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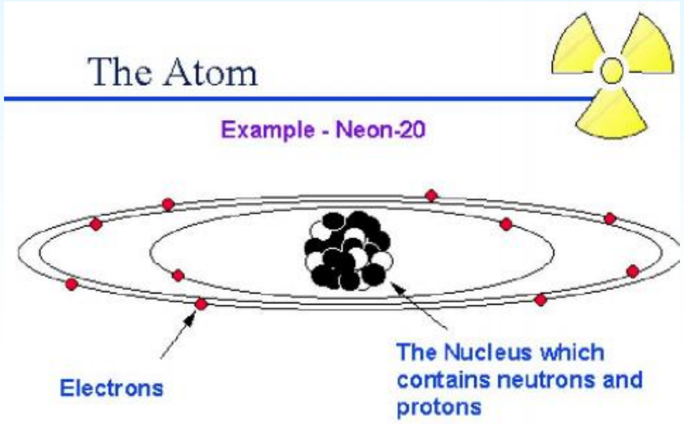
Fundamentals of Radiation

The Atom

- Protons
  - Positive Charge
  - 1 AMU
  - Determines element
- Neutron
  - Neutral Charge
  - "Nuclear Glue” to hold nucleus together
  - 1 AMU
- Electron
  - Negative Charge
  - Orbits nucleus
  - Determines atoms reactivity



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Nuclear Arithmetic

- Protons and neutrons are collectively called nucleons

where : $^{A}_{Z}X$

X = *Chemical symbol*

A = *nucleon number (sum of p and n)*

Z = *atomic number (# of p)*

1. Number of neutrons = A-Z
2. The nucleon number of an isotope is written as a suffix to the name ex. Hydrogen - 2

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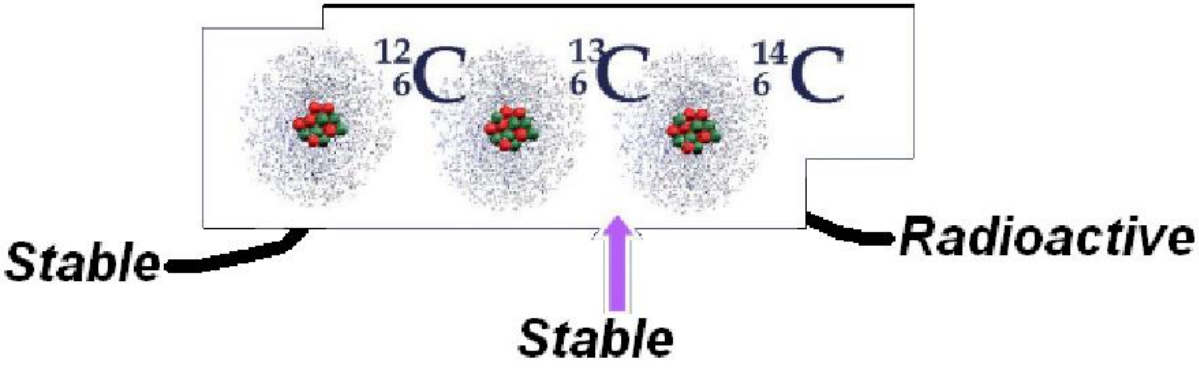
Radioisotopes

- Not all atomic nuclei are radioactive. Some nuclei are stable while others are radioactive; those that are radioactive are sometimes referred to as *RADIOISOTOPES*.



Radioactive Decay

- Radiation from radioactive materials is the result of radioactive decay. An atom with an unstable nucleus will "decay" until it becomes a stable atom, emitting radiation as it decays.
- Radioactivity comes from the atomic nucleus, not from the electron cloud.
- Without instruments, radioactivity cannot be seen, felt, smelled, tasted, or detected by human beings.
- For this reason, it went undiscovered until this century.

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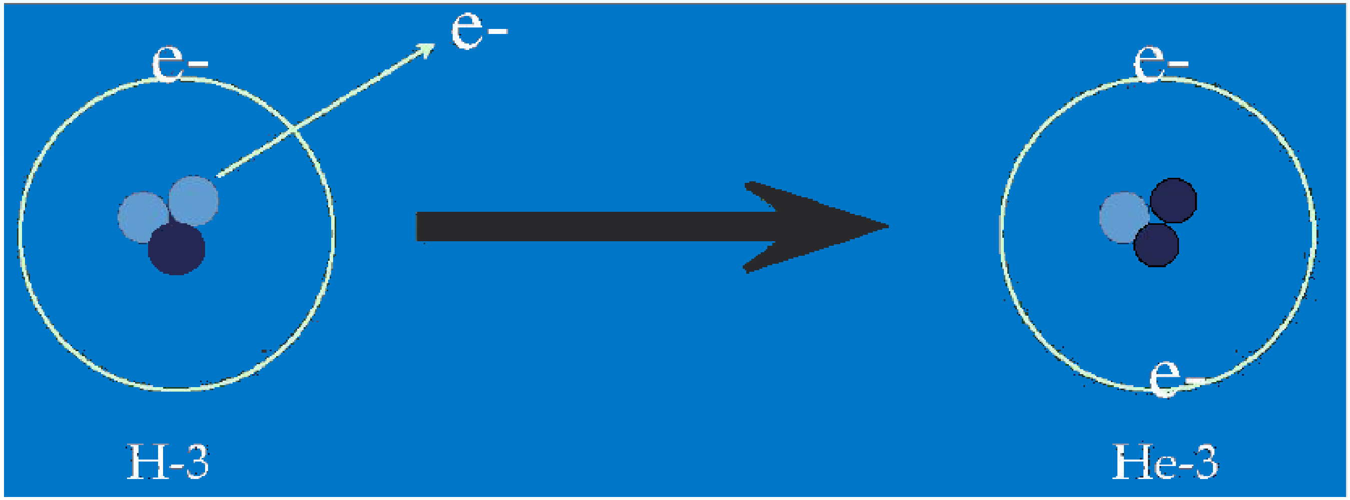
Where Does Radiation Come From?

