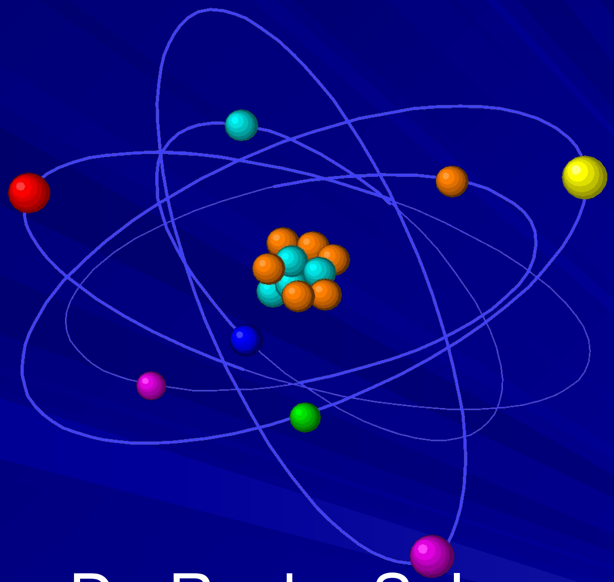
Radiation



Dr. Rasha Salama
PhD Community Medicine
Suez Canal University
Egypt

Definition of Radiation

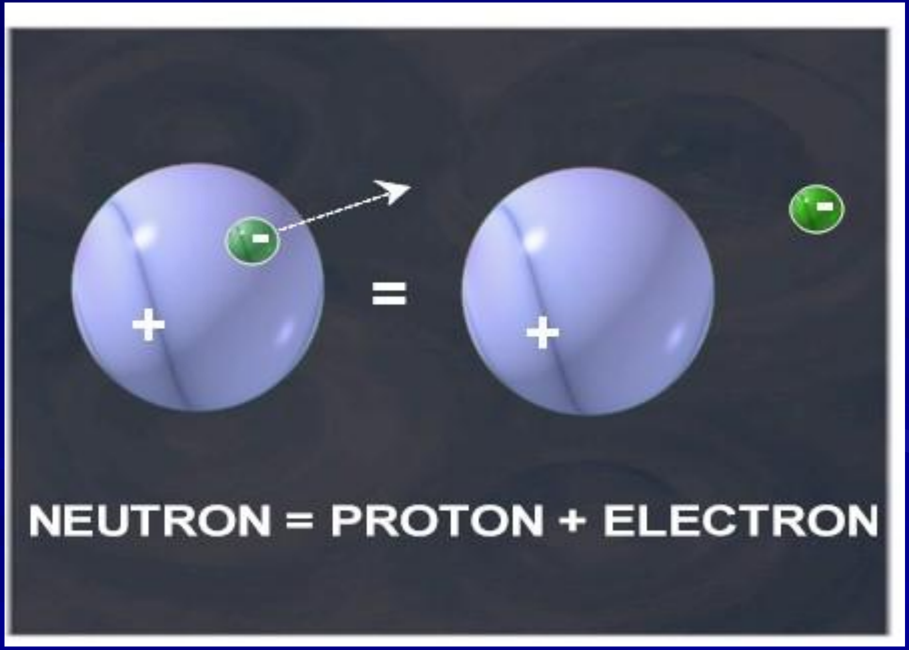
- "Radiation is an energy in the form of electro-magnetic waves or particulate matter, traveling in the air."

Nuclear Interactions

- Forces: There are many interactions among nuclei. It turns out that there are forces other than the electromagnetic force and the gravitational force which govern the interactions among nuclei.
- Einstein in 1905m showed 2 more laws: energy/mass, and binding energy

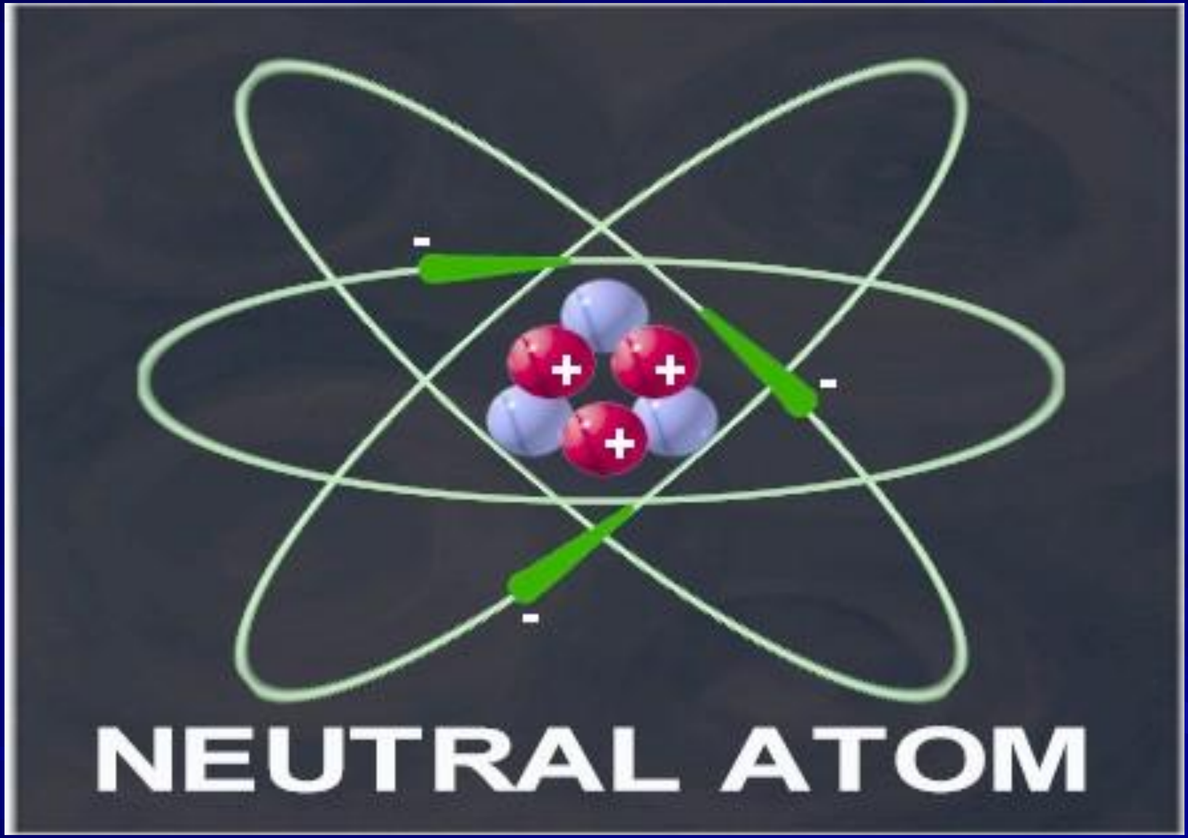
Radioactivity: Elements & Atoms

- Atoms are composed of smaller particles referred to as:
  - Protons
  - Neutrons
  - Electrons



Basic Model of a Neutral Atom.

- Electrons (-) orbiting nucleus of protons (+) and neutrons. Same number of electrons as protons; net charge = 0.
- **Atomic number** (number of protons) determines element.
- **Mass number** (protons + neutrons)



