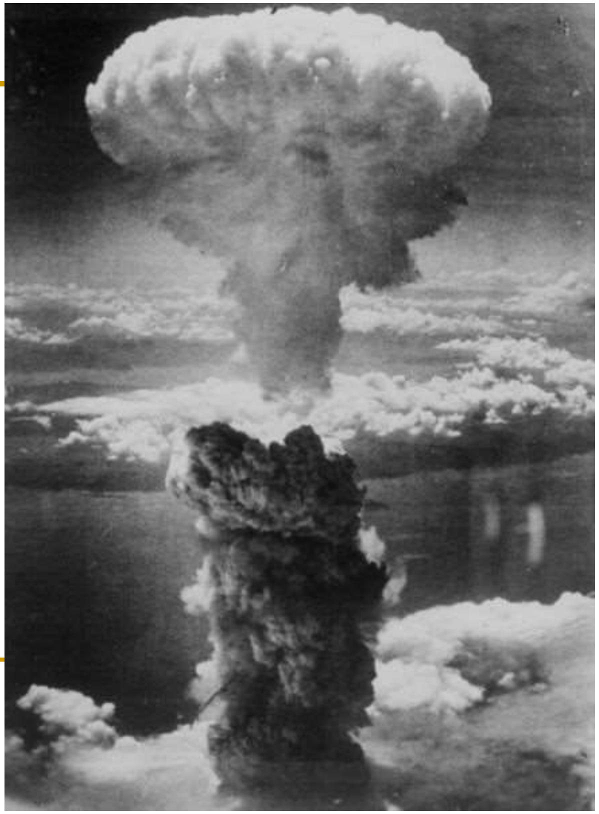
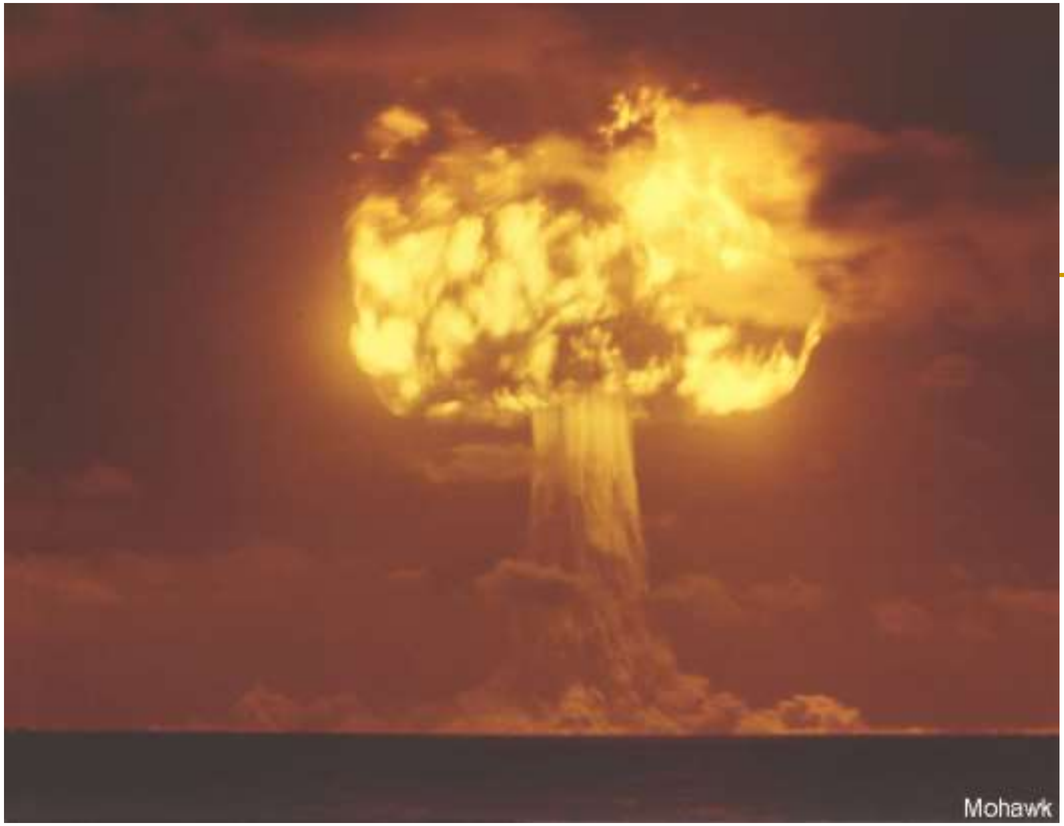
Nuclear Science





History of Radiation

1896 Henri Becquerel

Noticed that uranium stored next to photographic film wrapped in heavy paper affected the film and caused foggy spots.

1898 Marie & Pierre Curie

Discovered two new radioactive metallic elements, polonium and radium.

Radioactive Decay

- The spontaneous disintegration of a nucleus into a slightly lighter nucleus, accompanied by emission of particles, electromagnetic radiation, or both.

