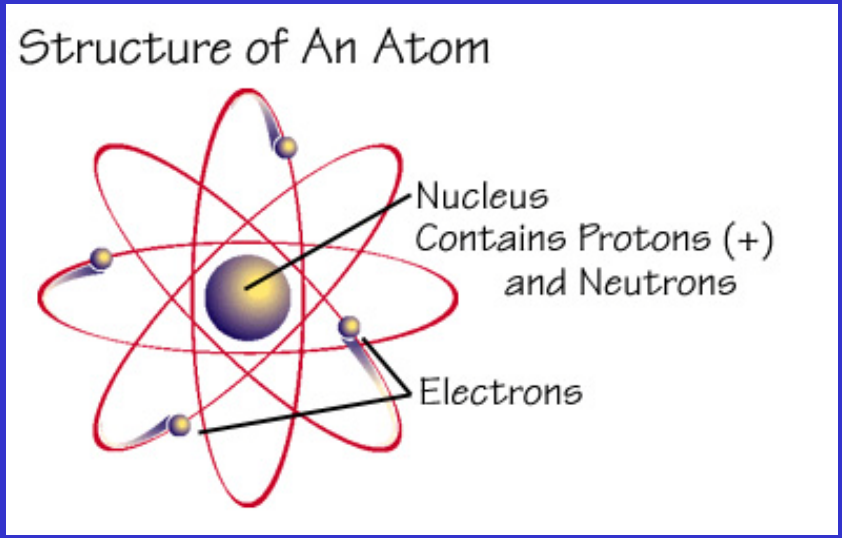
Industrial Radiography Health Physics Review

Purpose

- This may be a review to some students. Alternatively, it may be new information to those who are new in obtaining qualifications. In order to ensure all students mutually benefit from this course, it is necessary that we conduct this review/presentation.
    - NRC Training Center

The Atom

- Atoms are comprised of a center portion, the “nucleus,” and electrons that orbit the nucleus.
- The nucleus contains protons that have a positive electrical charge (+), and neutrons that do not have an electrical charge.
- There is one orbiting electron for each proton in the nucleus (one orbiting negative charge for each positive charge in the nucleus)



Ionizing Radiation

- Ionizing Radiation - is a form of energy that is sufficient to remove the orbital electrons from atoms, thus creating an ion (charged particle) pair.

- Forms of Ionizing Radiation - ionizing radiation may be either in the form of a particle, that is having mass, or in the form of a electromagnetic radiation (without mass).

- Particulate forms of Ionizing Radiation are: alpha, beta, and neutron.

- Electromagnetic Radiation forms of ionizing radiation are: X-rays and gamma rays (also called photons).

Nuclear Notation

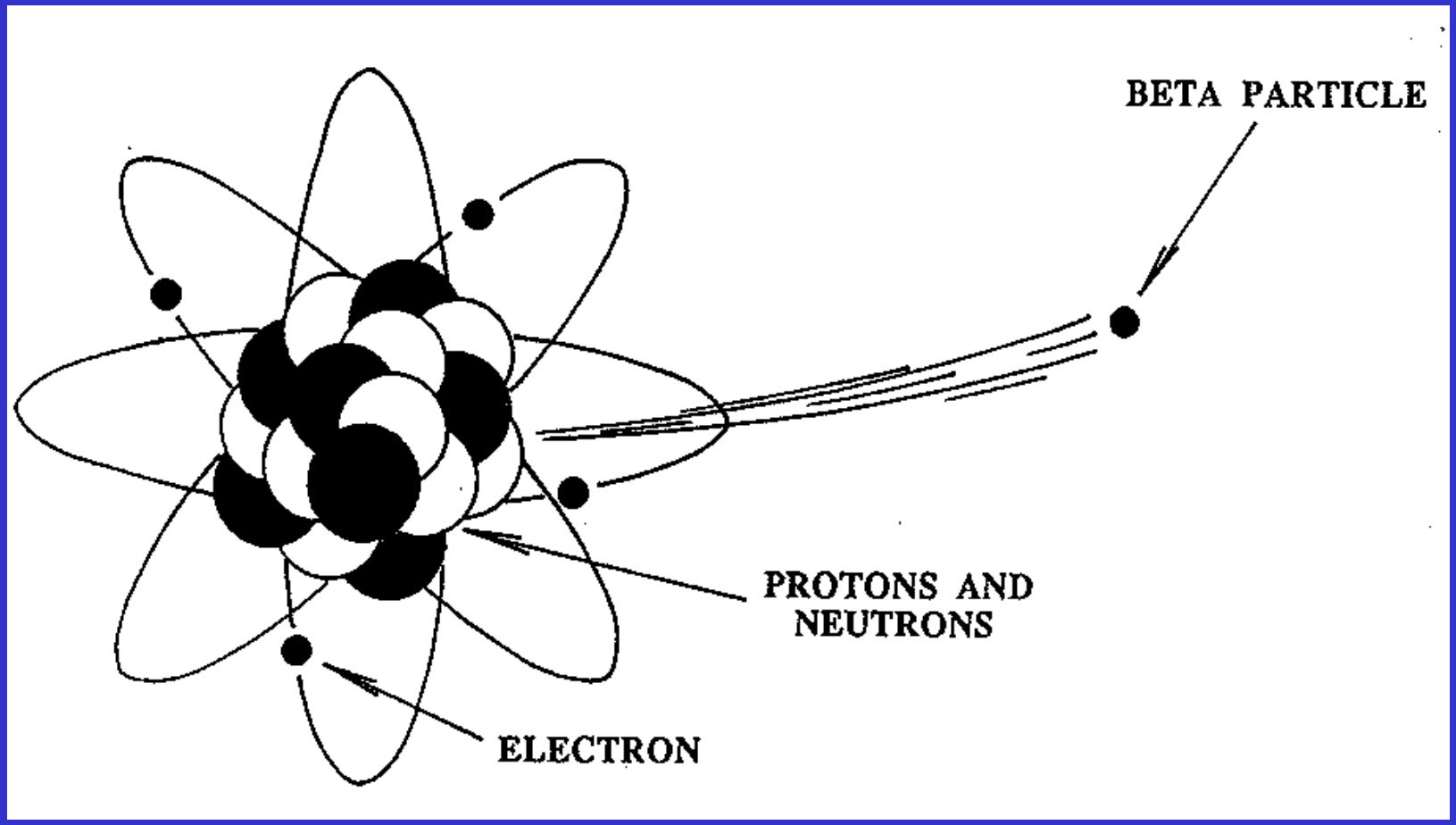
- ${}_{N}X^{A}$
- X is the symbol for the element,
- A is the Atomic Weight, the number of neutrons and protons in the nucleus,
- N is the Atomic Number, equal to the number of protons in the nucleus

