Interaction of particles and matter

D. Craig, WTAMU

2006–03–29

Heavy charged particles

A α particle or a proton travels a well-defined distance into a solid, liquid or gas before coming to rest. This is the **range** for a given energy.

Energy is lost by excitation and ionization of atoms in the medium, and elastic collisions with nuclei. Range depends on charge, mass and E of particle, density of medium, and ionization potential and A of particles in the medium.

Ranges in air for α and protons are shown in figure 14.19. A proton typically has a range 10$\times$ that of an α: at a given E, v is smaller and the charge is larger for an α.

The **energy loss rate** or **stopping power** is $-dE/dx$.

$$\frac{dE}{dx} \propto \text{KE for } v \ll c\text{, up to a max,}$$
$$\propto \text{ const with KE as } v \to c.$$
$$\propto \rho_{\text{medium}}$$
$$\propto Z^2_{\text{particle}}$$

See figure 14.20 for an example.

Electrons in matter

At $E < 1$ MeV, the energy losses occur by the same processes for electrons. However, the range is not well defined because of **straggling:** the electron undergoes large deflections.

There is also a loss by **bremsstrahlung:** the acceleration causes EM emission by the photon. At 10 MeV the loss from bremsstrahlung is about the same as from ionization.

Photons

Have no net charge, but still interact electromagnetically. For gamma photons:

- at low $E < 0.5$ MeV, photoelectric effect removes photons. E is transferred to electrons in atoms.

- at intermediate E, Compton scattering transfers some E to electrons in medium.

- A high $E > 1.02$ MeV, **pair production** creates electron-positron pairs as the photon passes near nuclei.

Attenuation

Photons attenuate with distance as

$$I(x) = I_0 e^{-\mu x},$$

where I_0 is the incident flux of photons, and μ is the **linear absorption coefficient** of the medium. See fig. 14.21 and table 14.2.

Radiation damage in matter

Depends on material and type/energy of radiation. Metals in reactors can be weakened by high neutron fluxes. Atoms are displaced from crystal lattice sites. Ionization can also induce defects in crystal lattices.

In biological materials, damage mainly due to ionization. Can cause cell death or biochemical changes, DNA damage.

Somatic damage is damage to body cells, DNA damage can increase cancer likelihood.

Genetic damage is to reproductive cells, can lead to sterility or defects in offspring (though most are fatal mutations.)

Next: units of dosage.