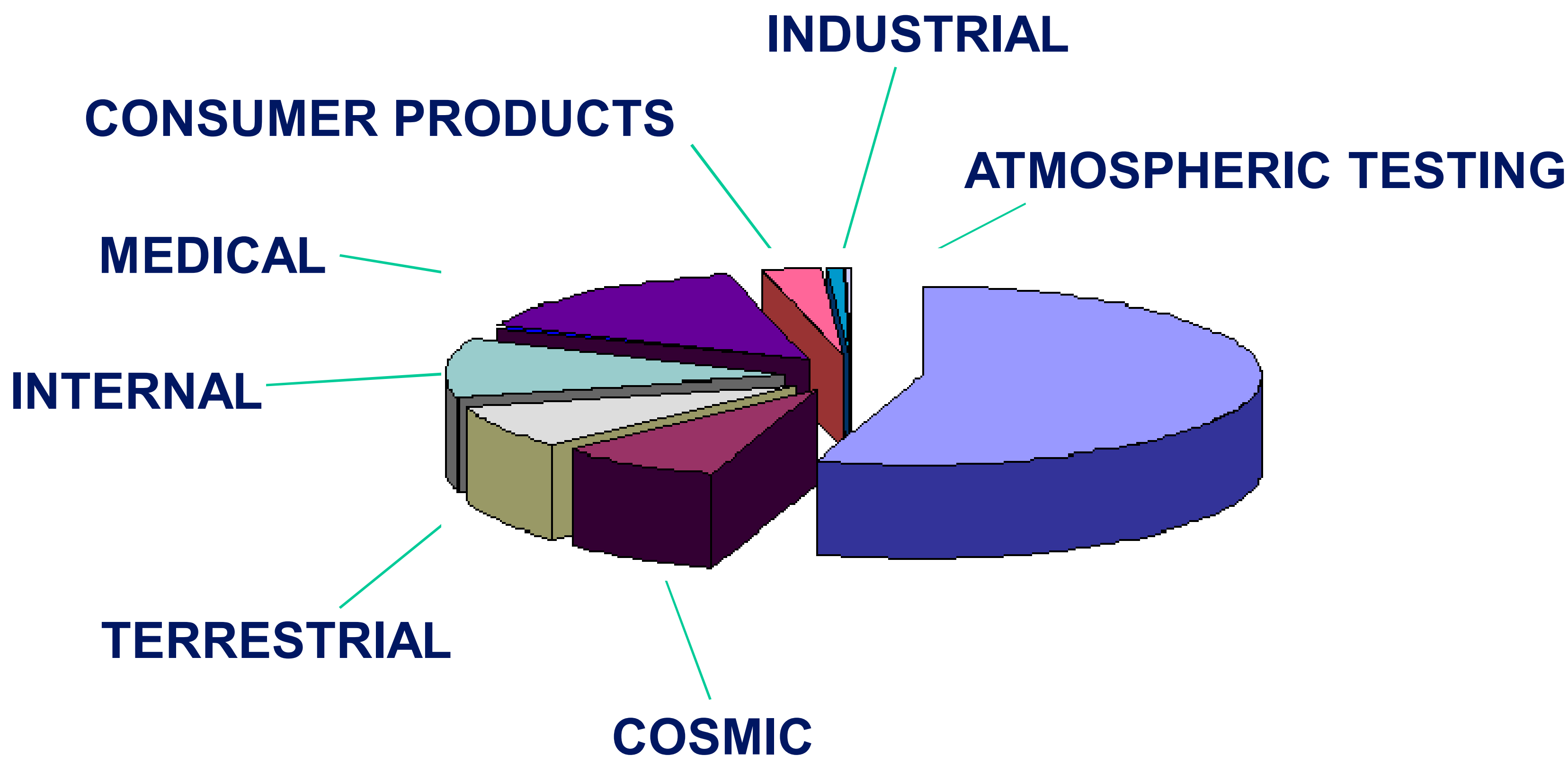
Background Sources of Ionizing Radiation

Background = natural *plus* man-made

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



Background Sources of Ionizing Radiation



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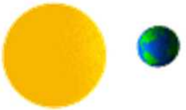
Natural Radiation Sources



SOURCE	AVG DOSE
COSMIC - sun & outer space	20 - 40 mrem/yr (0.2 – 0.4 mSv/yr)
TERRESTRIAL - Earth's crust	20 - 50 mrem/yr (0.2 – 0.5 mSv/yr)
INTERNAL - our own bodies	30 - 40 mrem/yr (0.3 – 0.4 mSv/yr)
RADON - Uranium in the Earth	120 - 200 mrem/yr (1.2 – 2 mSv/yr)

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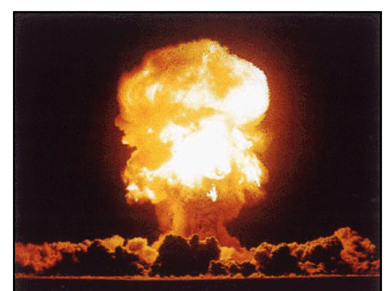
Man-Made Radiation Sources

SOURCE	AVG DOSE
Medical	40 - 54 mrem/yr (0.4 – 0.54 mSv/yr)
Consumer Products	10 mrem/yr (0.1 mSv/yr)
Industrial Uses	< 3 mrem/yr (< 0.03 mSv/yr)
Atmospheric Testing	< 1 mrem/yr (< 0.01 mSv/yr)



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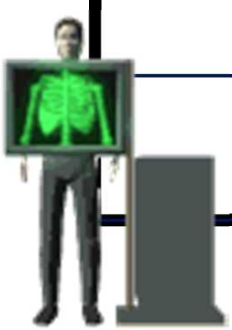
Radiation Doses
- Medical Procedures -

Radiation Therapy	600,000 mrem - tumor (6,000 mSv)
CAT Scan	5,800 mrem - head 1,500 mrem - lower spine (58 / 15 mSv)
Fluoroscope	5,000 mrem/min. - skin (50 mSv/min)
Mammogram	400 mrem - breast 0.2 mrem (low-dose screen) (4 - 0.002 mSv)
Dental X-Ray	55 - 65 mrem/shot - mouth (0.55 – 0.65 mSv)
Chest X-Ray	20 - 50 mrem/shot - chest (0.2 – 0.5 mSv/shot)



Radiation Doses
- Consumer Products -

PRODUCT	AVG DOSE
Cigarettes (1.5 packs/day)	8,000 mrem/yr - lungs (80 mSv/yr)
Dental Porcelain (old)	60,000 rem/yr - gums (600 mSv/yr)
Tinted Glasses (old)	4,000 rem/yr - eyes (40 mSv/yr)
Building Materials	7 mrem/yr - whole-body (0.07 mSv/yr)
Radium Dial Watch	6 mrem/yr - whole-body (0.06 mSv/yr)
Smoke Detector	1 mrem/yr - whole-body (0.01 mSv/yr)

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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)

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