Isotopes

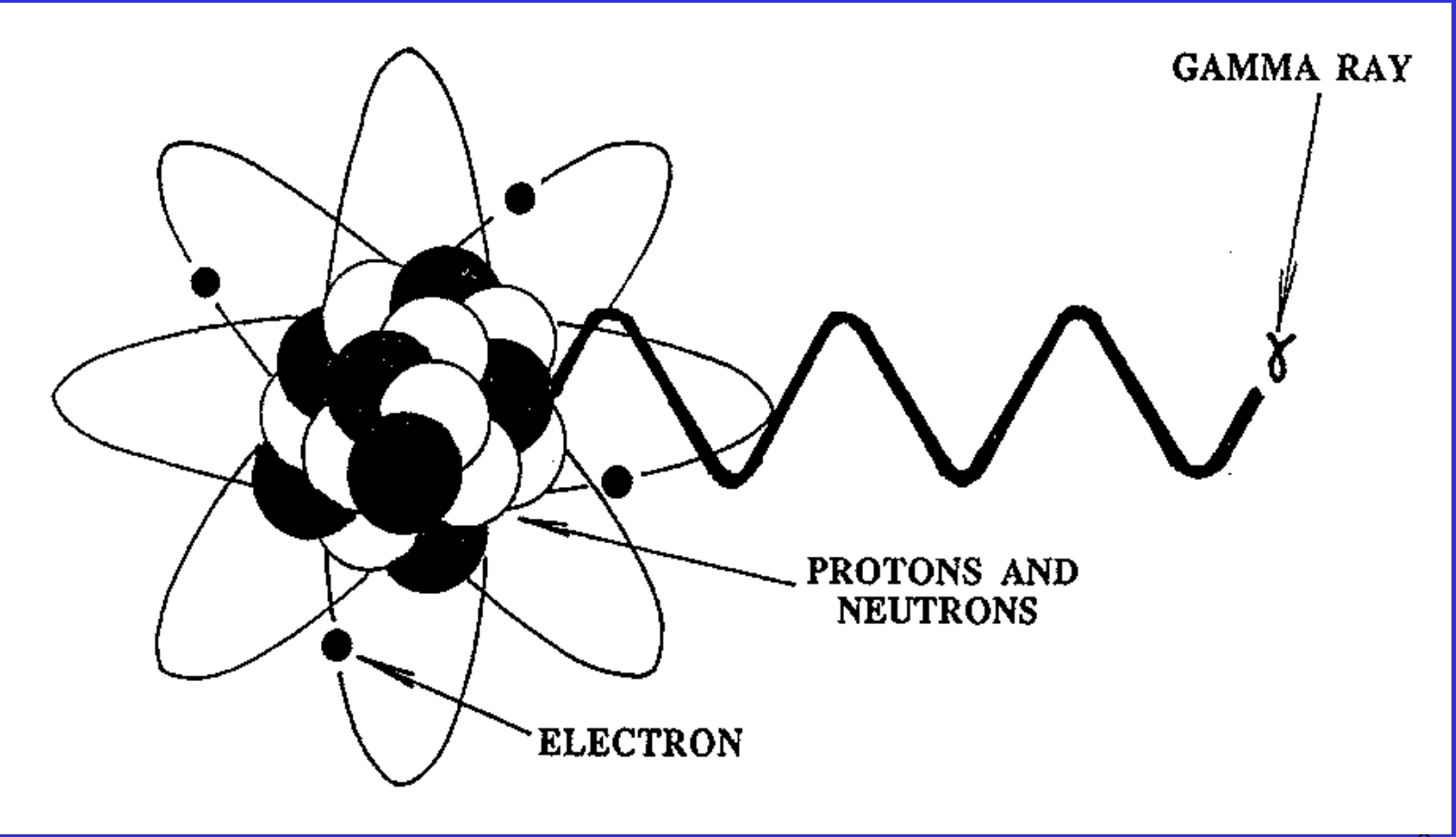
- $_{77}Ir^{191}$ Stable
- $_{77}Ir^{192}$ Radioactive

