

Radioactive Materials Safety Training

P. John Zoll
Radiation Safety Officer
313 Mellon Institute
Email: jzoll@andrew.cmu.edu
Office phone: 268-7502
Emergency phone: (412) 527-5617





Instruction

- Radionuclide User Training
 - web-based radionuclide basic power point presentation
 - written exam
 - practical radionuclide safety class
 - questions or concerns addressed by the Radiation Safety (RS) staff





Introduction

- Radiation and Radioactive Materials (RAM) are valuable tools in research.
- There are more than 30 labs using radionuclides at Carnegie Mellon University (CMU).
- RAM are used in a variety of disciplines ranging from the biological sciences to physics.



Purpose of Training

- Initial RS training
 - unsealed sources of ionizing radiation
 - sealed sources of ionizing radiation
 - fundamentals of radiation
 - definitions and units of radiation
 - background radiation
 - occupational limits
 - biological effects
 - protection principles
 - hazard evaluation and control
 - university specific license and program requirements





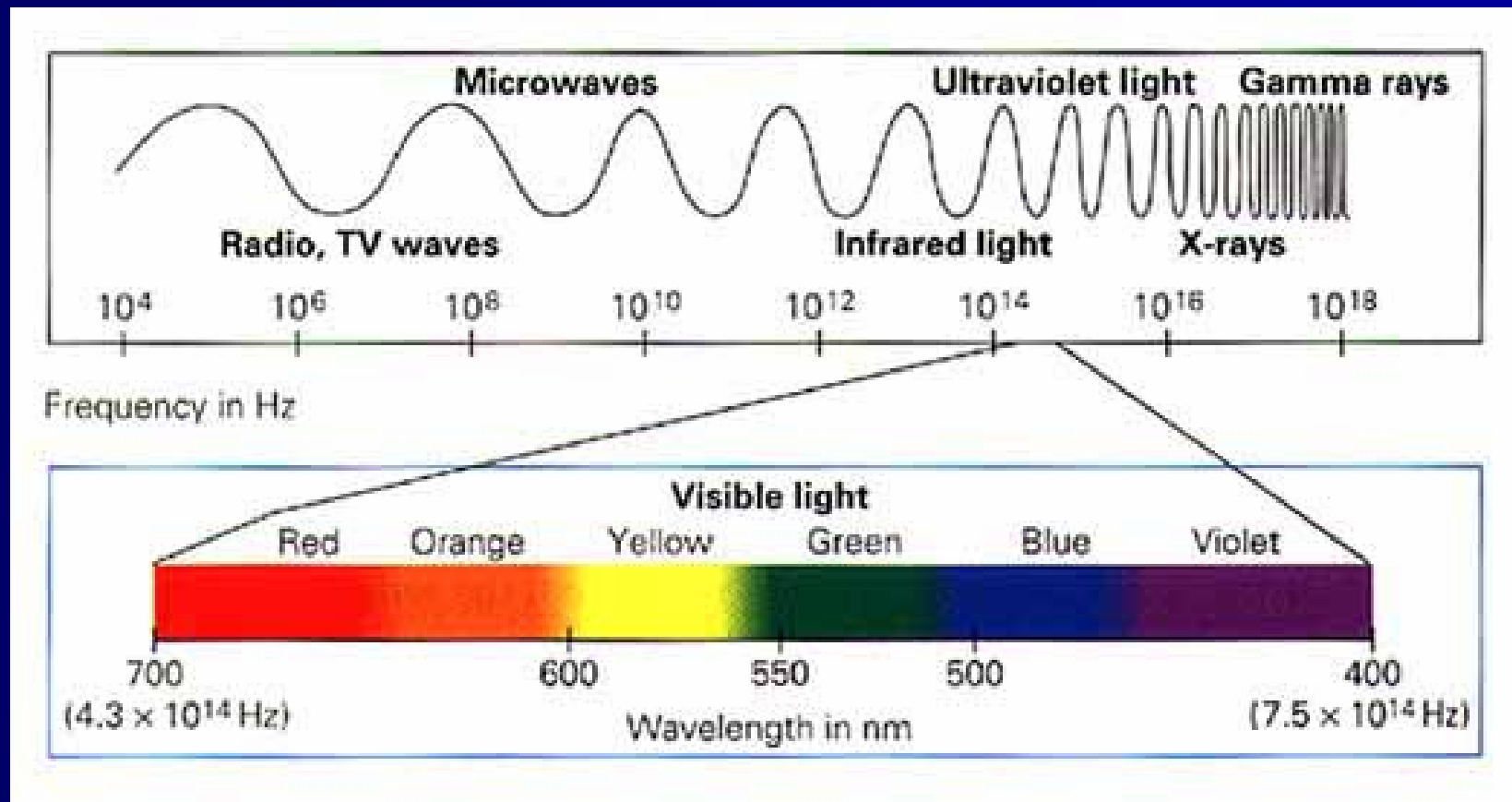
Radiation and You

- Radiation and RAMs are safe if used properly.
- Your exposure can never realistically be zero, because background radiation is always present.



