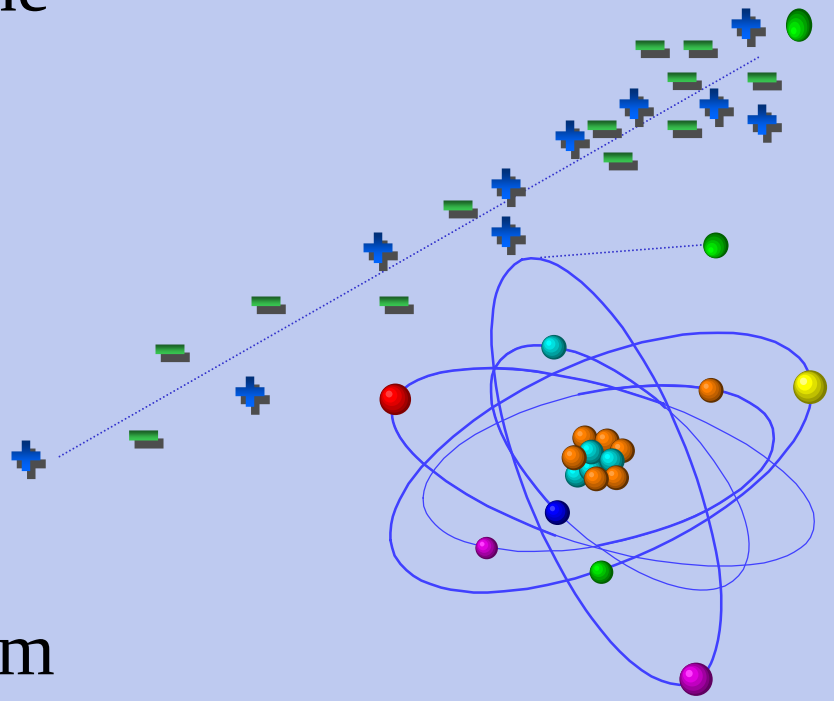
Radiation

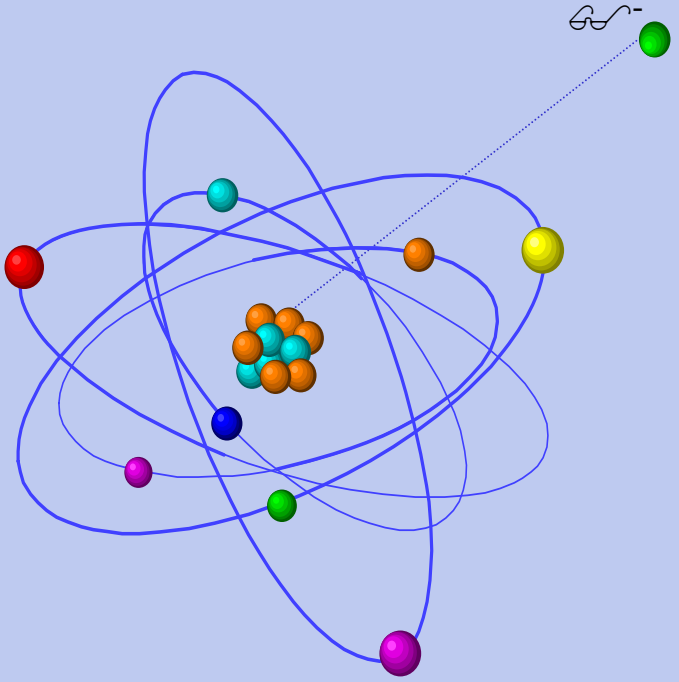
- Radiation: Energy in the form of particles or electromagnetic waves

- 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 of Activity

- **Curie (Ci):** 37 Billion transformations per second. (2.22 trillion per minute)
- **Bequerel (Bq):** 1 transformation per second.