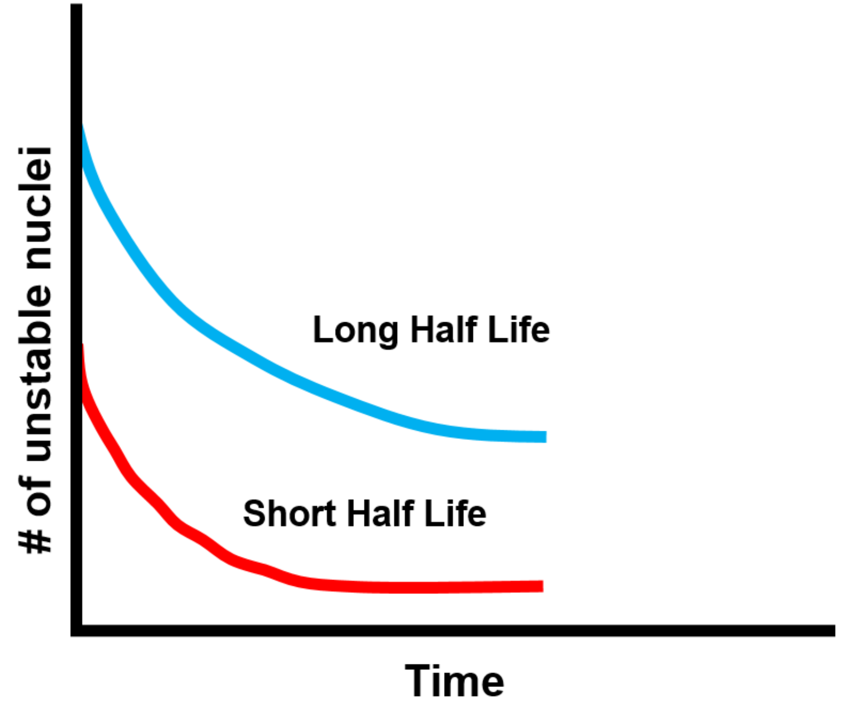
- Radiation results from an unstable nucleus



- This is called radioactive decay.

Radioactive Decay

- Radioactive decay is a random event
- Half life is the time it takes for half of the nuclei is a substance to undergo radioactive decay



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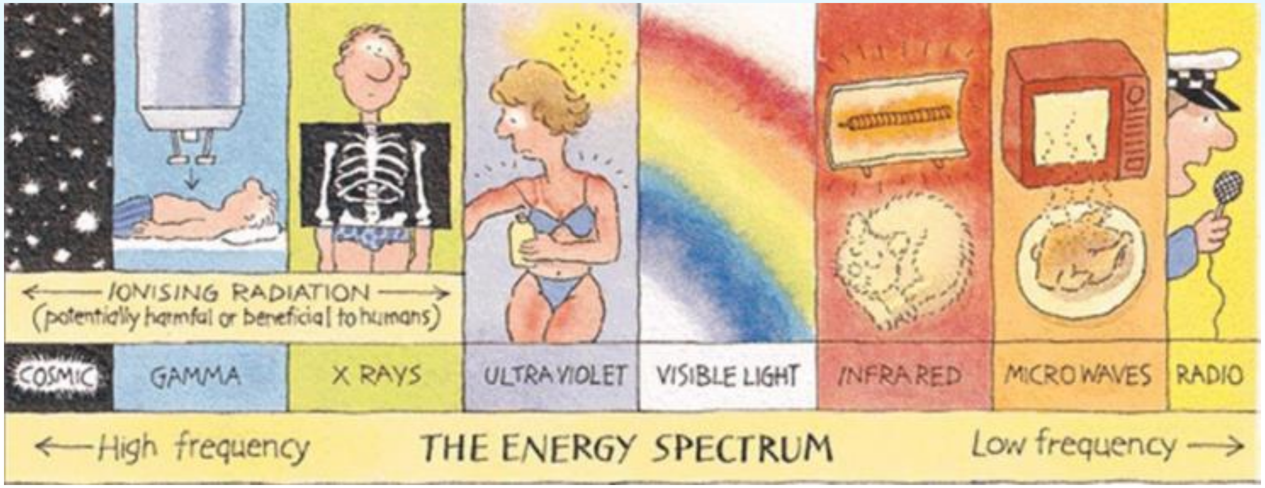
Electromagnetic Spectrum



- Radiations that can transfer enough energy to remove electrons from their atoms are referred to as “ionizing radiations". This is found in the high frequency portion of the electromagnetic spectrum.