Radiation

Part of the electromagnetic spectrum



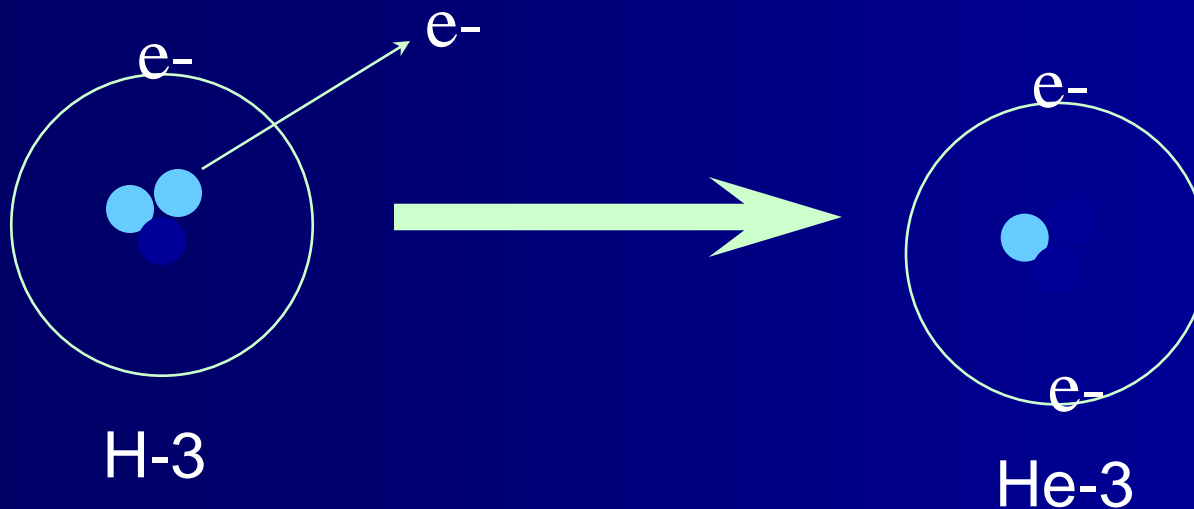


Types of Radiation

- Non-Ionizing
 - microwaves
 - sunlight
 - infrared waves
 - radiowaves
 - lasers
- Ionizing
 - Occurs from the addition or removal of electrons from neutral atoms.

Where Does Ionizing Radiation Originate?

Radiation results from an unstable nucleus



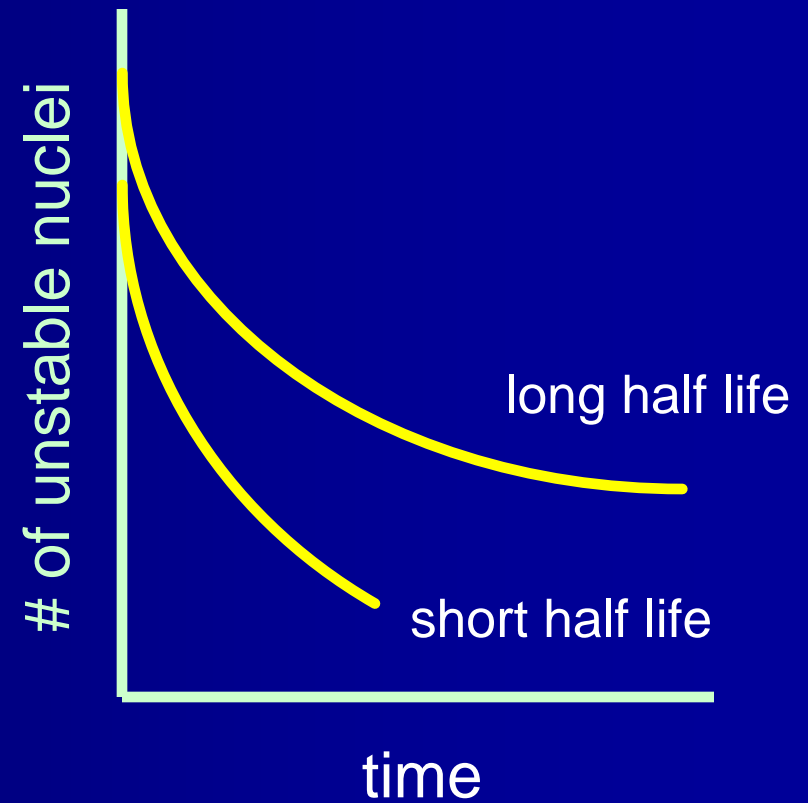
This is called **radioactive decay**





Radioactive Decay

- Radioactive decay is a random event.
- Half life is the time it takes for one-half of the radioactive atoms present to disintegrate or decay.