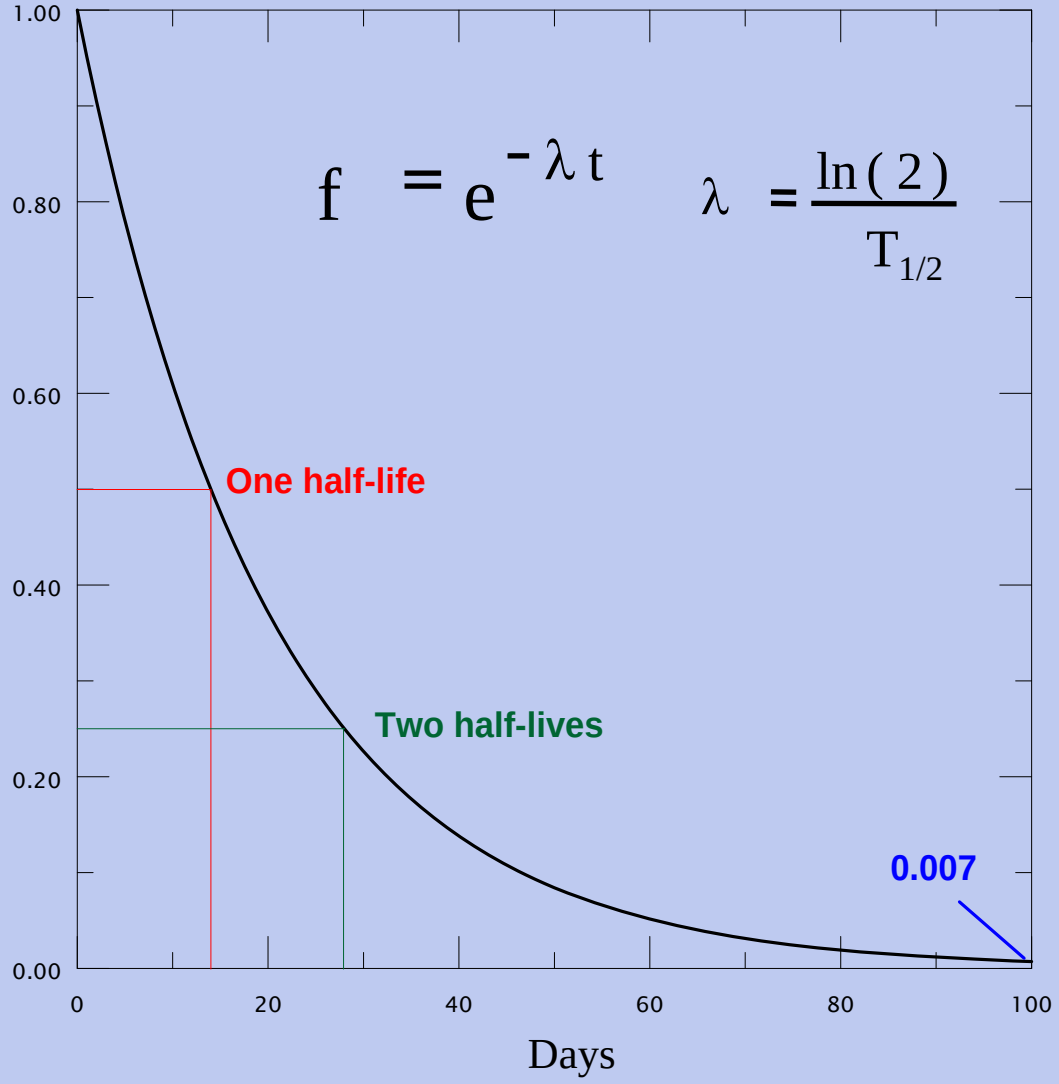
mCi and uCi are common quantities used in the lab (10 uCi up to 50 mCi).

0.0013 uCi (48 Bq) - Ra-226 in a 1 kg rock
0.12 uCi (4400 Bq) - K-40 in your body
330 pCi - C-14 in ¼ lb of beef

Half-Life

- Half-life is the amount of time needed for the activity to reach one half of the original amount.

