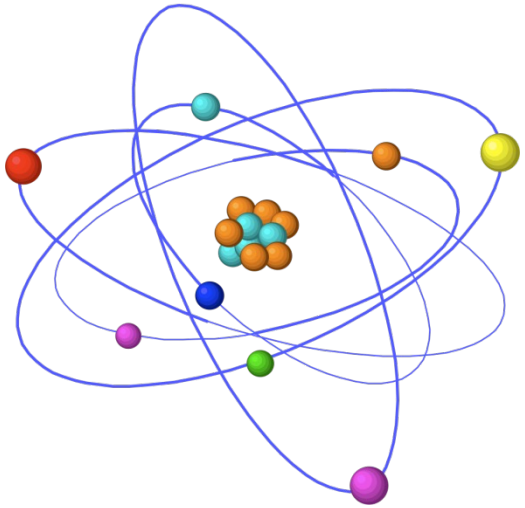
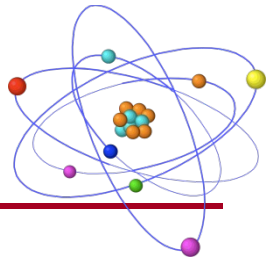
Radiation Safety Training



Jan Rydzewski, Ph.D., RSO

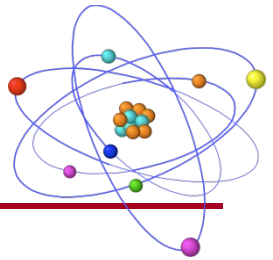
Objectives



- Radiation Safety Fundamentals
- On-the-Job Training
- Annual Refresher Training

FULFILLS REGULATORY REQUIREMENTS

Outline

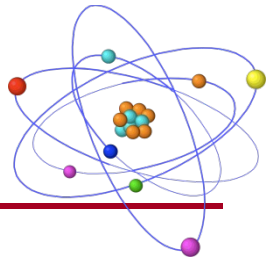


1. Introduction
2. MMRI Contacts & Responsibilities
3. Radiation Physics & Interaction with Matter
4. Sources of Radiation & Background Radiation
5. Occupational Radiation Dose & Dose Limits
6. Biological Effects of Ionizing Radiation
7. Monitoring – Dosimetry & Survey Meters
8. Safe Handling Practices and Minimizing Exposures **ALARA**
9. Man-made X-rays (Cabinet X-ray machines)
10. Federal and State Regulations
11. MMRI Radiation Safety Policies and Procedures

Introduction

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

Responsibility



Radiation Safety Officer (RSO)

Jan Rydzewski

– jrydzewski@mmrx.org

Alternate RSO

Ajith Welihinda

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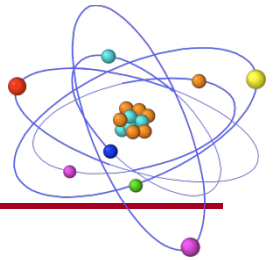
For documents pertaining to safety and licensing see the MMRI Radiation Safety Manual and Radiation Safety Program Intranet page:

Affiliates: http://50.0.117.214

MMRI Employees: http://192.168.1.24

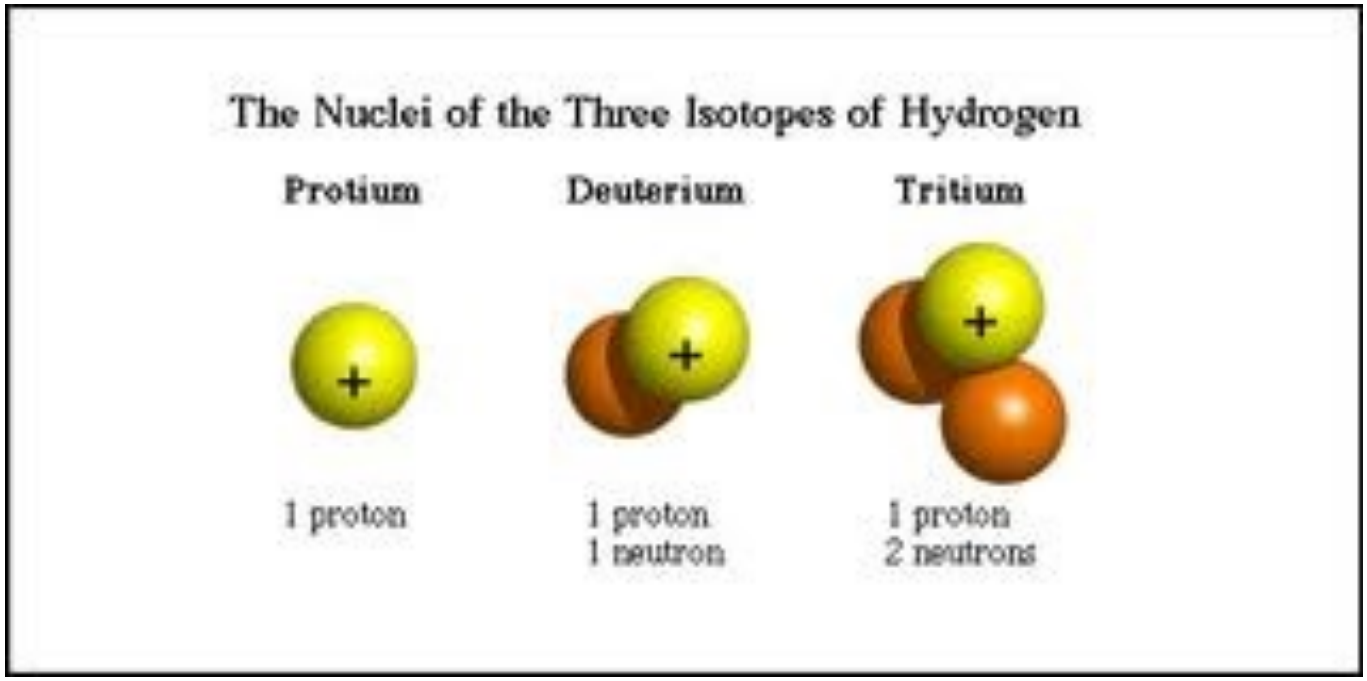
Sub-Atomic Particles



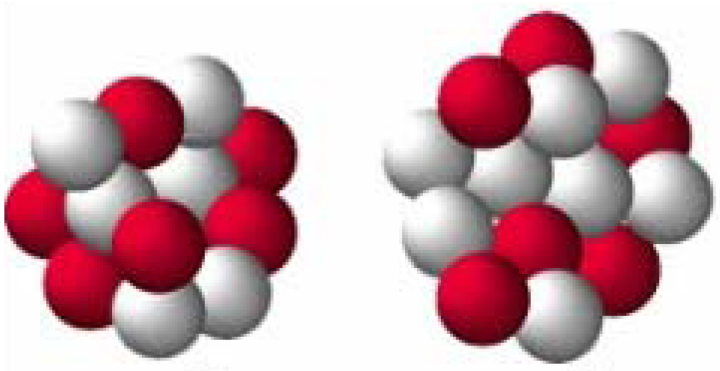
Particle	Charge	Mass (g)	Mass (amu)
Proton (p)	+1	1.672 x 10-24	1
Neutron (n)	0	1.675 x 10-24	1
Electron (e)	-1	9.110 x 10-28	1/1839

Atomic Number

An isotope of an element is an atom that contains the same number of protons (and thus is the same element), but a different number of neutrons



Nuclide Notation



$^{12}_{6}C$ $^{14}_{6}C$

Atomic mass (protons + neutrons)

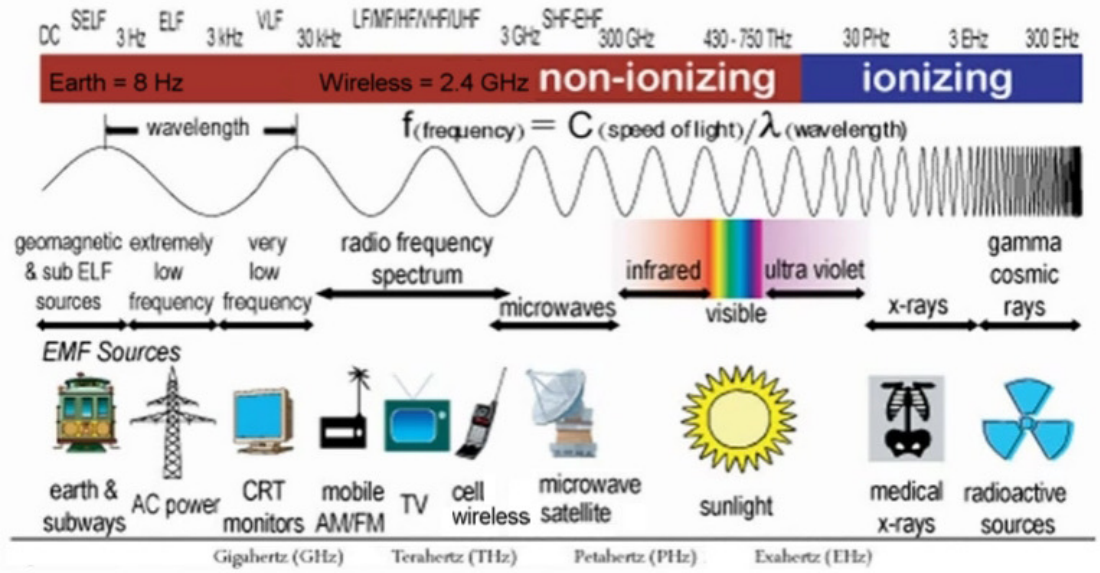
Atomic number (protons)

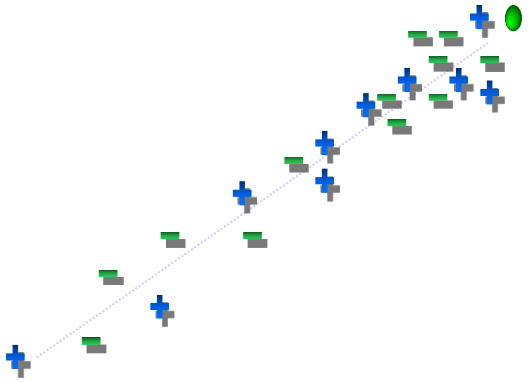
$^{12}_{6}C$

6 protons = 6 electrons

Ionizing Radiation

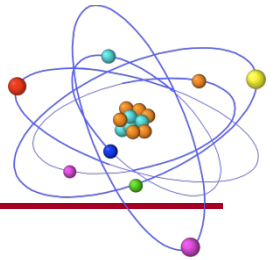
- **Radiation**:
  Energy in the form of particles or electromagnetic waves.



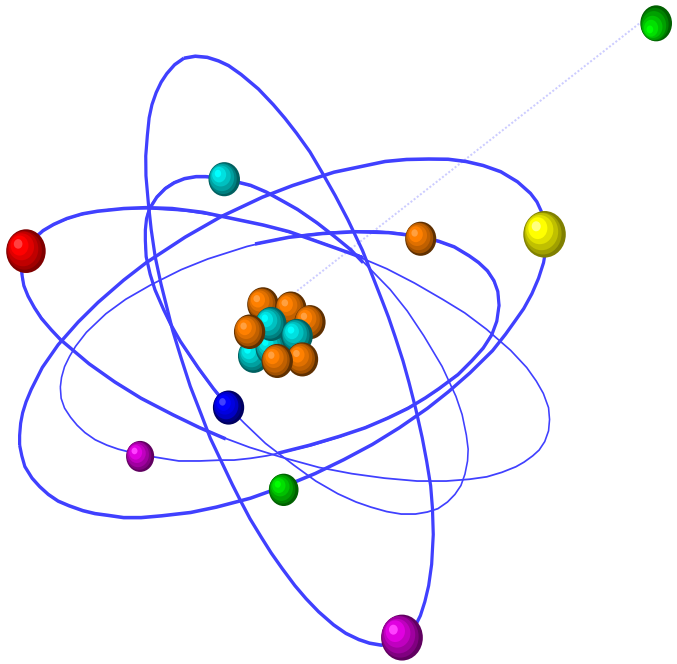


- **Ionizing Radiation**: Radiation with sufficient energy to remove an electron from an atom or molecule.