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Radiation in Research

- Radiation and radioactive materials can be valuable tools in research.
- Radioactive materials are used in a variety of STEM disciplines, ranging from the biological sciences to physics and materials science.
- There are several labs approved to use radioactive isotopes at UAH.

Radiation and You

- Radiation and radioactive materials are safe if used properly
- ***Background radiation*** is the ionizing radiation emitted from a variety of natural and artificial radiation sources
  - Your exposure can never realistically be zero, because background radiation is always present

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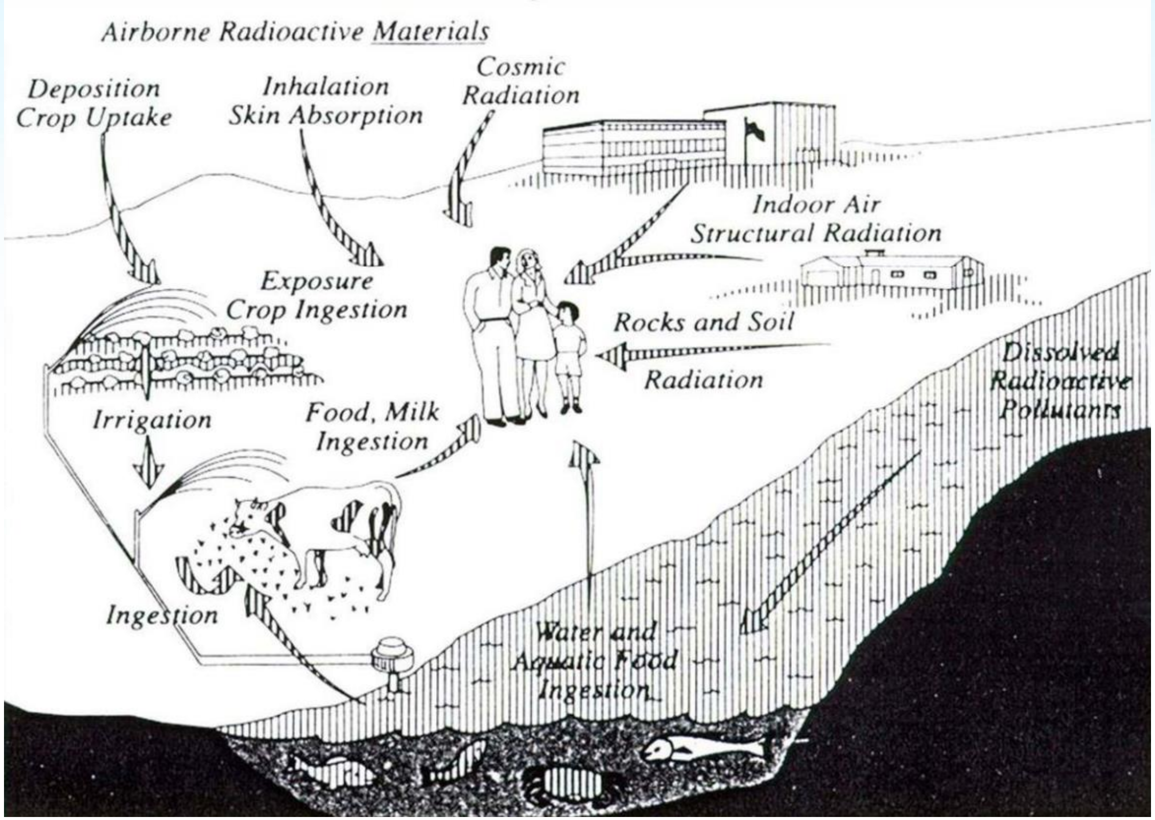
Background Sources of Radiation