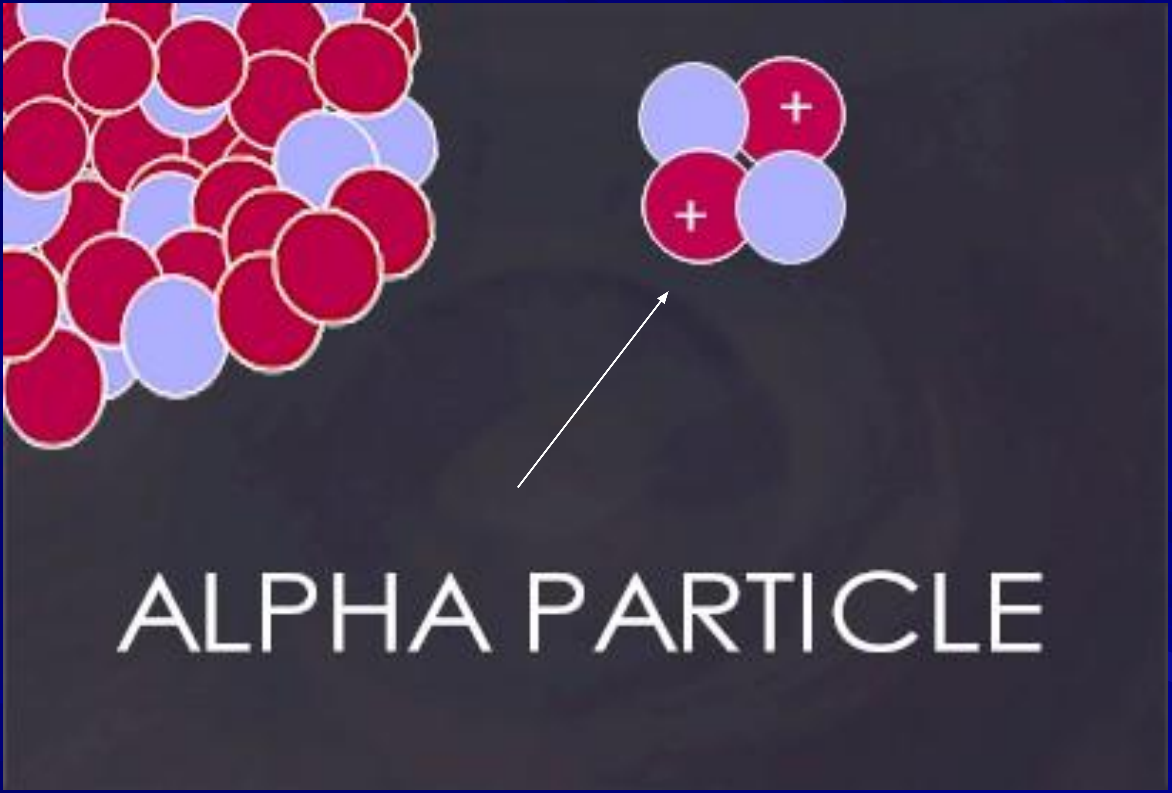
-
+
+
-
+
-
NEUTRAL ATOM

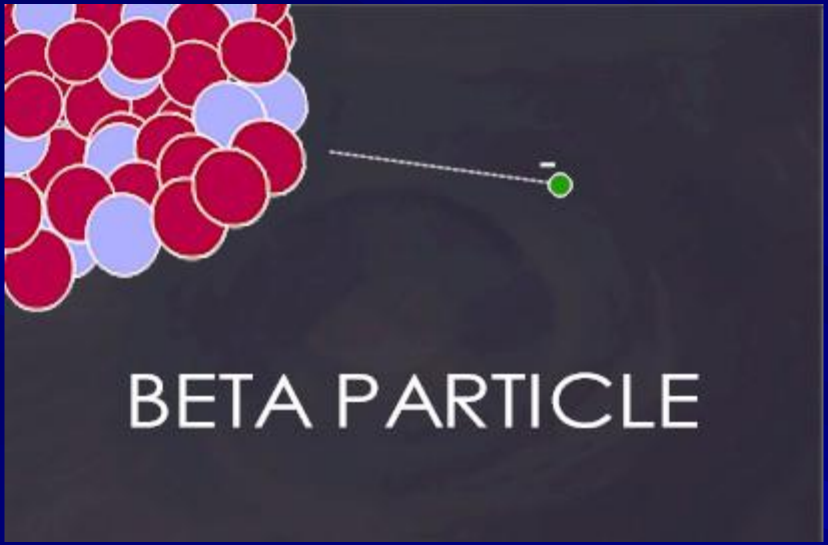
Radioactivity

- If a nucleus is unstable for any reason, it will emit and absorb particles. There are many types of radiation and they are all pertinent to everyday life and health as well as nuclear physical applications.

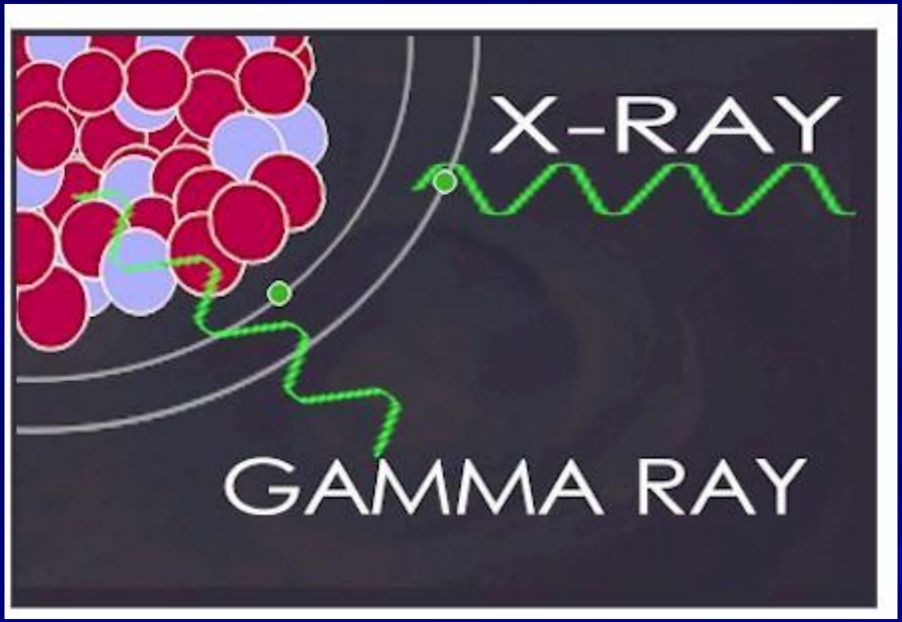
Ionization

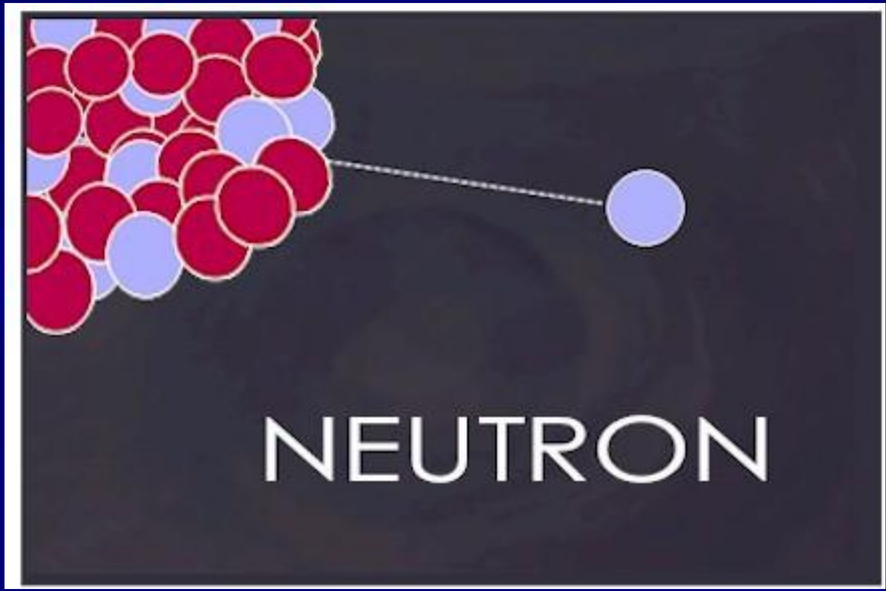
- Ionizing radiation is produced by unstable atoms. Unstable atoms differ from stable atoms because they have an excess of energy or mass or both.
- Unstable atoms are said to be radioactive. In order to reach stability, these atoms give off, or emit, the excess energy or mass. These emissions are called radiation.