Radioactivity

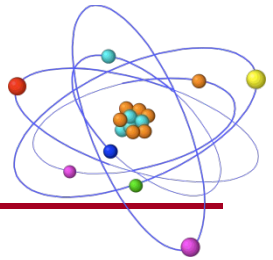


- The process by which unstable atoms spontaneously transform to new atoms* and in the process emit radiation.



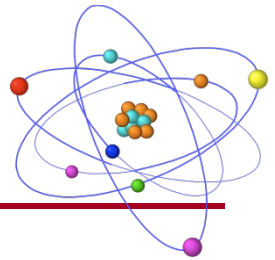
* The “new atom” may be the same atom in a lower energy state.

Units



Measurement	Unit
Energy	eV
Activity	Curie (becquerel)
Dose	Rad (gray)
Dose Equivalent	Rem (sievert)

Electron Volt



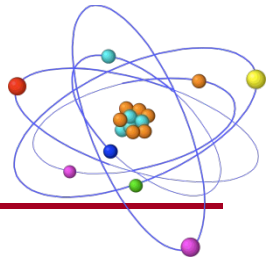
- Electron volt (eV) is the energy of ionizing radiation
- The electron volt is defined as the energy of an electron that has been accelerated through an electron potential of one volt

$$1 \text{ eV} = 1.602 \times 10^{-19} \text{ J}$$

1 keV = 1,000 eV
1MeV = 1,000,000 eV

The energy of visible light is about 2-3 eV

Activity



Activity is the number of disintegrations per second (dps).

The activity is a measure of the quantity of radioactive material

1 becquerel (Bq) = 1 disintegration per second (dps)

$1\ MBq = 1 \times 10^6\ dps$

$1\ GBq = 1 \times 10^9\ dps$

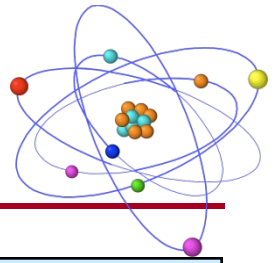
$1TB = 1 \times 10^{12}\ dps$

1 curie (Ci) = 37,000,000,000 dps

1 Ci = 37 GBq

1 Ci = 0.037 TBq

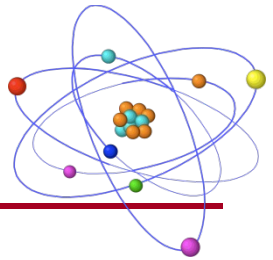
Dose Units



Quantity	Unit	What is Measured	Amount
Exposure	Roentgen (R) Coulombs/kg	Amount of charge produced in 1 kg of air by x- or gamma ray	1R = 2.58 x 10^{-4} C/kg
Absorbed Dose	Rad Gray (Gy)	Amount of energy absorbed in 1 gram of matter from radiation	1 rad = 100 ergs/gram 1 Gy = 100 rad
Dose Equivalent	rem Sievert (Sv)	Absorbed dose modified by the ability of the radiation to cause biological damage	rem = rad x quality Factor 1 Sv = 100 rem

1 R ≈ 1 rad ≈ 1 rem

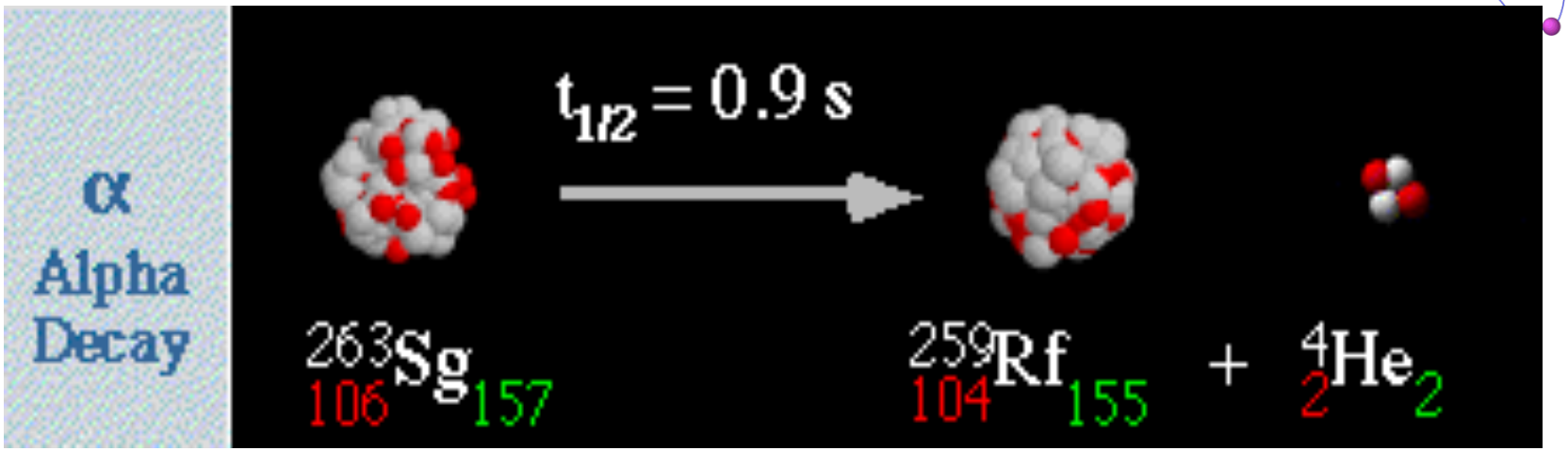
Types of Ionizing Radiation



Major Types

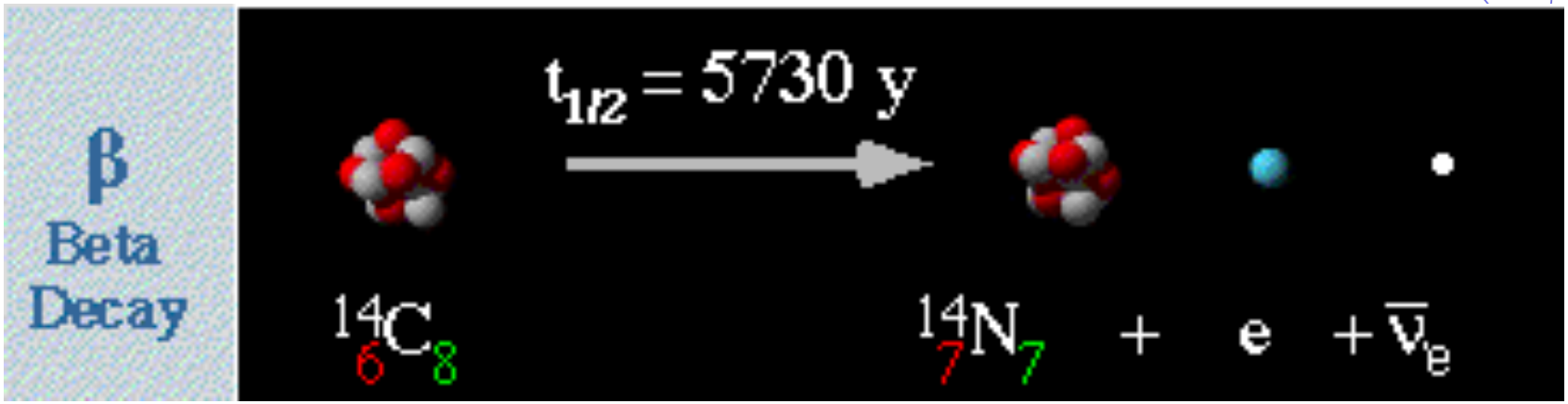
- Alpha
- Beta (Biological Research)
- Gamma
- X-ray

Alpha Decay



- Helium Nucleus – Very massive and doubly ionized
- Only a hazard via ingestion or inhalation of alpha emitter
- Not usually an external radiation hazard
- Stopped by paper and dead layer of skin
- Uranium, Thorium, Radon and radon daughters

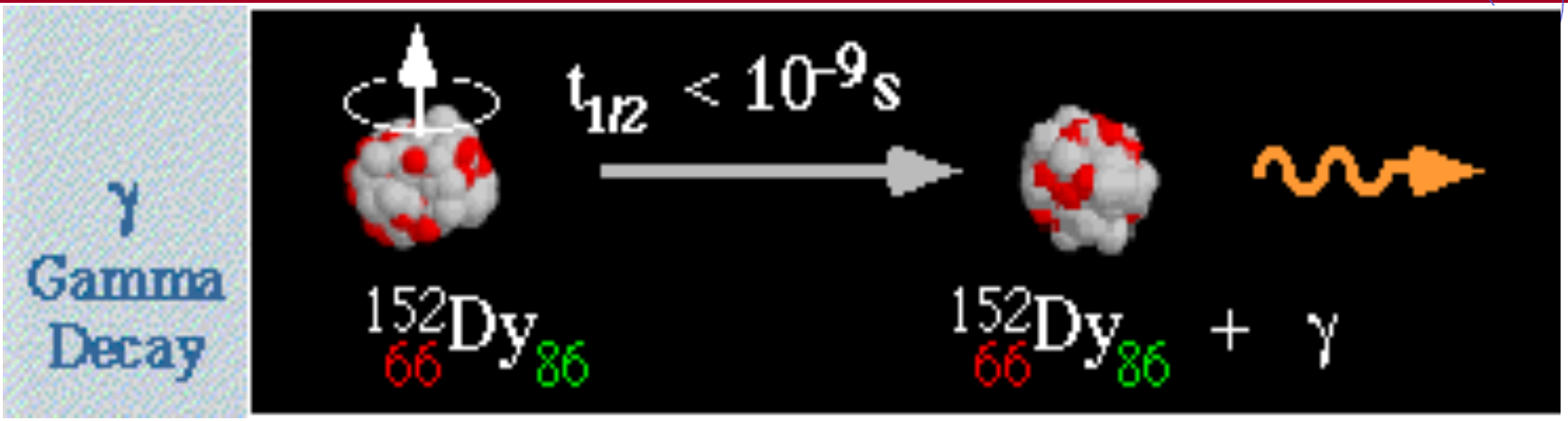
Beta Decay



Beta emission leads to the decomposition of a neutron to yield an electron and a proton. The electron is ejected as a beta particle and the proton is retained by the nucleus

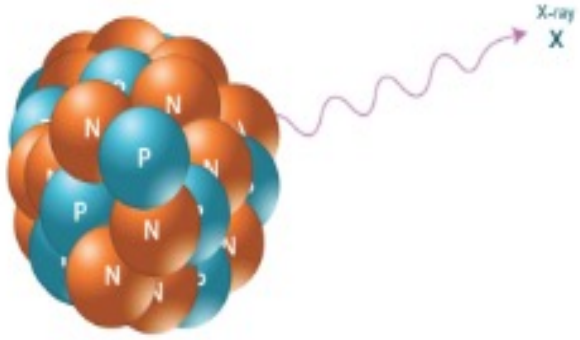
- Energetic electron – singly ionized
- External hazard to skin and eyes
- Internal hazard via ingestion or inhalation of beta emitter
- Produces bremsstrahlung radiation
- Commonly used for research: Phosphorus, Tritium, Carbon, Sulfur

Gamma Decay



- Gamma rays are photons – no charge
- Originate from the **nucleus** of an atom
- External radiation hazard to deep organs and tissues
- Internal hazard via ingestion or inhalation of gamma emitter
- Lead (high electron density) is good for shielding x and gamma rays
- cesium-137, iodine-131 (gamma/beta), Co-60