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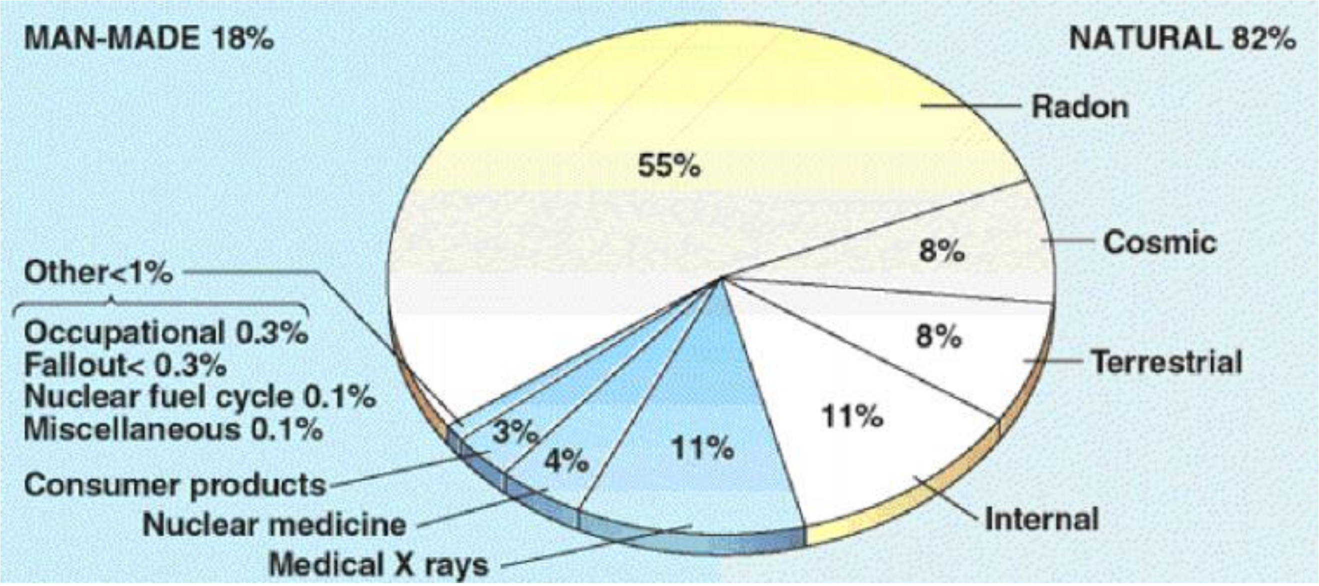
Average dose for a U.S. citizen to receive per year from background radiation is 360 millirem. This dose varies depending upon where the person lives.



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Half Life

- A property often used to describe a radioactive substance is known as the half-life.
- The half life is the time it takes for half of the unstable nuclei in the radioactive substance to undergo radioactive decay.
- There is a wide range of half-lives for isotopes; The half-life of P-32 is only 14.3 days whereas the half-life of C-14 is 5730 years.

Half Life

- ***Radioactive decay occurs randomly***, that is, it is not known when individual atoms will undergo decay. However, although the decay of individual atoms is random, *a radioactive substance, consisting of many atoms, will decay according to a known pattern.*

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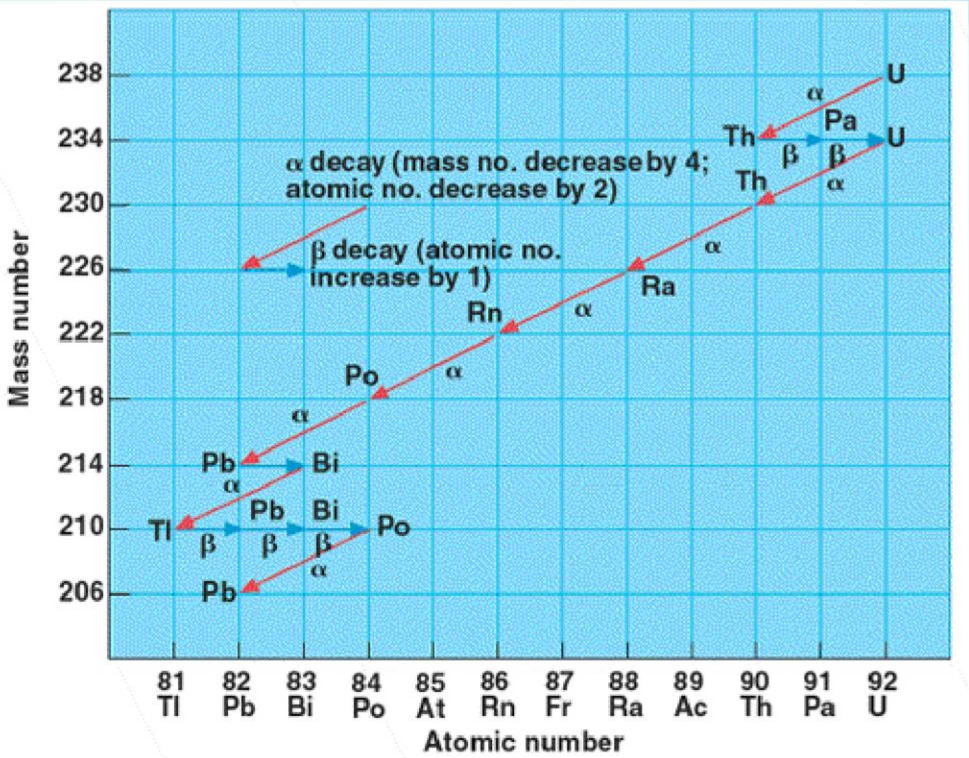

- Radioactive decay of Uranium to lead. A substance often progresses through several radioactive decays until it reaches a stable state.