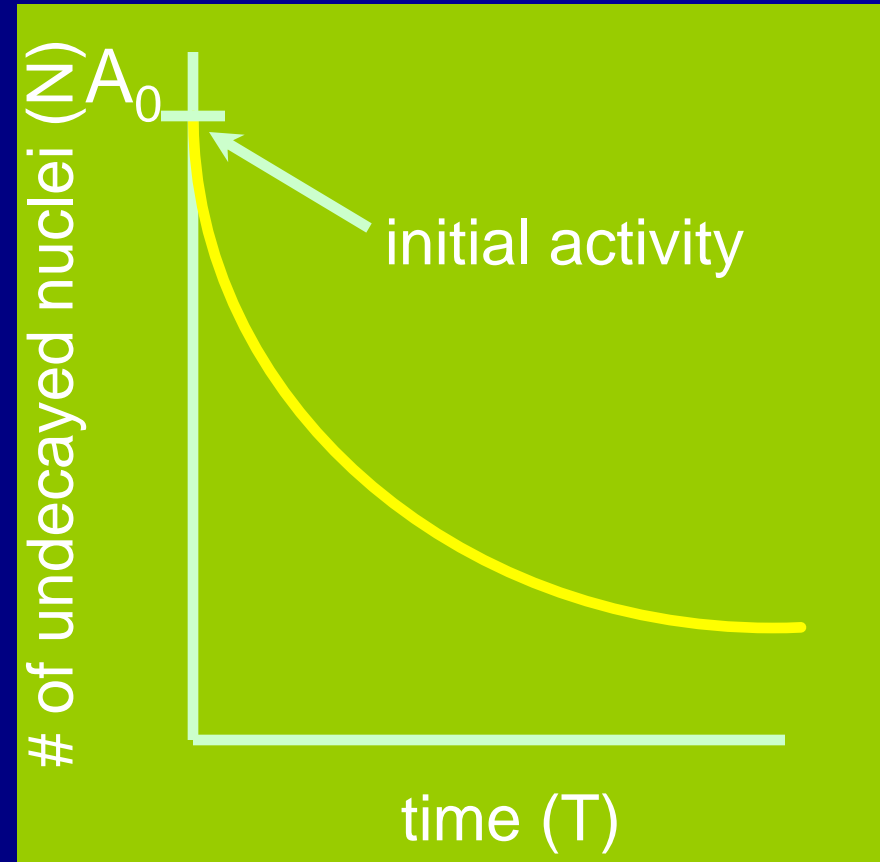
Radioactive Decay Equation

Activity (A):
number of nuclei
(N) that decay per
unit time

$$A(t) = dN/dt = -\lambda N(t)$$

$$A(t) = A_0 e^{-\lambda t}$$

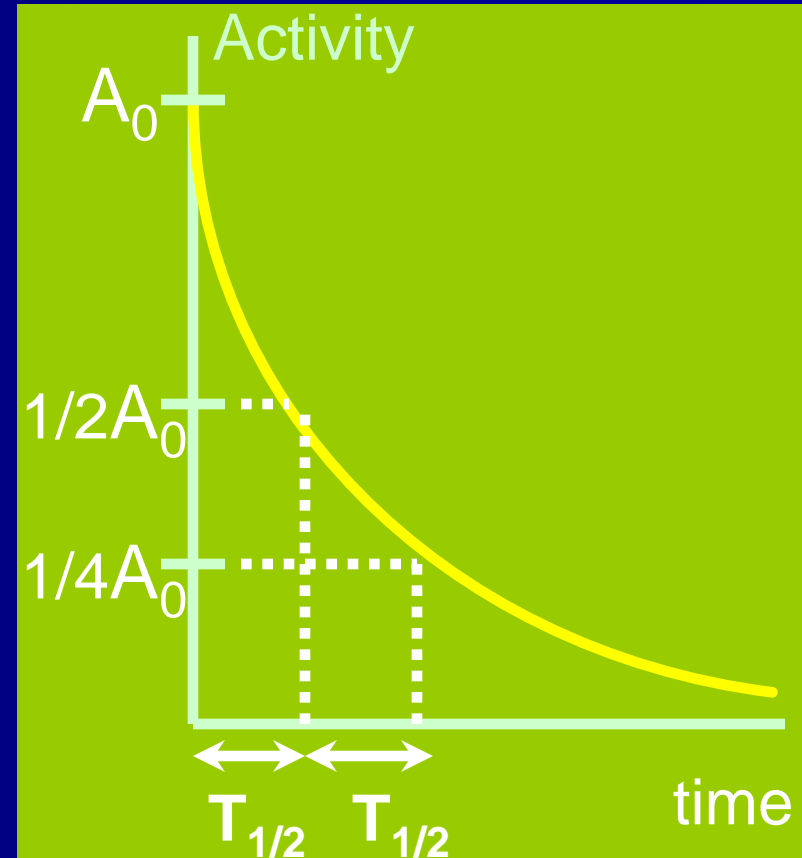
λ is called the decay
constant



Half-life & the Decay Constant

Half-life ($T_{1/2}$) is related to the decay constant according to this equation:

$$T_{1/2} = (\ln 2)/\lambda$$



Properties of Ionizing Radiation



Particles

■ Alpha, α

- Large, approximates a He nucleus

■ Beta, β

- Equivalent of an e^- emitted from a nucleus

Photons

■ Gamma, γ

- Originates in nucleus

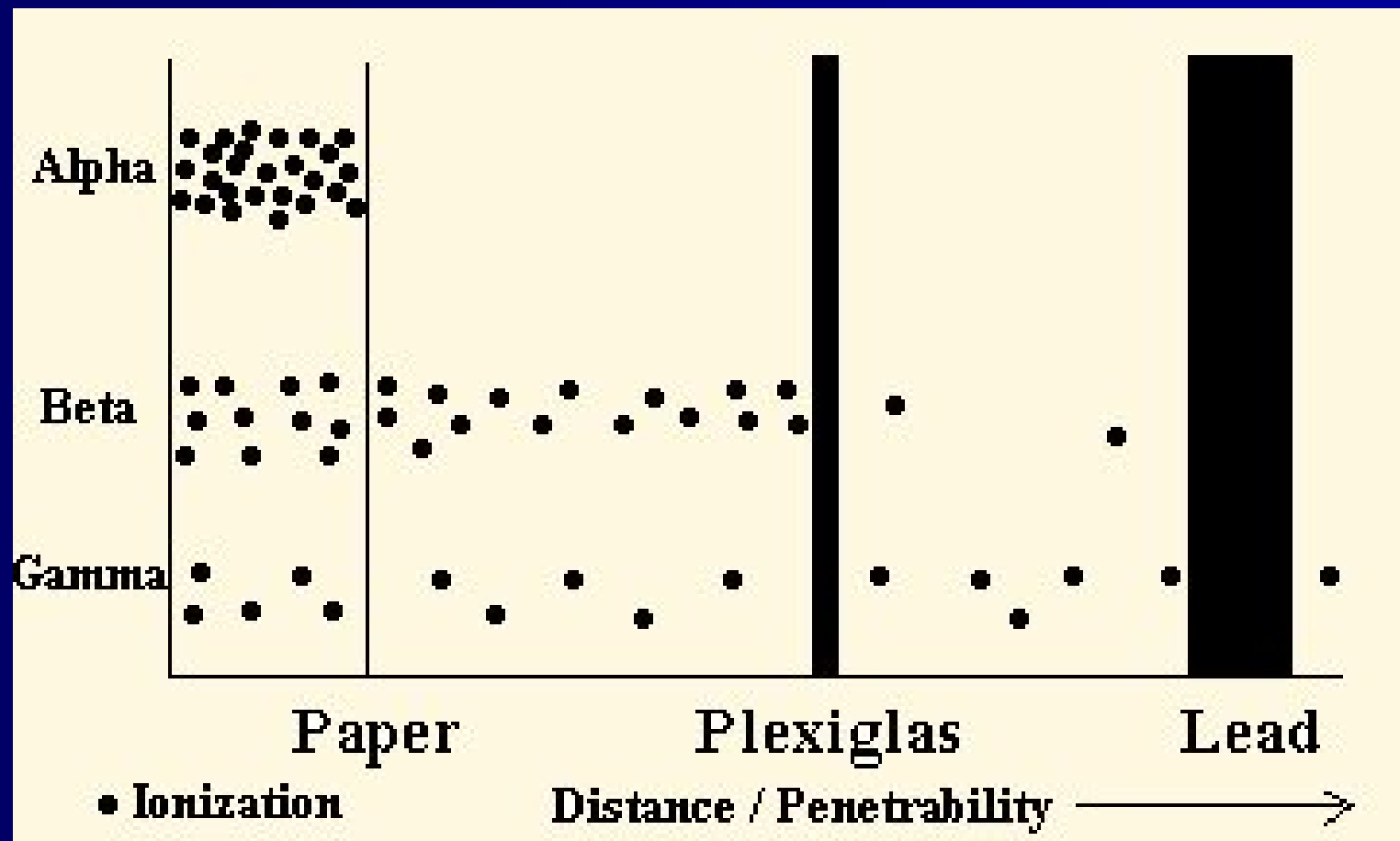
■ X-ray, X

- Originates from displacement of orbital e^-





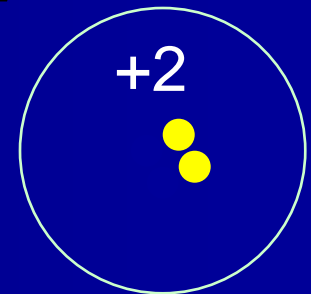
Penetrability



Properties

Alpha Particles

- consist of 2 protons and 2 neutrons
- have a +2 charge
- can only travel up to a few centimeters in air
- are stopped by the protective layer of your skin



Properties

Beta Particles

Beta particles:

- are either an electron (-1 charge) or positron (+1 charge)
- travel about 12 feet per MeV in air
- higher energy betas should be shielded with low Z (low density) materials, such as plexiglass/lucite or wood

β^+

β^-





Properties

Gamma Rays

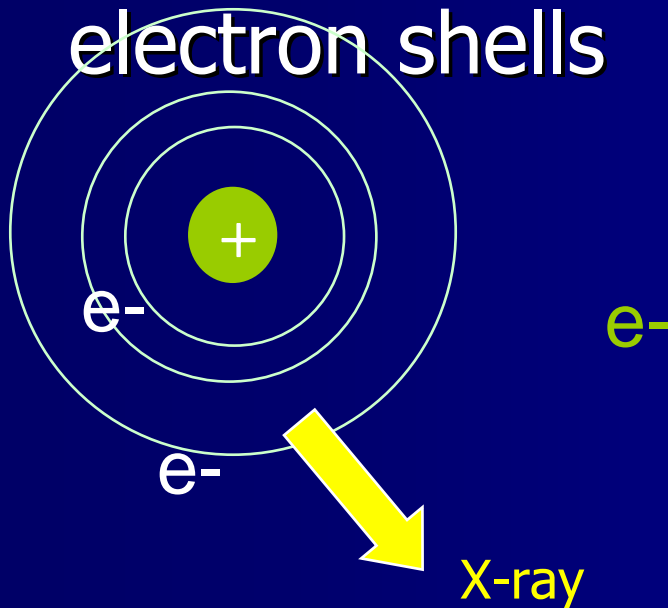
Gamma rays:

- are photons that originate from the nucleus of the atom
- do not carry a charge
- can cause ionizations when they interact with other atoms
- should be shielded with high Z materials, such as lead, if appropriate

Properties

Characteristic X-rays

Characteristic x-rays are generated when electrons are displaced and fall from higher energy to lower energy electron shells

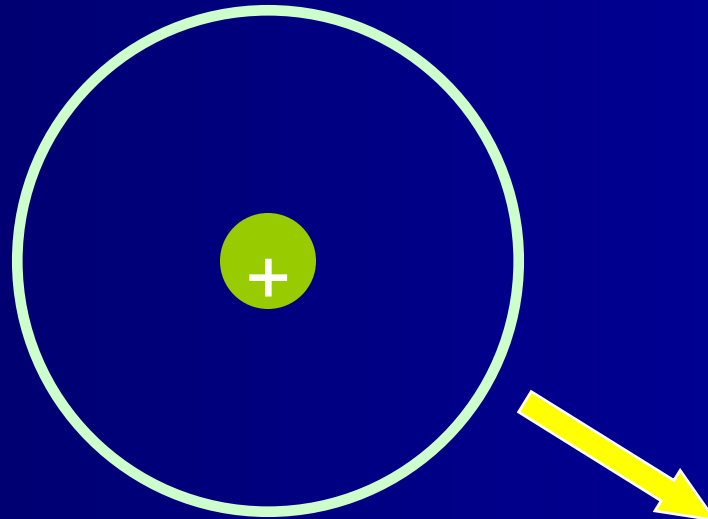


Properties

Bremsstrahlung X-rays

Bremsstrahlung x-rays are created when electrons are slowed down in the field of a nucleus

e⁻



X-ray





Radiation Measurement

- Quantity, also called Activity
 - Curie
 - Bequerel
- Intensity
 - Exposure
 - Absorbed Dose
 - Dose Equivalent





What Is a Curie?

- A commonly-used unit for measuring activity is the **curie (Ci)**.
- One curie is equal to 2.2×10^{12} disintegrations per minute (dpm).
- Typical activities found in a university lab are in the microcurie (μCi), to millicurie (mCi) range.
- Named for Marie Curie





CPM & DPM

- CPM is the counts per minute that a detector "sees".
- DPM or Disintegrations per Minute, are the actual events undertaken by the atom
- Since detectors aren't 100% efficient...

$$\text{DPM} = \text{CPM} / \text{Detector Efficiency}$$





What is a rem?

- The most commonly used unit for measuring radiation dose in people is the rem.
- Since the rem is a relatively large unit, it is more common to use the millirem (mrem), which is 1/1000th of a rem.
- But what does rem stand for?



A Rock Band?

An acronym for
or
"Roentgen Equivalent Mammal"

Definition: a rem is equal to the absorbed dose in rads multiplied by the quality factor, distribution factor, and any other necessary modifying factors



Natural Background Radiation

We are all exposed to ionizing radiation from natural sources at all times. This radiation is called natural background radiation, and its main sources are the following:

- radioactive substances in the earth's crust
- emanation of radioactive gas from the earth
- cosmic rays from outer space which bombard the earth
- trace amounts of radioactivity in the body.