X-ray Emission

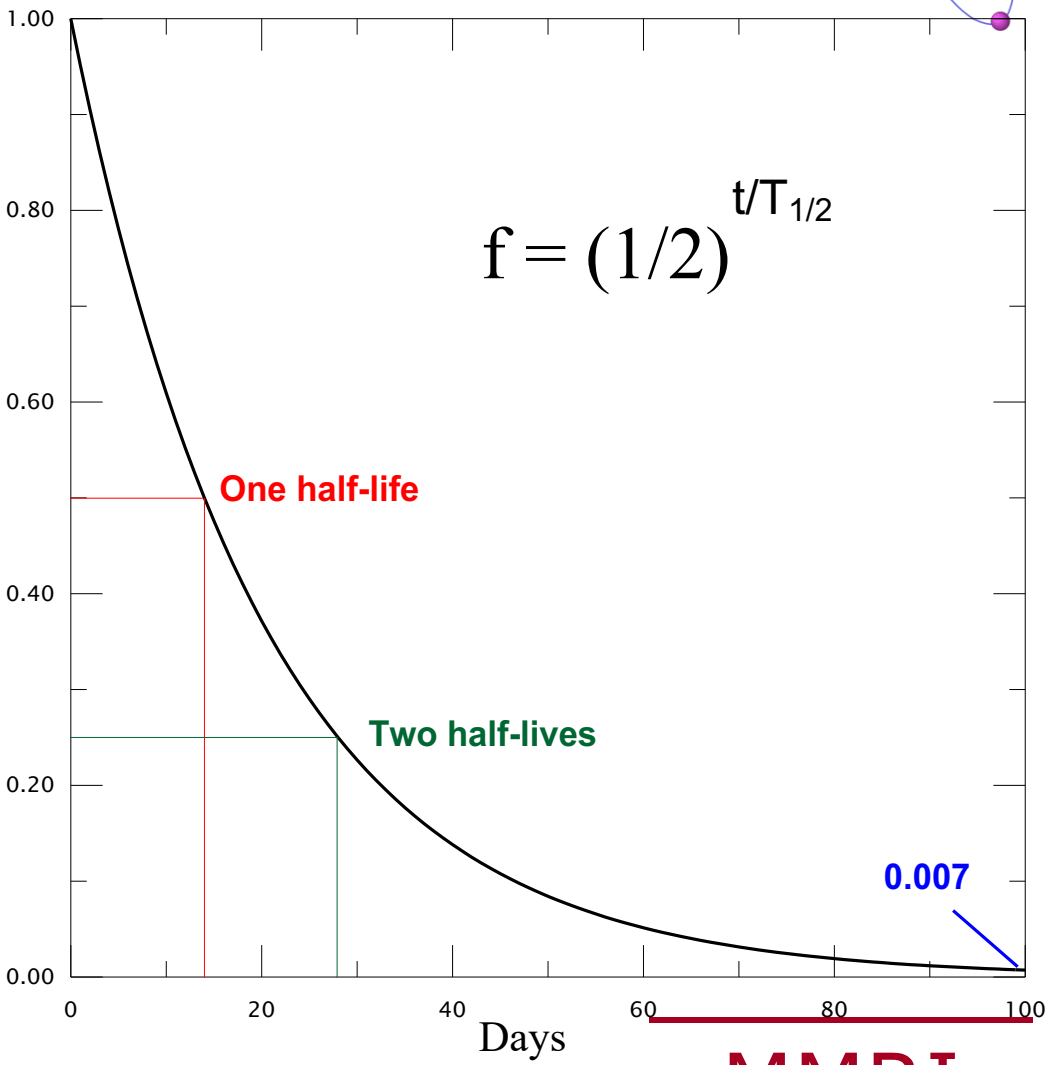


- X-rays are photons – no charge
- Originate from **electron cloud** around nucleus
- Less energy than gamma rays, but same hazards
- Lead (high electron density) is good for shielding x and gamma rays
- Man-made, extraterrestrial

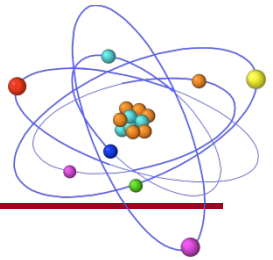
Half-Life

- The activity of any sample of radioactive material decreases or decays at a fixed rate which is a characteristic of that particular radionuclide
- Half-life is the amount of time needed for the activity to reach one half of the original amount.

10 half-lives = 0.1%

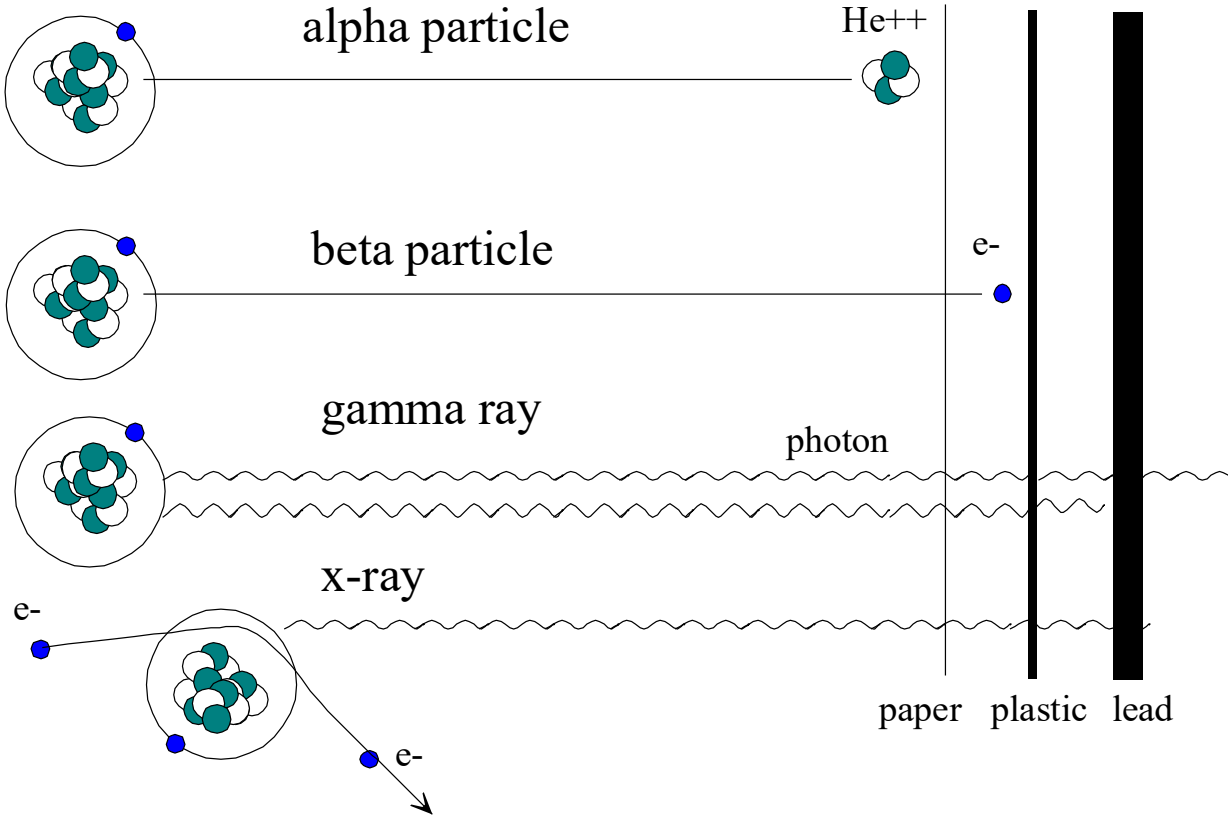


Isotopes Used for Research



	Half life	Decay	Energy		Monitor	Max Specific Activity (Ci/mmole)
			Emax	Emin		
^{125}I	60 days	γ (EC)	Auger electrons	0.035 MeV	γ Probe	2167
^{3}H	12.3 years	β	0.019 MeV	0.035 MeV	Swabs	28.8
^{14}C	5730 years	β	0.158 MeV	0.006 MeV	β counter	0.0624
^{35}S	87.4 days	β	0.157 MeV	0.049 MeV	β counter	1494
^{32}P	14.3 days	β	1.709 MeV	0.69 MeV	β counter	9131
^{33}P	25.4 days	β	0.249 MeV		β counter	5,118

Shielding


alpha particle
He++
beta particle
e-
gamma ray
photon
x-ray
e-
e-
paper
plastic
lead

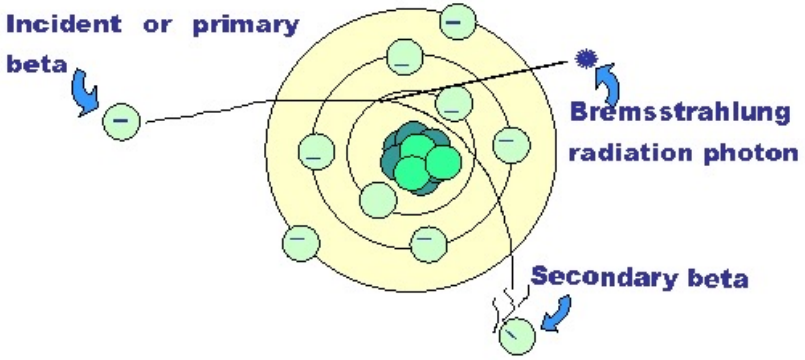
Interaction with Matter

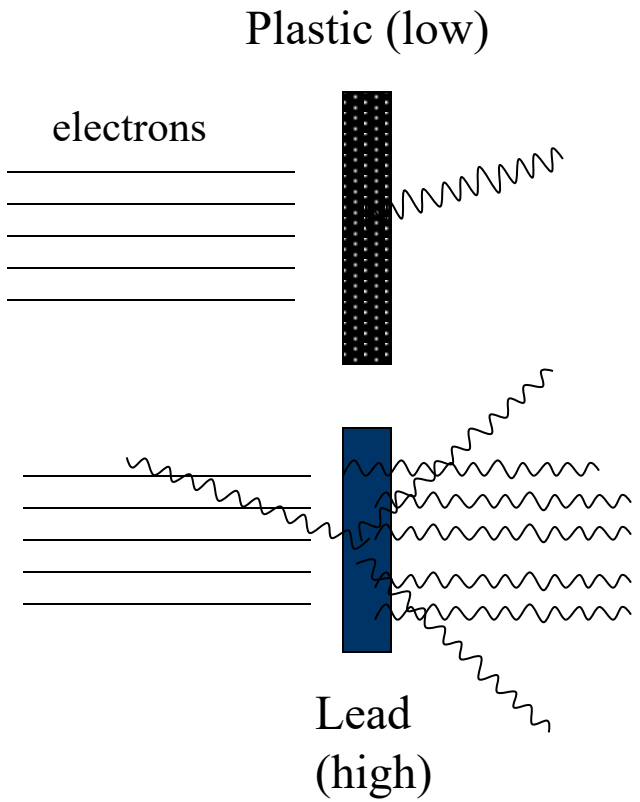
Bremsstrahlung x-rays are created when electrons are slowed down in the field of a nucleus.

•Bremsstrahlung x-ray intensity increases with increasing atomic number of absorber, and the average x-ray energy increases with increasing electron energy.

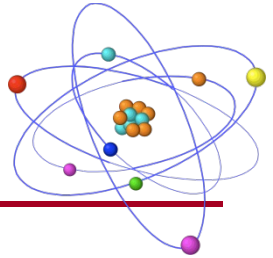
•**Example:**

P-32 is high energy beta emitter. This is why plexiglas, not lead, is used for shielding