$$f = \left(\frac{1}{2}\right)^{\frac{t}{T_{1/2}}}$$



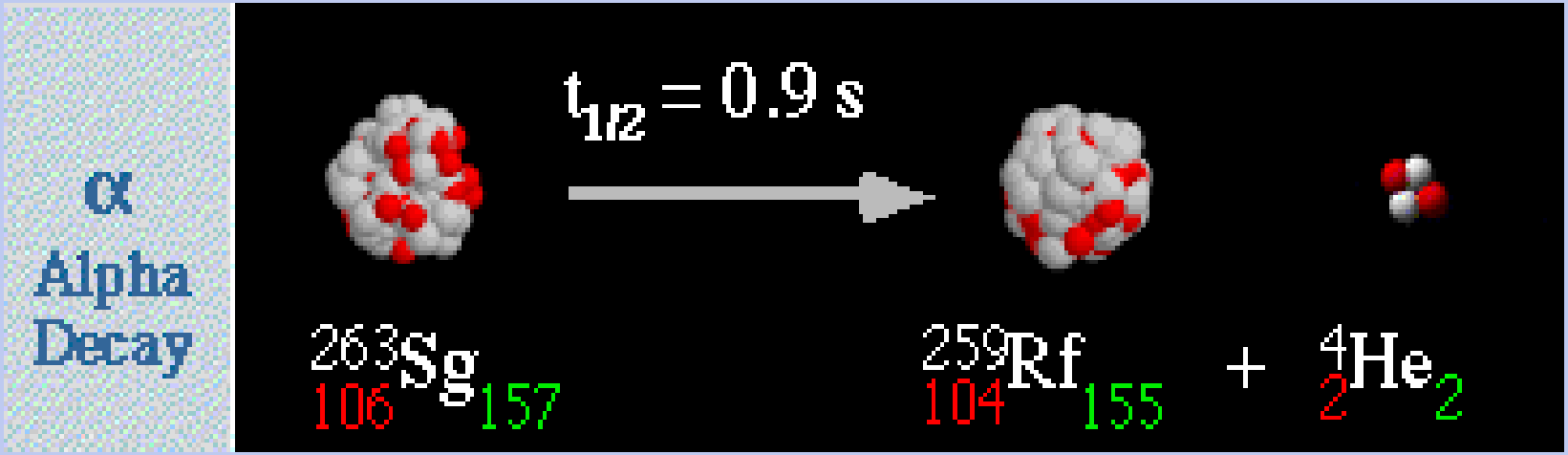
Definitions

- **Exposure** R (roentgen): Amount of charge produced per unit mass of air from x-rays and gamma rays.
- **Absorbed Dose** rad: Amount of Energy deposited per unit mass of material. 1Gy = 100 rad.
- **Dose Equivalent** rem: Risk adjusted absorbed dose. The absorbed dose is weighted by the radiation type and tissue susceptibility to biological damage. 1 Sv = 100 rem.
- Radiation weighting factors: alpha(20), beta(1), n(10).
- Tissue weighting factors: lung(0.12), thyroid(0.03), and gonads(0.25).