- $_{27}Co^{59}$ Stable
- $_{27}Co^{60}$ Radioactive

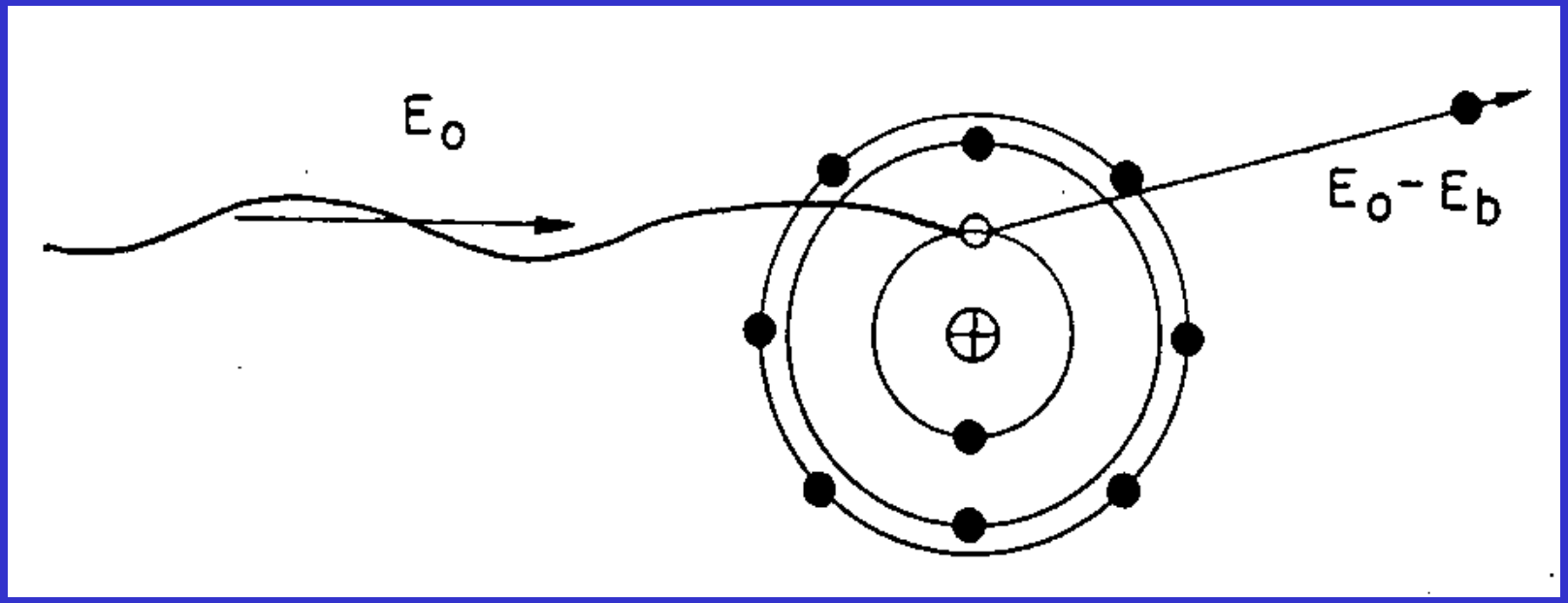
Beta Decay



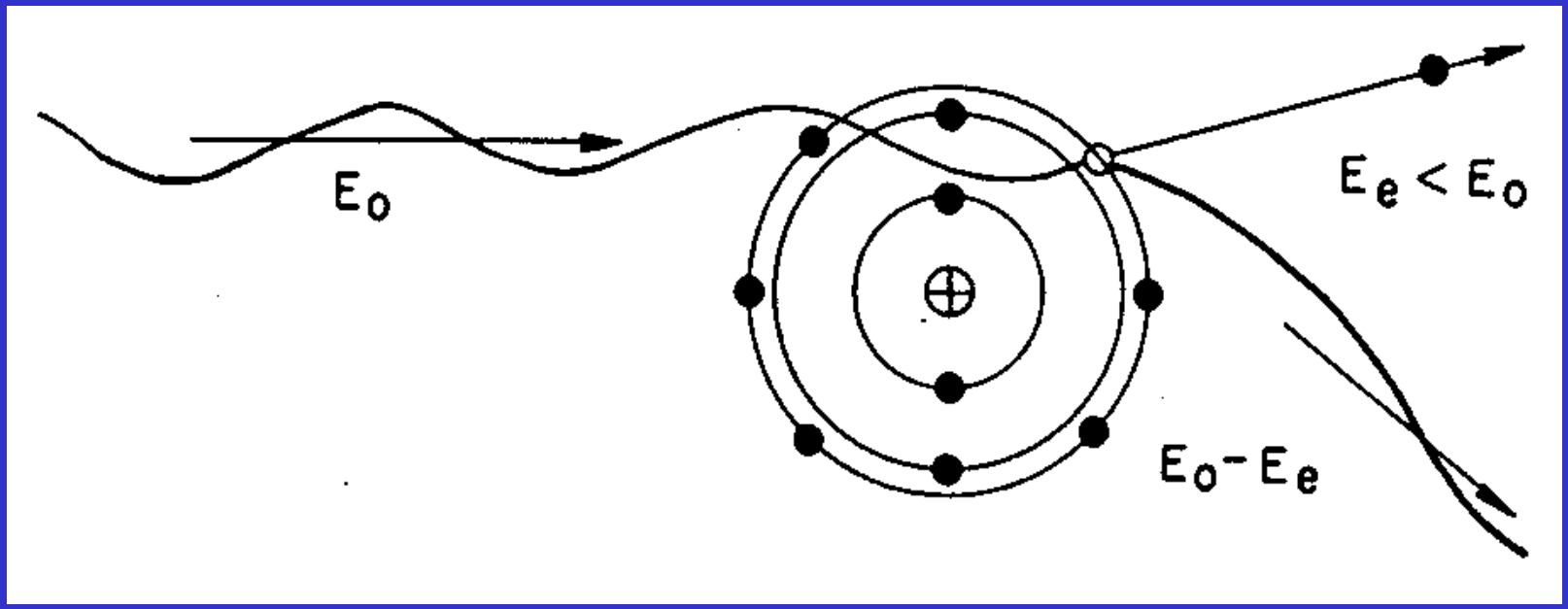
Gamma “Rays”