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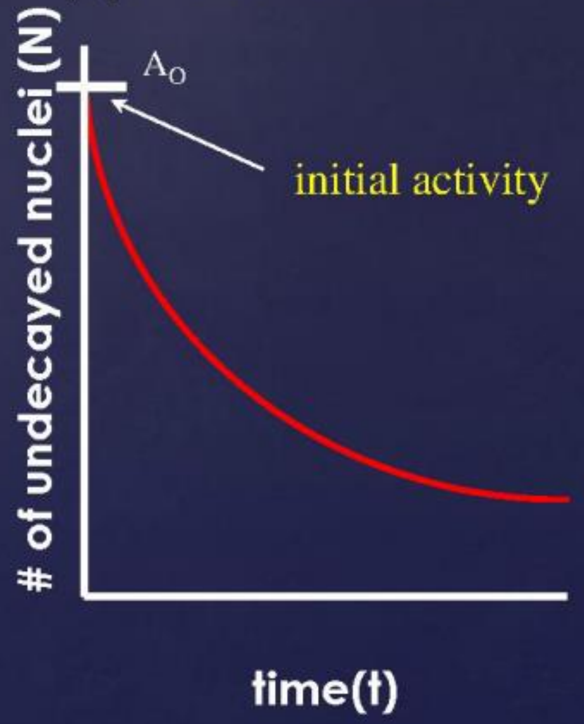
Radioactive Decay Equation

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

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

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

λ is called the decay constant



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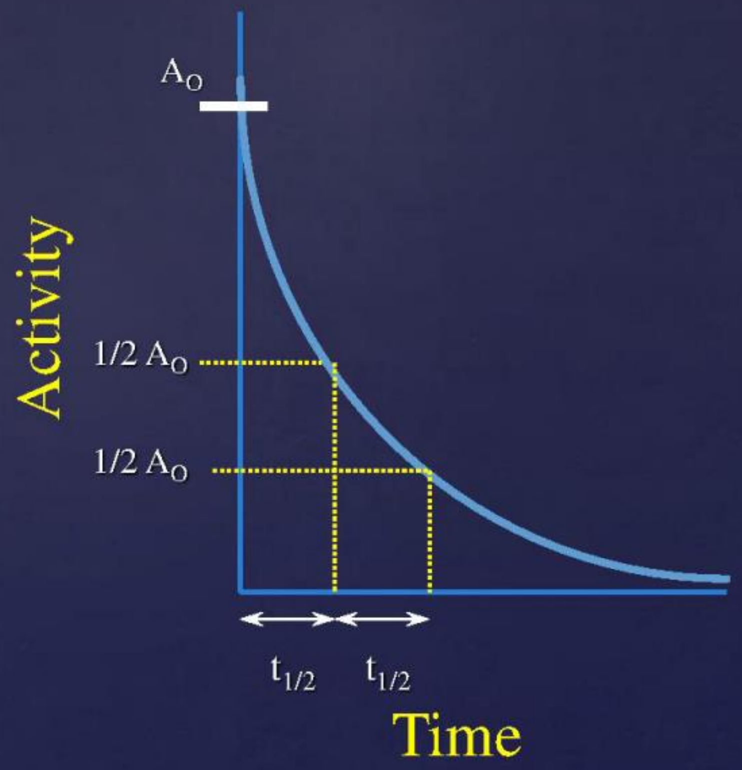
Half-life & the Decay Constant

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

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



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For example:
the half-life of P-32 is 14.3 days

- If you start with 100 microcuries(the unit of the microcurie will be explained later) of P-32, after 14.3 days there would be 50 microcuries left.
- After another 14.3 days there would be 25 microcuries left.
- After 10 half-lives, only about 1/1000th (actually 1/210, which is 1/1024) of the original will be left.

Radioactive Decay Emissions

- Alpha particles
- Beta particles
- Gamma Rays

Radioactive Emissions

- Alpha particles contain *two protons and two neutrons (a helium nucleus). They have an atomic number of 2.*

Alpha Properties

- Heavy particles and carry charge, they cannot travel very far; they typically travel up to a few centimeters in air, depending on their energy.
- Not generally considered to be an external radiation hazard, as they cannot penetrate the outer protective layer of your skin.
- Alpha's can be inhaled and through further decay, irradiate lung tissue, as in the case of radon and its daughter's.

Radioactive Emissions

- Beta particles are simply electrons. Beta radiation is a stream of electrons from the nucleus of the atom.

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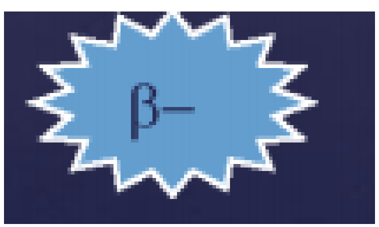
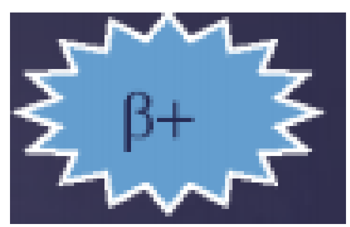
Properties - Beta Particles

- 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 materials such as Plexiglas/Lucite or wood





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Typical Beta Isotopes

Several ß emitters are used at UAH. These can be classified as low or high energy particles

Isotope	Energy MeV	1/2 Life
^{3}H	0.018	12.3 years
^{14}C	0.155	5570 years
^{32}P	1.71	14.2 days
^{33}P	0.215	25 Days
^{35}S	0.167	87.1 days