Background Radiation (mrem)

Natural sources = 300

Occupational = 0.9

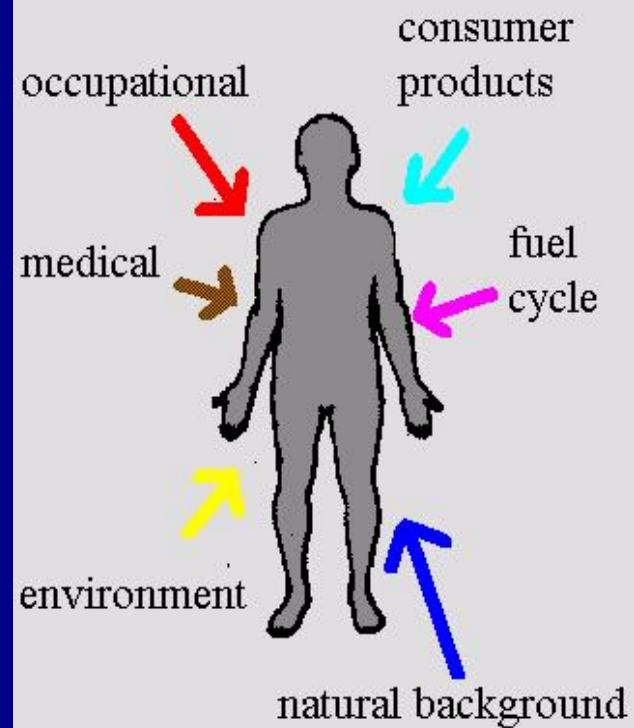
Nuclear = 0.05

Consumer = 5 - 13

Environmental = 0.06

Medical = 53

Sources of Radiation



(from NCRP Report 93)

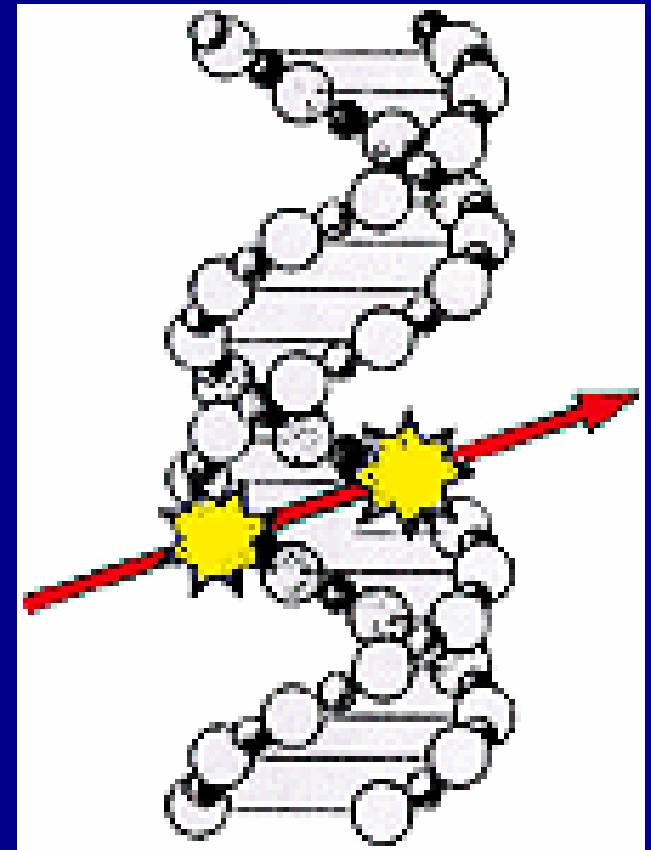
Biological Effects of Ionizing Radiation

- Mechanism of Damage
- Tissue Sensitivity
- Relative Risk
- Prompt vs. Delayed Effects
- Cancer Risks
- Teratogenic Effects



Mechanism of Damage

- Produce free radicals.
- Break chemical bonds.
- Produce new chemical bonds and cross-linkage between macromolecules.
- Damage molecules that regulate vital cell processes (e.g. DNA, RNA, proteins).





Tissue Sensitivity

- Proportional to the rate of proliferation of its cells
- Those cells that are the least specialized are the most radio-sensitive
- Tissues and organs are listed in the table to the left are from most radiosensitive to least radiosensitive:

Increasing Sensitivity----->

Blood forming organs
Reproductive organs
Skin
Bone and teeth
Muscle
Nervous System



Somatic

"Prompt" Effects

Acute Dose (rem)

Syndrome

100 - 1000



Hemopoietic

1000 - 5000



Gastrointestinal

5000 - 10000



Central Nervous
System





Cancer Risks

Excess Cancer Deaths after acute, one-time exposure to 10 rem per 100,000 People (BEIR V)

Adult Leukemia	95
Cancer of digestive system	230
Cancer of respiratory system	170

Leukemia risk (without excess 10 rem) was 685 excess deaths per 100,000 people (1980 Vital Statistics of the U.S.)





Teratogenic Effects

- **Teratogenic Effects** relate to the interference with the development of an embryo caused by a hazardous substance or agent





Maternal Factors & Teratogenic Effects

Maternal Factor	Pregnancy Outcome	Occurrence
Smoking		
< 1 pack/day	Babies weigh 5-9 oz less than avg	1 in 5
> 1 pack/day	Infant death	1 in 3
	Infant death	
Alcohol		
2 drinks/day	Babies weigh 2-6 oz less than avg	
2-4 drinks/day	Fetal alcohol syndrome	1 in 10
> 4 drinks/day	Fetal alcohol syndrome	1 in 3
Chronic alcoholism	Fetal alcohol syndrome	1 in 3 to 1 in 2
Radiation		
1 rem	Childhood leukemia deaths before 12 yrs	1 in 3333
1 rem	Other childhood cancer deaths	1 in 3571



Occupational Radiation Exposure Limits

- Whole body = 5,000 mrem/year
- Extremities = 50,000 mrem/year
- Eye = 15,000 mrem/year
- Fetus = 500 mrem/gestation period (declared pregnancy)
- Minor Occupational = 100 mrem/year
- Member of Public = 100 mrem/year