+
+
ALPHA PARTICLE

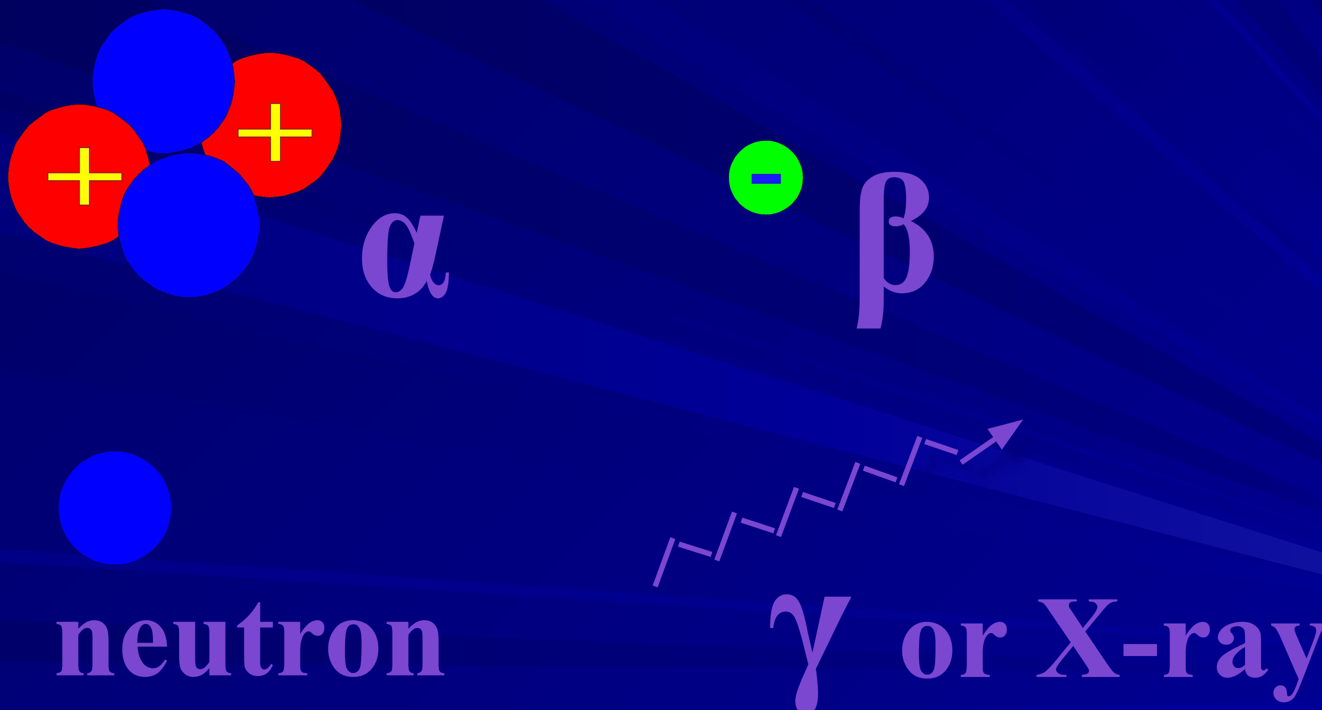


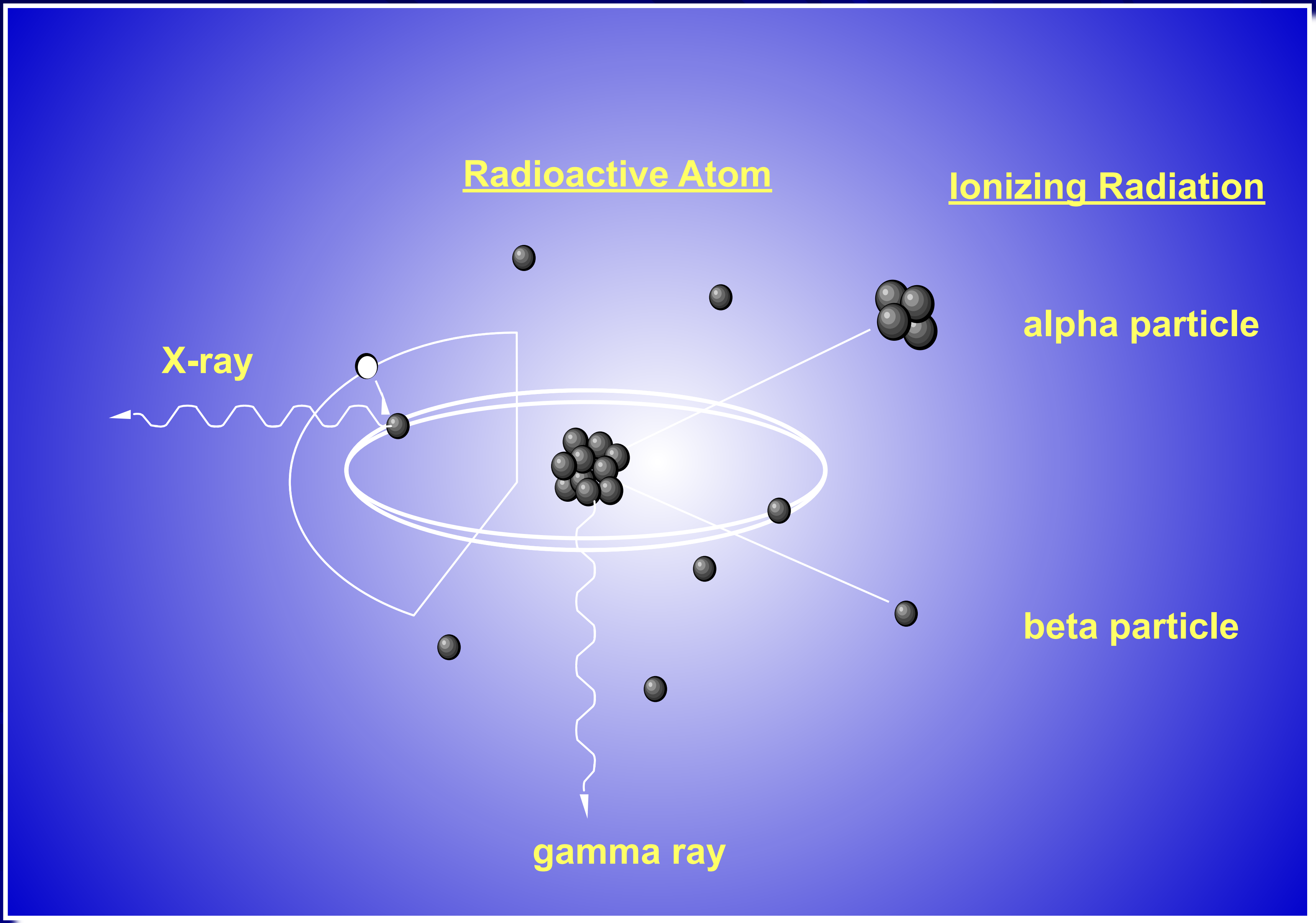
BETA PARTICLE


X-RAY
GAMMA RAY

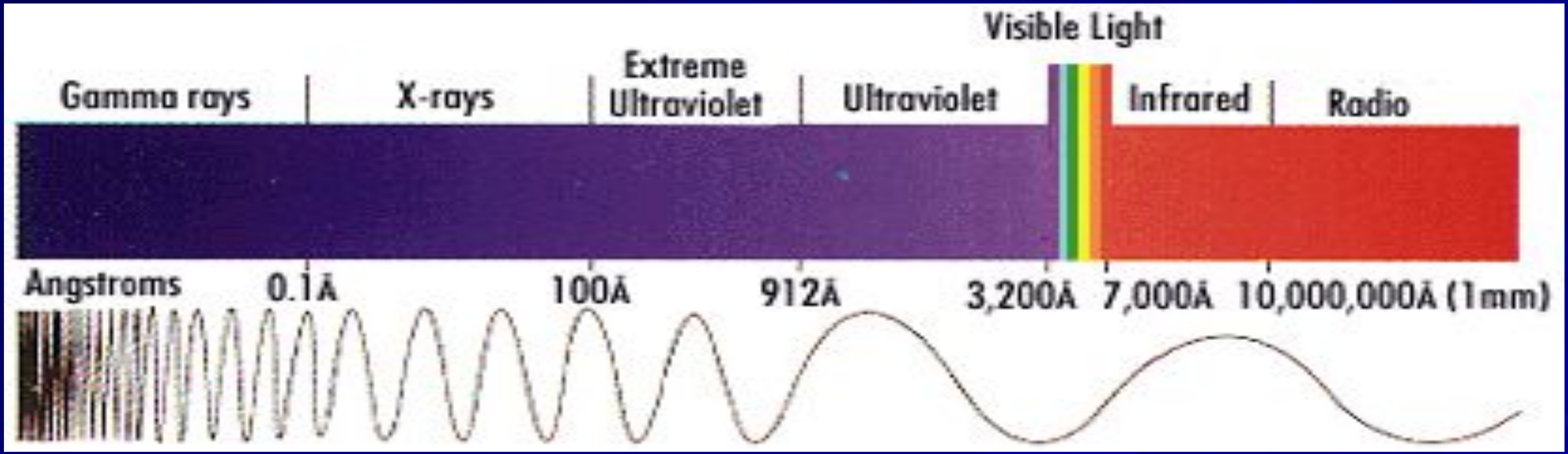

NEUTRON

Types or Products of Ionizing Radiation

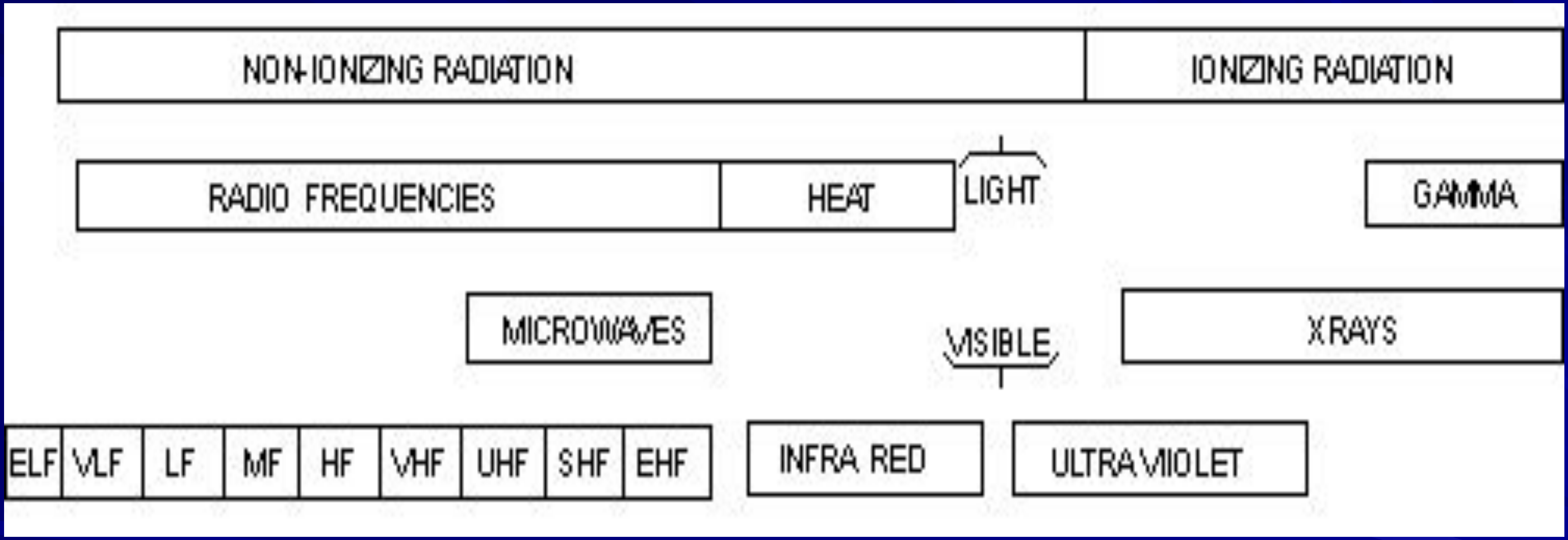


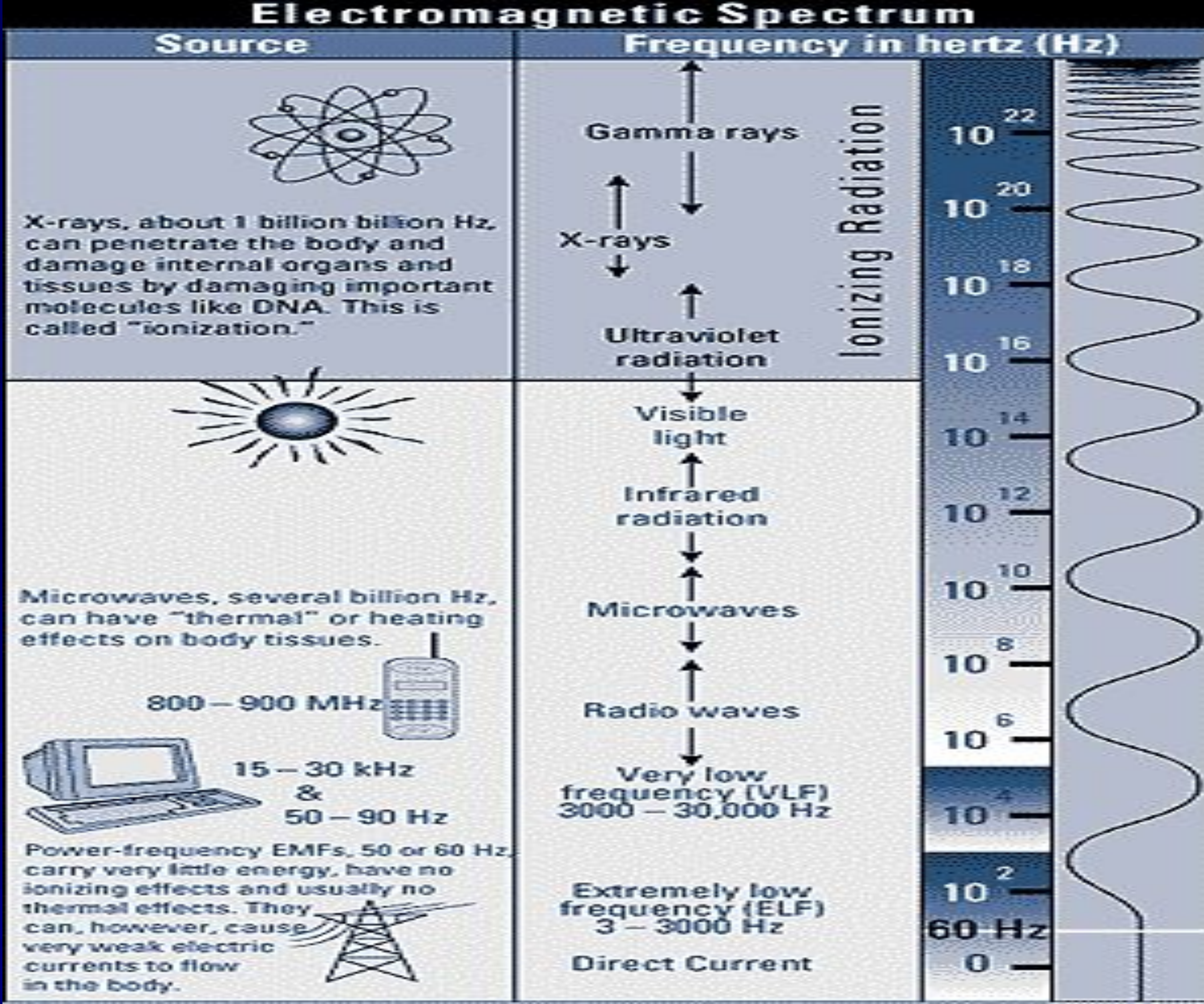

Radioactive Atom
Ionizing Radiation
alpha particle
X-ray
beta particle
gamma ray

- The electro-magnetic waves vary in their length and frequency along a very wide spectrum.



Visible Light
Gamma rays
X-rays
Extreme Ultraviolet
Ultraviolet
Infrared
Radio
Angstroms
0.1Å
100Å
912Å
3,200Å
7,000Å
10,000,000Å (1mm)


NON-IONIZING RADIATION
IONIZING RADIATION
RADIO FREQUENCIES
HEAT
LIGHT
GAMMA
MICROWAVES
VISIBLE
X RAYS
ELF
VLF
LF
MF
HF
VHF
UHF
SHF
EHF
INFRA RED
ULTRA VIOLET



Electromagnetic Spectrum
Source
Frequency in hertz (Hz)
X-rays, about 1 billion billion Hz, can penetrate the body and damage internal organs and tissues by damaging important molecules like DNA. This is called "ionization."
Microwaves, several billion Hz, can have "thermal" or heating effects on body tissues.
800 – 900 MHz
15 – 30 kHz
&
50 – 90 Hz
Power-frequency EMFs, 50 or 60 Hz, carry very little energy, have no ionizing effects and usually no thermal effects. They can, however, cause very weak electric currents to flow in the body.
Gamma rays
X-rays
Ultraviolet radiation