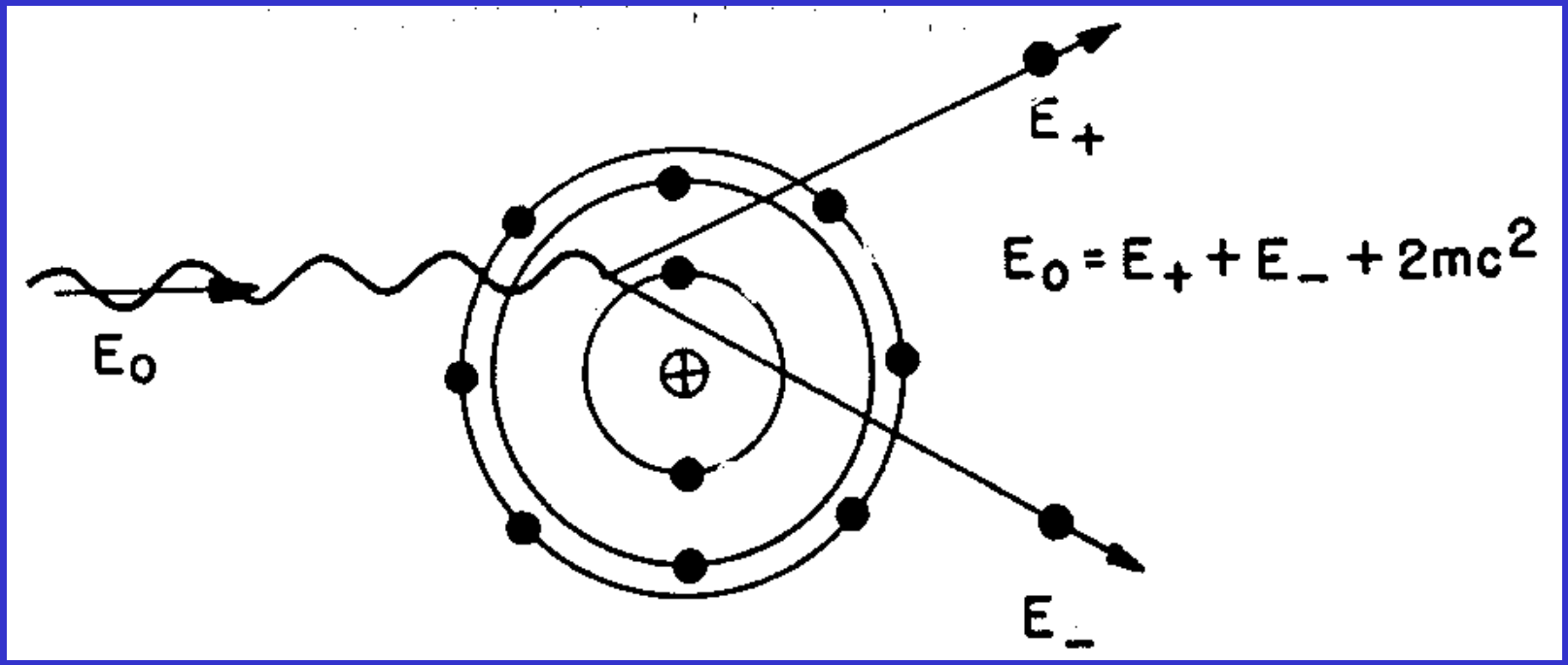
Photoelectric Effect



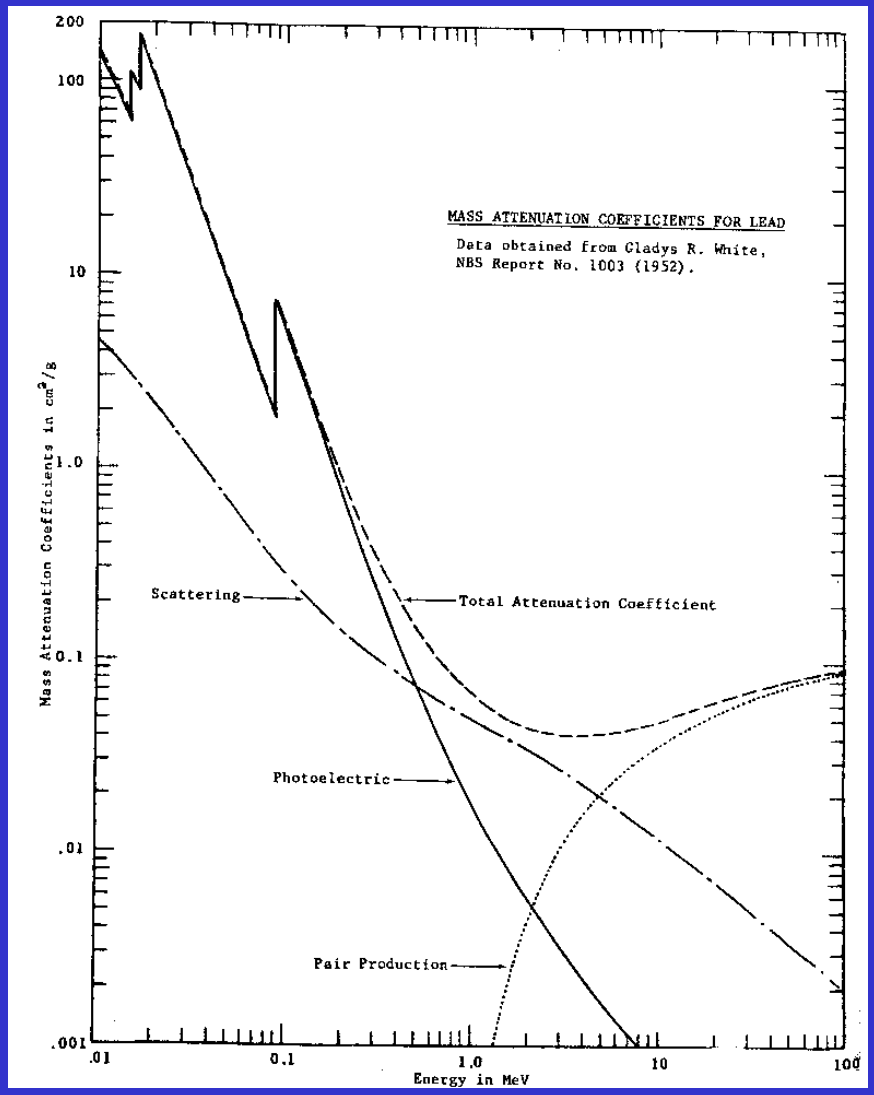
Compton Effect or “Scattering”