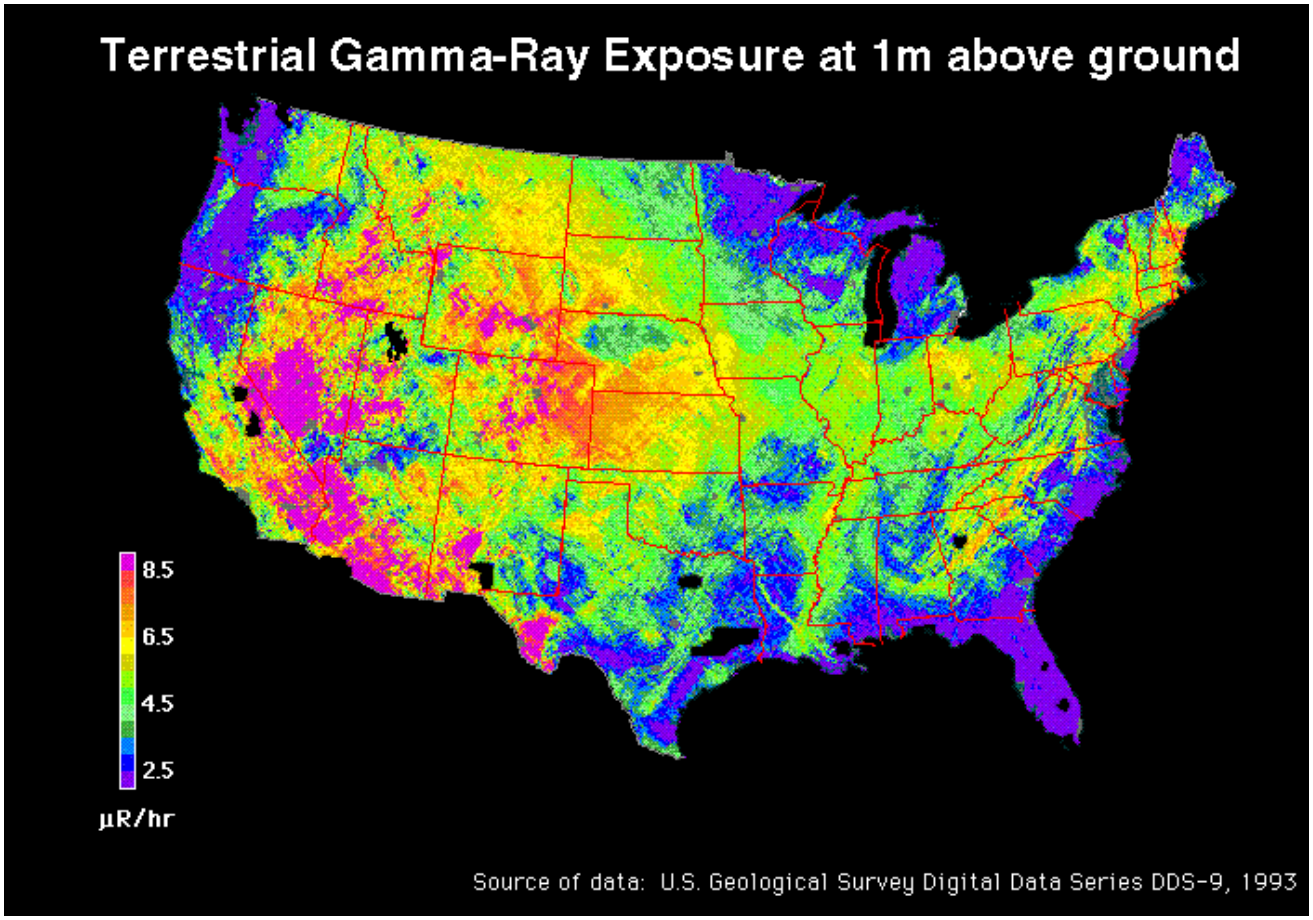


Sources of Radiation



- Sources of radiation can be divided into two categories:
  - Natural
  - Man-made

Radioactivity in the Earth



- Important radioactive elements include Uranium and Thorium
- Varies in different parts of the world

Cosmic Radiation

- The earth, and all living things on it, are constantly bombarded by radiation from outer space
- The amount of cosmic radiation varies in different parts of the world due to differences in elevation and to the effects of the earth's magnetic field

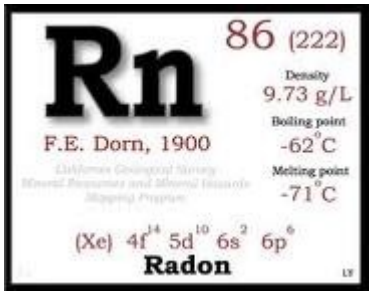
Natural Radioactivity in Your Body

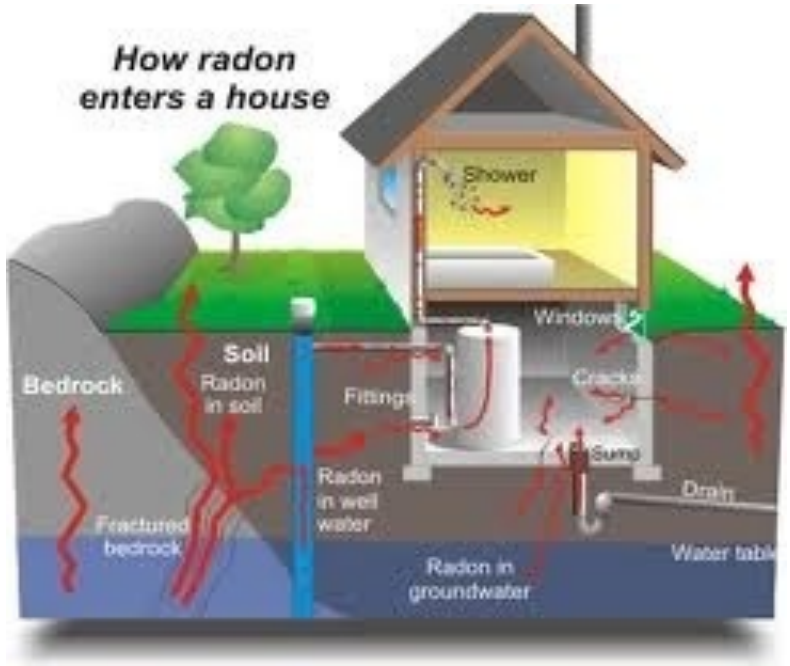
- People are exposed to radiation from radioactive materials inside their bodies
- Radioactive material is ingested with food and water
- Besides radon, the most important internal radioactive element is naturally occurring potassium 40

Nuclide	Activity
Uranium	30 pCi (1.1 Bq)
Thorium	3 pCi (0.11 Bq)
Potassium 40	120 nCi (4.4 kBq)
Radium	30 pCi (1.1 Bq)
Carbon 14	0.4 µCi (15 kBq)
Tritium	0.6 nCi (23 Bq)
Polonium	1 nCi (37 Bq)

Radon

- Radon 222 is a radioactive gas released from soil and rocks during natural decay of Uranium and Thorium
- Found in nearly all soils.
- Considered second leading cause of lung cancer
- Radon concentrations indoors depend on construction aspects
- Exposure can also be from water vapor during showering, cooking

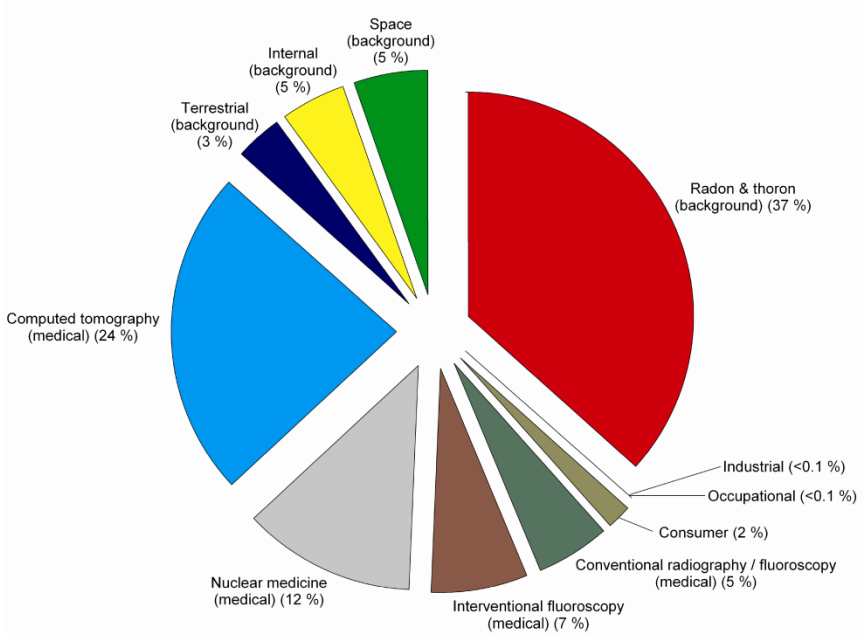




Man-Made Sources of Radiation

- X-rays
- Nuclear Medicine
- Nuclear power plants
- Smoke detectors
- Radioactive waste
- Uranium ores
- Radium dials
- Nuclear waste
- Air travel
- Radiopharmaceutical
- Consumer products
- Radiographic sources

Average Radiation Exposure to the Public



Source		Annual Dose (mrem/year)
Natural Bkgd	Terrestrial	22
	Internal Emitters (K-40, U, Th)	34
	Cosmic	28
	Inhaled Radon & Thoron	227
Man-made Bkgd	Industrial & Occupational	<1
	Consumer Products	13
Medical	Combined	300
	Total	620

From NRCP No.180, “Ionizing Radiation Exposure of the Population of the United States, 2009

Radiation Ranges in Tissue

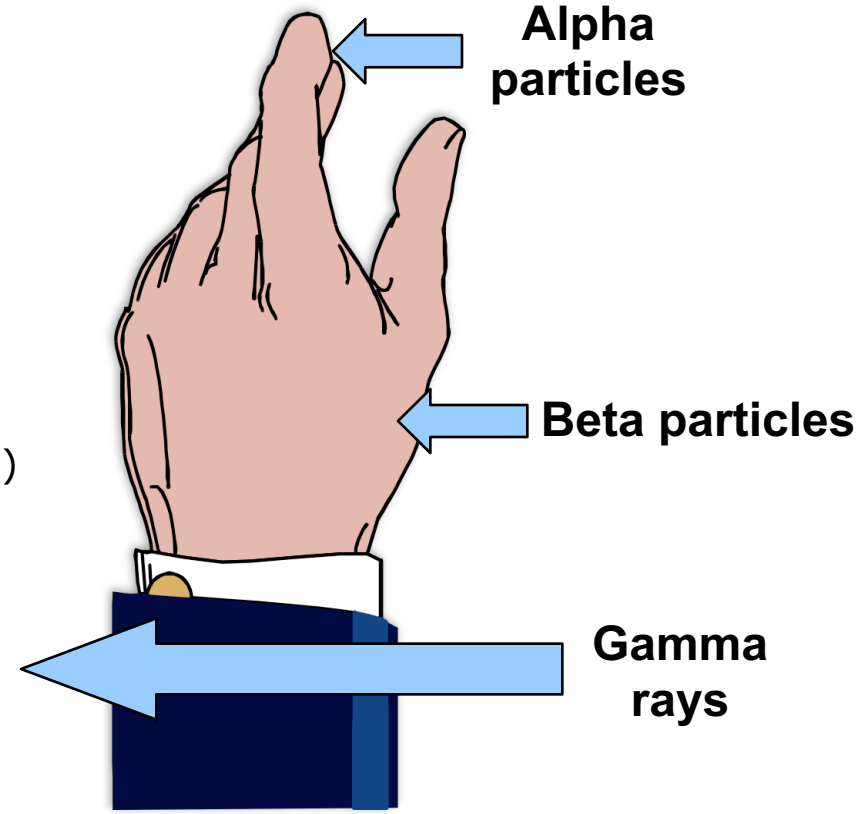
External radiation source

- alpha particles of ^{210}Po ..... None
- beta particles of ^{3}H ..... None
- beta particles of ^{32}P ..... 0.1 - 1.5 cm
- gamma rays of ^{60}Co ..... Infinity

Internal (absorbed) radiation source

(average linear dimension of a cell = 17.1 μm)

- alpha particles of ^{210}Po ..... 15 μm
- beta particles of ^{3}H ..... 5 μm
- beta particles of ^{32}P ..... 300 μm
- gamma rays of ^{60}Co ..... infinity