For whole body x or gamma-ray exposure

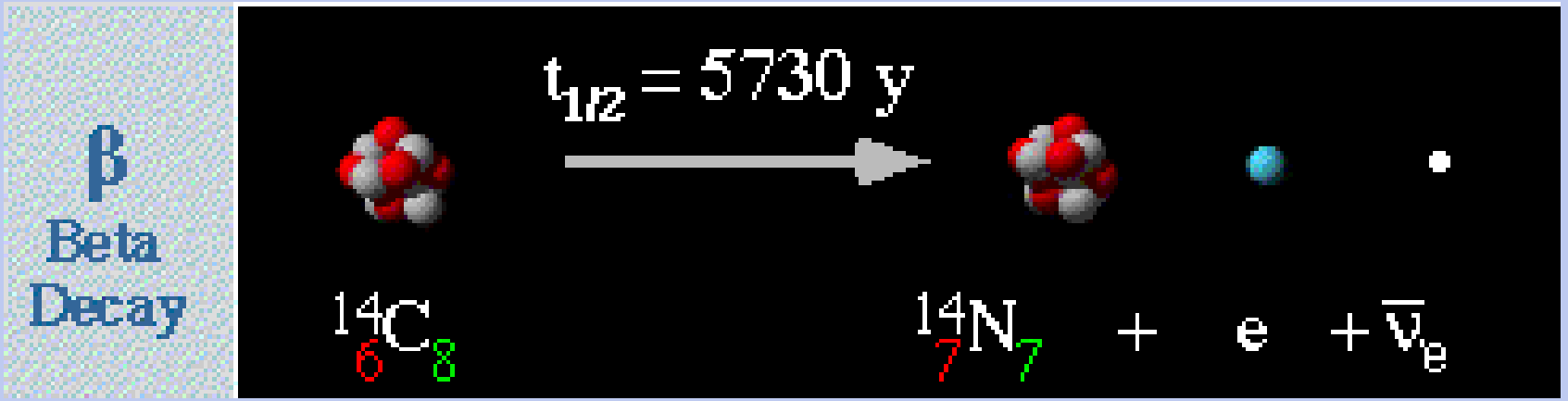
1 R ≈ 1 rad ≈ 1 rem

Alpha Decay



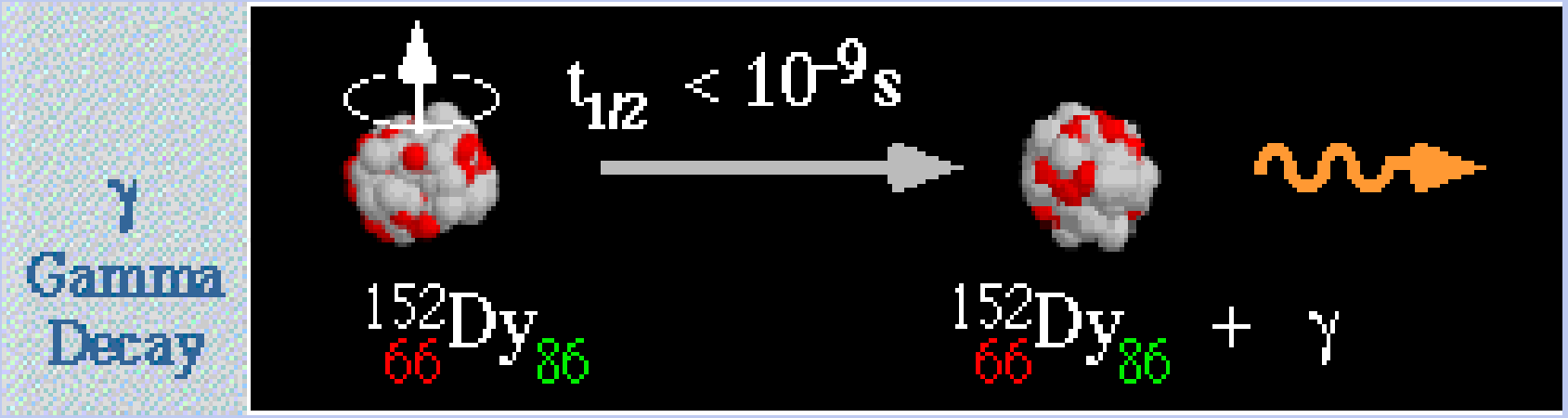
- Helium Nucleus – Very massive and doubly ionized
- Only a hazard via ingestion or inhalation of alpha emitter
- Not usually an external radiation hazard
- Stopped by paper and dead layer of skin
- Uranium, Thorium, Radon and radon daughters