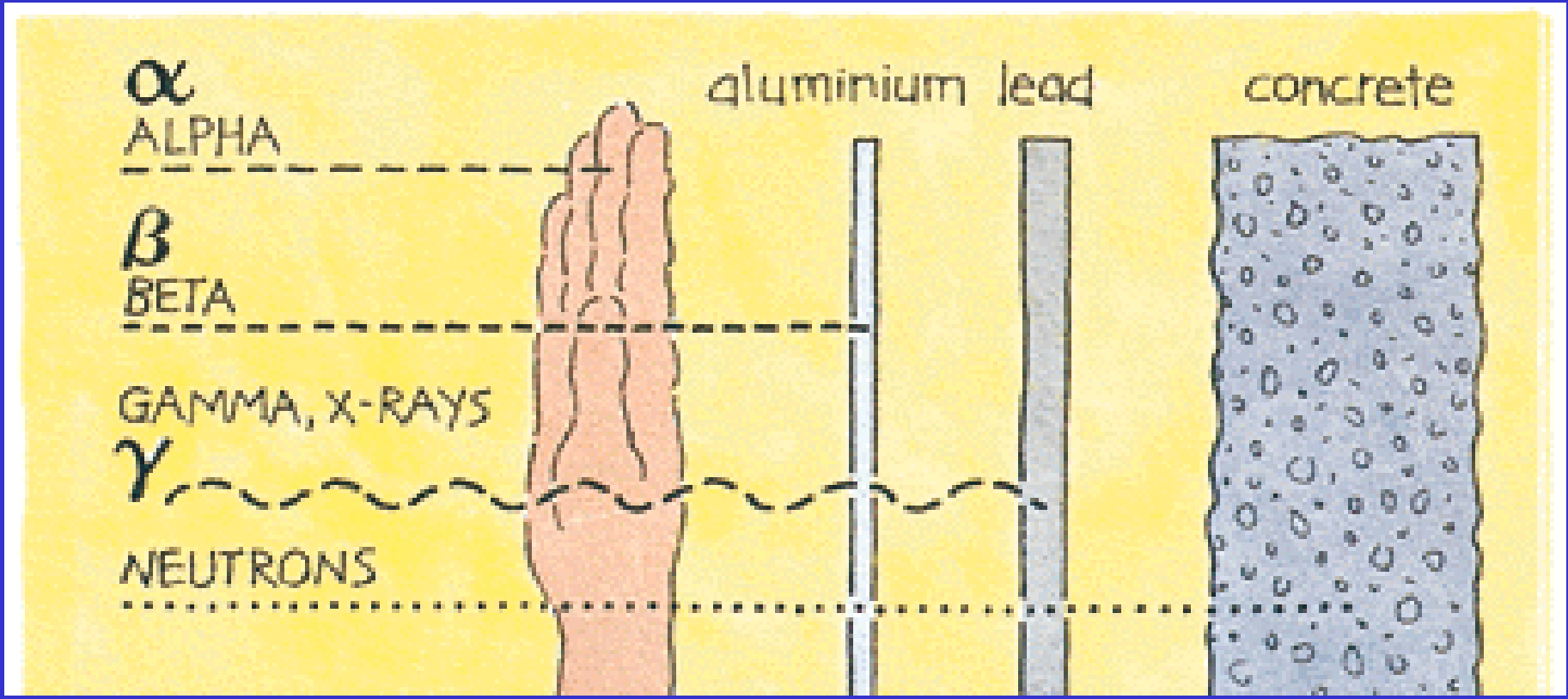
Pair Production



Gamma Interactions



Range of Ionization Radiation



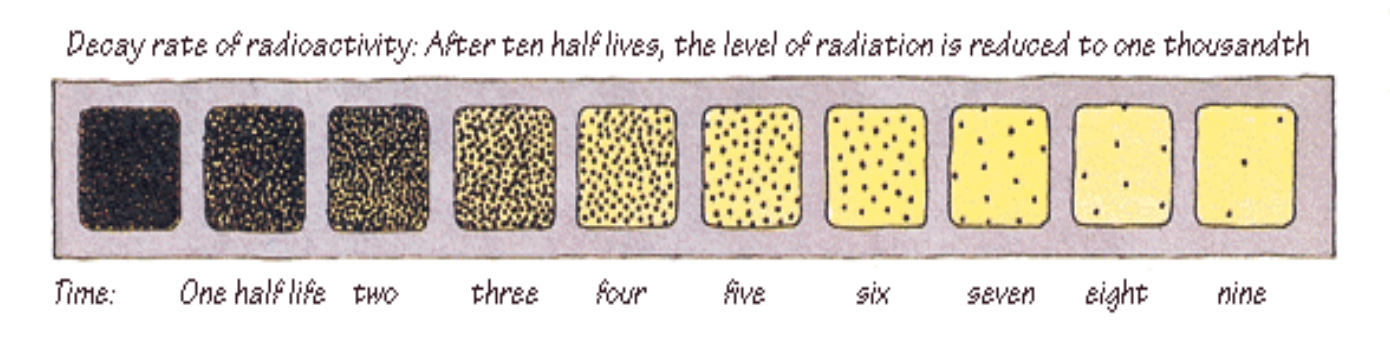
- Gamma & X-rays – Not totally stopped

Half-Value Layer (HVL)

- The amount of material needed to reduce the photon intensity by one-half (1/2).
- Radiography Rules of Thumb:
  - Ir-192 0.5 inches of steel
  - Co-60 0.5 inches of lead

Half Life

- The amount of time for half of the material to decay. After one half-life, 1/2 of the material remains. After another half-life 1/2 of 1/2 or 1/4th of the material remains. The amount remaining is the $(1/2)^n$ where n is the number of half-lives.