Visible light
Infrared radiation
Microwaves
Radio waves
Very low frequency (VLF) 3000 – 30,000 Hz
Extremely low frequency (ELF) 3 – 3000 Hz
Direct Current
Ionizing Radiation
10^{22}
10^{20}
10^{18}
10^{16}
10^{14}
10^{12}
10^{10}
10^{8}
10^{6}
10^{4}
10^{2}
60 Hz
0

Types of Radiation

- Radiation is classified into:
  - Ionizing radiation
  - Non-ionizing radiation

Ionizing Versus Non-ionizing Radiation

- **Ionizing Radiation**
  - **Higher energy electromagnetic waves (gamma) or heavy particles (beta and alpha).**
  - **High enough energy to pull electron from orbit.**
- **Non-ionizing Radiation**
  - **Lower energy electromagnetic waves.**
  - **Not enough energy to pull electron from orbit, but can excite the electron.**

Ionizing Radiation

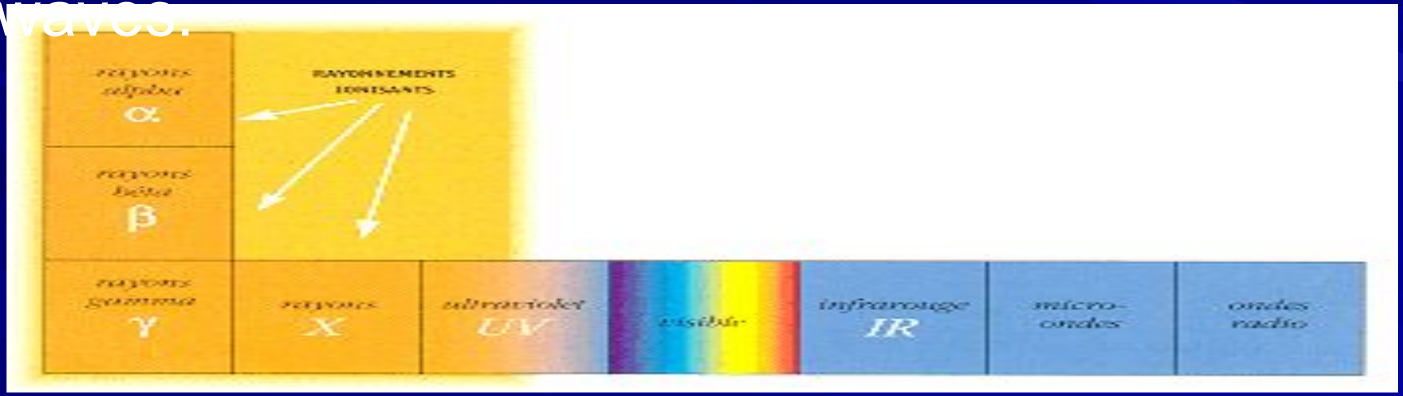
- Definition:

  “ It is a type of radiation that is able to disrupt atoms and molecules on which they pass through, giving rise to ions and free radicals”.

Another Definition

Ionizing radiation

A radiation is said to be ionizing when it has enough energy to eject one or more electrons from the atoms or molecules in the irradiated medium. This is the case of a and b radiations, as well as of electromagnetic radiations such as gamma radiations, X-rays and some ultra-violet rays. Visible or infrared light are not, nor are microwaves or radio waves.