Beta Decay

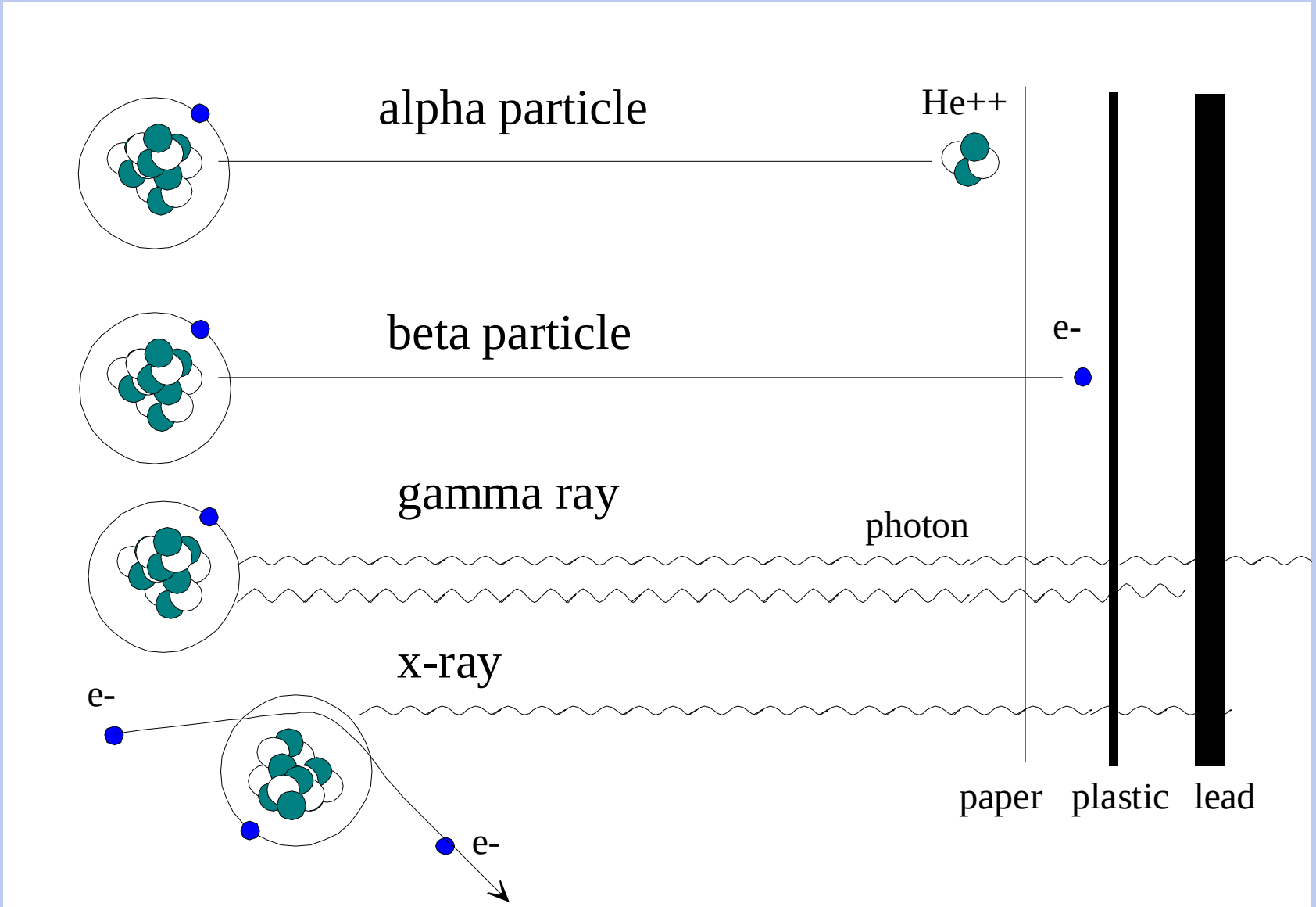


- Energetic electron – singly ionized
- External hazard to skin and eyes
- Internal hazard via ingestion or inhalation of beta emitter
- Produces bremsstrahlung radiation
- A 1 MeV beta can travel up to 12 feet in air and 1 cm in plastic
- Phosphorus, Tritium, Carbon, Sulfur

Gamma Decay

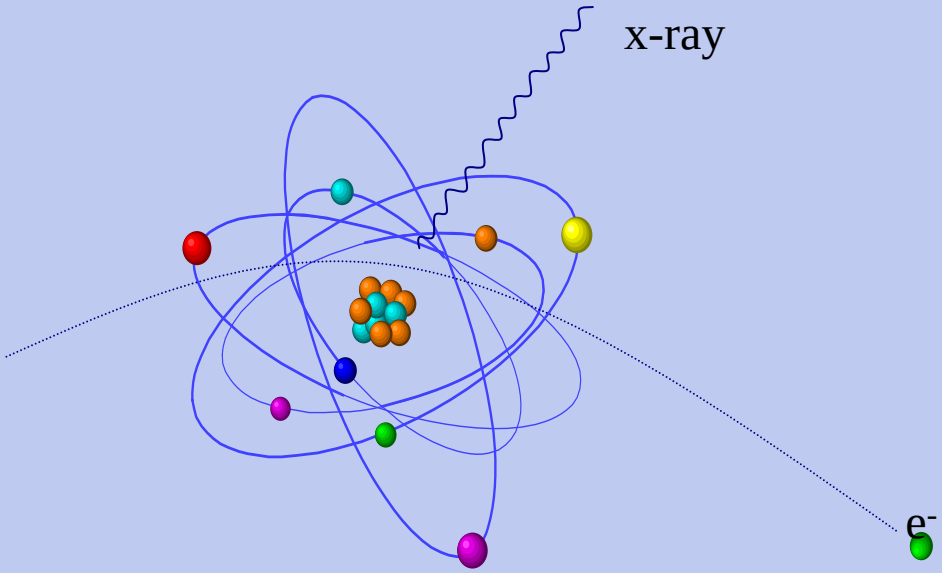


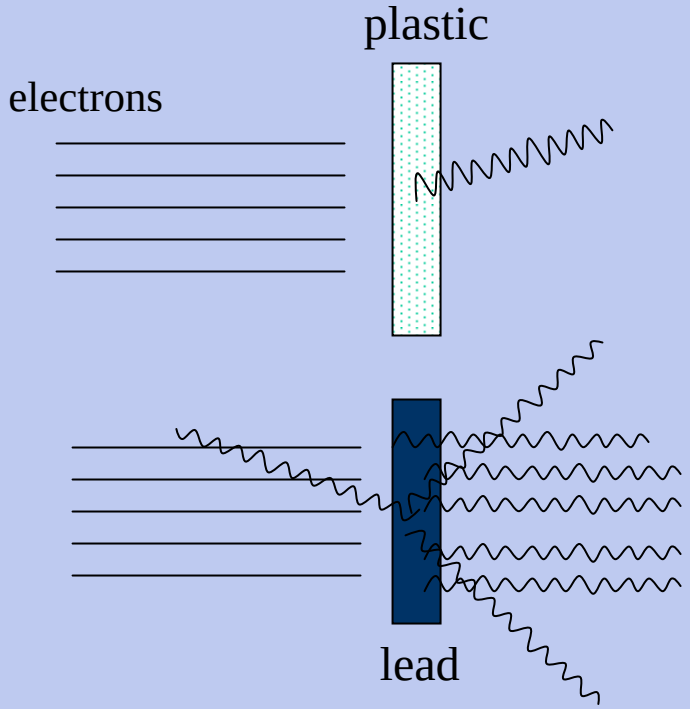
- X-rays and gamma rays are photons – no charge
- External radiation hazard to deep organs and tissues
- Internal hazard via ingestion or inhalation of gamma emitter
- Lead (high electron density) is good for shielding x and gamma rays
- Iodine 125 gammas (30 keV) can be easily stopped with 1/8 inch of lead