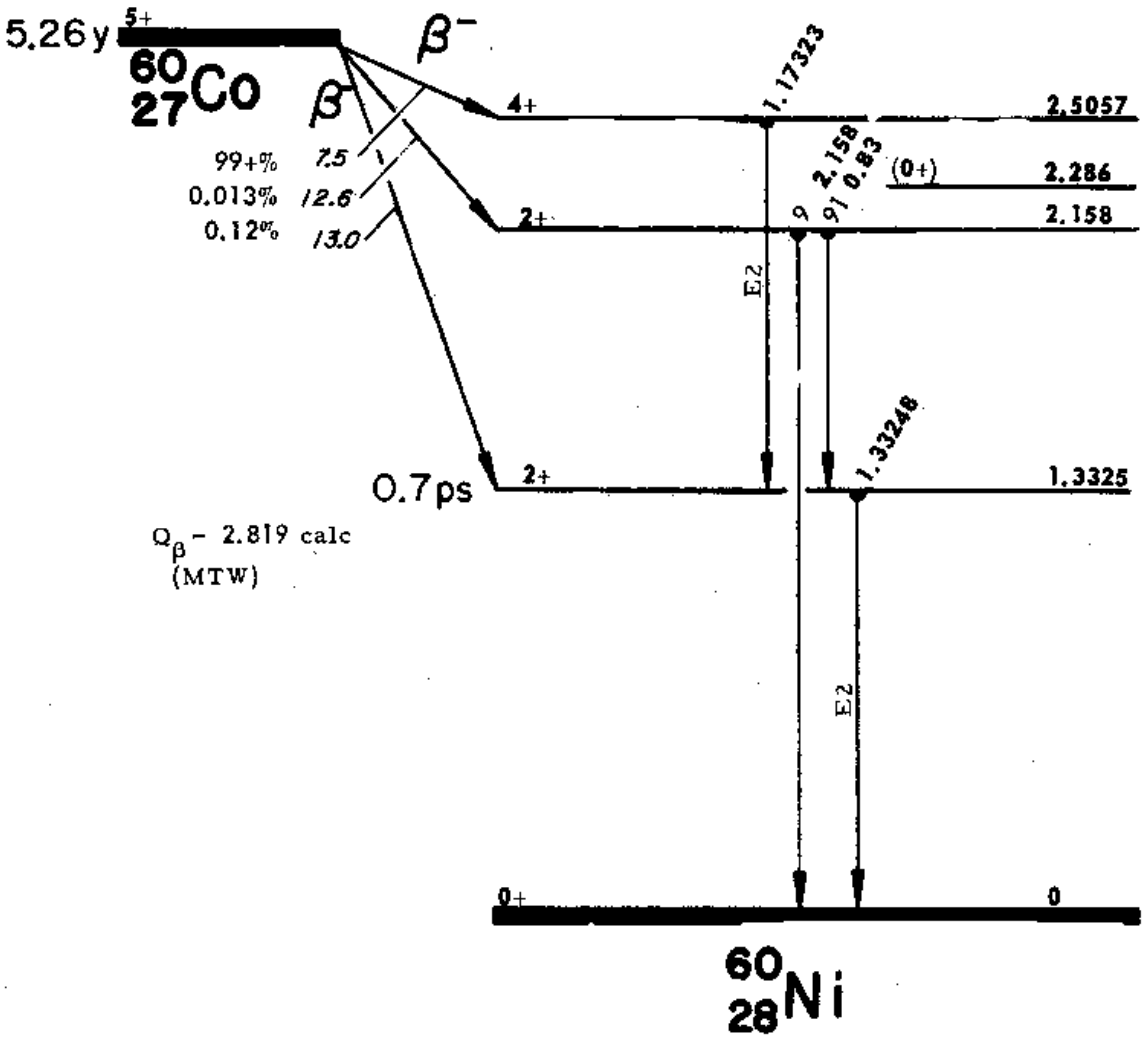
Half-Life

• Ir-192	74.2 days	1% per day
• Co-60	5.27 years	1% per month
• Cs-137	30 years	2% per year