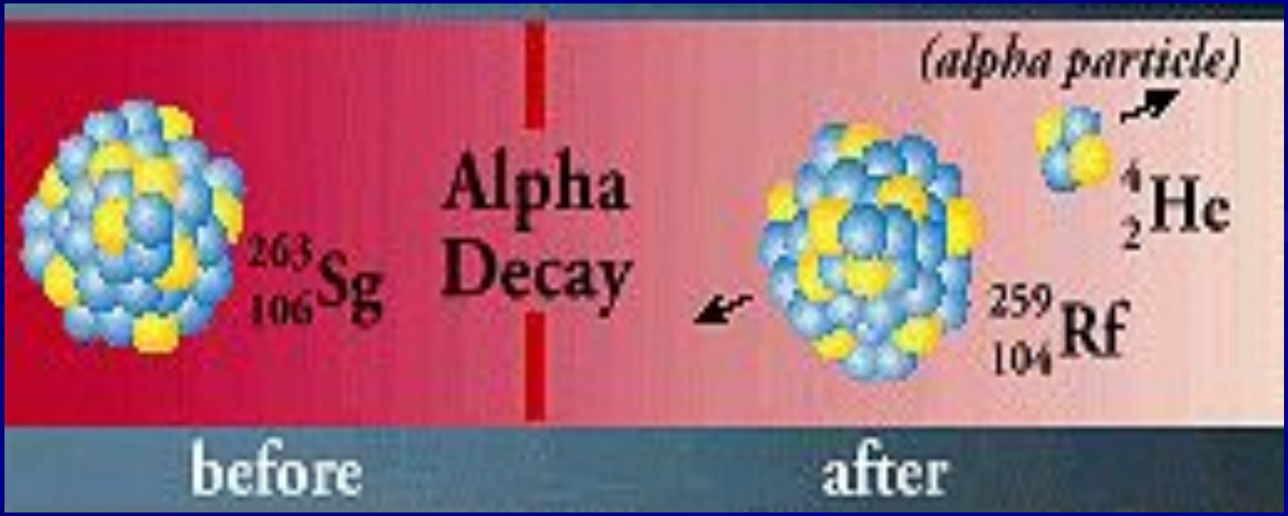
Primary Types of Ionizing Radiation

- Alpha particles
- Beta particles
- Gamma rays (or photons)
- X-Rays (or photons)
- Neutrons

Types and Characteristics of Ionizing Radiation

Alpha Particles

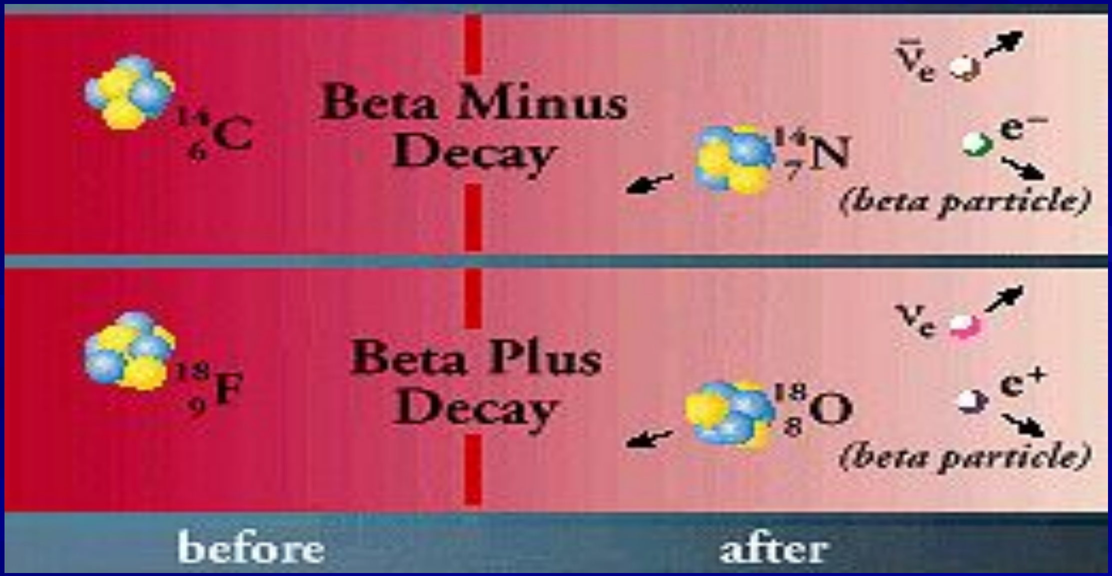
Alpha Particles: 2 neutrons and 2 protons
They travel short distances, have large mass
Only a hazard when inhaled



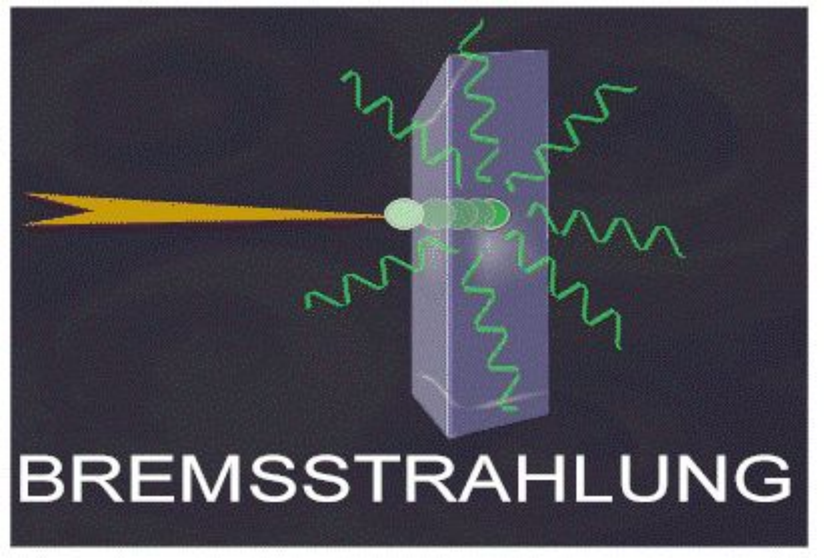
- ***Alpha Particles*** *(or Alpha Radiation)*: **Helium nucleus** (2 neutrons and 2 protons); +2 charge; heavy (4 AMU). Typical Energy = 4-8 MeV; **Limited range** (<10cm in air; 60µm in tissue); High LET (**QF=20**) causing **heavy damage** (4K-9K ion pairs/µm in tissue). **Easily shielded** (e.g., paper, skin) so an **internal radiation** hazard. Eventually lose too much energy to ionize; become He.

Beta Particles

Beta Particles: Electrons or positrons having small mass and variable energy. Electrons form when a neutron transforms into a proton and an electron or:

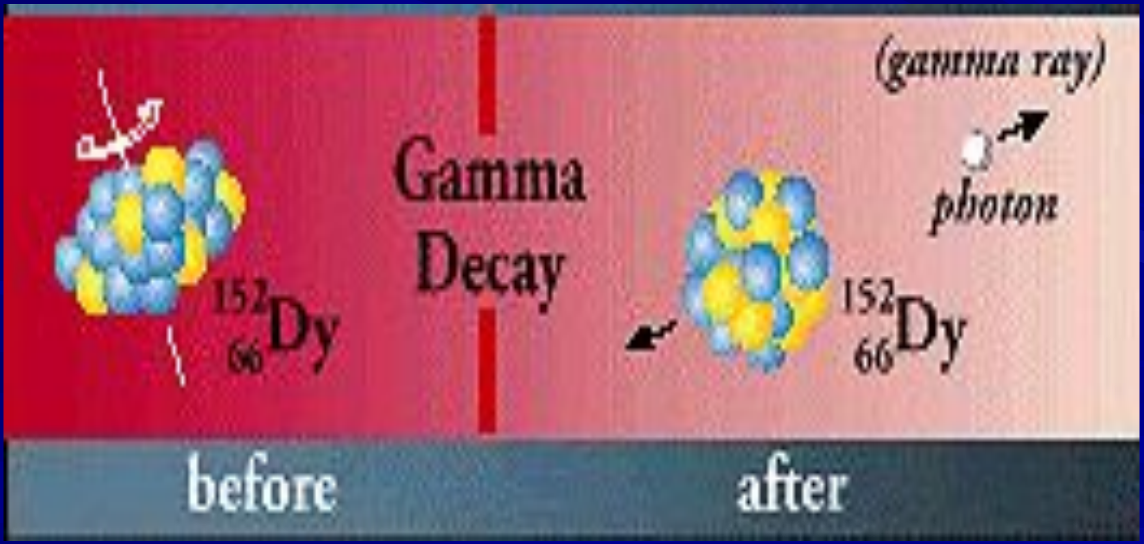


- ***Beta Particles***: High speed **electron ejected from nucleus**; -1 charge, light 0.00055 AMU; Typical Energy = several KeV to 5 MeV; Range approx. 12'/MeV in air, a few mm in tissue; Low LET (**QF=1**) causing **light damage** (6-8 ion pairs/μm in tissue). Primarily an internal hazard, but high beta can be an external hazard to skin. In addition, the high speed electrons may lose energy in the form of X-rays when they quickly decelerate upon striking a heavy material. This is called **Bremsstralung** (or Breaking) **Radiation.** Aluminum and other light (<14) materials are used for shielding.