Neutron shielding material depends on the energy of the neutrons

Bremsstrahlung X-Rays

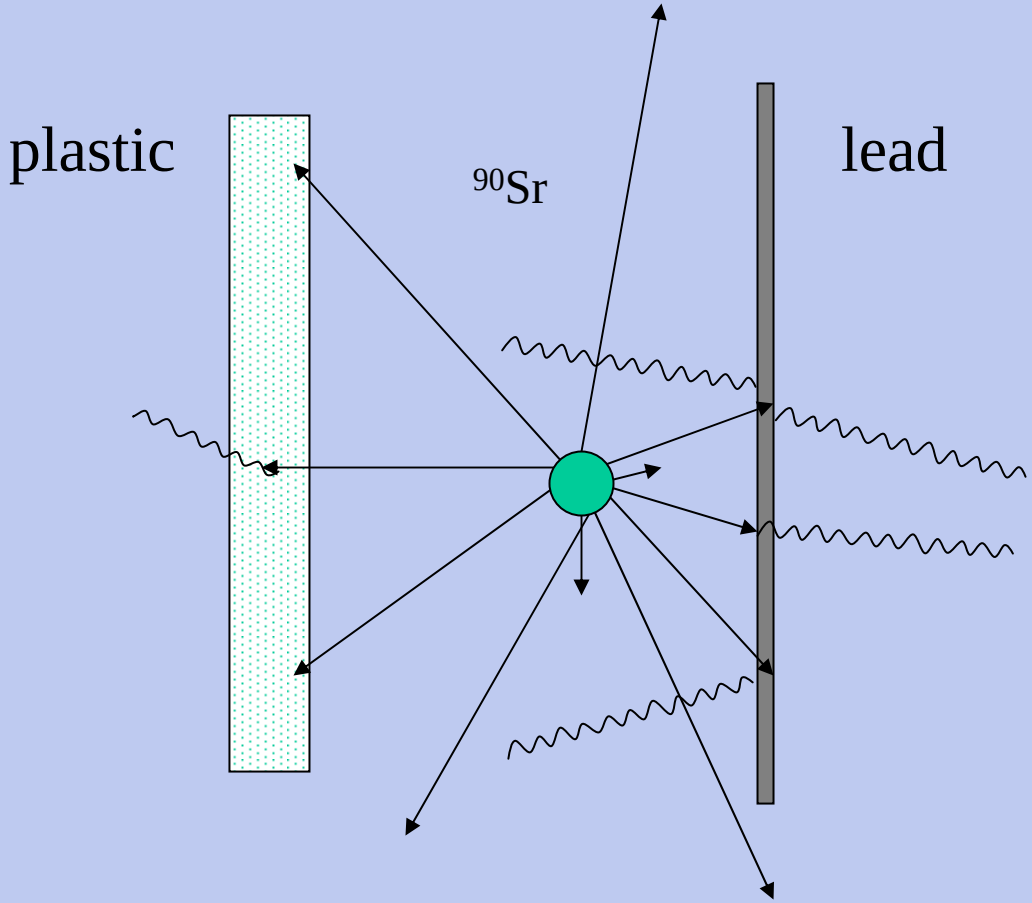




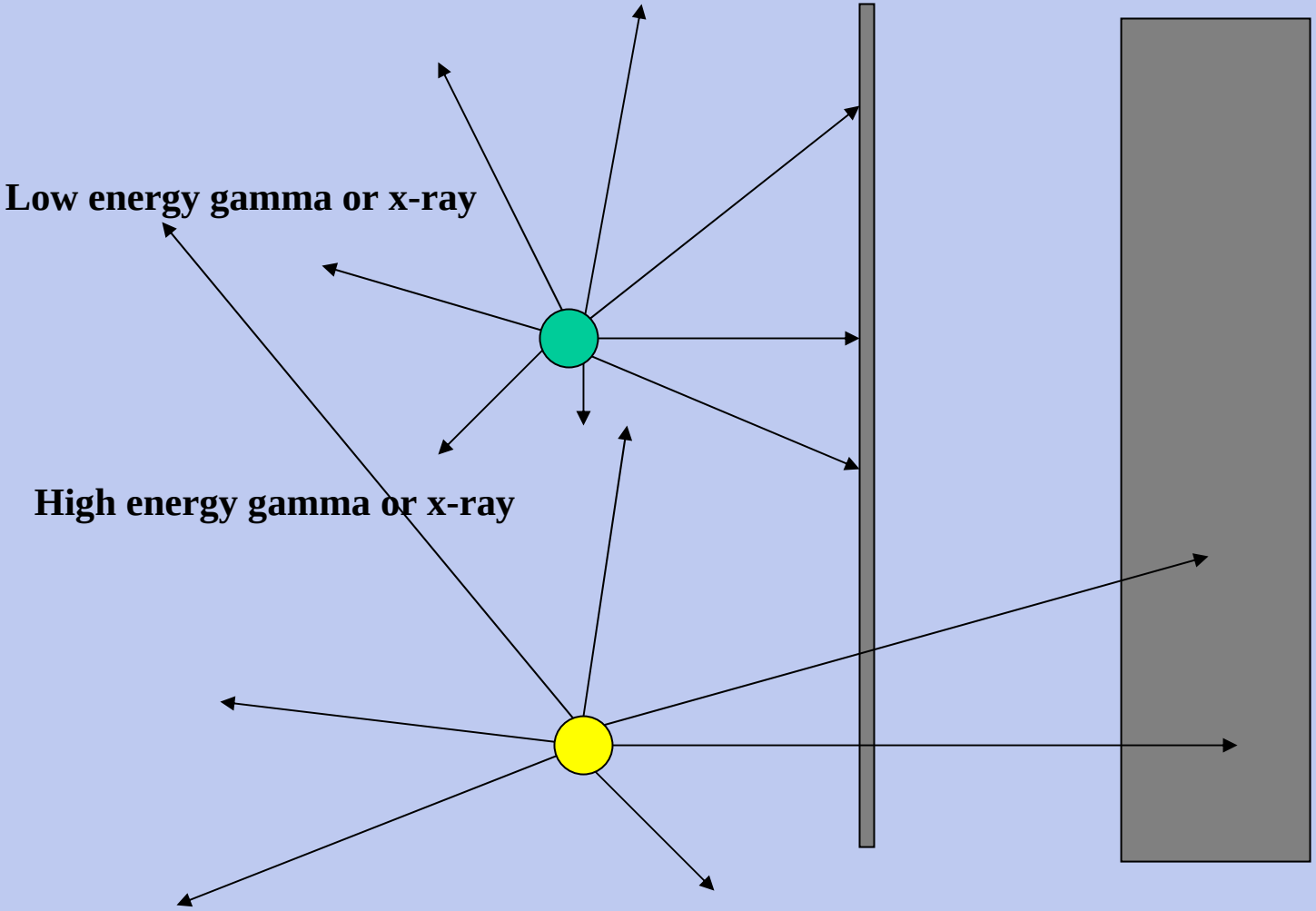
- Bremsstrahlung x-ray intensity increases with increasing atomic number of absorber, and the average x-ray energy increases with increasing electron energy.

  (activity of the source is also a factor)

Shielding for beta emitting material



Shielding for gamma emitting material



Annual Occupational Dose Limits

Whole Body	5,000 mrem/year
Lens of the eye	15,000 mrem/year
Extremities, skin, and individual tissues	50,000 mrem per year
Minors	500 mrem per year (10%)
Embryo/fetus*	500 mrem per 9 months
General Public	100 mrem per year

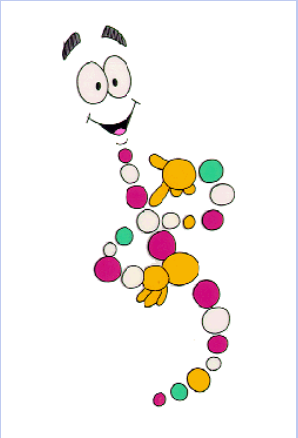
* Declared Pregnant Woman

Biological Effects

- Many groups exposed to ionizing radiation at high levels resulted in adverse effects.
- Somatic effects
  - Prompt - skin burns and cataracts
  - Delayed - cancer
- Genetic effects
- Teratogenetic effects

Cancer

- Radiation can damage cells through two methods;
  - Production of free radicals and
  - Direct damage to the DNA.
- Risk factor for radiation dose:
  - 4% increase in risk of dying of cancer for every 100 rem of dose.
  - Normal cancer risk is 20%.