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Radioactive Emissions

- Gamma rays *are a high energy form of electromagnetic radiation. They are similar to light waves but have shorter wavelengths and are more energetic.*

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Properties - Gamma Rays

- Gamma rays:
  - Are photons that originate from the nucleus of the atom
  - Do not carry a charge
  - Can cause ionization when they interact
  - Should be shielded with high Z materials, such as lead, if appropriate

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Possible Gamma Emitters

- ^{22}Na
- $^{36}C1$
- ^{125}I
- ^{131}I

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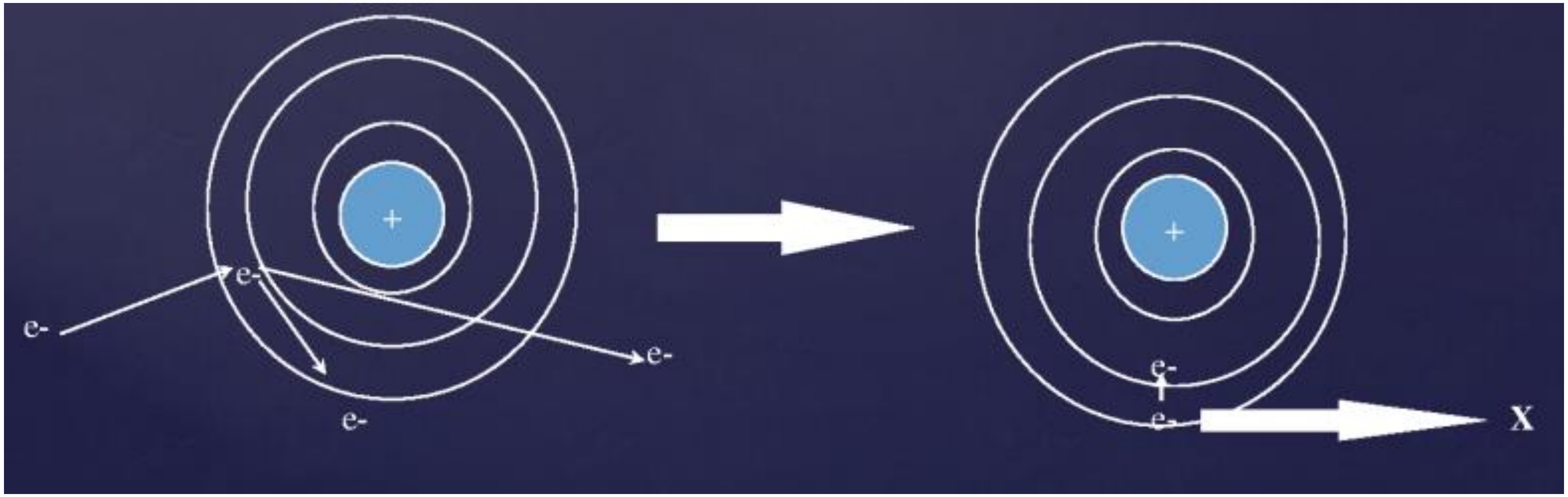
Properties - Characteristic X-rays

- *Characteristic X-rays* are generated when electrons fall from higher energy to lower energy electron shells



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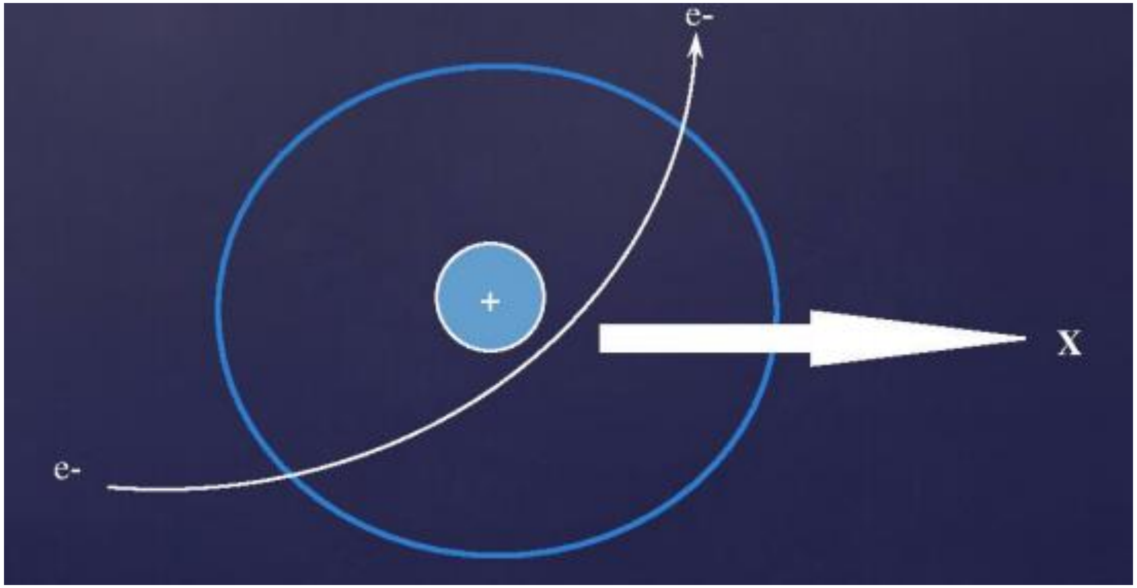
Properties - Bremsstrahlung X-rays