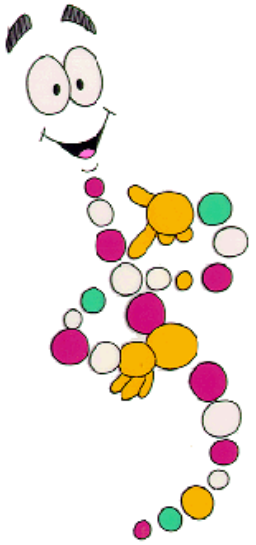


Biological Interactions

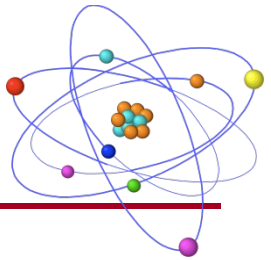
Mechanisms of Damage

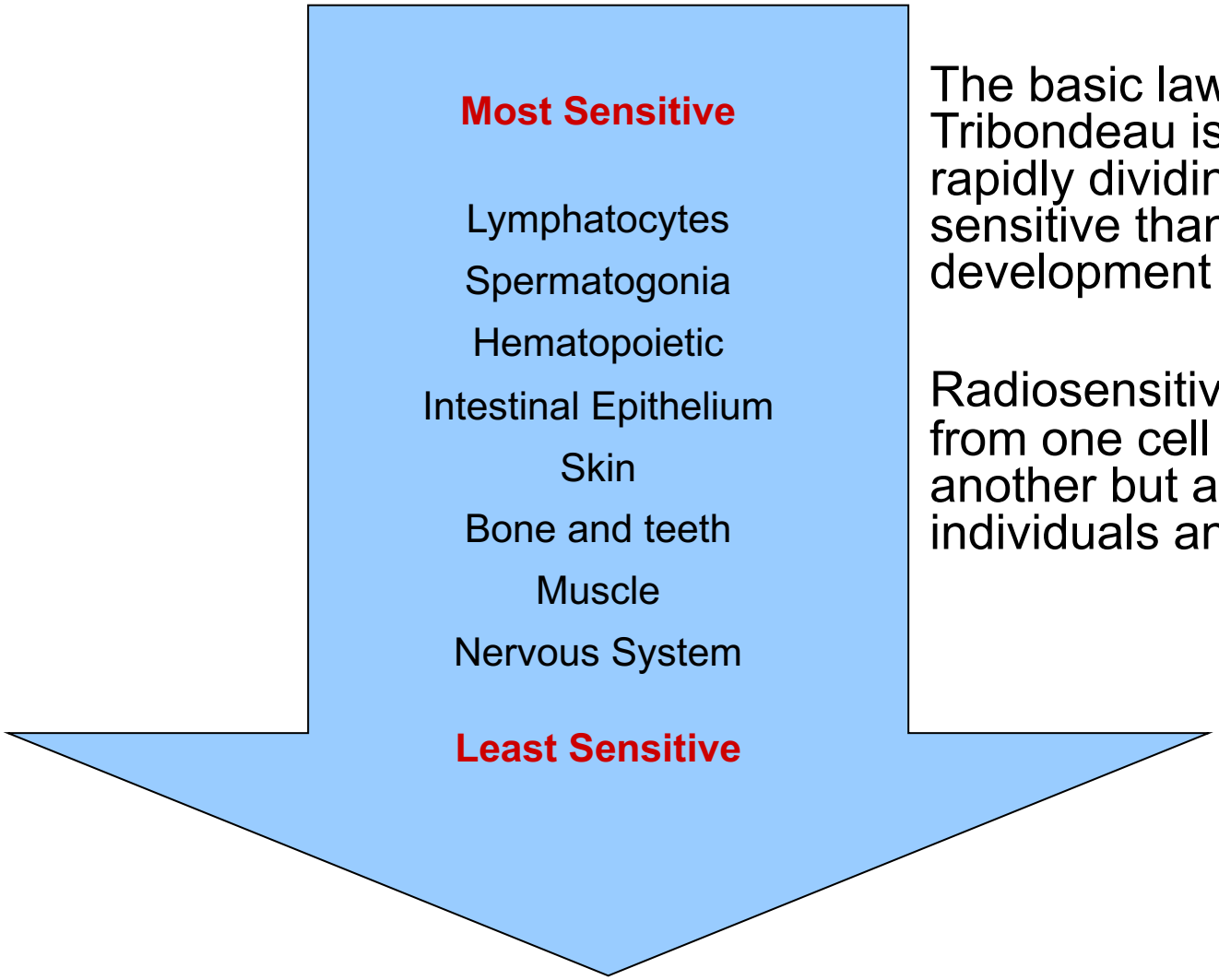
Injury to living tissues results from the transfer of energy to atoms and molecules in the cellular structure. Ionizing radiation can:

- 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

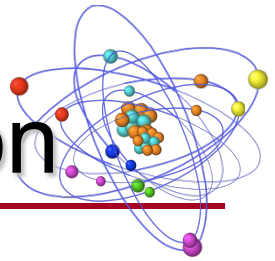




The basic law of Bergonie and Tribondeau is that young and rapidly dividing cells are more sensitive than cells with adult development

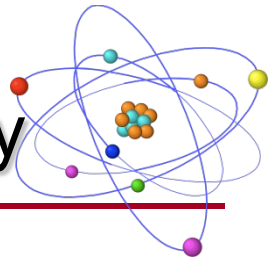
Radiosensitivity not only differs from one cell or tissue to another but also between individuals and genders

Biological Response to Radiation



- No change
- Mutation and repair
- Permanent change with limited effect
- Changes leading to cancer or other effects
- Death of cell / organism (minutes - years)

Effects of Radiation on the Human Body



Genetic

- appears in later generations due to cell damage of the reproductive organs

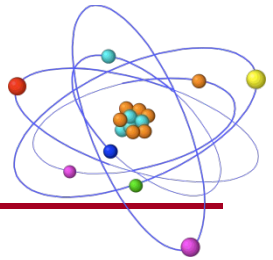
Somatic (organs and tissue)

- appears in the irradiated individual
- immediate or delayed effects

Stochastic

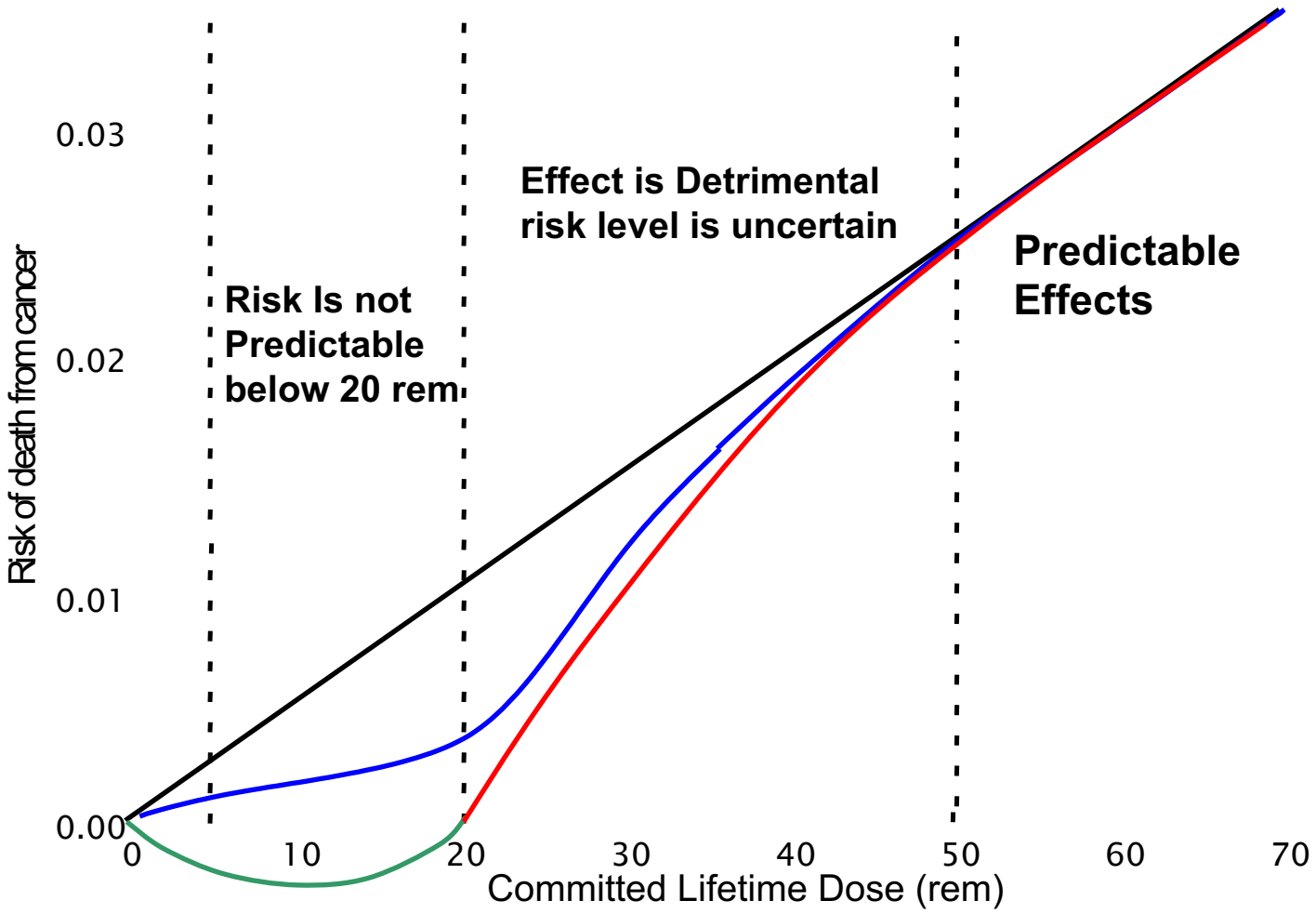
- refers to probability of biological effect due to ionizing radiation
- assumes effect is proportional to dose / dose rate, i.e., no safe threshold

Chronic Radiation Dose - Cancer



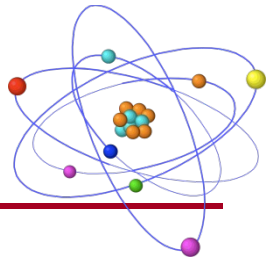
- Cancer is a stochastic effect (no threshold and is based on probabilities)
- Radiation induced cancer is the justification for today's protection standards
- Radiation may cause cancer but also used to treat cancer

Dose Response Relationship - Cancer



Occupational dose – above background

Dose Limits



	Radiation Worker[1]	Declared Pregnant Worker	General Public
Whole Body	5,000 mrem/year		100 mrem/yr[2]
Lens of the eye	15,000 mrem/year		
Extremities, skin	50,000 mrem/ year		
Embryo/fetus		500 mrem per 9 months	

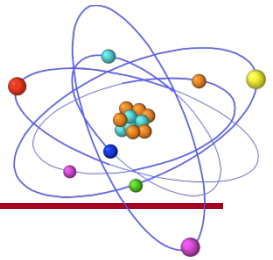
[1] Occupational dose limits for minors are 10% of the adult limit
[2] Excludes background radiation. Exposure rates must also not exceed 2 mrem in any one hour

Declared Pregnant Worker Dose Limits

- Restrict radioisotope use
- Provide “baby” dosimeters
- Restrict dose to 500 mrem over the pregnancy

NRC Regulatory Guide 8.13
“Instruction Concerning Prenatal Radiation Exposure”

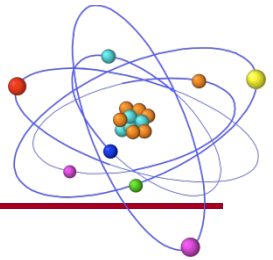
Internal Doses



CRITICAL ORGANS

- ^{3}H – Body water or tissue
- ^{14}C – Fat tissue
- ^{32}P – Bones
- ^{35}S – Gonads
- ^{125}I – Thyroid
- ^{57}Co – Large Intestine

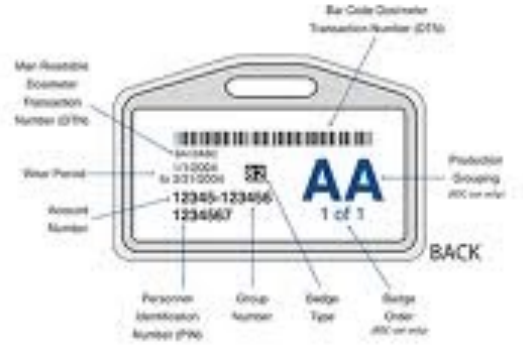
ALARA



ALARA - As Low As Reasonably Achievable

- Radiation protection philosophy
- Should be applied to maintain any dose at levels as low as are practicable

Radiation Monitoring - TLD Dosimetry

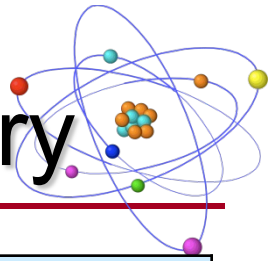


TLD - (thermoluminescent) contains a small radiation-sensitive lithium fluoride crystal

Both the body and ring badges do not detect radiation from beta emitters with energies less than 250keV. Consequently, dosimetry is not typically issued for persons using H-3, C-14, P-33 and S-35.

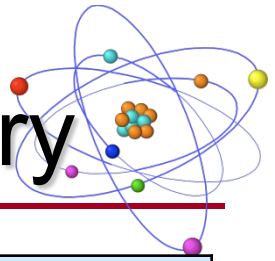
MMRI policy: All radiation users must wear a badge regardless of what isotope they use. Radiation lab is a shared space.