BREMSSTRAHLUNG

Gamma Rays

Gamma Rays (or photons): Result when the nucleus releases energy, usually after an alpha, beta or positron transition



X-Rays

X-Rays: Occur whenever an inner shell orbital electron is removed and rearrangement of the atomic electrons results with the release of the elements characteristic X-Ray energy

- ***X-*** *and* ***Gamma Rays***: **X-rays** are photons (Electromagnetic radiations) emitted **from electron orbits**. **Gamma rays** are photons emitted **from the nucleus**, often as part of radioactive decay. Gamma rays typically have higher energy (Mev's) than X-rays (KeV's), but both are unlimited.

Neutrons

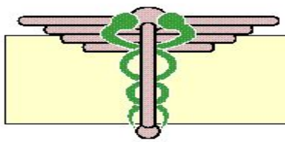
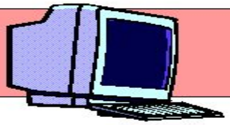
Neutrons: Have the same mass as protons but are uncharged

Radiation from Natural Sources

Source	mrem/year
Cosmic rays	28
The earth	26
Radon	200
The human body	25
Building materials	4

Transparency 4-1

Radiation from Manmade Sources

	Source	mrem/year
	Medical	90
	Fallout	5
	Consumer products	1
	Nuclear power	0.3

QUANTIFICATION OF RADIATION

- A. Quantifying Radioactive Decay
- B. Quantifying Exposure and Dose

A. Quantifying Radioactive Decay

Measurement of **Activity** in disintegrations per second (dps);

- 1 **Becquerel** (Bq) = 1 dps;
- 1 **Curie** (Ci) = 3.7 x 1010 dps;
- Activity of substances are expressed as activity per weight or volume (e.g., Bq/gm or Ci/l).

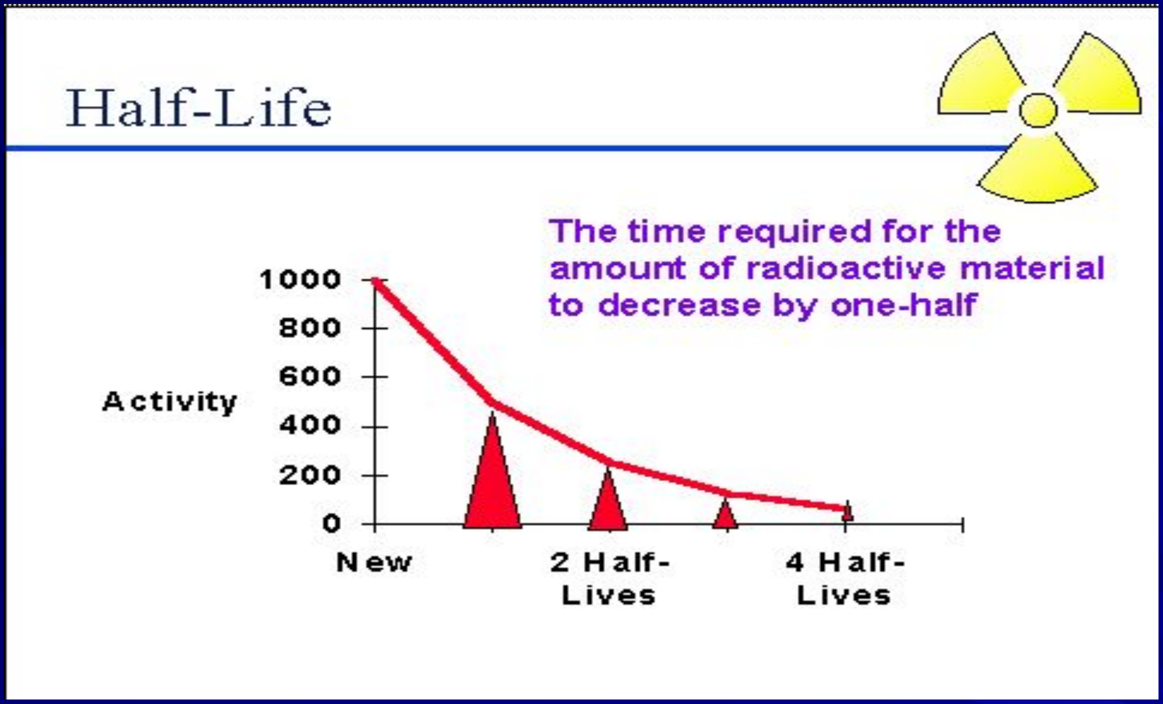
B. Quantifying Exposure and Dose

- Exposure: **Roentgen** 1 Roentgen (R) = amount of **X or gamma** radiation that produces ionization resulting in 1 electrostatic unit of charge in 1 cm3 of dry **air**. Instruments often measure exposure rate in mR/hr.

- Absorbed Dose: **rad** (Roentgen absorbed dose) = absorption of 100 ergs of energy from **any radiation** in 1 gram of **any material**; 1 **Gray** (Gy) = 100 rads = 1 Joule/kg; Exposure to 1 Roentgen approximates 0.9 rad in air.

- Biologically Equivalent Dose: **Rem (Roentgen equivalent man) = dose in rads x QF**, where QF = quality factor. 1 **Sievert** (Sv) = 100 rems.

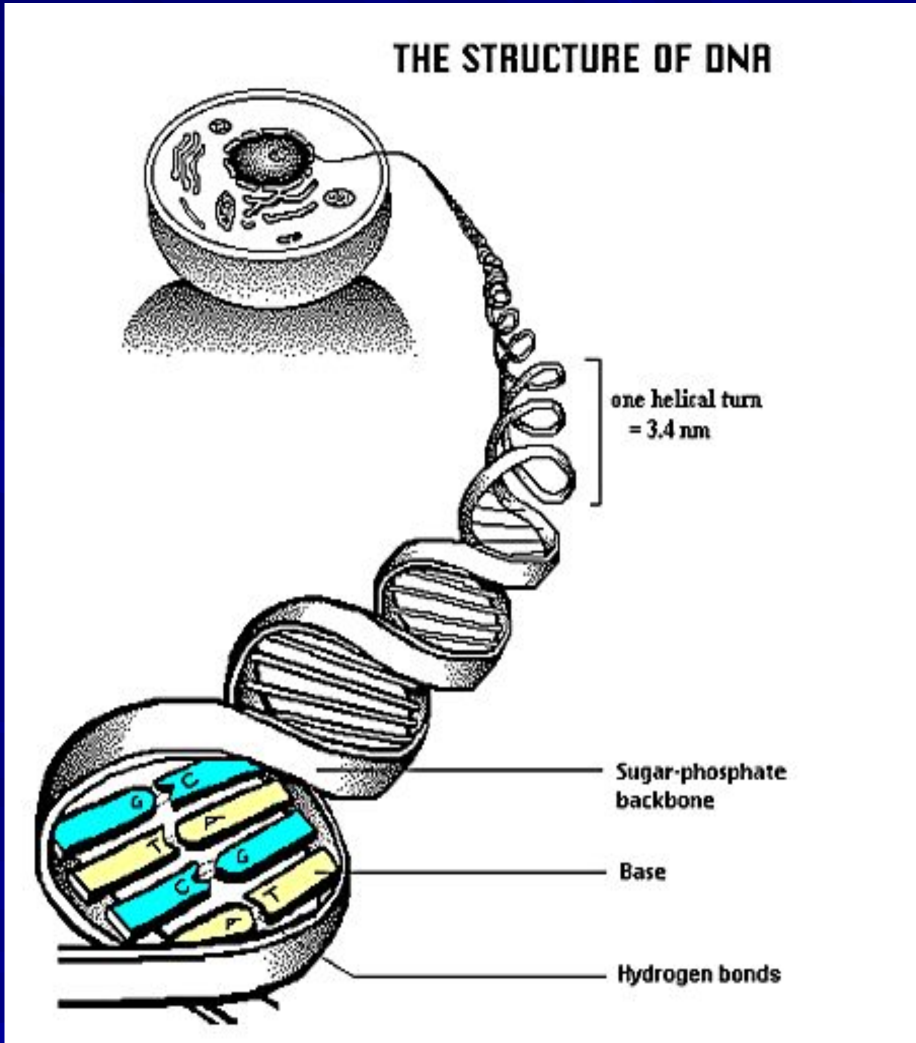
Half Life Calculation



$$N_t = N_o\left(\frac{1}{2}\right)^{\frac{t}{T_{\frac{1}{2}}}}$$

Ionizing Radiation at the Cellular Level

- Causes breaks in one or both DNA strands or;
- Causes Free Radical formation



Exposure Limits

- *OSHA Limits:* Whole body limit = 1.25 rem/qtr or **5 rem (50 mSv) per year.**
- Hands and feet limit = 18.75 rem/qtr.
- Skin of whole body limit = 7.5 rem/qtr.
- Total **life accumulation = 5 x (N-18) rem where N = age**. Can have 3 rem/qtr if total life accumulation not exceeded.
- Note: New recommendations reduce the 5 rem to 2 rem.