Types of Radioactive Decay

Alpha Emission (Decay)

$^{4}_{2}He$ or $^{4}_{2}\alpha$

- Nucleus emits an alpha particle (α)
- composed of 2 protons and 2 neutrons (He nucleus).
- has two positive charges, a mass number of 4
- can be stopped by a thin piece of paper or aluminum foil
- speed of 1/10 the speed of light

Beta Emission (Decay)

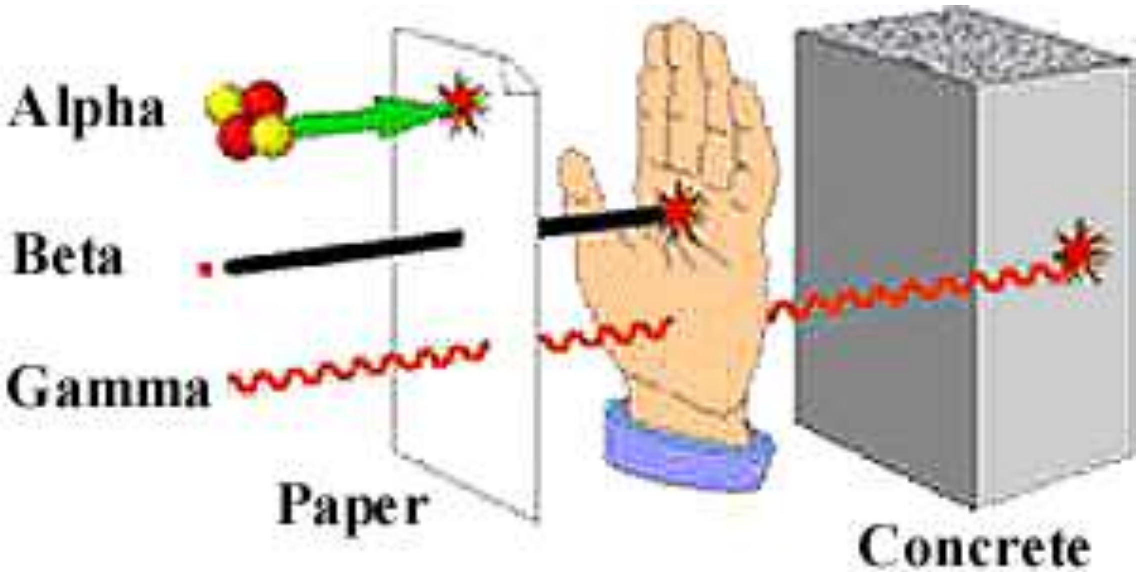
$$^{0}_{-1}\beta$$

- Beta particle (β) – identical to an electron. The nucleus changes a neutron to a proton and an electron and emits the electron.
- speed nearly equal to the speed of light
- single negative charge, no significant mass
- can be stopped by 1 cm of aluminum

Gamma Rays (γ)

- high energy photons. No mass, no charge. Accompany other forms of nuclear decay.
- produced by energy transitions in the nucleus
- the most penetrating radiation emitted
- travel at the speed of light
- stopped by a thick block of concrete

Illustration



http://www.radongas.com/images/alpha_penetration.gif

Half-Life

- $t_{½}$
- time required for half the amount of atoms (or mass) of a radioactive nuclide to decay.

$$\text{Remaining amount} = \frac{\text{Original amount}}{2^n}$$

n = number of half-lives passed.

USES OF NUCLEAR ENERGY

FISSION

- The splitting of a heavy nucleus into nuclei of intermediate mass

- During fission, neutrons are emitted and a large amount of energy is released.

A **chain reaction** is a series of nuclear fissions whereby some of the neutrons produced by each fission cause additional fissions. During an **uncontrolled** chain reaction, it would not be unusual for the number of fissions to increase a thousandfold within a few millionths of a second and can generate an incredible amount of energy, as happens in an atomic bomb (nuclear bomb).

By limiting the number of neutrons in the environment of the fissile nuclei, it is possible to establish a condition whereby each fission event contributes only one neutron that fissions another nucleus. In this manner, the chain reaction and the rate of energy production are **controlled** as in nuclear reactors used in commercial generation of electric power.

Fusion

- Occurs when two very-low-mass nuclei are combined or "fused" into a single, more massive nucleus. Ex: sun, stars, hydrogen bombs
- For a given amount of mass of fuel, a fusion reaction yields more energy than a fission reaction.
- Since nuclei are positively charged, they repel each other. Great temperatures (100,000,000 oC) are required to generate the kinetic energy required to bring the two nuclei together.

When compared to fission, fusion uses fuels such as deuterium ($^{2}_{1}H$) found in ocean water and is plentiful, cheap, and easy to separate from the common isotope of hydrogen ($^{1}_{1}H$). Fissile materials like uranium are much less available and supplies could be depleted within a century or two. However, the commercial use of fusion to provide cheap energy remains in the future.