Precautions of Use of Dosimetery



Always	Never
Wear assigned badges when handling a source	Share Dosimeters
Return used badges promptly after wear period	Disassemble your dosimeter
Report any loss, damage or contamination of dosimeters	Expose to heat
Store away from radioactive sources	Take to other facilities or home
	Intentionally expose to radiation
	Wear during medical procedures

Precautions of Use of Dosimetery



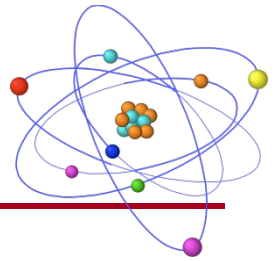
Whole Body	Extremity
Wear between neck and waist	The label side of the ring should usually face the palm
Wear with name on badge facing outwards	Wear gloves over the ring
If you lose, damage or fail to make dosimetery available for exchange you will be required to provide a detailed description of all radioactive sources in use during the wear period	

Radiation Survey Meters

- Contamination (cpm)
  - Geiger Mueller Counter (GM)

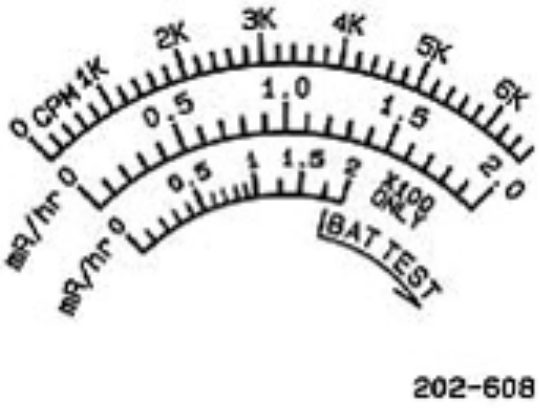
- Dose Rate (mrem/hr)
  - Ionization chamber

Calibration



- ✓ Radiation survey meters are required to be calibrated once per year
- ✓ The calibration date and the date that the next calibration is due is posted on a label on the side of the meter
- ✓ Do not use meters that are out of calibration

Using a Ludlum GM Meter



- Check battery condition – needle should go to BAT TEST line on meter
- Turn large switch to the lowest scale – turn on audio switch
- Note meter “background” reading in a location away from radiation source
- Place probe (window face down) about ½ inch from surface being surveyed
- Survey work area by slowly moving probe over surfaces, listen to audible “clicks” from survey speaker

Survey Monitoring: GM detectors

The efficiency of a meter for a specific source of radiation is given by the ratio of the meter count rate to the actual disintegration rate of the source (cpm/dpm)

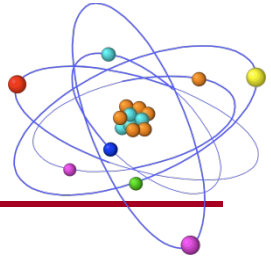
H-3	not detectable
C-14, S-35	0.2% - 0.8%*
P-32	3% - 8%
I-125	0.01% - 0.03%

* Not detectable if the detector window is covered with paraffin, film, plastic wrap, or other material

Liquid Scintillation Counter

- Excellent choice for detecting and measuring low energy beta
- Not portable – wipe or smears required for radiation survey use
- Requires more training to prepare samples and interpret results than other instruments

ALARA



The four main principles of radiation protection

Time
Distance
Shielding
Contamination Control

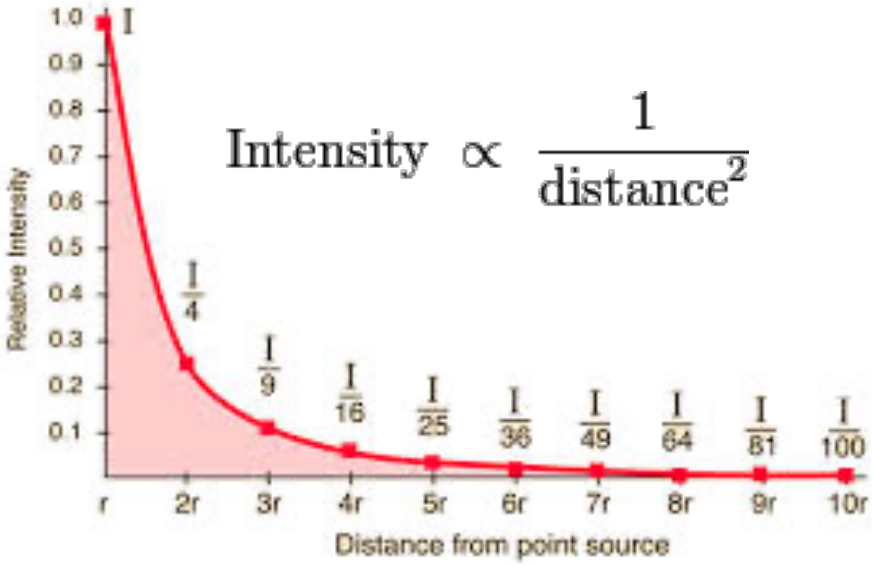
Time

Radiation exposure is directly proportional to the time spent in the field

Decreasing the time spent near a radiation source decreases radiation exposure

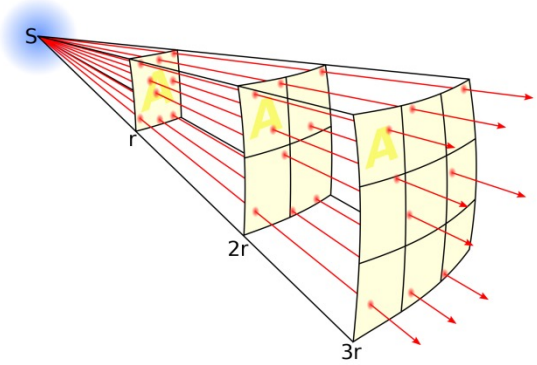
- ✓ Inform colleagues of the presence of the source
- ✓ Do not remove the source from its storage area until the last possible moment
- ✓ Practice “dry-runs”. Have a Standard Operating Procedure
- ✓ Understand where and when the radiation beam is present
- ✓ Return the source promptly

Distance - Inverse Square Law



Doubling distance from a point gamma or x-ray source, decreases dose rate by a factor of four

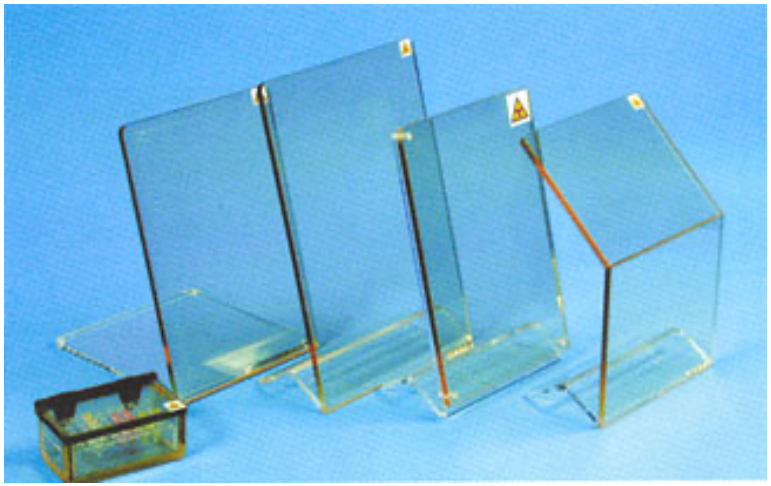
Tripling it decreases dose rate nine-fold



Increasing the distance from a radiation source decreases radiation exposure

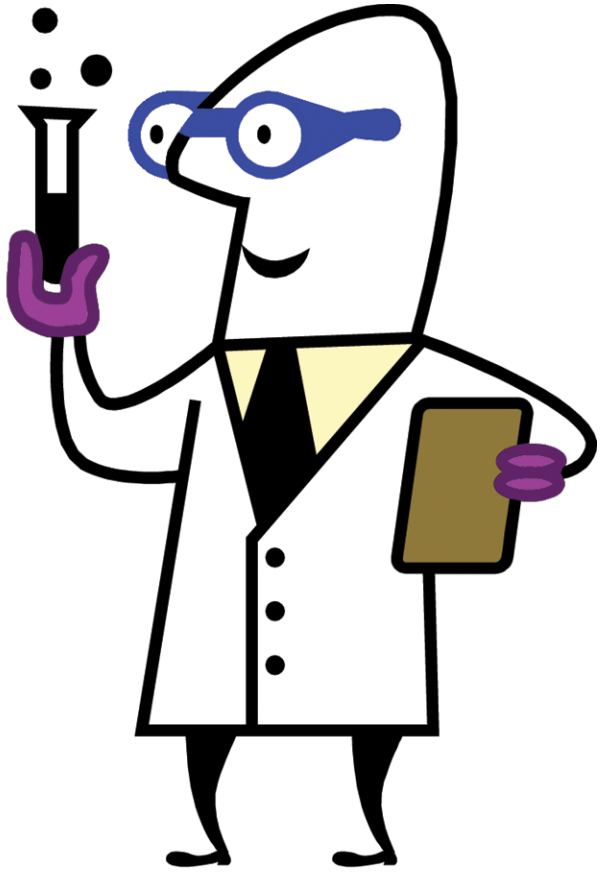
Shielding

- Increasing the shielding of a radiation source decreases radiation exposure
- Enclose x-ray or gamma sources in dense materials (lead, depleted uranium, or concrete)
- Use low Z materials (Plastic or glass) to shield a beta source



Personal Protection Equipment

- ✓ Gloves
- ✓ Lab coat
- ✓ Eyewear
- ✓ Pants
- ✓ Closed toe footwear



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

Safe Practices

NO

- Eating
- Drinking
- Smoking
- Applying cosmetics

Safety Data Sheets (Handout)

^{32}P	Nuclide Safety Data Sheet Phosphorous-32	^{32}P

I. PHYSICAL DATA

Radiation:	Beta (100% abundance)	
Energy:	Maximum: 1,710 keV; Average: 695 keV	
Half-Life [$T_{½}$] :	Physical $T_{½}$:	14.29 days
	Biological $T_{½}$:	Bone ~ 1155 days; Whole Body ~ 257 days[1]
	Effective $T_{½}$:	14.29 days
Specific Activity:	286,500 Ci/g	[10,600 TBq/g] max.
Beta Range:	Air:	610 cm [240 inches; 20 feet]
	Water/Tissue:	0.76 cm [0.33 inches]
	Plastic:	0.61 mm [3/8 inches]

II. RADIOLOGICAL DATA

Radiotoxicity[2]:	94.7 mrem/uCi [Lung] & 15.5 mrem/uCi [CEDE] of ^{32}P inhaled 29.9 mrem/uCi [Bone Marrow] & 8.77 mrem/uCi [CEDE] of ^{32}P ingested
Critical Organ:	Bone [soluble ^{32}P]; Lung [Inhalation]; GI Tract [Ingestion - insoluble compounds]
Exposure Routes:	Ingestion, inhalation, puncture, wound, skin contamination absorption
Radiological Hazard:	External Exposure [unshielded dose rate at 1 mCi ^{32}P vial mouth[3]: approx. 26 rem/hr], Internal Exposure & Contamination

III. SHIELDING

Shield ^{32}P with 3/8 inch Plexiglas and monitor for Bremstrahlung; If Bremstrahlung X-rays detected outside Plexiglas, apply 1/8 to 1/4 inch lead [Pb] shielding outside Plexiglas
The accessible dose rate should be background but must be < 2 mR/hr

IV. DOSIMETRY MONITORING

Wear radiation dosimetry monitoring badges [body & ring] if regularly handling mCi quantities of ^{32}P

V. DETECTION & MEASUREMENT

Portable Survey Meters: Geiger-Mueller
Wipe Test: Liquid Scintillation Counting is an acceptable method for counting ^{32}P wipe tests

VI. SPECIAL PRECAUTIONS

- Avoid skin contamination [absorption], ingestion, inhalation, & injection [all routes of intake].
- Store ^{32}P (including waste) behind Plexiglas shielding [3/8 inch thick]; survey (with GM meter) to check adequacy of shielding (accessible dose rate < 2 mR/hr; should be background); apply lead [Pb] shielding outside Plexiglas if needed.
- Use 3/8 inch Plexiglas shielding to minimize exposure while handling ^{32}P.
- Use tools [e.g. Beta Blocks] to handle ^{32}P sources and contaminated objects; avoid direct hand contact.
  - Always have a portable survey meter present and turned on when handling ^{32}P.
- ^{32}P is not volatile, even when heated, and can be ignored as an airborne contaminant[4] unless aerosolized.

