

One electron volt (eV) of energy is

$$E = qV = 1.6 \times 10^{-19} \text{ Coul} \times 1 \text{ Volt} = 1.6 \times 10^{-19} \text{ Joule}$$

It is of the order of atomic ionization energies.

eV: x-rays, MeV: nuclear rays, GeV: baryon prod'n, TeV: LHC

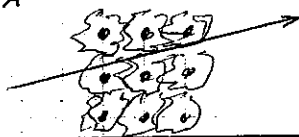
What does matter look like to incoming radiation?

Gas: Mostly empty space: Molecules separated ≈ 15 molec. diam.

Condensed: All atoms have about the same size!

$$\text{Separation} = \sqrt[3]{\frac{V_{\text{tot}}}{N_{\text{atom}}}} = \sqrt[3]{\frac{A}{\rho N_A}} \Rightarrow R \times 10^{-10} \text{ m}$$

but 2 electrons + A mass



Electrically charged: Nonpenetrating, Ionizing

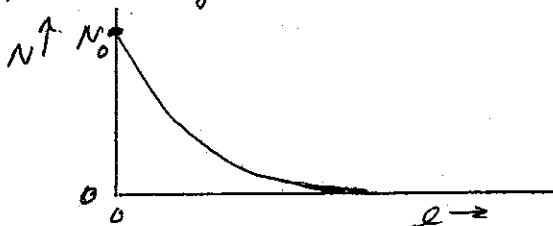
1. Heavy (compared to electron) $\mu, \pi, p, \alpha, \dots$
 Flow through electron clouds (football + fly), losing energy to electrons in many small steps, with rare nuclear deflections

2. Electrons (+ positrons) "beta rays".
 Also slowed down by collisions with electrons, but bounce around.
 [An electron can lose only $\frac{1}{2}$ its energy!]

Electrically neutral: Penetrating (exponential absorption) Ionizing

3. X-rays: "gamma rays", electromagnetic (EM) waves, photons
 Absorbed occasionally by an electron.

4. Neutrons: Collide only with nuclei (Eventually captured by one).
 Can pass through a lot of matter before hitting a nucleus.



$$N(x) = N_0 e^{-x/\lambda}$$

λ = "mean free path"

Other

5. Microwaves: long wavelength EM radiation, $\lambda > 10$ mm

Non ionizing.

[Possibility of molecular excitations!]

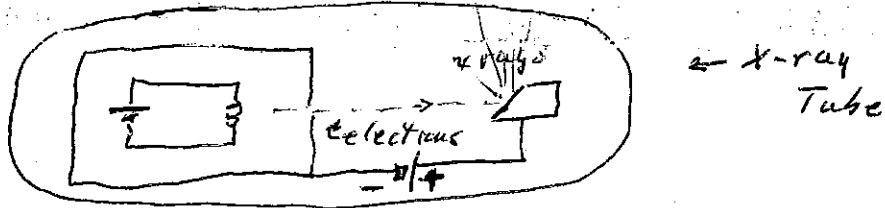
6. Cosmic Rays. Highest energy, Very penetrating, Unknown origin
 Includes neutrinos, Showers. AMANDA + ICE CUBE
 Magnetic field reversals.

(OVER)

X-rays Roentgen 1895 Used medically ever since

Bone shadows: Ca has high electron density (of H, C, N, O)
(All atoms are about the same size!)

Easily produced by "Bremsstrahlung" (slowing down radiation).



The x-rays are EM radiation from violent collisions of electrons with the anode nuclei.

X-rays also have the right wavelength for interference studies of crystal structure. DNA was unraveled this way.

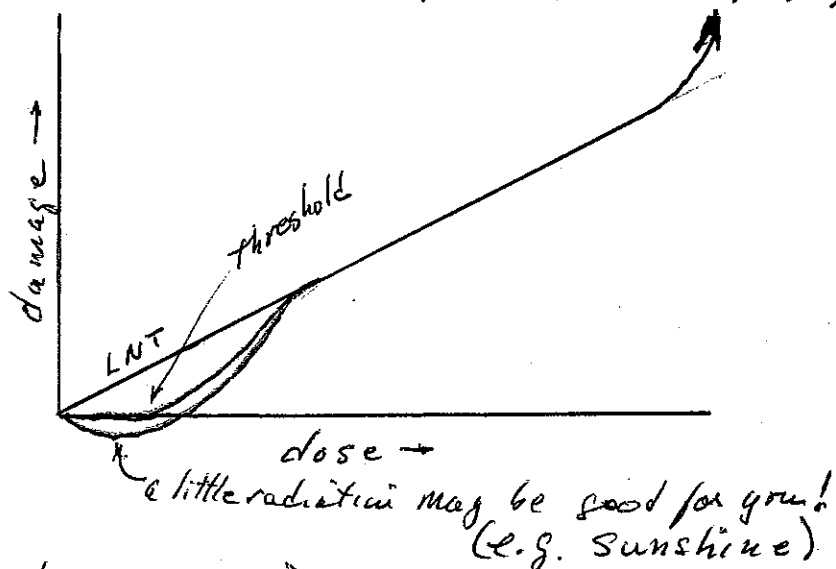
Medical Diagnosis, imaging, therapy, tomography

Cancer cells more damageable than healthy ones.

Radiation dose: Energy deposition

1 Sievert of radiation dose is 1 Joule of energy ^{absorbed by} into every kg of mass

LNT Controversy
(Linear
No Threshold)



Cosmic rays and cancer in Denver.
evolution