ALARA

Practice of keeping exposure to radiation:

As

LOW

As

Reasonably

Achievable

- CMU is committed to keeping radiation exposures to personnel ALARA



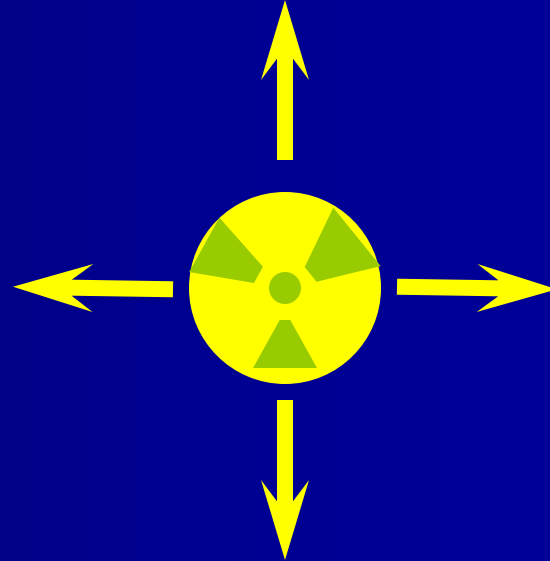
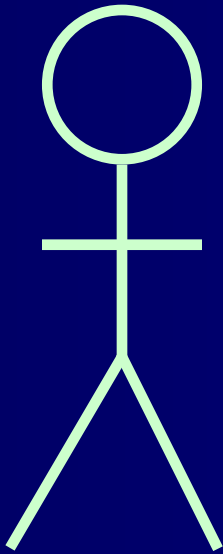
Radiation Protection

- The three principles of radiation protection:
 - Time
 - Distance
 - Shielding



Time

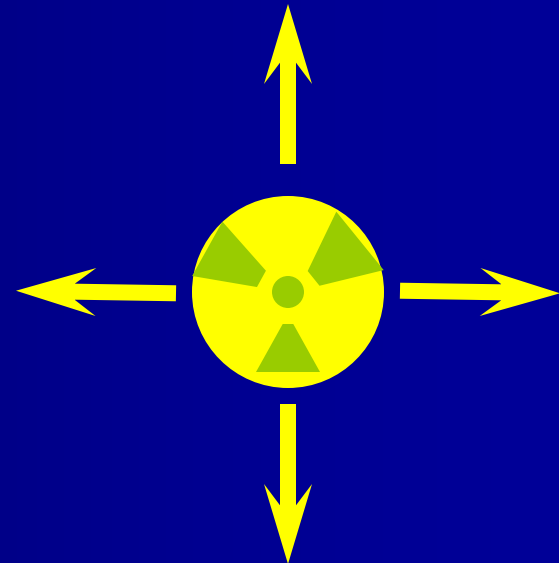
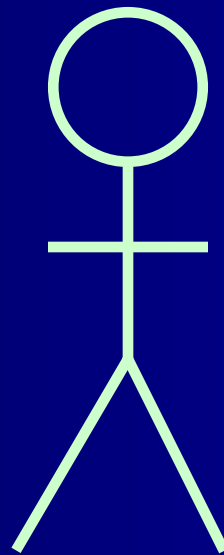
- Decreasing the time spent near a radiation source decreases radiation exposure





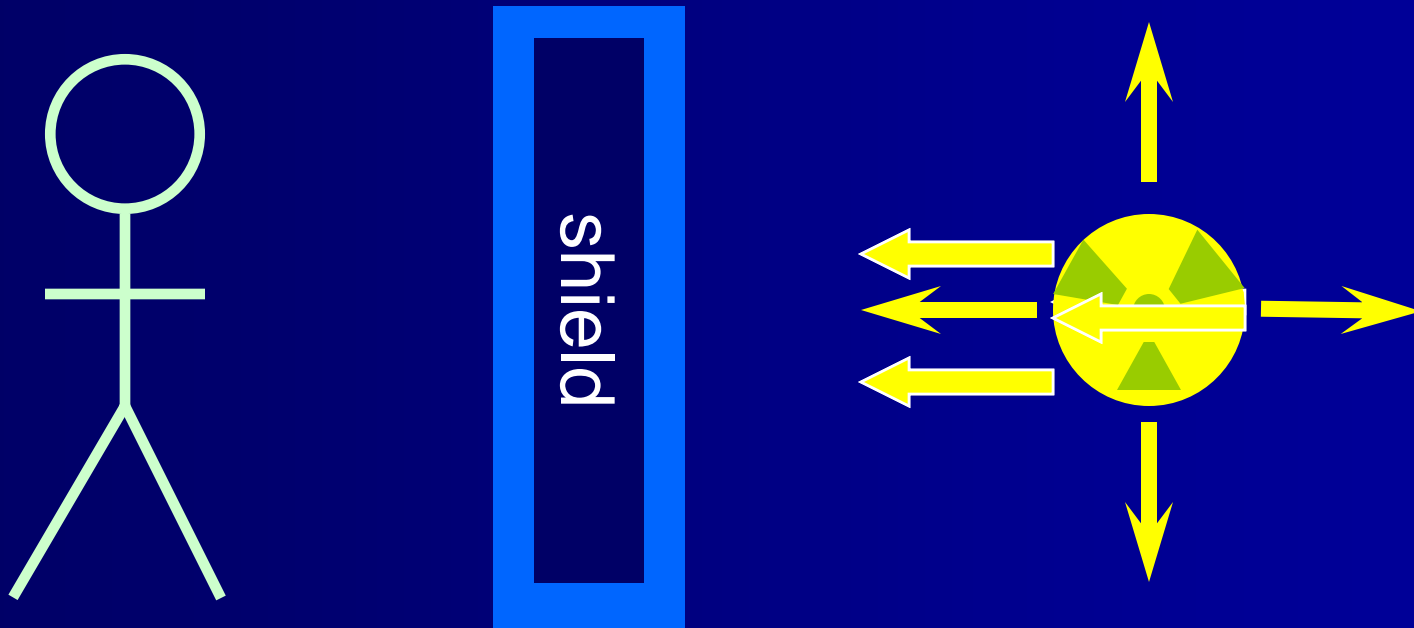
Distance

- Increasing the distance from a radiation source decreases radiation exposure



Shielding

- Increasing the shielding of a radiation source decreases radiation exposure





Shielding Beta Emitters

- H-3, C-14, S-35 do not require shielding for the quantities typically used
- Higher energy beta emitters, such as P-32, may need to be shielded
- Shield with low Z materials, such as plexiglass or wood
- Do NOT shield with high Z materials, such as lead - you can actually generate additional radiation in the form of x-rays!
remember bremsstrahlung?