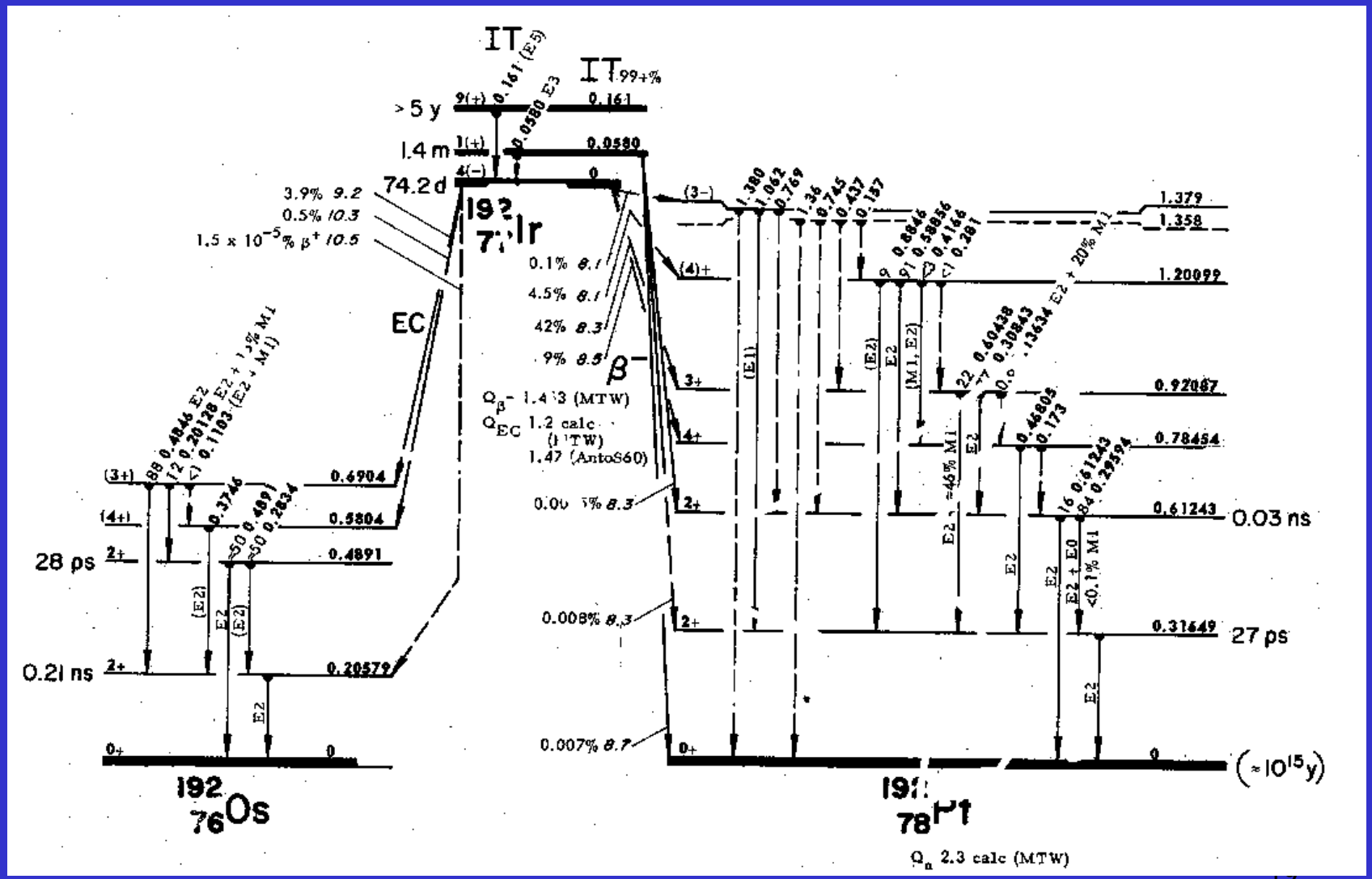
Activity

- "Activity" is the quantity or amount of radioactive material.
- Bequerel (Bq) is the international unit for activity. 1 Bq = 1 disintegration per second (1 dps).
- Curie (Ci) activity of 1 gram of Ra-226
  1 Ci = 3.7×10^{10} dps = 3.7×10^{10} Bq = 37 GBq

Cobalt-60 Decay Scheme



Ir-192 Decay Scheme



Roentgen

- Exposure – amount of x or gamma radiation that will produce 1 esu of charge in equilibrium in 1 dry cubic centimeter of air under STP conditions.

RAD

- Absorbed Dose
- Amount of ionizing radiation that will deposit 100 ergs per gram of material
- 100 rads = 1 Gray

REM

- Roentgen equivalent man, mouse, monkey or mammal.
- Dose Equivalent (REM) = Absorbed Dose (RAD) x Quality Factor
- Provides a means of comparison for the different types of ionizing radiation to produce the same biological damage.
- 100 rem = 1 Sievert

Gamma Constants

- Co-60 14 R/h/Ci @ 1 ft
- 1.3 R/h/Ci @ 1 m

- Ir-192 5.2 R/h/Ci @ 1 ft
- 0.48 R/h/Ci @ 1 m

- Cs-137 3.4 R/h/Ci @ 1 ft
- 0.32 R/h/Ci @ 1 m

Inverse Square Law

- $I_1 \times d_1^2 = I_2 \times d_2^2$

Biological Effects

Biological Effects - Low Doses

- Stochastic effects - “random,” the probability of the effect increases with dose, e.g., cancer, genetic.