External/Internal Exposure Limits for Occupationally Exposed Individuals

Annual Dose Limits

	Adult (>18 yrs)	Minor (< 18 yrs)
Whole body*	5000 mrem/yr	500 mrem/yr
Lens of eye	15000 mrem/yr	1500 mrem/yr
Extremities	50000 mrem/yr	5000 mrem/yr
Skin	50000 mrem/yr	5000 mrem/yr
Organ	50000 mrem/yr	5000 mrem/yr

Maximum Permissible Dos Equivalent for Occupational Exposure	
Combined whole body occupational exposure	
Prospective annual limit	5 rems in any 1 yr
Retrospective annual limit	10-15 rems in any 1 yr
Long-term accumulation	(N-18) x5 rems. where N is age in yr
Skin	15 rems in any 1 yr
Hands	75 rems in any 1 yr (25/qtr)
Forearms	30 rems in any 1 yr (10/qtr)
Other organs, tissues and organ systems	
Fertile women (with respect to fetus)	0.5 rem in gestation period
Population dose limits	0.17 rem average per yr

(Reprinted from NCRP Publication No. 43, Review of the Current State of Radiation Protection Philosophy, 1975)

Community Emergency Radiation

Hazardous Waste Sites:

- Radiation above background (0.01-0.02 m rem/hr) signifies possible presence which must be monitored. Radiation above 2 m rem/hr indicates potential hazard. Evacuate site until controlled.

Your Annual Exposure

Activity	**Typical Dose**
Smoking	280 millirem/year
Radioactive materials use in a UM lab	**<10 millirem/year**
Dental x-ray	10 millirem per x-ray
Chest x-ray	8 millirem per x-ray
Drinking water	5 millirem/year
Cross country round trip by air	5 millirem per trip
Coal Burning power plant	0.165 millirem/year

- **HEALTH EFFECTS**
- *Generalizations:* Biological effects are due to the ionization process that destroys the capacity for cell reproduction or division or causes cell mutation. A given total dose will cause more damage if received in a shorter time period. A **fatal dose is (600 R)**

- *Acute Somatic Effects*: Relatively immediate effects to a person acutely exposed. Severity depends on dose. Death usually results from damage to bone marrow or intestinal wall. Acute **radio-dermatitis** is common in radiotherapy; chronic cases occur mostly in industry.

ACUTE DOSE(RAD) EFFECT

0-25	No observable effect.
25-50	Minor temporary blood changes.
50-100	Possible nausea and vomiting and reduced WBC.
150-300	Increased severity of above and diarrhea, malaise, loss of appetite.
300-500	Increased severity of above and hemorrhaging, depilation. Death may occur
> 500	Symptoms appear immediately, then death has to occur.

- *Delayed Somatic Effects*: Delayed effects to exposed person include: Cancer, leukemia, cataracts, life shortening from organ failure, and abortion. Probability of an effect is proportional to dose (no threshold). Severity is independent of dose. Doubling dose for cancer is approximately 10-100 rems.

- *Genetic Effects*: Genetic effects to off-spring of exposed persons are irreversible and nearly always harmful. Doubling dose for mutation rate is approximately 50-80 rems. (Spontaneous mutation rate is approx. 10-100 mutations per million population per generation.)

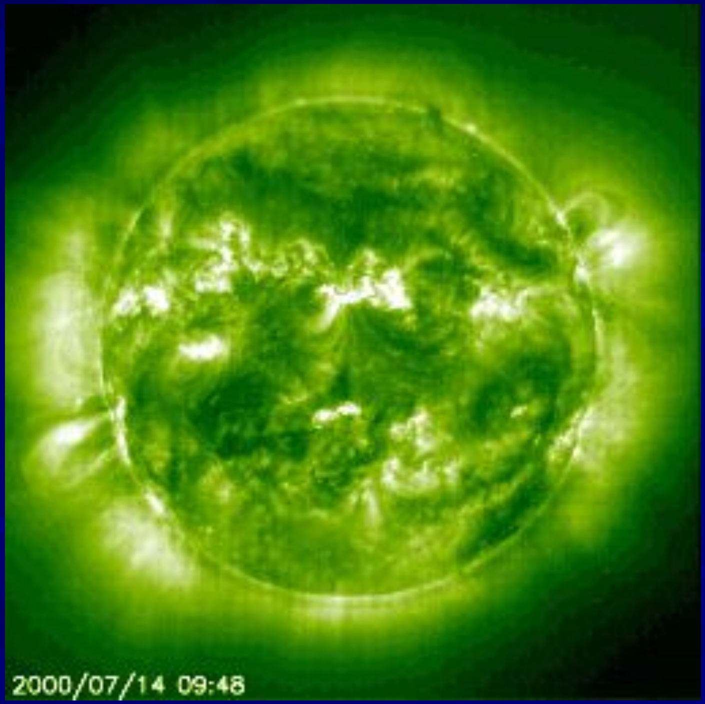
- *Critical Organs*: Organs generally most susceptible to radiation damage include: Lymphocytes, bone marrow, gastro-intestinal, gonads, and other fast-growing cells. The central nervous system is relatively resistant. Many nuclides concentrate in certain organs rather than being uniformly distributed over the body, and the organs may be particularly sensitive to radiation damage, e.g., isotopes of iodine concentrate in the thyroid gland. These organs are considered "critical" for the specific nuclide.

Non-ionizing Radiation

- Definition:

“ They are electromagnetic waves incapable of producing ions while passing through matter, due to their lower energy.”