Shielding Gamma Emitters

- Lead shielding may be required for certain quantities of gamma emitters in use, such as I-125 or Cr-51
- If lead shielding is used, be careful not to contaminate it with long-lived radionuclides, use of absorbent coverings can prevent this



Protective Clothing

- gloves
 - lab coat
 - eyewear
 - closed toe footwear
- (no sandals!)





Contamination Control

- Change gloves frequently, especially after handling RAM or contaminated items
- Monitor yourself and your work area frequently for contamination
- Make sure to wash your hands after finishing an experiment



Avoid Ingesting RAM

- Don't bring hands or objects to your mouth when performing an experiment
- Eating, drinking, smoking and applying cosmetics are strictly forbidden in radionuclide use areas
- Never mouth pipette
- Food doesn't belong in a refrigerator which stores RAM

(food shouldn't be in a lab, period)





Avoid Inhaling RAM



- Make sure that you have proper ventilation for your experiment
- When using volatile materials, use a fume hood which has been certified

Radioactive Signs & Labels

- Radionuclide use areas should be clearly marked
- Use warning signs/labels on
 - work areas
 - radioactive waste containers
 - sinks
 - refrigerators
 - equipment
- Radiation Safety must be contacted whenever these items & areas need to be removed from dedicated RAM use





Using H-3, C-14 & S-35

- Shielding is not needed for quantities typically in use at CMU
- Survey meters are ineffective for detecting these radionuclides, therefore, contamination surveys must be performed using wipes and a Liquid Scintillation Counter (LSC)



Using P-32

- Shielding should be constructed from a low density material such as wood or plexiglass
- Do NOT use lead shielding, x-rays can be generated





Using Free I-125 (NaI)

- Perform iodination as quickly as possible in a certified fume hood.
- Reduce (iodine to iodide) all fractions, liquid waste and equipment used ASAP.
- Store unused portions and items which cannot be reduced inside a sealed bag with activated charcoal in a fume hood.
- First time iodinators will be observed by RS staff prior to iodinating alone



Emergency Procedures

- Protection of personnel is **always** the first priority
- Call 268-2323 and 268-7502 in case of:
 - serious injury combined with radiation exposure/radioactive contamination
 - fire or explosion in a radionuclide area
- In the case of high radiation exposure without contamination, contact the RS Office (8-7502)



And Another Thing About Spills...



- You will **not** be penalized for reporting a spill, but on the other hand...





Contamination Surveys

- Required after EVERY use of unsealed RAM
- Survey
 - Yourself
 - Entire work area
 - Any non-radioactive area that has the potential of becoming contaminated
- Use a survey meter first

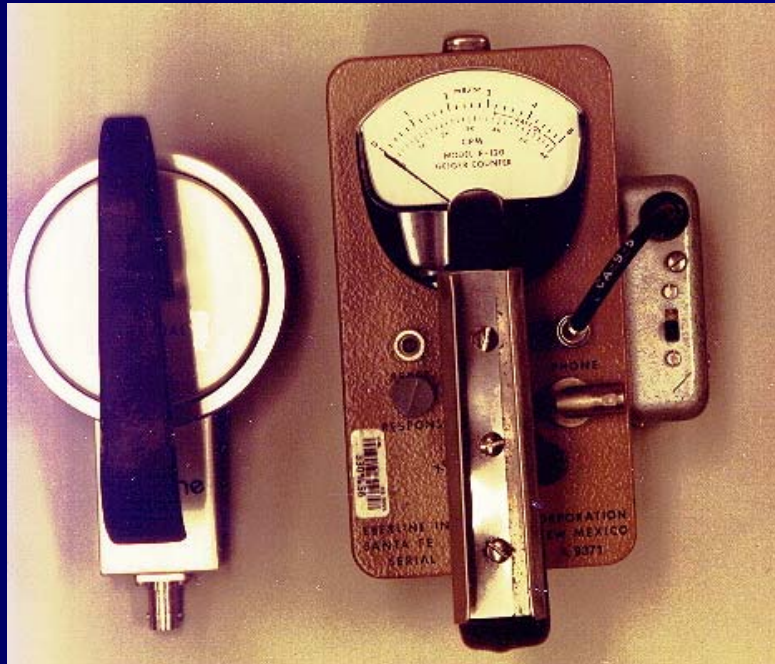
Contamination is indicated by readings that are 2x bkg

 - Storage/waste areas must be < 0.1 mR/hr
- Follow up by performing and documenting a wipe test and counting on a LSC
 - Contamination ≥ 200 dpm must be cleaned and retested until below 200 dpm

Note: while P-32 is easily detectable with a survey meter, H-3, C-14 & S-35 have lower energies and a wipe test must be used for detection

Step-by-step Guide to Direct Monitoring

Before You Start



- 1 Don protective equipment (e.g, gloves).
- 2 Check your Geiger counter:
 - battery test
 - note background radiation level
 - turn on speaker
 - check probe with check source

Step-by-step Guide to Direct Monitoring



How-to

- 3 Switch Geiger counter to lowest multiplier, usually X1
- 4 Hold probe window 1 cm from the surface you are surveying
- 5 Move probe over surface at a rate of about 2-3 cm/second
- 6 If/when you hear an increase in clicks, freeze the probe and move in an expanding circle until the size and intensity of the contamination is determined