- Linear No Threshold
  - Every dose has an associated incremental risk.
- Hormesis?

Biological Effects - Risk

- 1 rem = 4 in 10,000 chances of fatal cancer.
- Fatal cancer incidence = 1 in 5, or (2,000 out of a population of 10,000).
- If each person in a population of 10,000 received a dose of 1 rem, there would be 4 additional fatal cancers so the total number of fatal cancers from natural incidence and the dose of 1 rem would be 2004 (RG 8.29).

Biological Effects - Low Doses

- Deterministic “Non-stochastic” - threshold effects, severity increases with dose once a threshold is exceeded, e.g. erythema (skin reddening), cataracts to the lens of the eye

Biological Effects - High Doses

- Acute radiation syndromes:
  - hematopoetic (100 rad),
  - gastrointestinal (500 rad),
  - central nervous system (2000 rad)
- Mid-lethal Dose
  - LD^{50}_{30} 450 rad (acute whole body dose).

Background Radiation

- Background radiation is from terrestrial, cosmic, and radon. The background dose is about 360 mrem/yr (1 mrem a day)

- Background and medical doses are not considered as part of the occupational dose.

Occupational Dose Limits Summary

Lens of Eye
15 rem/yr

Whole Body
5 rem/yr

Skin of Whole Body
50 rem/yr

Organs
50 rem/yr

Extremities
50 rem/yr