- All earth surface system components emit radiation---the sun and the earth are the components we are most interested in
- The sun emits radiation composed of high energy infrared radiation, visible light, and ultraviolet radiation collectively known as shortwave radiation (SW)
- The earth emits radiation composed of lower energy infrared radiation collectively known as long-wave radiation (LW)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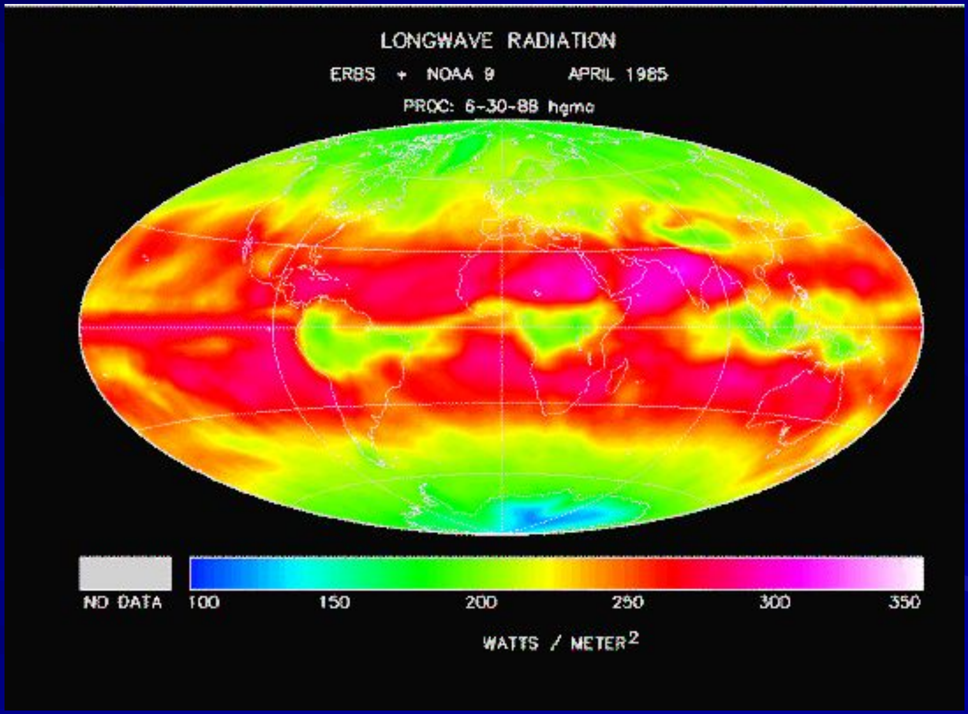
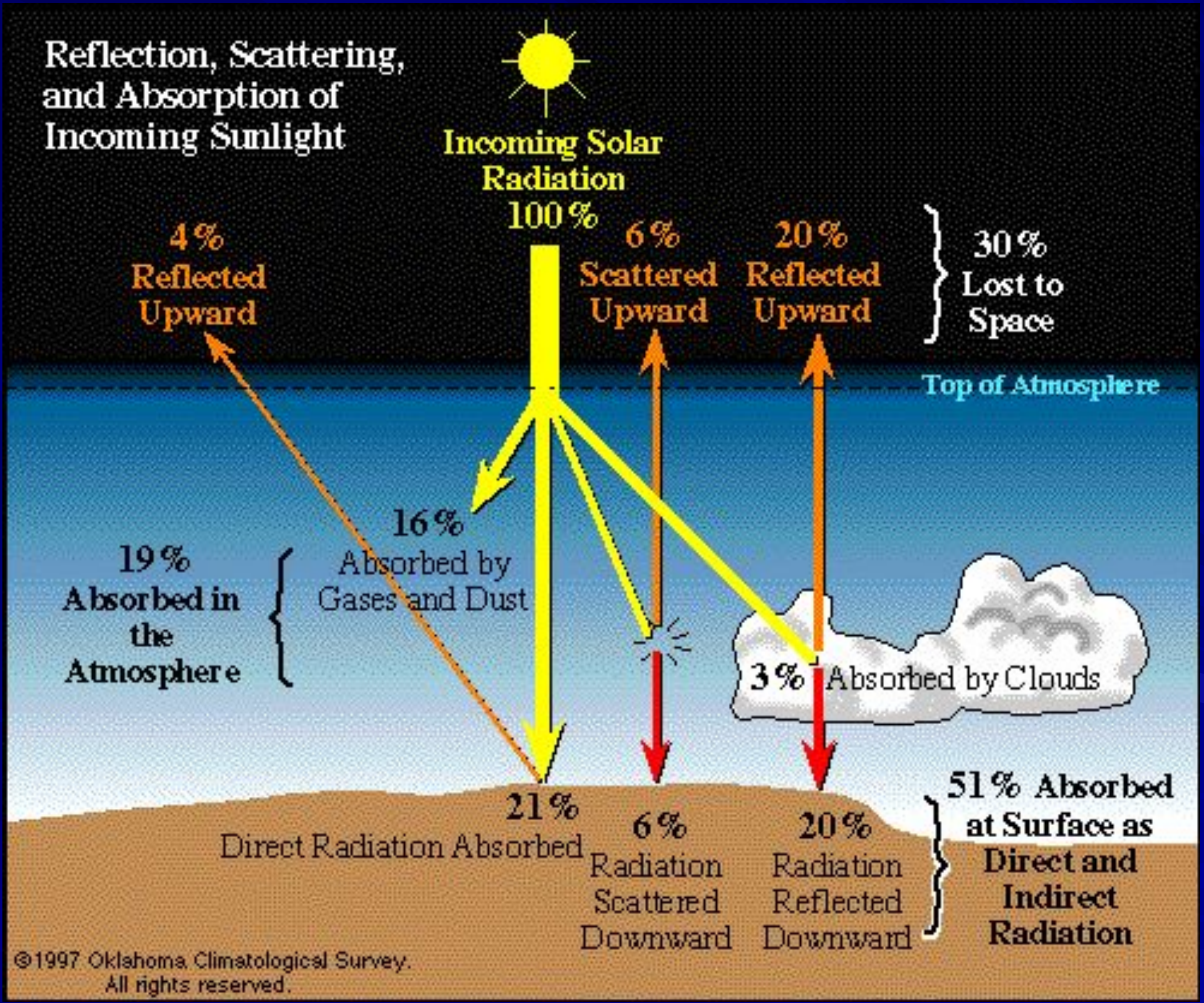
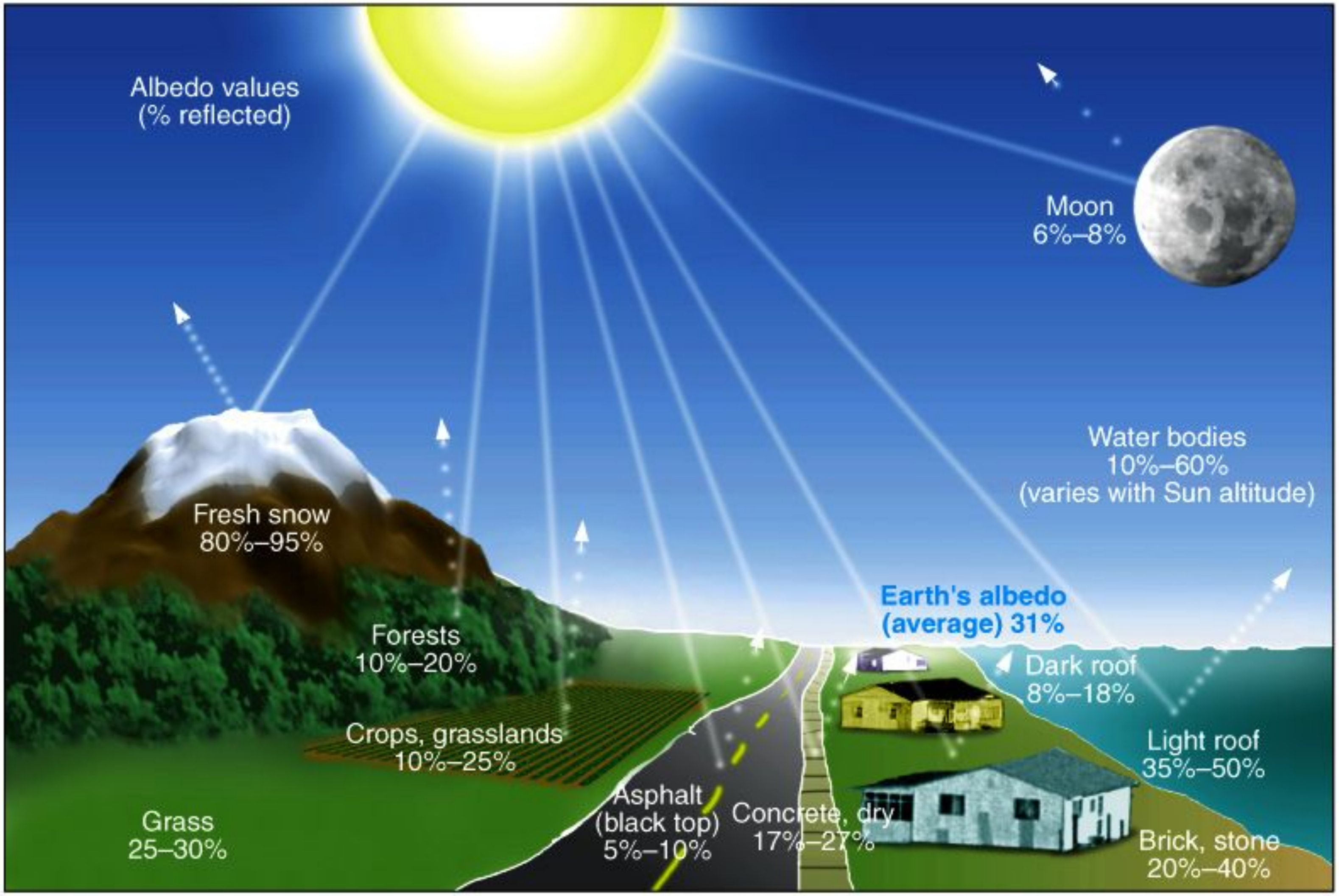

LONGWAVE RADIATION
ERBS + NOAA 9 APRIL 1985
PROC: 6-30-88 hgmo
NO DATA
100
150
200
250
300
350
WATTS / METER2

Path of incoming solar radiation



Albedo: a measure of how well a surface reflects insolation



Examples on Non-ionizing Radiation Sources

- Visible light
- Microwaves
- Radios
- Video Display Terminals
- Power lines
- Radiofrequency Diathermy (Physical Therapy)
- Lasers

GAMMA

ULTRA V

VISIBLE

INFRARED

TV

AM

RF

Other Manmade Sources of Non-Ionizing Radiation



Effects

- **Radiofrequency Ranges (10 kHz to 300 GHz)**
  - **Effects only possible at ten times the permissible exposure limit**
  - **Heating of the body (thermal effect)**
  - **Cataracts**
  - **Some studies show effects of teratoginicity and carcinogenicity.**

RADIATION CONTROLS

- A. Basic Control Methods for External Radiation

- Decrease Time
- Increase Distance
- Increase Shielding

- **Time**: Minimize time of exposure to minimize total dose. Rotate employees to restrict individual dose.
- **Distance**: Maximize distance to source to maximize attenuation in air. The effect of distance can be estimated from equations.
- **Shielding**: Minimize exposure by placing absorbing shield between worker and source.

B. Monitoring

- *Personal Dosimeters*: Normally they do not prevent exposures (no alarm), just record it. They can provide a record of **accumulated exposure** for an individual worker over extended periods of time (hours, days or weeks), and are small enough for measuring localized exposures Common types: Film badges; Thermoluminescence detectors (TLD); and pocket dosimeters.

- *Direct Reading Survey Meters and Counters*: Useful in **identifying source** of exposures recorded by personal dosimeters, and in **evaluating potential sources,** such as surface or sample contamination, source leakage, inadequate decontamination procedures, background radiation.

Common types:

- **Alpha □ Proportional or Scintillation counters**
  Beta, gamma □ Geiger-Mueller or Proportional counters
  X-ray, Gamma □ Ionization chambers
  Neutrons □ Proportional counters


x100
x10
x1
bat.
off
493
VICTOREEN
phone

- *Continuous Monitors*: Continuous direct reading ionization detectors (same detectors as above) can provide read-out and/or alarm to monitor hazardous locations and alert workers to leakage, thereby **preventing exposures**.
- *Long-Term Samplers*: Used to measure average exposures over a longer time period. For example, charcoal canisters or electrets are set out for days to months to measure radon in basements (should be <4 pCi/L).

Elements of Radiation Protection Program

- *Monitoring of exposures*: Personal, area, and screening measurements; Medical/biologic monitoring.
- *Task-Specific Procedures and Controls*: Initial, periodic, and post-maintenance or other non-scheduled events. Engineering (shielding) vs. PPE vs. administrative controls. Including management and employee commitment and authority to enforce procedures and controls.
- *Emergency procedures*: Response, "clean-up", post clean-up testing and spill control.
- *Training and Hazard Communications* including signs, warning lights, lockout/tagout, etc. Criteria for need, design, and information given.
- *Material Handling*: Receiving, inventory control, storage, and disposal.

Thank You