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



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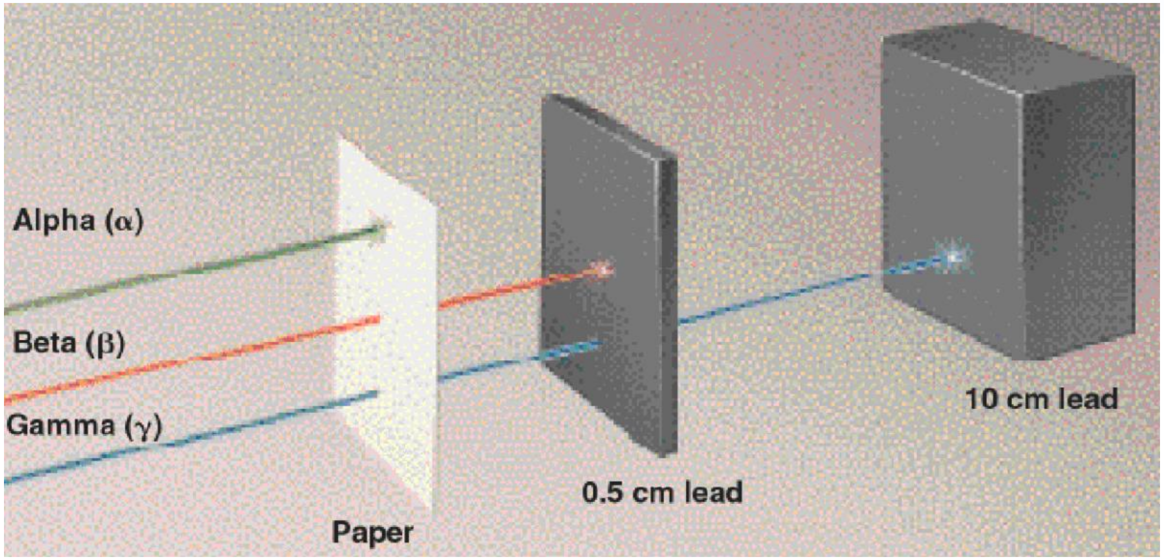
Penetrating Power

- The penetrating power of radiation varies in part due to their masses and their charges
- Protection from radiation - distance and shielding



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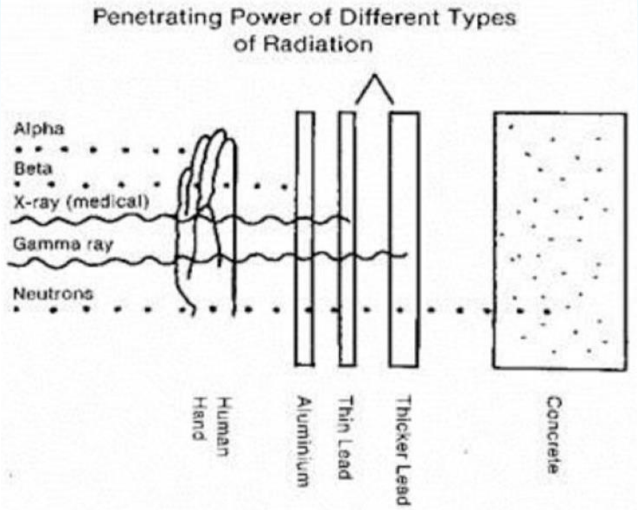
Penetrating Power

- Alpha - outside of body little damage, not able to penetrate skin. Inside of the body causes much damage to tissues cells DNA and Proteins
- Beta - some harm but much less than alpha can go through skin
- Gamma - is the most harmful easily penetrates skin and damages DNA and Cells as it “rips” through



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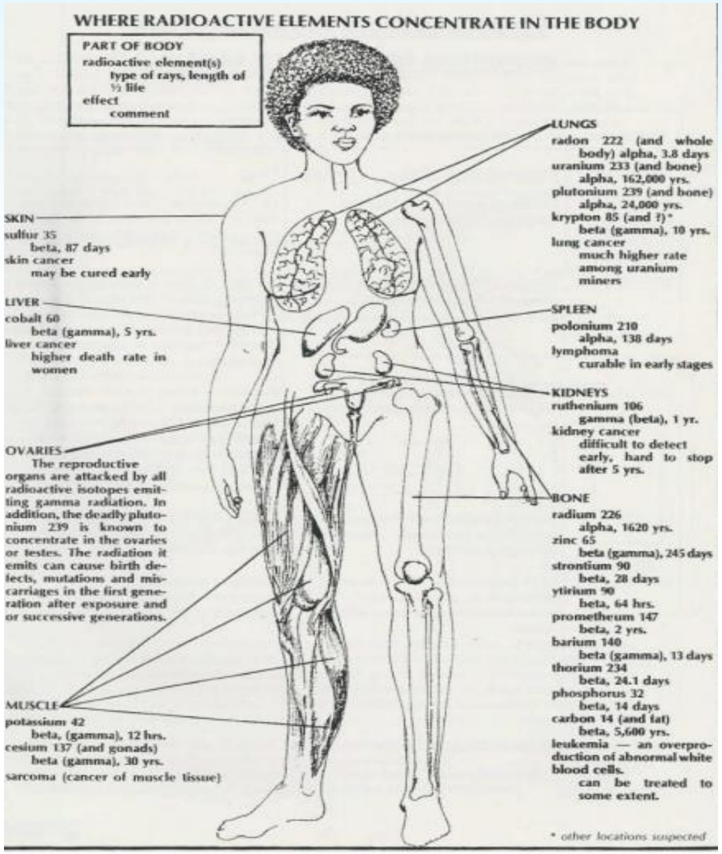
Exposure