Personnel Monitoring



Whole Body Thermoluminescent Dosimeter (TLD)



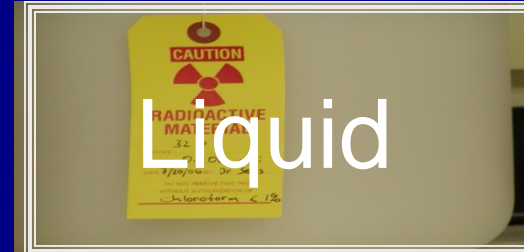
Ring TLD

- Personnel monitoring devices are assigned to those persons likely to receive 10% of the annual dose limit of 5 rem
- Dosimetry and Training Application (*Complete and bring to practical training class.*)





Radioactive Waste Types





Radioactive Waste

- Segregate waste by radionuclide first, then by:
 - Dry waste (may include small vials containing liquids providing there is sufficient absorbent material to prevent liquids from pooling at the bottom)
 - Liquid wastes from all RAM lab processes (NO SINK DISPOSALS!)
 - Organic liquids from inorganic liquid wastes
 - Sharps
 - Liquid Scintillation Vials
- Dry waste containers must be lined with yellow bags provided by RS

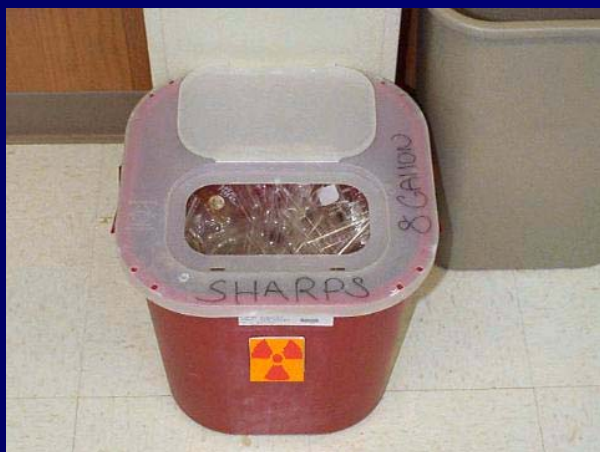


Liquid Waste

Store only in containers provided by RS with secondary containment

- Filter out solids (use 60 mesh screen)
- pH must be adjusted to between 6.8 and 8.0
- Be sure to include all chemical components on tag

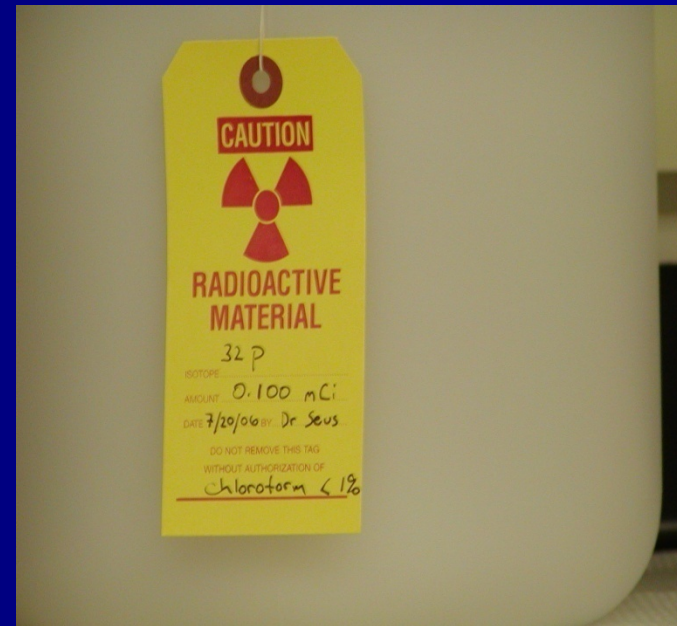
Radioactive "Sharps"



- Radioactive sharps are items such as Pasteur pipettes, syringes and hypodermic needles
- Most glass items (test tubes, vials, etc.) can be decontaminated and should *not* be disposed of as radioactive sharps
- Contact the RS Office (8-7502) for radioactive sharps containers

Radioactive Waste Contents Tag

- Tag used for all rad waste containers
- Fill out all data fields:
 - Isotope
 - Amount (in mCi)
 - Date
 - By (PI's name)
- "Chloroform, 1%" added to denote chemical constituent in liquid waste container





Radioactive Carcasses

- Prior arrangements must be made with RS (8-7502) for disposal of radioactive carcasses



Radioactive Waste Pickup

- To request a pickup of radioactive waste call the RS Office
- Have the following information ready:
 - caller's and authorization holder's name
 - waste location and lab phone
 - whether the waste is liquid or solid
 - radionuclides and their activities
 - number of containers to be picked up
- Close bag with a plastic zip tie (provided) and affix tag



Radionuclide Authorization



- The principal investigator of each RAM lab is issued a Radionuclide Authorization (RA)
- This document should be present in the laboratory's RAM logbook
- The RA tells you where and how your lab is allowed to use RAM

**READ YOUR LAB'S RADIONUCLIDE
AUTHORIZATION!**





Radiation Worker's Rights

- These rights are illustrated in the Notice to Employees. This notice is posted in all areas having RAM. You are guaranteed the right to:
 - Work in safe environment
 - Have your questions and concerns addressed
 - Speak to a regulator (NRC, PA DEP) if questions or concerns are not properly addressed
 - Report unsafe work practices
- Read Notice to Employees
- [PA DEP](#)



Radiation Worker Responsibilities

- Follow the rules and attempt to maintain ALARA at all times.
- Do not escort untrained personnel or contractors.
- Adhere to safety practices instituted to minimize risk.





For Further Information...

- To have questions addressed and to schedule the practical session, contact the RS Office
 - Phone: 268-7502
 - jzoll@andrew.cmu.edu
 - Web site [CMU EH&S - Radiation](#)
 - Location 313 Mellon Institute





On-line Evaluation

- You must complete the on-line evaluation
- After completing the on-line evaluation, you will be prompted to submit a request to obtain the practical portion of the radiation safety training.

[Link to the On-line Evaluation](#)