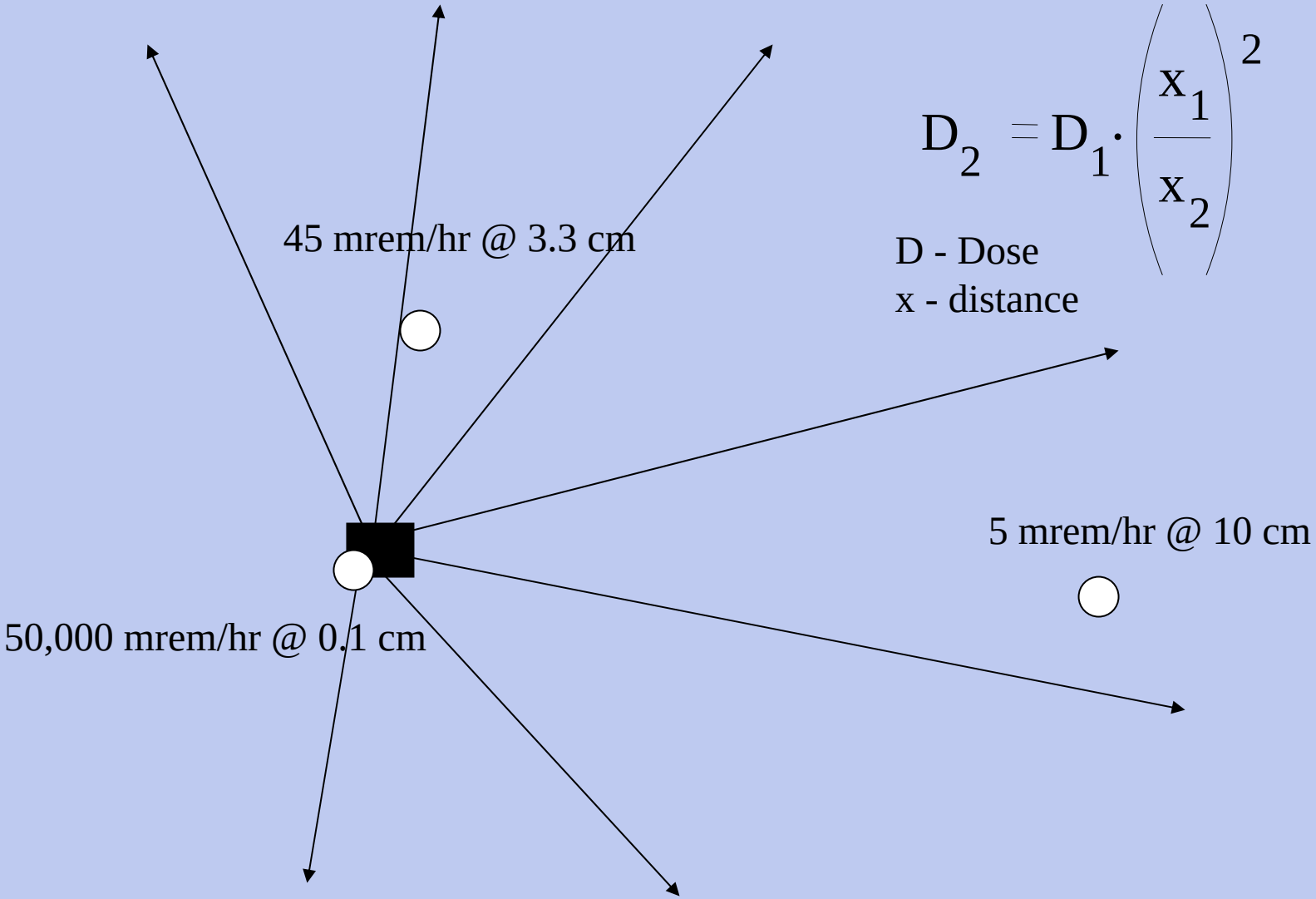


ALARA

- ALARA - As Low As Reasonably Achievable

- Time
- Distance (inverse square law)
- Shielding
- Contamination Control

Inverse Square Law

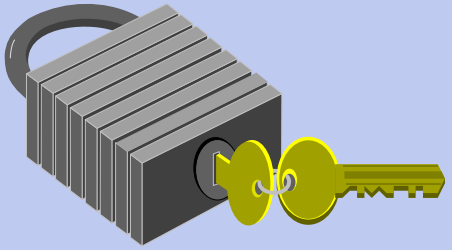


$$D_2 = D_1 \cdot \left(\frac{x_1}{x_2} \right)^2$$

D - Dose
x - distance

Security and Transportation

- All radiation sources must be kept locked up when not in use.
- Experiments left unattended should be labeled “Experiment in Progress.”
- An up-to-date use log of all sources must be kept at the storage location.
- All radiation laboratories will be locked when unattended for extended periods.
- When you are the means for security, you must challenge unknown persons entering the lab.
- Sources can only be used in a registered radiation laboratory.



General Radiation Safety

- **No** food or beverages in the lab
- Keep a survey meter conveniently close by
- ALARA - time, distance, and shielding
- Label radioactive materials and equipment