- Elements tend to concentrate in certain parts of the
  - I – Thyroid
  - S – Skin
  - P – Bone
  - H – Throughout



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Radiation Units

- There are specific units for the amount of radiation you receive in a given time and for the total amount of exposure you are subjected to.

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Measuring radioactivity rates - What Is a Curie?

- ***This is the amount of radioactivity in a sample (the amount of radioactivity = activity)***
- A commonly-used unit for measuring activity is the curie(Ci)
- 1 curie is equal to 2.2 x 10^{12} disintegrations per minute (dpm)
- Typical activities found in a university lab are in the microcurie (µCi) to millicurie (mCi) range

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Measuring radioactivity rates - What is a Becquerel (Bq)

- *The amount of radioactive material which decays at a rate of one disintegration per second (dps)*
- This is the SI unit of radioactive material or activity

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CPM & DPM

- CPM is the counts per minute that a detector “sees”
- DPM are the actual disintegrations (release of energy) by a radioactive sample [disintegrations per minute]
- ***Since detectors aren't 100% efficient...***

DPM = CPM / Detector Efficiency

(the detector efficiency for the specific radioisotope, that is)

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Radiation Dose vs Rate

- Dose is the amount of radiation you were actually exposed to:
  - **Roentgen** - This can only be used to describe an amount of gamma and X-rays, and only in air. One roentgen is equal to depositing in dry air enough energy to cause $2.58E^{-4}$ coulombs per kg. It is a measure of the ionizations of the molecules in a mass of air. (NOT a or b particles)

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What is a REM?

- **REM** - The most common used unit for measuring radiation dose in people is the rem
- **REM** = *Roentgen equivalent for man*, a roentgen (an international unit of X-or gamma-radiation) adjusted for the atomic makeup of the human body
- Since the rem is a relatively large unit, it is more common to use the millirem (mrem), which is 1/1000th of a rem

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Rem is a Dose Equivalent

- The Dose equivalent is the product of the absorbed dose in tissue times a quality factor
- This relates the absorbed dose in human tissue to the effective biological damage of the radiation.
- Not all radiation has the same biological effect, even for the same amount of absorbed dose.
  - Rem = Quality factor x dose in rads
  - Sievert is the SI unit of dose equivalent

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Quality factors

X and gamma rays	1
Beta particles	1
Thermal Neutrons	2
Fast Neutrons	10
Protons	10
Alpha particles	20

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Other "Dose" Units

- **Rad** (Radiation Absorbed Dose)- this is the amount of exposure to any type of material from any type of radiation measured in Joules/kg tissue
- The **Gray** is the absorbed dose that corresponds to the transfer of 1 joule to 1 kg of material (SI unit). Does not relate to biological effects.

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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)
- Minors = 500 mrem/year
- Rad workers = 100 mrem/year over background

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Average Doses Experienced in a Year

- Natural sources = 300 mrem
- Medical = 53 mrem
- Occupational = 0.9 mrem
- Nuclear Fuel = 0.05 mrem
- Consumer products = 5-13 mrem
- Misc. environmental = 0.06 mrem

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Units Review

Rate - of disintegration

- DPM
- Curie
- Becquerel (SI)
- NOT CPM

Dose - amount of radiation exposed

- Roentogen
- Rad
- Gray (SI)
- REM (equivalent)
- Sievert (SI equivalent)

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What's Next?

This presentation provided basic information concerning radioactivity.

1. The next slide has a link to a quiz that must be passed with 75% correct to work with radioactive materials at UAH
2. After the test has been completed, contact OEHS at oehs@uah.edu to provide notice that you have taken the test.
3. Upon receipt of a passing score, radiation workers must review the UAH Radiation Safety Procedures and submit a declaration of receipt of the training (link at the end of the presentation). The Radiation Safety Procedures presentation is important for you to review because it includes information on protection yourself from radiation.
4. The Authorized User will provide radiation workers with lab-specific training.

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Acknowledge Training

Click here to acknowledge receipt of training

If you have any questions contact:

Office of Environmental Health and Safety
Physical Plant Building
301 Sparkman Drive
Huntsville, AL 35899

oehs@uah.edu

256-824-6053

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