[1] NCRP Report No. 65, p.88
[2] Federal Guidance Report No. 11 [Oak Ridge, TN; Oak Ridge National Laboratory, 1988], p. 122, 156
[3] Dupont/NEN, Phosphorous-32 Handling Precautions [Boston, MA; NEN Products, 1985]
[4] Bevelacqua, J. Contemporary Health Physics [New York; John Wiley & Sons, 1995], p. 282

^{35}S	Nuclide Safety Data Sheet Sulfur-35	^{35}S

I. PHYSICAL DATA

Radiation:	Beta (100% abundance)	
Energy:	Maximum: 167.47 keV; Average: 48.8 keV	
Half-Life [$T_{½}$] :	Physical $T_{½}$:	87.44 days
	Biological $T_{½}$:	623 days [unbound ^{35}S]; 90 days [bound ^{35}S]
	Effective $T_{½}$:	44 - 76 days [unbound ^{35}S]
Specific Activity:	42,707 Ci/g	[1,580 TBq/g] max.
Beta Range:	Air:	26 cm [10.2 inches]
	Water/Tissue:	0.32 mm [0.015 inches]
	Plastic:	0.25 mm [0.010 inches]

II. RADIOLOGICAL DATA

Radiotoxicity[1]:	2.48 mrem/uCi [CEDE] of ^{35}S inhaled 0.733 mrem/uCi of ^{35}S ingested
Critical Organ:	Testis
Exposure Routes:	Ingestion, inhalation, puncture, wound, skin contamination absorption
Radiological Hazard:	External Exposure – None from weak ^{35}S beta Internal Exposure & Contamination - Primary concern

III. SHIELDING

None required - mCi quantities not an external radiation hazard

IV. DOSIMETRY MONITORING

Urine bioassay is the most readily available method to assess intake [for ^{35}S, no intake = no dose]
Provide a urine sample to Radiation Safety after any accident/incident in which an intake is suspected

V. DETECTION & MEASUREMENT

Portable Survey Meters: Geiger-Mueller [~10% efficiency]
Beta Scintillator [~5% efficiency]
Wipe Test: Liquid Scintillation Counting is the best readily available method for counting ^{35}S wipe tests

VI. SPECIAL PRECAUTIONS

- Avoid skin contamination [absorption], ingestion, inhalation, & injection [all routes of intake]
  - Many ^{35}S compounds and metabolites are slightly volatile and may create contamination problems if not sealed or otherwise controlled. This occurs particularly when ^{35}S amino acids are thawed, and when they are added to cell culture media and incubated. Therefore vent thawing ^{35}S vials in a hood. Incubators used with ^{35}S will have an activated charcoal trap placed in the incubator. Possibility of volatilization must be taken into account when surveying after use.

[1] Federal Guidance Report No. 11 [Oak Ridge, TN; Oak Ridge National Laboratory, 1988], p. 122,156

Safe Handling Data

Isotope	Half Life	Critical Organ	Shielding Energy Radiation	Energy (Mev)	Beta Range in Air	Shielding
^{3}H	12.3 Years	W.Body	Beta	0.0186	6 mm	None
^{14}C	5730 Years	W.Body	Beta	0.156	24 cm	None
^{32}P	14.3 Days	Bone	Beta	1.71	610 cm	Plexiglas, 1 cm
^{33}P	25.3 Days	Bone	Beta	0.249	50 cm	None
^{35}S	87.4 Days	W. Body	Beta	0.167	26 cm	None

X-ray Generation

SPECTRAL ami HTX Imaging System with X-Ray Capabilities

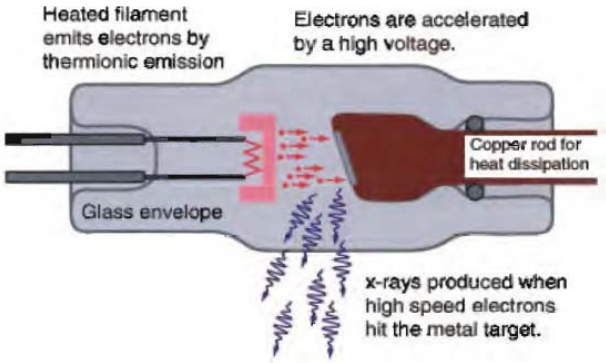
- General purpose imager: fluorescence, luminescence, photographic, **X-ray**
- **Authorized Personnel**: Jan Rydzewski, Puja Ravikumar
- Registered with the California Department of Public Health, Radiologic Health Branch
- Produces X-rays up to 40kV energy
- Steel enclosure blocks X-rays from leaving the instrument
- Meets Federal radiation performance standard for cabinet X-ray systems

X-ray Generation

SPECTRAL ami HTX Imaging System with X-Ray Capabilities

- Radiation leak-tested upon installation
- **No dosimetry required**
- Hardware safety interlocks (checked annually)
- Requires special training & exam before use
- Can only be activated using key
- Requires Radiation Protection and Safety Program
- No radiation license required

X-ray Generation

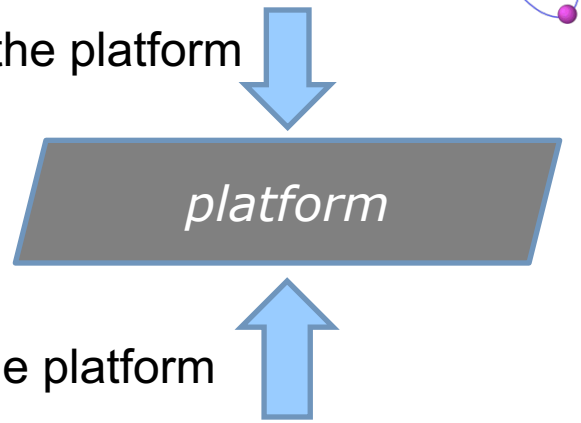


X-ray generator used in ami HTX Imager

- Metal filament is heated up to a very high temperature allowing electrons from the metal to "boil" off.
- Electrons are then accelerated across the glass tube to a positively charged anode.
- Most electrons collide with the metal anode and generate heat, some of the electrons lose their energy in the form of x-rays

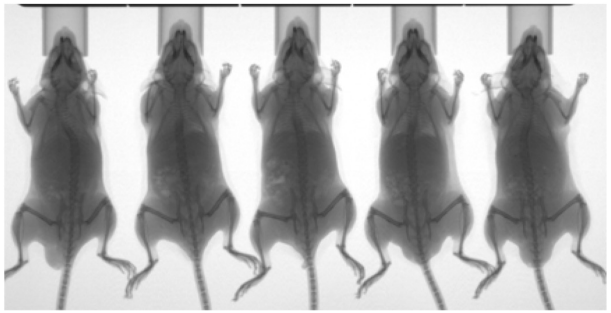
X-ray Imaging Using the ami HTX

Camera sweeps above the platform

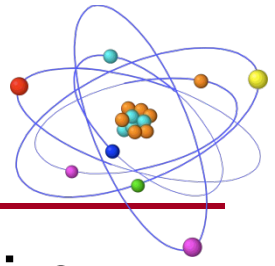


X-rays are generated for 10-15 s from below the platform (10-40keV, 0-100uA)

Tissue will absorb photons from X-ray beam according to the density/thickness and chemical composition of the tissue.



Government Regulations

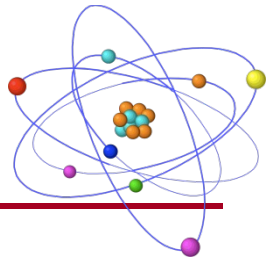


In order to obtain and use radioactive materials, a Radioactive Materials License must be obtained from the State of California.

The Radiologic Health Branch (RHB) is within the Food, Drug, and Radiation Safety Division of the Department of Public Health.

- Enforces the laws and regulations
  - Regulations implementing the laws are in Title 17, California Code of Regulations, Division 1, Chapter 5, Subchapters 4.0, 4.5, & 4.6.
- Administers a radiation control program.
  - Licensing
  - Inspection of facilities using radiation
  - Investigation of radiation incidents
  - Surveillance of radioactive contamination in the environment.

RSO Responsibilities



- Stop unsafe activities
- Supervise decontamination
- Ensure security
- Control disposal
- Interact with NRC and other authorities
- Maintain Records
- Audit program annually
- Perform surveys
- Train personnel
- Investigate abnormal events

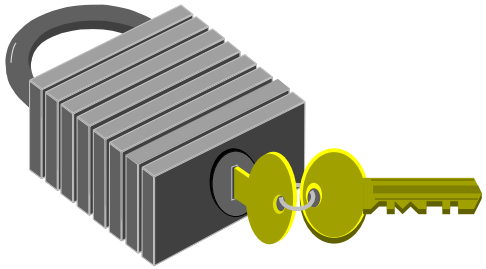
Material Receipt and Accountability

- Licensees must maintain records of receipt, transfer, and disposal of licensed materials

Security

Ensure that radioactive materials are secured

- Keep an up-to-date use log



- Sealed sources and source vials must be locked in a secured container when not in use
- Rooms must be locked when unattended
- Challenge unknown persons entering the lab

Posting Radiological Identification System

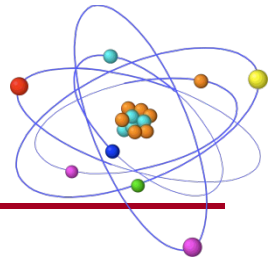
Posting	Required
 Radioactive Material	Area where RAM amount exceeds 10 times the specified limit
 Radiation Area	> 0.005 rem/hr at 30 cm from the source
 High Radiation Area	> 0.1 rem/hr at 30 cm from the source
 Very High Radiation Area	>500 rads/hr at 1 m from the source

Labeling Sources

Sources Labeled with:

- Isotope
- Activity
- Date
- Inventory ID Number (if applicable)

Notice to Employees



CALIFORNIA DEPARTMENT OF PUBLIC HEALTH

NOTICE TO EMPLOYEES

STANDARDS FOR PROTECTION AGAINST RADIATION

CALIFORNIA RADIATION CONTROL REGULATIONS (CALIFORNIA CODE OF REGULATIONS, TITLE 17, SECTION 30255)

The California Radiation Control Regulations include standards for protection against radiation hazards. The State Department of Public Health has primary responsibility for administering these standards which apply to both employers and employees. Enforcement is carried out by the Department of Public Health or its authorized inspection agencies.

EMPLOYEES' RESPONSIBILITIES

You should know and understand those California radiation protection standards and your employer's operating and emergency procedures which apply to your work. You should comply with these requirements for your own safety and the safety of others. Report promptly to your employer any condition which may lead to or cause a violation of these standards or employer's operating and emergency procedures.

SCOPE OF THE STANDARDS

The Standards for Protection Against Radiation define:

1. Limits on exposure to radiation and radioactive materials;
2. Actions to be taken after accidental exposure;
3. Working conditions requiring personnel monitoring, safety surveys, engineered controls, and safety equipment;
4. Proper use of caution signs, labels, and safety interlock devices;
5. Requirements for keeping worker exposure records and reporting of such exposures;
6. The requirement for specific operating and emergency procedures for radiation work; and
7. The rights of workers regarding safety inspections.

EMPLOYERS' RESPONSIBILITIES

Your employer is required to:

1. Comply with the requirements of the California Radiation Control Regulations, departmental orders, and license conditions;
2. Post or make available to you copies of the Radiation Control Regulations, any license issued thereunder, and your operating and emergency procedures;
3. Post any notice of violation of radiological working conditions; and
4. Provide you with information on your exposure to radiation.

REPORTS ON YOUR RADIATION EXPOSURE HISTORY

1. California Radiation Control Regulations require your employer to give you a written report if you receive an exposure greater than the limits set in the radiation safety standards. Basic limits for occupational radiation exposure can be found in Section 30253 referencing title 10, Code of Federal Regulations, part 20. Limits on exposure to radiation and exposure to concentrations of radioactive material in air are specified in title 10, Code of Federal Regulations, part 20, subpart C.
2. If the radiation protection standard, under 10 CFR 20 (subpart F) requires that your radiation exposure be monitored, your employer must, upon your request, (a) give you a written report of your exposures upon termination of your employment, and (b) advise you of your exposures annually.

INSPECTIONS

The Department or one of its contractors will inspect your workplace from time to time to ensure that health and safety requirements are being followed and that these requirements are effective in protecting you. Inspectors may confer privately with you at the time of inspection. At that time you may direct the inspector's attention to any condition you believe is or was a violation of the safety requirements.

In addition, if you believe at any time that any health and safety requirements are being violated, you or your workers' representative may request that an inspection be made by sending a complaint to the Department of Public Health or other official agency. Your complaint must describe the specific circumstances of the apparent violation and must be signed by you or your workers' representative. The Department is required to give your employer a copy of any such complaint. Names may be withheld at your request. You should understand, however, that the law protects you from being discharged or discriminated against in any way for filing a complaint or otherwise exercising your rights under the California Radiation Control Regulations.

POSTING REQUIREMENTS

Copies of this notice must be posted in a sufficient number of places in every establishment where employees are employed in activities regulated by the California Radiation Control Regulations, to permit employees working in or frequenting any portion of a restricted area to observe a copy on the way to or from their place of employment.

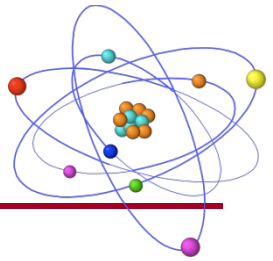
FOR RADIOLOGICAL EMERGENCY ASSISTANCE (24/7), PHONE 1-800-852-7550
To contact the Radiologic Health Branch, phone (916) 327-5106 or go to:
http://www.cdph.ca.gov/programs/Pages/RadiologicHealthBranch.aspx

RHB 2364 (5/09)

A "Notice to Employees" is posted in common places where employees frequently pass.

The Notice provides information about how to contact California Public Health Radiological branch and describes worker's rights and responsibilities

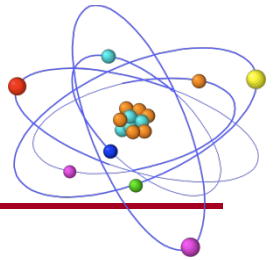
MMRI Radiation License



- License is approved by California Department of Health Services, Radiologic Branch
- Must be renewed every 10 years (Exp. July 9, 2030)
- Changes to license require an amendment which must be approved BEFORE work can be done
- Inspections are on a five-year cycle (last inspection Nov 2021)
- Allowed possession of up to 20 mCi each of

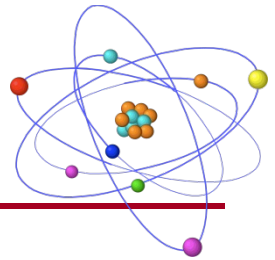
  ^{14}C, ^{3}H, ^{32}P, ^{33}P, ^{35}S

MMRI Operational Procedures



- Training and approval
- Ordering
- Receipt of Radioactive Material
- Inventory
- Disposal
- Monitoring
- Emergency and Spill Response

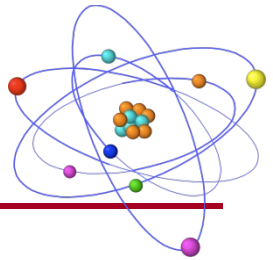
Training and Approval



Before you can use radioactive materials:

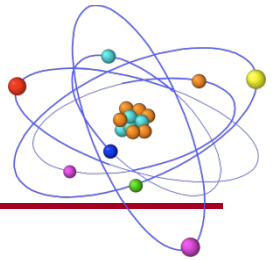
1. Read MMRI Radiation Safety Manual
2. Read "Radiation Safety Fundamentals Training" and answer study questions
3. Fill out Statement of Training and Experience (RH2050)
4. Complete PI Radiation Use Application (RUA)
5. Complete "Approval for Use of Radioactive Materials" Form
6. Meet with the RSO for training and review of all forms
7. RSO will assign appropriate dosimetry and detection equipment

Ordering Radioactive Materials



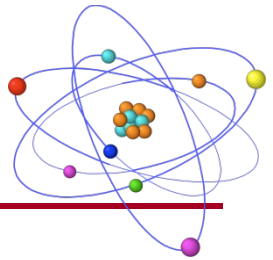
- Only RSO or ARSO can order radioactive materials under MMRI license
- RSO or ARSO makes sure that what you are ordering is under MMRI radiation license and does not go over the possession limit.
- RSO or ARSO determines if the requestor is trained and has the proper equipment to handle the material safely.

Receipt of Radioactive Material



- Radioactive materials can only be received during business hours.
- The package must be inspected and surveyed by the RSO, ARSO or designated end-user within 3 hours of receipt. Results are recorded into the log.
- An inventory number is assigned and a user log is created.
- The amount of radioactive material is recorded at each use and the waste stream is recorded as liquid or solid.

Inventory and Use Logs



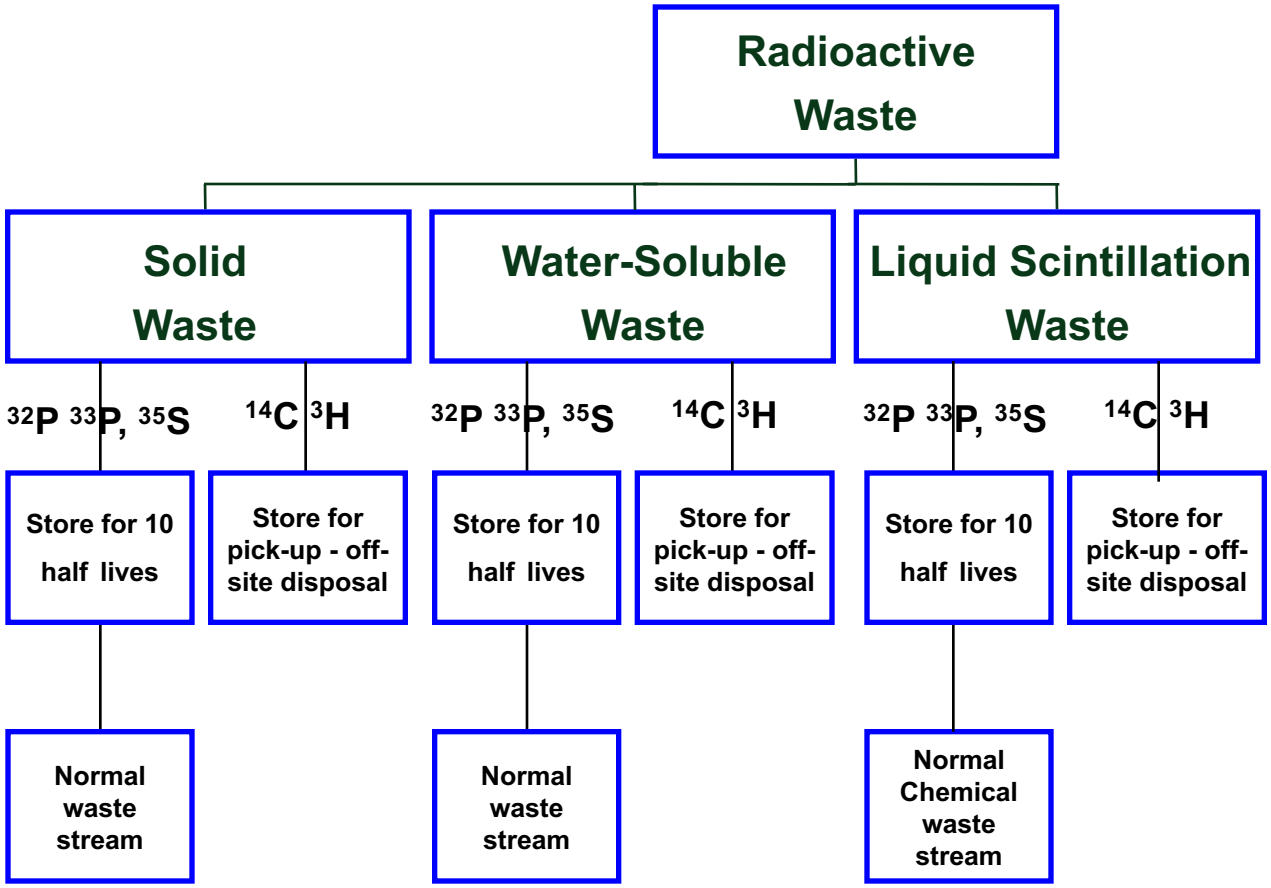
Inventory of all radioactive materials is required to keep track of all radioactivity at MMRI:

- Amount received
- Amount, user and date of each use
- Amount put in waste (liquid, solid or LSC)

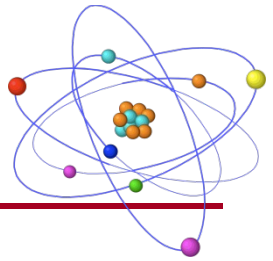
Use Log is used for:

- reporting amount of radioactive waste on hand on Dec 31 of each year
- Inventory is used for disposal records

Disposal

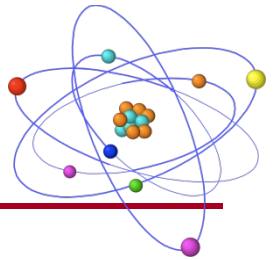

Radioactive Waste
Solid Waste
Water-Soluble Waste
Liquid Scintillation Waste
^{32}P ^{33}P, ^{35}S
^{14}C ^{3}H
^{32}P ^{33}P, ^{35}S
^{14}C ^{3}H
^{32}P ^{33}P, ^{35}S
^{14}C ^{3}H
Store for 10 half lives
Store for pick-up - off-site disposal
Store for 10 half lives
Store for pick-up - off-site disposal
Store for 10 half lives
Store for pick-up - off-site disposal
Normal waste stream
Normal waste stream
Normal Chemical waste stream

Monitoring



- Dosimetry badge/ring – all users
- Experimental surveys over work area (Ludlum)
- Wipe surveys (LSC) – Monthly or when contamination is suspected
- All results are recorded

Spills



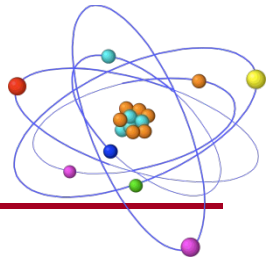
Follow guidelines as posted in the Radiation Laboratory

1. Notify RSO or ARSO

2. If an injury occurs, first attend to injured person and insure personal safety.

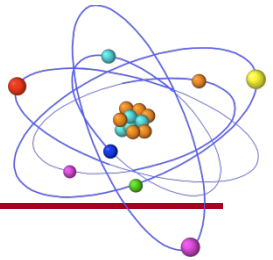
3. Evacuate and cordon off affected area

Spills



4. Assess the size of the spill
5. Call RSO or ARSO for supervision of cleanup.
6. Cleanup procedure:
    - Obtain necessary supplies.
    - Cover spill with absorbent.
    - Push spill towards center.
    - Decontaminate area in sections.
    - Check for contamination (record).
    - Re-clean as necessary.
    - Inform Radiation Safety Officer of fixed contamination.

Spills

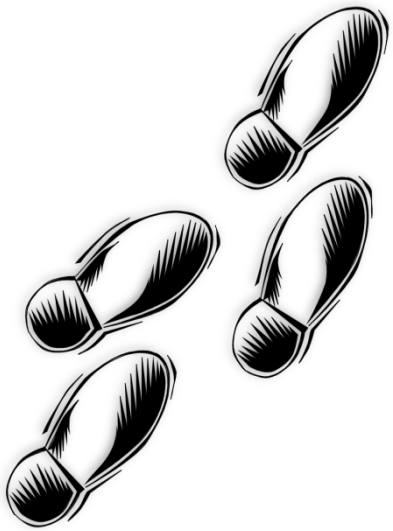


Personal Decontamination

- Use tepid water and mild soap.
- Avoid causing abrasions to skin.
- Wash for a few minutes, dry and monitor (fingernails too!)
- Careful monitoring is the only way to measure progress.

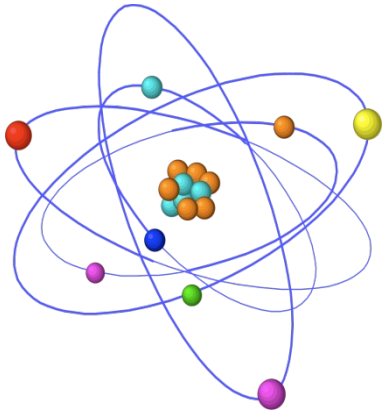
Spills

Leaving contaminated area



- Monitor self (especially feet, hands and lab coat).
- Leave lab coat behind if contaminated and remove dosimeter badge.
- Put up sign and lock door.

THINK SAFETY



PLAN

PRACTICE

REVIEW